Fisheries and Oceans Canada — Pêches et Océans Canada

Science — Sciences

C S A S — **S C C S**

Canadian Science Advisory Secretariat — **Secrétariat canadien de consultation scientifique**

Research Document 2002/064

Document de recherche 2002/064

Not to be cited without
permission of the authors *

Ne pas citer sans
autorisation des auteurs *

Status of Cultus Lake Sockeye Salmon *(Oncorhynchus nerka)*

État du stock de saumon rouge (*Oncorhynchus nerka*) du lac Cultus

N.D. Schubert, T.D. Beacham, A. J. Cass, T.E. Cone, B.P. Fanos, M. Foy, J.H. Gable, J.A. Grout, J.M.B. Hume, M. Johnson, K.F. Morton, K.S. Shortreed, M.J. Staley and R.E. Withler

Fisheries and Oceans Canada
Lower Fraser Area
100 Annacis Parkway, Unit 3
New Westminster, B.C. V3M 6A2

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

This document is available on the Internet at:

* 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.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

Ce document est disponible sur l'Internet à:

http://www.dfo-mpo.gc.ca/csas/

ISSN 1499-3848 (Printed)

Canada

ABSTRACT

This report documents an assessment of the status of Cultus Lake sockeye salmon (*Oncorhynchus nerka).* Sockeye escapements have declined precipitously on all cycles in recent years, a decline that is coincident with an earlier timing of migration into the river that is part of the broader phenomenon affecting all late run Fraser River sockeye populations. In association with early migration, there also has been a decline in spawning success that has resulted in the failure to observe a single successful spawner in some years. These observations led to the Pacific Science Advice Review Committee's request for a status report on this stock.

The Cultus sockeye population is among the most intensively studied salmon stocks in British Columbia. Studies of spawner abundance, lake characteristics and juvenile production began with the work of the Pacific Biological Station in the 1920's and have continued until the present with the work of the International Pacific Salmon Fisheries Commission and the Department of Fisheries and Oceans. This report summarizes or provides detailed data regarding: watershed geomorphology; lake limnology and fish ecology; sockeye life history; enhancement history; predator and exotic species control; spawner counts since 1925; sockeye fry assessments (lake hydroacoustic and trawl survey); smolt counts since 1926; fishery management processes and objectives; fishery catches and total returns since 1952; and marine distribution and migratory timing. These data are used to evaluate trends in escapements, juvenile abundance, catch and total return, and to calculate freshwater and total survival indexes and exploitation rates. Based on the available data and the analytic results, we provide an evaluation of the stock's productive capacity and current status, and use a simulation model based on Bayesian stock-recruitment analyses to evaluate future stock trajectories under different scenarios of prespawn mortality and exploitation.

Cultus is a potentially large stock (current escapements are a small fraction of the level that would utilize a substantial part of the stock's productive capability) that is less productive than the sockeye stocks with which it comigrates. The escapement of Cultus sockeye adults declined by 51% over the last three generations, a continuation of a trend that began following the construction of the Weaver Creek spawning channel in the late 1960's. The rate of decline is consistent with an *Endangered* classification as defined by the IUCN. There are two causal factors: exploitation rates that have exceeded the optimum rate associated with maximum sustainable yield in most years between 1952 and 1995; and extremely high prespawn mortalities that have occurred since the onset of the early migration in 1995. The result is a current effective spawner population that is less than 4% of the long term average on each of the four cycles. Our model simulations suggest that if the current conditions of high prespawn mortality continue, even in the absence of any fishing mortality, the prognosis for the stock is critical: the probability of extinction is conservatively estimated at one in three. If exploitation continues at moderate levels, the modelled rate of decline over three generations is >80% and the probability of extinction is >50%, conditions consistent with a *Critically Endangered* classification as defined by the IUCN.

We recommend the development of a risk assessment framework that evaluates risks of different fisheries and recovery options in terms of their cultural, ecological, economic and social values. While the framework is being developed, current mitigation efforts should continue and fisheries should be managed under a precautionary approach that recognizes the uncertainty associated with the early migration phenomena, and its potential severity, by minimizing exploitation rates to reduce the near-term probability of extinction and slow the rate of decline in spawner abundance. We also recommend the development of a comprehensive recovery plan that integrates options to improve freshwater survival with harvest controls and other measures, as well as the Department's support for the ongoing and new studies required to provide information important to our understanding of stock status and to the development of the risk assessment framework and recovery plan.

RÉSUMÉ

Ce rapport présente une évaluation de l'état du stock de saumon rouge (*Oncorhynchus nerka*) du lac Cultus. Depuis quelques années, les échappées pour tous les cycles de montaison ont fortement chuté, ce qui a coïncidé avec une montaison en rivière plus hâtive qu'auparavant, phénomène qui touche toutes les populations de saumon rouge à montée tardive du fleuve Fraser. Cette montaison plus hâtive a aussi été associée à une baisse du succès de reproduction ce qui a eu comme résultat que, certaines années, aucun géniteur ayant réussi à frayer n'a été observé. Ces observations ont incité le Comité d'examen des évaluations scientifiques du Pacifique à demander un rapport sur l'état de ce stock.

La population de saumon rouge du lac Cultus est un des stocks de saumon les plus intensément étudiés de la Colombie-Britannique. D'abord menées par la Station biologique du Pacifique dans les années 1920, les études sur les caractéristiques du lac, l'abondance des géniteurs et la production de juvéniles se poursuivent encore avec les travaux de la Commission internationale du saumon du Pacifique et du ministère des Pêches et des Océans. Ce rapport présente des données détaillées ou résumées sur la géomorphologie du bassin versant, les caractéristiques limnologiques du lac, l'écologie des poissons, le cycle de vie du saumon rouge, l'historique de sa mise en valeur, le contrôle des prédateurs et des espèces exotiques, l'abondance des géniteurs depuis 1925, l'abondance des alevins (relevés hydroacoustiques et relevés au chalut), l'abondance des saumoneaux depuis 1926, les processus et objectifs de gestion de la pêche; les captures et les remontées totales depuis 1952 ainsi que la répartition en mer et le moment des migrations. Ces données servent à évaluer l'évolution des échappées, de l'abondance des juvéniles, des captures et des remontées totales, ainsi qu'à calculer les indices de survie en eau douce et de survie totale et les taux d'exploitation. En nous fondant sur les données disponibles et les résultats des analyses, nous évaluons la capacité de production et l'état actuel du stock et nous utilisons un modèle de simulation fondé sur des analyses stock-recrutement bayésiennes pour prévoir l'évolution future du stock selon différents scénarios d'exploitation et de mortalité préfraie.

Le stock du lac Cultus est potentiellement considérable (les échappées actuelles ne constituent qu'une petite fraction de la capacité de production du stock), mais il est moins productif que les stocks de saumon rouge avec lesquels il migre. Depuis trois générations, l'échappée de saumons rouges du lac Cultus a diminué de 51 %, ce qui constitue une poursuite de la tendance qui a débuté après la construction de la frayère artificielle du ruisseau Weaver à la fin des années 1960. Ce taux de déclin correspond à la catégorie *menacé d'extinction* de la classification de l'UICN. Deux facteurs sont mis en cause : les taux d'exploitation qui ont dépassé le taux optimal lié au rendement équilibré maximal la plupart des années durant la période de 1952-1995 et les taux de mortalité préfraie extrêmement élevés qui ont eu lieu depuis l'avènement de la migration hâtive en 1995. En raison de ces facteurs, la population actuelle de géniteurs réels représente moins de 4 % de la moyenne à long terme pour chacun des quatre cycles. Nos simulations indiquent que, si la mortalité préfraie élevée se maintient, même sans mortalité par pêche, le pronostic est alarmant : nous estimons de façon conservatrice que le stock a une chance sur trois de disparaître. Si l'exploitation continue à des taux modérés, notre modèle donne un taux de déclin supérieur à 80 % sur trois générations et une probabilité d'extinction supérieure à 50 %, ce qui correspond à la catégorie *gravement menacé d'extinction* selon la classification de l'UICN.

Nous recommandons d'élaborer un cadre permettant d'évaluer les risques posés par différentes pêches et les options de rétablissement du stock selon leurs valeurs culturelles, écologiques, économiques et sociales. Entre-temps, les travaux d'atténuation des impacts devraient se poursuivre et les pêches devraient être gérées selon une approche de précaution qui reconnaît l'incertitude liée au phénomène de migration hâtive (et sa gravité possible), en minimisant les taux d'exploitation pour réduire la probabilité d'extinction à court terme et le taux de déclin de l'abondance des géniteurs. Nous recommandons aussi d'élaborer un plan de rétablissement détaillé qui intègre des options visant à améliorer la survie en eau douce avec des limites de captures et d'autres mesures. Enfin, nous recommandons que le ministère soutiennent les études actuelles et nouvelles pour fournir les données dont nous avons besoin pour mieux comprendre l'état du stock et élaborer le cadre d'évaluation des risques et le plan de rétablissement.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0. INTRODUCTION

The Fraser River system supports the largest population of sockeye salmon *(Oncorhynchus nerka*) in the world (Northcote and Larkin 1989). Sockeye spawn in over 150 natal areas, ranging from small streams to large rivers and lakes, that are distributed throughout the accessible portion of the Fraser system. The stocks are divided into four groups based on similar timing during their return migration to natal areas: the early run (migrates through the lower Fraser River from late June to late July); the early summer run (mid-July to mid-August); the summer run (mid-July to early September); and the late run (early September to mid-October). The late run comprises 52 populations that spawn in the lower Fraser, Harrison-Lillooet, Seton-Anderson and South Thompson systems. It includes the Cultus, Birkenhead, Harrison, Weaver, Portage and Shuswap stocks as well as the world famous Adams sockeye. Late run sockeye migrate from the open ocean into the Strait of Georgia in August where they typically remain for up to six weeks before resuming their migration into the Fraser River in September and early October. Since 1995, the migration into the river has been progressively earlier. In the most extreme case (2000) the delay was only one day, resulting in a median river entry in mid-August compared to the normal late September. While the cause of the early migration is currently unknown, the consequences have been dramatic. Early migration has been associated with high levels of mortality along the migratory route and in terminal areas, as well as elevated levels of prespawning mortality (PSM) in the natal streams and lakes. These mortalities are caused by heavy infestations of *Parvicapsula minibicornis,* a parasite that attacks the kidneys and gills (St-Hilaire *et al.* 2001). Although the parasite occurs in most Fraser River sockeye stocks, it has caused significant mortality only among early migrating late run sockeye.

Cultus Lake and Sweltzer Creek, its outlet stream, are part of the Vedder-Chilliwack System located in the eastern Fraser Valley approximately 112 km upstream from the Strait of Georgia (Fig. 1). Cultus is a small lake (6.3 km^2 area) that supports a sockeye population that is among the most intensively studied salmon stocks in British Columbia. Studies of spawner abundance, lake characteristics and juvenile production began with the work of the Pacific Biological Station in the 1920's (*e.g.,* Foerster 1929a, 1929b, 1929c 1934, 1936a; Ricker 1935, 1937, 1938a) and have continued until the present with the work of the International Pacific Salmon Fisheries Commission (IPSFC) (*e.g.,* Howard 1948; Cooper 1952) and the Department of Fisheries and Oceans (DFO) (*e.g.,* Ricker 1952). As a result, there is a wealth of data related to lake limnology and fish community structure as well as accurate abundance information for the sockeye fry, smolt and adult life stages.

The number of Cultus sockeye returning to spawn (the escapement) has steadily declined on all but the 1999 cycle since the late 1960's, and has declined precipitously on all cycles in recent years (Table 1). Coincident with the recent sharp escapement declines, the timing of the migration into the river and lake has become progressively earlier as part of the broader phenomenon affecting all late run sockeye populations. There has been an alarming decline in spawning success beginning in 1995 that culminated with the failure to observe a single successful spawner in the last three years. In response to these trends, the Cultus Lake Sockeye Recovery Planning Team was formed in early 2002 to document the status of this stock and to develop a recovery plan. This report amalgamates the work of the Team's Stock Assessment/Fisheries Management and Habitat work groups to provide a single comprehensive assessment of the status of the Cultus sockeye stock. The report is organized in six sections: Section 1 outlines the characteristics of the lake and stock, and describes the management process for the fisheries that harvest the stock; Section 2 documents data sources; Section 3 outlines the techniques used to analyse the data; Section 4 presents the results of stock status and extinction probability assessments; Section 5 provides conclusions; and Section 6 proposes recommendations to address the conclusions.

1.1 CULTUS LAKE

1.1.1. Watershed Geomorphology

Cultus Lake lies at an elevation of 43 m in the Cascade Mountains of the Coast Belt of the Canadian Cordillera. The Coast Belt is made up largely of granites and metamorphosed sedimentary and volcanic rocks that formed 50 to 200 million years ago. The bedrock is commonly mantled by several meters of till, sandy gravel or rock fragments; less than 10% of the mountain area is exposed rock. The bedrock can be grouped into four units: dark, fine grained volcanic (basalt, andesite), sedimentary (sandstone, siltstone, and conglomerate), granitics (granite, granodiorite, quartz diorite, diorite) and foliated sedimentary and volcanic rock. Metamorphosed sedimentary and volcanic rocks occur widely in the Cascade Mountains and form the small hills of the eastern Fraser Valley (*e.g.,* Chilliwack Mountain). They are characterized by a planar fabric (foliation), formed during burial, deformation and metamorphism of the rock, that reduces its strength and causes some rock types to weather into thin platy fragments. Exposed bedrock on Vedder Mountain and east of Cultus Lake is made up of thinly layered, dark argillite, and lesser phyllite, gneiss, limestone, and chert. Volcanic rock with interlayers of limestone, argillite, and sandstone is exposed on mountain slopes in the upper Chilliwack River basin.

The gently rolling Fraser Valley uplands (< 250 m elevation) are underlain by Ice Age sediments (glacial till, gravel and sand) deposited during the Pleistocene Epoch (two million to 11,000 years ago) by streams flowing off the melting ice, marine clay and silt and beach gravel and sand. Most such sediments date to the end of the last glaciation (11-25,000 years ago) when areas below 200 m elevation were covered by the sea. Deposits older than the last glaciation (clay, silt, sand, gravel, till) are exposed only in steep escarpments along the margins of uplands. The bases of some escarpments (*e.g.,* Chilliwack Valley) are undercut by streams, making them vulnerable to landslides.

Most landslides in the Fraser Valley involve Ice Age sediments and are triggered by intense rainstorms. In contrast, many of the landslides in the Coast and Cascade Mountains are in bedrock (rockfalls and rockslides). The Fraser River and its tributaries, and gently sloping fans at the mouths of rivers such as the Chilliwack, are zoned as moderate to high flood hazard. Liquefaction of material due to earthquake is rated low for the Cultus Lake area except in the areas of relatively loose, saturated lowland sediments (*i.e.,* modern sediments).

1.1.2. Limnology

Cultus Lake, located 10 km south of the town of Chilliwack, is one of the most heavily utilized residential and recreational lakes in British Columbia. It is drained at its northern end by Sweltzer Creek, that in turn flows into the Chilliwack River 3.0 km downstream from the lake (Fig. 2). The lake's major tributary, Frosst Creek, drains an agricultural area at the southern end of the lake. The lake has a surface area of 6.3 km², a drainage basin of 65 km², and a mean and maximum depth of 32 m and 41 m, respectively. The lake is steep-sided and has a littoral area (*i.e.,* the zone where light penetrates to the bottom) of only 74 ha, 12% of the total surface area. Water residence time is 1.8 years and, like most coastal British Columbia lakes, Cultus is a warm monomictic lake (*i.e.,* it is thermally stratified except during the winter overturn). Hydraulic loading peaks during the frequent rain events in late fall and winter (November to February), with a secondary snowmelt peak occurring in May. The lowest discharge occurs in August and September.

The limnology of Cultus Lake can be characterized from data collected in 2001 (Shortreed and Morton, unpublished) and earlier data from the 1930's (Ricker 1937) and the 1960's to 1970's (Goodlad *et al*. 1974). Seasonal thermal stratification is strong and prolonged, with a thermocline developing in early May and lasting until late November. The summer thermocline depth averages 6-8 m, and temperatures in the surface layer (the epilimnion) exceed 20º C. Maximum summer temperatures at 5 m average 20-21º C, while fall lake bottom temperatures average 5.8-6.5º C (range: 4.6-6.5º C). Water clarity is relatively high, with an average euphotic zone (the zone where there is sufficient light for net primary production) depth of 16.7 m, 100% deeper than the thermocline. Secchi-disk depths average 10-11 m.

Compared to other coastal lakes, Cultus is well-buffered and alkaline with an average total alkalinity and pH of 64 mg $CaCO_3$/L and 7.6, respectively; these values are similar to the 1930's levels (80 and 7.4) when methodological differences are considered. Conductivity (156 µS/cm) and total dissolved solids (107 mg/L) are among the highest for any British Columbia sockeye nursery lake. Goodlad *et al.* (1974) reported a similar average conductivity of 167 µS/cm in the late 1960's and early 1970's. Nutrient loading is relatively high compared to other sockeye nursery lakes, with spring overturn concentrations of nitrate and total phosphorus of 120 µg N/L and 6.0 µg/L, respectively. Epilimnetic nitrate concentrations decline to very low levels (<1.5 µg N/L) from August to October.

In 2001, epilimnetic phytoplankton biomass (as chlorophyll) was <2 µg/L for most of the growing season; however, a hypolimnetic chlorophyll maximum of 3-7 µg/L centred at a depth of 15 m persisted from June to October. Ricker (1938b) reported *Melosira, Asterionella, Dinobryon*, and *Ceratium* as common large phytoplankton genera in Cultus Lake; these same genera were common in 2001, although quantitative comparisons cannot be made. The seasonal average photosynthetic rate of 394 mg $C{\cdot}m^{-2}{\cdot}d^{-1}$ is the highest of any sockeye nursery lake in the Fraser system. Zooplankton biomass is also relatively high, with a seasonal average of 1,396 mg dry wt/m². *Daphnia* make up a high proportion (74%) of the biomass. *Diacyclops bicuspidatus* is the most abundant zooplankter, followed by *Daphnia sp*. and other species such as *Eubosmina coregoni* and *Epischura sp.* These species were also dominant in the 1930's (Ricker 1938b) and in the late 1960's and early 1970's (Goodlad *et al.* 1974), and the numbers or biomass were roughly similar to current estimates although methodological differences prevent quantitative comparisons. Cultus Lake contains the parasitic copepod *Salmincola californiensis*, a species known to infect sockeye and cause mortality in juvenile sockeye salmon (Kabata and Cousens 1977); its impact on Cultus sockeye has not been assessed.

Although Cultus is a coastal lake in terms of location and climate, its water chemistry, productivity, and plankton community structure are more similar to interior lakes (Shortreed *et al.* 2001). Nutrient chemistry and phytoplankton productivity place Cultus in the upper range of oligotrophy and among the more productive sockeye nursery lakes in British Columbia. Lake productivity is strongly phosphorus-limited; additional phosphorus loading could have a dramatic effect on lake productivity and water quality. The abundant zooplankton community and its large *Daphnia* population is attributable both to its high productivity and to the low numbers of limnetic planktivores in the lake. In October, 2001, the density of age-0 *O. nerka* (sockeye or kokanee) was only 70/ha.

1.1.3. Fish Ecology

Nineteen species other than sockeye salmon are known to occur in Cultus Lake. These include six species of Pacific salmon, chinook (*O. tshawytscha*), coho (*O. kisutch*), chum (*O. keta*), pink (*O. gorbuscha*), coastal cutthroat trout (*O. clarki clarki*), and both steelhead and rainbow trout (*O. mykiss*), (FISS, http://www.bcfisheries.gov.bc.ca/fishinv/), as well as Dolly Varden (*Salvelinus malma*), Cultus pygmy sculpin (*Cottus sp*.), prickly sculpin (*C. asper*), threespine stickleback (*Gasterosteus aculeatus*), largescale sucker (*Catostomus macrocheilus*), longnose dace (*Rhinichthys cataractae*), mountain whitefish (*Prosopium williamsoni*), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth chub (*Mylocheilus caurinus*), redside shiner (*Richardsonius balteatus*) and western brook lamprey (*Lampetra richardsoni*). Midwater trawls in the limnetic zone have frequently caught sockeye, Cultus pygmy sculpins, threespine sticklebacks, and redside shiners; coho and chum fry have been caught only rarely and, on a single occasion, a river lamprey (*Lamptera ayresi*) was captured (J. Hume, unpublished data). Coho salmon, Cultus pygmy sculpin and northern pikeminnow are of particular interest. Unlike most coho stocks, which are anadromous, a large proportion of Cultus Lake coho do not migrate to sea (Foerster and Ricker 1941; Foerster and Ricker 1953a). Forester and Ricker (1953a) estimate that 50-80% of the coho population residualizes in the lake (Foerster and Ricker 1953a).

The Cultus pygmy sculpin is a strictly limnetic species that evolved from the stream-rearing coastrange sculpin (*C. aleuticus*)(Cannings and Ptolemy 1998). They are smaller than coastrange sculpins (maximum size <50 mm), with mature individuals as small as 29 mm (Ricker 1960). Their morphology has adapted to the limnetic life-cycle by reducing bone density and increasing sub-dermal lipids to allow vertical migration in the water column (sculpins do not have a swimbladder). The Cultus pygmy sculpin is listed by Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as *threatened* and by the Province of British Columbia as critically *imperilled* (Cannings *et al.* 1994) due to its single known location in Cultus Lake. A similar fish in Lake Washington is probably a case of independent, parallel evolution (McPhail and Lindsey 1986).

The northern pikeminnow is a large piscivorous cyprinid widely distributed throughout the Fraser River and other major British Columbia river systems. Predation by pikeminnow is known to be an important source of mortality for juvenile salmonids in the Fraser and Columbia river systems (Foerster and Ricker 1941; Ricker 1941; Foerster 1968; Friesen and Ward 1999). In Cultus Lake, pikeminnow spawning occurs along the lake shore from late June to mid-July. Because pikeminnow have a high fecundity (up to 40,000 eggs/female) and a long life span (up to 20 years), their populations can increase rapidly under favourable conditions. This is apparent in Cultus Lake where the number of pikeminnow >200 mm in length increased from 8,400 in 1935 to 40,000 in 1991 (Hall 1992). Young pikeminnow inhabit the littoral zone where they consume mostly insect larvae. When mature (>250 mm), they occupy both the littoral and limnetic (or sublittoral) zones and feed almost entirely on smaller fish; they prey heavily on juvenile sockeye when they are available. Mature pikeminnow cannibalize their offspring in the littoral zone, particularly during spawning in the early summer.

1.1.4 Eurasian Watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum*) is an exotic perennial macrophyte that was introduced to eastern North America in the late 1800's. It spreads widely and rapidly, displacing native plants, infesting recreational areas, slowing the water flows and changing fish habitats to the detriment of some species (*e.g.,* salmon) and the benefit of others (*e.g.,* pikeminnow). Watermilfoil propagates by fragmentation (asexual reproduction), root nodes and seed production, but spreads mainly through the former. In the littoral zone of lakes, it establishes dense patches with up to 100 stems growing from a single large root mass. Watermilfoil affects sockeye salmon by encroaching on spawning habitat as well as providing juvenile pikeminnow with refuges against adult cannibalism (R. Gregory, DFO, personal communication), thereby increasing adult pikeminnow recruitment and potential predation on juvenile sockeye.

Control of watermilfoil is important in restoring lake ecosystems because of the plant's broad impacts on littoral fish assemblages, insect communities (Keasts 1984; Sloey *et al.* 1997) and water quality (Unmuth *et al.* 2000). A successful control program requires a comprehensive approach that documents the extent of infestation, uses removal methods tailored to specific ecosystems, and assesses the program's overall effectiveness (Newroth 1993). Watermilfoil control has been attempted using mechanical, chemical and biological means (Aiken *et al.* 1979): mechanical removal is expensive but can be effective if carried out annually; the use of herbicides has potentially deleterious effects on other ecosystem components; and research is continuing on the introduction of the watermilfoil weevil (*Euhrychiopsis lecontei*), an exotic species, into watermilfoil-infested lakes.

Information on the impacts of watermilfoil on Cultus sockeye comes from the British Columbia Ministry of Environment (MOE) mapping surveys carried out from 1977 to 1991, from DFO dive surveys of sockeye spawning area in the early 1980's, and from observations of fish predator-prey relationships in the lake's littoral zone. Watermilfoil was first observed in Cultus Lake in 1977, likely an inadvertent introduction from interior lakes by boaters (R. Truelson, MOE, pers. comm; D. Barnes, DFO, pers. comm.). From 1977 to 1991, the watermilfoil distribution in the littoral zone nearly doubled and shifted from mainly sparse patches to dense mats. By 1991, it covered 22 ha of the lake's 74 ha littoral area (Truelson 1992); subsequent distributions have not been monitored.

Dive surveys of Lindell Beach in 1982 indicated that dense patches of watermilfoil had displaced sockeye from areas that had previously been used for spawning (K. Morton, unpublished data). This led to a watermilfoil removal program along Lindell Beach the following summer; large numbers of sockeye spawners returned to cleared areas that fall. The removal program was not continued in 1984 because of expected low sockeye returns and consequently, watermilfoil distribution increased from covering only 10% of the spawning habitat in 1983 to >30% in 1984. In subsequent years, the Cultus Lake Park Board mechanically removed watermilfoil from areas associated with the recreational beaches (including Lindell Beach) that comprise 12% of the total littoral area at an annual costs of $15,000 per year. This program is expected to terminate in 2003.

Observations of chum salmon spawning in lower Fraser River sloughs suggest that redd digging successfully keeps spawning areas free of rooted plant growth (M. Foy, DFO, pers. comm.). Given sufficient spawner numbers, they potentially could slow or prevent the encroachment of watermilfoil in the spawning areas. Given current sockeye abundances, however, there are likely enough beach areas that remain suitable for spawning (this cannot be confirmed until the spawning areas are mapped and dive surveys document the extent of watermilfoil coverage).

1.1.5. Watershed Use

The name Cultus derives from the lake's early use for spirit quests by First Nations peoples. Because its popularity eventually made the lake worthless for such uses, in Chinook Jargon (a trading language used among northwest tribes and Europeans) the name Cultus means worthless (Chilliwack Museum and Archives).

In the late 1800's and early 1900's, Cultus Lake became popular for camping and outdoor recreation, leading to the creation of Cultus Lake Park in 1924. Cottages began to appear at this time and, beginning in 1942, the area evolved from a summer resort to a year-round community. Housing development has been restricted to small areas on the northeast and northwest sides of the lake and at Lindell Beach. Farming occurs near the south end, and tree harvesting has occurred in the upland areas. Activities with direct impacts to the lake's littoral zone include the removal of shoreline vegetation, shoreline alteration and the encroachment by wharves and piers, especially near the spawning areas. Activities that impact the tributary streams include channelization and the removal of riparian vegetation. Of special concern is the potential degradation of the quality of the lake's surface and ground water inputs as a result of seepage from septic systems, agricultural runoff and the domestic use of fertilizers.

Today, recreation is the primary activity as 92% of the lake's 18 km shoreline is within either Cultus Lake Provincial Park (656 ha along the east and west shores) or Cultus Lake Municipal Park (244 ha along the north shore). The parks have a total of 580 campsites as well as three large swimming and day use areas, the most popular of which is located at the lake outlet where it borders 400 m of Sweltzer Creek (sand has been added to the swimming beach in this area). The parks currently receive about 1.5 million visitors annually, making Cultus one of the most heavily utilized lakes in British Columbia. With the exception of the day use area at the lake outlet, all park areas are closed from late fall to early spring. During the summer months, Cultus Lake is extremely popular for recreational boating; recreational fishing for any species is not a major activity. The lake has a marina, two boat rental facilities and four boat launch ramps. While there is no reliable estimate of boat numbers, at times Cultus Lake is so congested that the Canadian Coast Guard has recommended protocols and traffic patterns to avoid collisions.

1.2. CULTUS SOCKEYE LIFE HISTORY

The Chilliwack River system supports two temporally, spatially and genetically distinct sockeye stocks, an early summer run stock that spawns in Chilliwack Lake and the upper Chilliwack River and a late run stock that spawns in Cultus Lake. Late run sockeye mature predominantly in their fourth year and exhibit a quadrennial abundance pattern typified by a strong dominate cycle, a moderate sub-dominant cycle and two relatively weak cycle years. With greater than 90% of Cultus sockeye maturing in their fourth year, it follows this pattern with strong subdominant (1998) and dominant (1999) cycles followed by two relatively weak cycles (2000 and 2001) (Table 1).

Maturing Cultus sockeye normally (until recently) migrate through the lower Fraser River in September and October and into Cultus Lake from late September to early December, a protracted period of about ten weeks that is considerably longer (by 2-6 weeks) than that of most other Fraser River sockeye stocks (DFO, unpublished data). Cultus sockeye spawn from late November through December, the latest spawning of the Fraser sockeye stocks (Schubert 1998). The pre-spawning behaviour and distribution of sockeye in Cultus Lake has not been documented. Historically, spawning has occurred along the lake foreshore at Lindell Beach, Snag Point, Spring Hole and Mallard Bay (Forester 1929a) as well as in Sweltzer and Spring creeks (Howard 1948); however, spawning is now primarily confined to the lake foreshore at Lindell Beach (Fig. 2). While lake-spawning is common among sockeye populations, few stocks other than Cultus depend almost exclusively on this strategy. Lake spawning occurs at a depth of 0.5 to 6 m in discrete locations along the foreshore. Brannon (1967) describes the spawning area as weathered shale alluvial materials that extend 60 m from shore before dropping into deep water. Groundwater percolates through much of the spawning area at a constant year-round temperature of 8°C, with poorer percolation in the peripheral areas that reduces oxygen availability and temperatures. Since 1995, spawners may have shifted to other unknown areas; none have been observed at Lindell Beach.

Fry emerge from the gravel over a protracted period between April and July, the duration of which reflects the variation in incubation environments as well as the lengthy spawning period (Brannon 1967). The fry school and move offshore into deeper water immediately after emergence, an atypical behaviour for Fraser sockeye that Brannon speculates is an adaptation to the dense predator populations in Cultus Lake. Newly emergent fry move into deeper water as early as April; most of the population is well off-shore by early May (Mueller and Enzenhofer 1991). From June to November, sockeye fry are distributed throughout the limnetic zone. When the lake is thermally stratified, the night-time distribution of sockeye is generally just below the thermocline in a layer 5-10 m deep. As the thermocline weakens in the fall, the fry layer becomes wider and somewhat deeper. During the day, fry are presumably on the bottom because daytime acoustic transects detect very few fry-size targets in the water column. The fry rear in the lake for up to two years, although most migrate to sea as smolts after one year. A small proportion of the fry may residualize in the lake (Ricker 1938c, 1959). This life history pattern, however, has not been reported since it was first observed by Ricker. The smolt migration begins in late March and continues into June. Fraser sockeye smolts move quickly through the estuary and into the Strait of Georgia in April and May (Healey 1980). They migrate northward through Johnstone Strait by July, then northwest along the coast and offshore into the Gulf of Alaska where they rear with other sockeye stocks for about two years.

Cultus sockeye mature primarily as four year olds, although small proportions also mature after one winter at sea as three-year-old jacks or three winters at sea as five-year-old adults. Maturing sockeye migrate from the north Pacific Ocean during the summer, making their landfall along a broad section of the coast before entering the Strait of Georgia in August through either Johnstone or Juan de Fuca straits. The proportion that migrate through the northern approach (termed a *northern diversion*) varies from year to year, with higher diversions through Johnstone Strait during *El Nino* years when warmer sea surface temperatures extend north into coastal B.C. They normally remain in the Strait of Georgia in the vicinity of the Fraser River for up to eight weeks before resuming their migration into the river. The delay in the Strait of Georgia is not typical of stocks in other timing groups or river systems and is poorly understood. In recent years, the delay has become progressively shorter, resulting in the arrival of spawners at Cultus Lake as early as mid-August.

1.3. CULTUS SOCKEYE GENETICS

The genetic structure of North American sockeye populations is determined both by their ancestral origin during the last glaciation and by the nursery lake in which the juveniles rear (Wood 1995). Sockeye stocks up and downstream of the Fraser Canyon are genetically distinct based on mitochondrial, allozyme and microsatellite data (Wood *et al.* 1994; Bickham *et al.* 1995; Withler *et al.* 2000). A comparison of genetic differentiation with geographic distance shows that genetic and geographic distances are not related (Withler *et al.* 2000). Rather, differences reflect an independent post-glacial colonization of the lower Fraser from the Bering refuge and of the upper Fraser from the Columbia refuge (Wood *et al.* 1994). Specific studies on population structure derived from the *DAB-*β*1* MHC locus (Miller *et al.* 2001) and six microsatellites among 30 populations (Withler *et al.* 2000) shows significant differentiation among lower Fraser populations, with Cultus the most distinctive. The population most similar to Cultus sockeye is the Chilliwack, which is located in the same tributary system but is isolated from Cultus by distinctly different breeding seasons.

In common with most other Fraser sockeye nursery lakes, there were several transplants early in the twentieth century of other sockeye populations into Cultus Lake (Aro 1979). Several million Birkenhead fry were released in 1920-1922, and similar numbers of Harrison and Pitt fry may have been released in 1915. The Cultus population, however, shows no evidence of genetic introgression with Birkenhead, Harrison or Pitt sockeye (R. Withler, DFO, Pacific Biological Station, pers. comm.). These transplant attempts apparently failed. By contrast, two other transplants in the Fraser system, of multiple sockeye stocks to Upper Adams River and Fennell Creek, resulted in genetic similarities at microsatellite loci between the host and introduced populations (Withler et al. 2000). Consequently, if the Cultus transplants had been successful, it likely would have been revealed in the microsatellite analyses.

Additional genetic loci (14 microsatellite loci and one major histocompatibility complex locus, MHC) and an extended range of baseline populations (13,000 samples from 46 populations) recently have been analyzed. Genetic differentiation (reproductive isolation) has been quantified using the co-ancestry coefficient, F_{ST}[1], calculated using GDA software (Lewis and Zaykin 2001). F_{ST} statistics at the microsatellite loci are generally above 0.10 for most comparisons with Cultus (range: 0.094 (Chilliwack) to 0.191 (Cayenne)) (Table 2), a value that would be expected for pairs of populations exchanging no more than three effective spawners per generation. This indicates a significant level of genetic differentiation between Cultus and all other populations, including Chilliwack. Differentiation is even more marked at the single MHC locus, with most F_{ST} values greater than 0.20 (range: 0.006 (Pitt) to 0.646 (Kynoch)). This shows that Cultus is genetically distinct both at neutral loci such as microsatellites and at a locus under selection such as MHC, and confirms the results from previous allozyme loci and mitochondrial DNA analyses. Cultus sockeye, therefore, constitute a genetically very distinct and unique population in British Columbia.

Cultus sockeye exhibit unique adaptations for their local environment: a) on their spawning migration, Cultus sockeye delay in the Fraser estuary for up to eight weeks before resuming their migration into the river, a behaviour that is unique to the stocks that comprise the Fraser late run sockeye group. This delay reduces exposure to adverse freshwater environments but permits breeding when environmental conditions optimize egg, alevin and fry survivals; b) Cultus adults remain in the lake for as long as three months before breeding, holding in local environments that are much cooler than those along the freshwater migratory pathway; c) breeding occurs over two months and extends beyond the normal range for other populations. Brannon (1967) hypothesizes that the protracted spawning period is an adaptation of populations in ecosystems with highly variable spring weather and constant-temperature incubation environments. Under these conditions, variation in emergence timing are related primarily to the time of egg deposition (although Cultus incubation times are progressively shorter for later spawners thereby compressing the fry emergence period), providing little ability to compensate for environmental variability. Different parts of the emergence curve are favoured sufficiently often to sustain their associated spawning times; and d) the fry school and move offshore into deeper water immediately after emergence, an atypical behaviour for Fraser sockeye that is likely an adaptation to the dense lake predator populations (Brannon 1967).

1.4. ENHANCEMENT

1.4.1. Hatchery

Cultus sockeye have been used for a variety of experimental and augmentation purposes since the first Cultus hatchery was constructed in 1916. From 1918 to 1924, an annual average of 4.7 million eggs (range 1.2 to 10.5 million) were taken by the hatchery for subsequent planting as eyed eggs, release as free-swimming fry (Foerster 1968) or transplant to other rivers (Foerster 1946). Few outside stocks were transplanted into Cultus, with the exception of Harrison and upper Pitt fry that may have been released into the lake in 1915 and 1920, and Birkenhead fry that were released in 1921 and 1922 (Aro 1979). In 1925, the Biological Board of Canada began an evaluation of the effectiveness of these enhancement techniques. An experiment was designed on a system-wide scale to evaluate: natural production (1930, 1934) by counting all spawners at the weir and allowing them to spawn naturally in the lake and tributaries; fry releases (1926, 1929, 1932) by intercepting all spawners below the weir, stripping the eggs and releasing the subsequent fry into the lake; and eyed egg plants (1928, 1933) by similarly intercepting all spawners and planting the eggs in streams tributary to the lake. The three treatments were evaluated by enumerating the subsequent smolts and comparing egg-to-smolt survivals among methods. The experiment was originally planned to alternate treatments over 12 years to enable the testing of each method once per cycle. Ultimately, the tests did not proceed on the dominant 1927-cycle because abundances exceeded the capacity of the hatchery. The study terminated in 1934 because no difference

[1] F_{ST}, calculated from a correlation of genes across individuals within and among populations, indicates the degree of reproductive isolation of a population. The higher the F_{ST} value (maximum 1), the more closely individuals are related to each other within a population and the less to individuals in other populations.

was noted in egg-to-smolt survival, in part reflecting the over-riding impact of the lake's large predator populations as well as significant egg losses associated with hatchery procedures (Forester 1968). We conclude, therefore, that although the 1925-1933 interventions were on a large scale, they were unlikely to have impacted the apparent production dynamics of the stock. In subsequent years, hatchery interventions focused on the removal for experimentation of small numbers of adults (<5%) that were unlikely to have impacted stock production dynamics. The lake has also received transpants of other species; in various years from 1919-1987, it was stocked with 190,000 cutthroat, 850,000 rainbow and 78,000 steelhead. In 1934, 64,000 marked kokanee yearlings were released into Sweltzer Creek to determine whether they would adopt an anadromous life-cycle; 0.14% returned as adults in 1937 (Foerster 1947). And, curiously, 400,000 lake whitefish were transplanted into Cultus Lake from Ontario in 1920.

1.4.2. Predator Control

Potential predators of Cultus sockeye include salmonids such as coho, trout and kokanee, as well as Dolly Varden char, northern pikeminnow and sculpins (Ricker 1941). Northern pikeminnow, while not the most voracious predator in the lake, can have a substantial impact on sockeye due to their high numbers. The control of such predators is recognized as a method to increase the survival of juvenile salmonids. For example, the reduction of northern pikeminnow populations in the lower Columbia and Snake rivers by 25% (through a reward program) increased salmonid survival by 23% (Firesen and Ward 1999). Similarly, the reduction in northern pikeminnow populations in northern Idaho lakes by 90% contributed to doubling an index of kokanee and rainbow trout abundance (Jeppson and Platts 1959).

The first predator control project in Cultus was conducted in the 1930's after Foerster (1938) documented high freshwater mortality among sockeye juveniles and Ricker (1933) demonstrated that predation by piscivorous fish was an important causal factor. A predator removal project was conducted in 1935-1938, when almost 39,000 fish, 29,500 of which were northern pikeminnow, were removed using a variety of gear that included bottom-set and floating gillnets, seines, bait lines and cage traps; the IPSFC continued the work until 1942, removing an additional 19,000 fish (Table 3) (Foerster and Ricker 1953b). Removal efficiency was evaluated from annual catchability indices, as well as partial mark-recapture estimates of the pikeminnow population in 1935 and 1938. Foerster and Ricker (1941) reported a 90% reduction in the char and large pikeminnow (> 200 mm) populations from 1935 to 1938, a subsequent three-fold increase in sockeye freshwater survival (from 3.1% to 10.0%) and an increase in sockeye smolt size. Foerster and Ricker (1953b) reported a large decline in pikeminnow abundance from 1935 to 1937, little change in 1938-1939, a sharp increase back to the original 1935 level by the end of 1941 followed by a decrease in 1942. They hypothesized a close relationship between pikeminnow abundance and sockeye fry survival. In a review of the project, however, Ward (1953) noted a failure to investigate ecosystem linkages and questioned the sustainability of benefits to sockeye. Based on these assessments, we conclude that predator removal increased freshwater and possibly marine survivals for the 1934-1938 brood years, but likely not for the 1939-1941 broods. These projects, therefore, would introduce a small positive bias in any assessment of stock productivity spanning those years.

The second predator control and population estimation project was conducted in 1990-1992 (Levy 1990a; Hall 1992). Over 11,000 pikeminnow, an estimated 24% of the vulnerable population, were removed using purse seines, trap nets, beach seines and gill nets. Because the duration of the project was short and the magnitude of the reduction in population size was small relative to the earlier project, we conclude that it was unlikely to have an impact on the apparent production dynamics of the stock.

1.4.3. Captive Broodstock

In 2000-2001, efforts to enhance Cultus sockeye were implemented in an *ad hoc* response to the collapse in escapements and spawning success. Spawners were removed from the fence and held at the Cultus Lake Laboratory; 7,000 and 25,000 eggs were fertilized in 2000 and 2001, respectively (see *Enhancement Work Group* report). Due to genetic concerns, the 2000 brood smolts (3,800) were released in the spring of 2002 and replaced with 2,000 wild smolts for rearing as captive brood stock. Of the 2001 brood, 17,000 fry survived; the disposition of those fish will be determined at a later date. The scope and success of these enhancement efforts should be evaluated when interpreting future returns modelled for this stock.

1.5. FISHERIES MANAGEMENT

1.5.1 Management Process

Fraser River sockeye have been managed in an intensive, integrated international and domestic system for over half a century. In the area specified under treaty with the United States (US) (termed the *Convention Area* until 1984 and the *Panel Area* since 1985, roughly encompassing Juan de Fuca Strait, southern Strait of Georgia, south-west coast of Vancouver Island), sockeye have been managed bilaterally by the IPSFC in 1946-1984 and by the Pacific Salmon Commission (PSC) since 1985. In other areas, they are managed domestically by Canada or the US. The PSC's Fraser River Panel uses pre-season forecasts and in-season data acquisition programs to actively regulate the fisheries (Woodey (1987); PSC (2001)). The Panel and domestic regulatory bodies meet in-season to evaluate run size and escapement data and to determine commercial fishing regulations.

Fishing plans are established for each of the four run groups by considering the escapement goals, pre-season forecasts, and constraints such as by-catch of other species or stocks of concern. Historically, within each group the larger stocks were actively managed, the smaller stocks ignored. Because the Cultus population is small relative to co-migrating stocks such as Adams and Weaver, it has not been managed as a discrete stock throughout the history of the Fraser River sockeye fishery. On the 1998 and 1999 cycles, the late run fisheries are actively managed to achieve gross escapement and catch objectives for the dominant and sub-dominant Adams stock group; on the 2000 and 2001 cycles, they are managed to achieve similar objectives for Weaver sockeye, especially since 1969 with the first returns of enhanced sockeye to the spawning channel. In addition, earlier marine area fisheries directed at the summer run also harvest late run sockeye. The cumulative impacts of the directed harvest of the numerically dominant summer and late run stocks determine the harvest and exploitation rate patterns of Cultus sockeye.

From 1987 to 1999, DFO developed and refined a plan to increase Fraser River sockeye production that in part entailed the implementation in the 1990's of a reduction in average exploitation rates from 75-85% to 65-70%. Escapement targets were set through fixed harvest rate and fixed escapement policies to meet general rebuilding objectives, with the maximum exploitation rate of 65-70% intended to allow escapements to increase in future years. The anticipated effect on passively managed late run stocks such as Cultus was to limit the overall exploitation rate by capping exploitation rates in by-catch fisheries, whether directed at summer run or late run target stocks or stock aggregates.

In 2001, it was recognized that high mortalities associated with the early upstream migration of late run sockeye posed a conservation risk under existing harvest policies; the Fraser Panel reached a bilateral agreement to limit the exploitation rate on late run sockeye, excluding Birkenhead, to a maximum of 17%. Further to the agreement was the provision that Canadian and US fishers were not to exceed a 60% harvest rate on summer run sockeye. In 2002, bilateral agreement has been reached to limit the total fishery exploitation rate of late run sockeye, excluding Birkenhead, to a ceiling of 15%. The harvest of late run sockeye will be limited to incidental by-catch in fisheries directed at co-migrating summer run stocks.

1.5.2 Fisheries

Fraser River sockeye can be harvested along the full extent of their spawning migration pathway, from the point of landfall along the coast until their entry onto the spawning grounds in B.C.'s interior. The majority of the harvest is taken in large mixed-stock ocean fisheries, although a significant proportion can be taken in the Fraser River fisheries. The major Canadian fisheries are (Fig. 3):

- <u>North Coast</u>: The north coast fisheries can be significant harvesters of Fraser sockeye when oceanographic conditions cause a more northerly landfall and the use of the north approach to the Strait of Georgia. Most of the catch is taken in Area A purse seine and Area F troll fisheries off the west coast of the Queen Charlotte Islands; however, Fraser sockeye have not been harvested in these fisheries since 1998 due to recent fishery restrictions;

- West Coast Vancouver Island: The Area G troll fishery off the west coast of Vancouver Island was, until recently, the first major fishery to harvest Fraser sockeye south of Cape Caution. This fishery was particularly effective on dominant and subdominant Adams, but also successfully harvested summer run and other late run stocks. It has been severely restricted since 1994 to protect coho along the west coast of Vancouver Island (areas 121 to 127);
- Johnstone Strait: Fraser River sockeye migrating through Johnstone Strait have been subjected to intensive fisheries in many years. Most of the sockeye catch is taken by the Area B purse seine fleet, although Area D gillnet and Area G and Area H troll fisheries also operate in the area and are capable of significant harvests;
- Juan de Fuca Strait: Historically, large Area B purse seine and Area E gillnet fisheries harvested significant numbers of Fraser sockeye in Juan de Fuca Strait (Area 20). Since 1994, the Area B purse seine fishery has been severely restricted and the Area E gillnet fishery has been closed to protect coho stocks present in the area;
- Strait of Georgia and Fraser River: These fisheries include an Area H troll fishery in the Strait of Georgia, small Area B purse seine and Area E gillnet fisheries in Sabine Channel, and an Area E gillnet fishery that operates in the lower Fraser River and in the Strait of Georgia. The catches in these fisheries tend to be small, with the exception of the in-river Area E gillnet fishery that can harvest large numbers of sockeye;
- First Nations: The majority of the First Nations catch of Fraser sockeye occurs in set and drifted gill net fisheries occurring throughout the Fraser but especially in the lower river. Smaller but significant catches are also taken in seine and gillnet fisheries conducted under special licence in marine waters;
- Recreational: Relatively small sockeye-directed recreational fisheries occur in the southern Strait of Georgia, Juan de Fuca and Johnstone straits, and in the lower Fraser River. Other fisheries in Fraser River tributaries such as the Vedder-Chilliwack have low sockeye encounter rates and are required to release sockeye;
- Test Fisheries and Charter Fisheries: Various low impact test fisheries and research charter fisheries are conducted throughout the migration path of Fraser River sockeye for assessment purposes.

The major US fisheries are:

- Juan de Fuca Strait: Small scale drifted gillnet fisheries are conducted by US Treaty Indians along the inside coast of Washington and in Juan de Fuca Strait;
- Puget Sound: Fisheries are conducted by both Treaty Indian and non-Indian fishers in waters bounded by Juan de Fuca and Haro straits and the Strait of Georgia. Treaty Indians use purse seines and gillnets; non-Indian fishers use purse seines, gillnets and reef nets. Historically, these fisheries harvested large numbers of Fraser River sockeye (up to 50% of the total allowable convention area catch). Since 1985, they have been curtailed under the terms of the Pacific Salmon Treaty. In 2001, the Juan de Fuca Strait and Puget Sound fisheries were restricted to 16.5% of the total allowable catch of Fraser River sockeye;
- Ceremonial and Subsistence Fisheries: Small catches of Fraser River sockeye are taken for ceremonial and subsistence purposes in United States Treaty Indian fisheries.

2.0. DATA SOURCES

The PSC maintains a stock-specific production database that compiles biological information for Fraser River sockeye, including escapement, catch, age composition, fecundity, fry and smolt estimates, circuli counts and other data. It is used as a common data source in this report; the sources of the information compiled in the database are described below.

2.1. ESCAPEMENT

Cultus Lake was selected as an experimental system in the 1920's because its size is convenient for complete biological study, it is accessible by road year-round, it does not freeze during the winter and it is drained by a small creek not prone to freshet that can be completely fenced (Foerster 1929a). Fences for the enumeration of returning spawners have operated every year since 1925; consequently, the time series of accurate escapement data is among the longest in the region. The fence, located in Sweltzer Creek approximately 200 m downstream from the lake outlet, is installed at the start of the migration (normally mid/late September) and removed at its completion in early/mid December. Total counts are available for every year; daily counts are available since 1941. Since 1996, the fence has been installed progressively earlier to adjust for the recent abnormally early migrations.

Migrants are counted through the fence several times each 24-hour period, especially from 6-9 a.m. when the migration is heaviest. The frequency of the counts is determined by the magnitude of the daily migration; the fence is closed to migration between counts. All migrants are counted and recorded by species. For sockeye, jacks and adults are recorded separately based on a visual inspection of morphological characteristics and body size. Visual estimates are unable to discriminate between small adults and large jacks; consequently, errors are likely. Because sex identification based on visual observation is prone to error, after 1993 the adult count has been apportioned to sex based on the sex ratio in the carcass recovery sample.

Biological information is obtained from carcasses recovered at the fence and on the spawning grounds. Historically, weekly spawning ground surveys were conducted on foot along Lindell Beach from mid-October to mid-December. The extent and frequency of the surveys declined in the 1980's and early 1990's; most recoveries were obtained from the fence. Since 1999, weekly surveys were re-implemented over an expanded period from early September to mid-December; they are augmented by boat surveys of non-traditional spawning areas when operationally possible. During each survey, all recovered sockeye carcasses are incised to confirm sex and spawning success (recorded as 0%, 50% and 100%). Up to 120 males and 120 females and all jacks are sampled for scales, otoliths, and postorbital-hypural plate and standard lengths. In recent years, low escapements and recovery rates have resulted in small sample sizes and, on occasion, the failure to recovery any female carcasses. The sex ratio from the samples is applied to the adult fence count to estimate the escapement by sex. Females were also sampled for fecundity from 1925 to 1944, but fecundity has not been recorded since 1944.

2.2. FRY ABUNDANCE

The Cultus Lake Laboratory houses the Department's lake assessment group; consequently, the lake's limnetic fish community has been studied extensively on an opportunistic basis during trawl and hydro-acoustic surveys conducted to test equipment or as part of other studies.

Mid-water trawl surveys have been conducted in various months from 1975 to 2001. We report on surveys conducted in late fall (October 15 to November 30) when the fish are near the end of their growing season. The lake is divided into two sections with the boundary approximately at the midpoint of its long axis; there are three evenly spaced transects in the southern section and four in the northern section. All surveys are nocturnal when fish are dispersed near the thermocline and within the working range of the trawl and hydroacoustic systems (McDonald and Hume 1984; Burczynski and Johnson 1986; Levy 1990b). Mid-water fish are collected with a 3 x 7 m trawl to determine species and age composition (Enzenhofer and Hume 1989). Trawling depth (0-40 m), duration (1-45 minutes) and location depend on fish targets observed on the chart recorder. In most years, captured fish are killed using an overdose of anaesthetic and preserved in 10% formalin for at least one month before lengths and weights are recorded. Sockeye age composition is determined from scales and length-frequency analysis. In the 1990's, species, age and target strength were used to apportion the fish density for each transect.

Hydro-acoustic surveys have been conducted from 1977 to 2001 using various techniques at different times of the year. From 1977 to 1983, data were collected using a Simrad EY-M echo-sounder with a 70-kHz transducer producing an 11° beam (at –3dB) and recorded for later processing; data were analyzed using a modified duration in-beam technique (Thorne 1988). Since 1985, data have been collected with a Biosonics 105 dual beam echosounding system with a 420-kHz dual beam (6°/15°) transducer and are digitally recorded and later processed as described by Burczynski and Johnson (1986). The two types of equipment produce estimates that differ by only 4% (Unpublished DFO data); however, we report only on estimates that correspond to the fall trawl samples, all of which were produced using Biosonics gear.

In each section, transect data are averaged to estimate the section's mean density. Section population estimates are the product of the mean density and the surface area; section estimates are summed to estimate the total lake population. Mean lake density is the ratio of the lake population estimate and the total surface area. Variances (reported as 95% confidence limits) are calculated for the density of each section, then weighted by the square of the section area. The variance of the lake population estimate is the sum of the weighted variances divided by the square of the lake area.

2.3. SMOLT ABUNDANCE

The sockeye smolt emigration from Cultus Lake was first assessed in 1926, perhaps the first such assessment for a wild salmon stock (Foerster 1929c). Fences, installed at the Cultus Lake outlet for the enumeration of emigrant smolts, were operated from 1926 to 1945 and sporadically from 1953 to 1978; more recent assessments have been conducted in 1990-1992 and 2001-2002.

The fence and trap are installed at the onset of the migration in mid-March to early April and operate until its completion in late May to mid-June. They operate continuously during the emigration and are inspected regularly during each 24-hour period. Each day, smolts are removed from the live box, identified to species, counted and released below the fence; a portion of the smolts is systematically sampled for lengths and weights. In most years, scales are taken to estimate age composition; in some years, however, age composition is estimated from length-frequency distributions rather than scale samples. Typically, age-2 smolts comprise about 1% of the run.

2.4. FISHERIES

2.4.1 Catch

The in-season management of Fraser River sockeye utilizes information on daily catch by gear and area for Canadian and US fisheries. These data are collected from commercial and non-commercial fisheries from Alaska to Washington, with most of the harvest occurring south of Cape Caution in Panel Area and Canadian non-Panel Area fisheries (Fig. 3).

Commercial fisheries account for the majority of Fraser sockeye catches. Catches in Canadian and US purse seine, gill net, troll and reef net fisheries are estimated during and immediately after each opening. In the Panel Area, PSC staff estimate catch within 24 hours of the completion of a fishery from catch and CPUE data obtained from telephone surveys of major fish buyers in both countries and from gear counts provided by each country. These estimates are updated as landings are confirmed by follow-up surveys of all licensed fish processors. In Canadian non-Panel south coast waters, DFO staff use a combination of on-ground hail data and gear counts to provide estimates of catch during and immediately after the close of commercial openings, with updates provided as landings are confirmed. Catch estimates are updated from post-season fish tickets (US) and dock tallies and sales slips (Canada). Final estimates are reported to the agencies by landed weight, thereby necessitating the collection of weekly average weights by user group to transform the data from fish tickets and sales slips into numerical catch estimates. Commercial catch estimates are subject to underestimation bias due to unreported catch from fisher take-home and unreported sales; however, the bias is likely very small relative to the total annual catch of Fraser and Cultus sockeye.

Non-commercial fisheries directed at Fraser sockeye include marine and in-river Canadian First Nations fisheries, US ceremonial Tribal fisheries, marine and in-river recreational fisheries, and charter or selective fisheries. These fisheries are monitored by the agencies; catch estimates are provided to the Panel in a timely fashion. First Nations fisheries in the lower Fraser River are assessed either by a mandatory landing program or an intensive access point-overflight study (*e.g.,* Alexander 2001). The lower Fraser recreational fishery is typically a sockeye non-retention fishery except for short periods during the summer run; encounter rates on the late run (August and September) are typically low (Schubert 1992; unpublished DFO data). Similarly, the recreational fishery in the Vedder-Chilliwack River, while intensive, is a sockeye non-retention fishery with low encounter rates (only 11 were encountered in 2001; unpublished DFO data).

2.4.2 Stock Composition

The PSC uses scale pattern analysis to separate mixed stock fishery catches into stock groups (*e.g.,* late run). Since 1948, three methods have been used to assign mixed stock fishery catches to component stocks: manual triangulation, final 3-variable discriminant function analysis (DFA), and preliminary 3-variable DFA.

The manual triangulation technique, described by Henry (1961), was used by the IPSFC for the 1948-1975 brood years. It is a univariate technique that compares circuli frequencies among baseline stocks with those sampled in mixed stock fisheries by superimposing baseline plots over the mixed stock patterns. The method is limited when more than four or five stock groups are present; consequently, in complex mixed stock fisheries it requires the grouping of similar stocks and the use of timing data to estimate stocks present in low proportions. While stocks present in large proportions can be adequately assessed using this method, minor stock groups are prone to overestimation bias. As a result, estimates of Cultus sockeye through 1975 are less reliable than those since 1976, when the more accurate multivariate DFA technique was introduced. Assumptions related to stock group weighting, and the availability and vulnerability of stocks outlined in the next paragraph also apply here.

The final 3-variable linear DFA technique, described by Gable and Cox-Rogers (1993), was used by the PSC for the 1976-1991 brood years. Baseline standards for dominant age classes, obtained from within year spawning ground scale samples, are used to assign stock proportions to mixed stock fishery catches. A general trend with DFA and maximum likelihood techniques is for large point-estimate biases when stocks with similar scale measurements differ greatly in abundance; stocks present in low proportions tend to be overestimated. Point estimate bias is controlled by grouping stocks with similar scale patterns and timing, and by using a bias correction procedure (Cook and Lord 1978). To further control bias in post-season racial analyses, stock groups expected to comprise less than 5% of the mixture (stocks at the tails of their migrational distribution or minor stocks excluded from pooled groups) are excluded from the DFA models. For these stocks, catch is reconstructed from timing and abundance in the escapement and First Nations catch. While precision can be an issue in stock estimates from individual samples, bias in the component of the annual production estimates associated with catch is minimized through the techniques outlined above. In addition to the assumptions common to DFA applications, the following also apply to estimates for individual stocks: a) the weighting of single stocks within the stock group are accurate (spawning ground escapements and First Nations catch estimates are accurate); b) the vulnerability of all stocks in the group are equal; and c) the timing and terminal abundance of small stocks are accurately estimated.

The preliminary 3-variable DFA technique was used by the PSC for the 1992-1997 brood years. Production estimates for these years will be reassessed in the future using the final 3-variable linear DFA technique. In general, the assumptions outlined for the final DFA apply; however, the tailing procedure to minimize small stock bias is not used. Consequently, there is an increased probability of positive bias in stock groups present in small proportions. For Cultus sockeye, this bias is mitigated by the accuracy of the fence counts, low exploitation in First Nations fisheries, and low commercial exploitation rates in recent years; stock-specific catch estimation errors in recent years should be small.

2.5. AGE COMPOSITION

The age notation used in this report specifies total age as a full case numeral and freshwater age as a subscript, *e.g.* 4_2 denotes a four-year-old that migrated to sea in its second year. Scales can be used to determine the age of a fish when collected from marine waters or after only short freshwater migrations. Age is estimated by counting the number of annuli, *i.e.,* zones of crowded, thin or incomplete circuli that indicate a sudden decrease in growth associate with winter (Clutter and Whitesel 1956).

Scale samples are collected from commercial, test and other fisheries and are shipped to the PSC office for analysis. The scale samples provide information on stock composition by age class for use in the in-season management by the Fraser River Panel. Daily samples are obtained from up to six commercial and test fisheries through the period of active in-season management. Application of age composition estimates to the daily catch estimates by area and to daily gross escapement estimates generate estimates of stock production by age class.

As sockeye migrate upstream to their natal streams their scales reabsorb, beginning with the marine growth zone, and cannot be used for age determination. Instead, age is estimated from otoliths, a bony structure not affected by resorption. Each year, DFO collects otoliths and matching scale, sex and length data from over 30 Fraser River sockeye stocks for use by the PSC in stock identification and age determination.

2.6. TOTAL RETURN

Total return is estimated from the escapement, measured at the Sweltzer Creek fence using the methods described in Section 2.1, and the catch in mixed stock marine and river fisheries estimated using the methods described in Section 2.4.2. Both catch and escapement are allocated to the appropriate brood years using the ageing methods described in Section 2.5. Escapements are assumed to have been counted at the fence without significant measurement error. Possible mortality associated with the early migration of late run stocks that may occur along the migratory route prior to arrival at the fence is not included in the total return. While other late run stocks are known to die along the migratory route, Cultus sockeye are more likely to die while holding in the lake after migrating past the Sweltzer Creek fence because the short distance from the estuary limits the duration of the riverine migration (mortality is likely associated with an atypically long period in freshwater). This assumption is supported by a failure to observe sockeye carcasses in the Vedder or Chilliwack rivers or Sweltzer Creek in most years. The only exception is 1999, when anglers reported a small number of carcasses in the Vedder River In August and September, and sockeye were observed holding in the Vedder River in December.

2.7. MARINE DISTRIBUTION AND TIMING

Migration patterns of Fraser River sockeye are inferred from catch and stock identification data collected over the past half century (Gilhousen 1960; Henry 1961), with independent confirmation of general timing and migratory pathways from early tagging studies reported by Foerster (1936b) and Verhoeven and Davidoff (1962). Because the Cultus is a small stock, the tagging studies provide the most reliable distribution and timing information.

Verhoeven and Davidoff (1962), in an analysis of marine tagging experiments conducted in 1938-1948, reported that Cultus sockeye migrated past Sooke in late August but could not identify the duration or peak of the run because few tags were recovered at the fence. More definitive data are available from a smolt fin clip study of Cultus sockeye conducted in 1930, 1932 and 1933 (Foerster 1936b) and in 1938 (Table 4). Cultus sockeye were present in Johnstone Strait from mid-July to early September, at Sooke in Juan de Fuca Strait from mid-July to the end of September (mid-August to early September peak), at Salmon Banks in Puget Sound from mid-July to early October (mid/late August peak) and at Point Roberts in Puget Sound from mid-July to mid-October (mid-August to early September peak).

2.8. FORECASTS

Population size is forecast for most Fraser sockeye stocks as part of the preseason fishery management process. The forecasts use escapement estimates to predict adult abundance using techniques that include Ricker, non-linear (power), geometric mean return-per-spawner, juvenile and sibling models (*e.g.,* Cass 2000, 2001). The Cultus forecasts did not consider recent declines in spawning success or potential unaccounted *en route* mortalities; consequently, they are not used in this report. Instead, we report model results that use similar input data under a variety of assumptions regarding PSM and exploitation rate.

2.9. TRADITIONAL KNOWLEDGE

First Nations peoples have occupied the Fraser Valley for several thousand years. Their traditions include an integral connection to the salmon that spawn and pass through their territories. Their experience and knowledge is passed to future generations in stories and ceremonies that relate and record the world around them, including the experience of the salmon people. The elders are keepers of this knowledge.

Traditional knowledge is important to our understanding of the Cultus sockeye stock. Of particular utility is information related to the timing and abundance of Cultus sockeye both for the period that fence data exist and before. In addition, any stories of large-scale mortality may be useful to place the current situation in a long-term perspective. The Soowahlie First Nation has been asked to share their traditional knowledge, stories and experiences on Cultus sockeye. If the elders agree, this information should be collected and documented through an interview process. The results of these interviews should then be related to the other information sources related to timing, abundance and early migration or high mortality.

3.0. ANALYTIC METHODS

3.1. SURVIVAL

3.1.1. Freshwater Survival Index

The freshwater survival index relates smolt production to the total adult escapement; egg-to-smolt survival was not used because spawning success and fecundity were not assessed consistently over the period of record. The index for each brood year, expressed as smolts per adult spawner, is the sum of the age-1 smolts in year *n+2* and the age-2 smolts in year *n+3,* divided by the adult escapement in year *n*. Age-2 smolt estimates were not available for eight broods; however, this has little effect on the index in these years as the age-2 proportion of the smolt population is small (1% average).

3.1.2. Marine Survival

The marine survival rate relates annual age-1 smolt production to subsequent returns of ages 4_2 and 5_2 adults in the catch and escapement. Survival for brood year *n*, expressed as a percentage, is the sum of age-4_2 adults in the catch and escapement in year *n+4* plus age-5_2 adults in the catch and escapement in year *n+5*, divided by the age-1 smolt production in year *n+2*.

3.1.3. Total Survival Index

The total survival index relates adult brood year escapement to subsequent total returns in the catch and escapement. The index for brood year *n*, expressed as return per spawner (R/S), is the sum in the catch and escapement of age-3_2 jacks in year *n+3* plus ages 4_2 and 4_3 adults in year *n+4* plus ages 5_2 and 5_3 in year *n+5*, divided by the adult escapement in year *n*.

3.2. TOTAL RETURN

The calculation of both cohort recruitment and total annual adult return requires the apportioning of mixed stock catches into stock groups using stock composition estimation procedures described in Section 2.4.2. The analytic procedures are: a) Cultus sockeye are grouped with other late run sockeye stocks that have similar scale patterns based on base-line standards derived from within year spawning ground scale samples; b) the annual group catch, estimated for each mixed stock fishery that encounters Fraser sockeye, is the sum of the group catch across all weeks and fisheries for the entire season; and c) catches of individual stocks within the group are estimated using a ratio of the gross escapement of the individual stock (Cultus) to the total gross escapement for the group (Cultus plus all other late run stock in the pooled stock group).

This method minimizes overestimation bias associated with stocks present in small proportions in mixed stock fisheries The accuracy and precision of the catch by stock estimates is dependent on: the performance of the DFA models in individual return years; the assumptions associated with the correct use of multivariate DFA being met; the accuracy of the gross escapement ratio estimator; and the accuracy of the assumptions of equal vulnerability of each stock in the pooled group being achieved.

The manual triangulation technique was used to discriminate the 1948-1975 brood Cultus sockeye in mixed stock fisheries (Section 2.4.2). A 1981 analysis identified an erroneous assumption regarding the upstream migration timing of a subset of late run stocks that caused an over-assignment of catch to Cultus sockeye in September and October and an overestimate of their terminal abundance (J. Woodey, *pers. comm.*). This error, affecting brood years 1948-1972, was compounded in marine area catches that were estimated from terminal area stock composition estimates. The production database has been adjusted to correct the errors in the estimates of total annual catch of Cultus sockeye; however, similar corrections have not been made to address the errors in fishery-specific catches. Consequently, our evaluations of catch, total return, survival and exploitation rate use the entire time series in the production database, while our evaluation of fishery-specific catch is restricted to 1974-2001.

3.2.1. Cohort Recruitment

Cohort recruitment, the total return (escapement and catch in all fisheries) summed across all years from a single annual escapement, is used primarily in productivity assessments (*e.g.,* spawner-recruitment models, survival rates). Recruitment estimates are available for Cultus sockeye since the 1948 brood year. For each brood, total return sums subsequent catch and escapement for that cohort across all years, *i.e.* total return for brood year *n* is the sum of the age-4 adult catch and escapement in year *n+4* and the age-5 catch and escapement in year *n+5*.

3.2.2. Annual Return

Annual return, the total return (escapement and catch in all fisheries) of adults of all age classes in a single year, is used to calculate exploitation rates. Total return estimates are available for Cultus sockeye since 1952. For each year, total return sums adult catch and adult escapement in that year.

3.3. EXPLOITATION RATE

Exploitation rate (ER) is the fraction of the total adult return (catch plus escapement) that is caught in all fisheries, including First Nation, commercial and recreational fisheries in marine areas and in the Fraser River. Annual ER, calculated by return year, is the ratio of the catch in all fisheries and the sum of the escapement measured at the Sweltzer Creek fence plus the catch in all fisheries. We report ER's for 1952 to 2001; in prior years, techniques were not yet developed to permit the estimation of stock-specific catch and total return. Since the onset of the early migration of Cultus sockeye, we assume that all associated prespawn mortality occurs in Cultus Lake (see Section 2.6).

3.4. MONTE CARLO SIMULATIONS OF PROJECTED ADULT RETURN

We developed a simulation model to evaluate the potential effects of high prespawn mortality (PSM) and depressed spawner-to-fry survival on subsequent production. A Bayesian stock-recruitment (SR) analysis was used to quantify uncertainties in population dynamics (*e.g.*, productivity, habitat carrying capacity) and simulate future population sizes. The data used in this SR analysis is adult escapement (1948-1997) and age-4 and age-5 recruits (1952-2001). A range of PSM's (40-90%) and ER's (0-50%) were explored to simulate future trajectories of escapement.

3.4.1. The Spawner-Recruitment (SR) Model

The SR relationship is described by a quantitative model of the form:

$$R_t = g(S_t, \theta) \qquad \text{(Equation 3.1)}$$

where recruitment R_t is produced by spawners S_t with suitable parameters θ. The most widely applied model to quantify the population dynamics of Pacific salmon is the two parameter form of the Ricker model (Ricker 1954):

$$g(S_t, \theta) = \alpha S_t e^{-\beta S_t} \qquad \text{(Equation 3.2)}$$

where parameters α and β, respectively, are the recruits-per-spawner (R/S) at low spawning stock size and the density dependent parameter that describes the rate that the R/S decrease as the spawning population S_t increases. The Ricker model is dome-shaped with declining recruitment at higher stock sizes. Mechanisms that can lead to a Ricker-shaped stock-recruitment curve include over-crowding on the spawning sites and density-dependent growth coupled with size-dependent mortality (Hilborn and Walters 1992).

Another classical model used in stock-recruitment analysis is the Beverton-Holt model (Beverton and Holt 1957):

$$g(S_t, \theta) = \frac{\alpha S_t}{\beta + S_t} \qquad \text{(Equation 3.3)}$$

where α is the maximum number of recruits produced and β is the spawning stock that produced on average $\alpha/2$ recruits. Here, recruitment increases asymptotically as stock size increases. Deriso (1980) and Schnute (1985) provide a generalized three-parameter SR model where the third parameter is a shape parameter that determines the form of the model where the Ricker and Beverton-Holt models are special cases. We use a version of the Deriso-Schnute model proposed by Schnute and Kronlund (1996) and reformulated by Schnute *et al.* (2000):

$$g(S_t, \theta) = \frac{S_t}{1-h^*}\left[1 + \gamma h^*\left(1 - \frac{S_t}{S^*}\right)\right]^{1/\gamma} \qquad \text{(Equation 3.4)}$$

where the parameters S^* and h^* represent the spawning stock size and the ER associated with the maximum sustainable yield (MSY), respectively. The third parameter γ defines the curve shape including the classical Ricker (γ=0) and Beverton-Holt (γ=1) models. From Schnute and Kronlund (2002; eq. T1.7), the classical density dependent parameter β is computed as:

$$\beta = \frac{h^*}{(1+\gamma h^*)S^*}. \qquad \text{(Equation 3.5)}$$

The spawning escapement that maximizes recruitment is then

$$\frac{1}{\beta}. \qquad \text{(Equation 3.6)}$$

Published SR analyses show little distinction between the Ricker and Beverton-Holt fits (Hilborn and Walters 1992; Fig. 7-15); consequently, we confine the SR analysis to the Ricker form of Equation 3.4.

Theoretically, substituting effective female spawners for total spawners in the SR relationship reduces both uncertainty in parameter estimates and bias that results from overestimating spawner potential when spawning success is poor. Because small sample sizes prevented the direct estimation of spawning success in many years, we use total adult escapement in this analysis.

3.4.2. Parameter Estimation Methods

Parameter estimation is based on non-linear Bayesian methods using S-PLUS software developed by Schnute *et al.* (2000). Because uncertainty plays a major role in the analysis, the deterministic model

(Equation 3.4) is extended stochastically using a Bayes posterior inference function that captures parameter uncertainty related to inherent noise in the data. The method uses the posterior sampling methods obtained by the Metropolis version of the Markov chain Monte Carlo (MCMC) algorithm (Gelman *et al.* 1995; Chap. 11). The Bayesian approach is favoured over likelihood methods because complex parameter distributions can be readily incorporated into policy evaluation.

The MCMC approach is described in detail by Schnute *et al.* (2000; Appendix B). In summary, it requires a random movement in step sizes proportional to the standard error for each parameter from a current parameter vector θ to a new acceptable point θ' specified by a defined probability of acceptance. An acceptable θ' becomes the next point in the sample sequence. The sampling algorithm is initialized with the modal $\hat{\theta}$ estimate and repeated until the desired sample size from the Bayes posterior distribution is obtained. Each sample parameter vector represents one possible version of the population dynamics.

The population dynamics depend not only on the choice of hypothesis or model but also on the error structure. We adopt a log-normal error model. Under the assumption of independent survival through sequential life history stages, the random variation around a SR curve is expected to be log-normal. Peterman (1981) could not reject the assumption of log-normality for Skeena sockeye and it appears that lognormal distributions are found in many SR data sets (Hilborn and Walters 1992). The residuals η_t from the fitted curve are defined as:

$$\eta_t(\theta) = \sum_{t=1}^{N} \left[\log R_t - \log g(S_t, \theta) \right], \qquad \text{(Equation 3.7)}$$

where N is the number of (R_t, S_t) data points.

The residual sum of squares Q is:

$$Q(\theta) = \sum_{t=1}^{N} \eta_t(\theta)^2 \qquad \text{(Equation 3.8)}$$

and the standard deviation of the residuals σ is:

$$\sigma = \frac{1}{N+1} \sqrt{Q(\theta)}\,. \qquad \text{(Equation 3.9)}$$

As in Schnute *et al*. (2000), we adopt the simple prior distribution $P_0(\theta)$ where the prior on each parameter is uniform across an admissible range and zero elsewhere. For h^* the admissible range is (0,1). The lower limit of the prior for S^* is 0. The basis for choosing the upper limit of S^* is less obvious. All previous SR analyses indicate relatively low uncertainty in the productivity parameter h^* and high uncertainty in S^* due to high recruitment variation for a given level of spawners (Collie and Walters 1987; Cass 1989; Schnute *et al.* 2000). Schnute *et al*. (2000) showed that the 80% h^* - S^* posterior confidence regions included the maximum observed S for most summer run Fraser sockeye stocks. Independent estimates of spawning capacity for Fraser lakes based on the correlation between photosynthetic rate and sockeye smolt biomass predict freshwater juvenile capacity is maximized within or near the maximum observed S in three of the four lakes studied (Hume *et al.* 1996; Shortreed *et al.* 2000). We chose to confine the range in the prior for S^* to $0 < S^* < \max(S)$.

Following methods presented in Schnute *et al.* (2000), we choose the standard non-informative prior $P_0(\sigma) \propto 1/\sigma$ for the scale parameter σ so that $P_0(\log\sigma) \propto 1$. The posterior distribution $P(\theta,\sigma)$ is then specified by:

$$P(\theta,\sigma) \propto \frac{1}{\sigma^{N_i+1}} \exp\left[-\frac{1}{2\sigma^2} Q(\theta)\right] P_0(\theta) . \qquad \text{(Equation 3.10)}$$

The modal estimate $\hat{\theta}$ corresponds to the maximum value of $P(\theta,\sigma)$ and is the initial value used to start the MCMC sampling procedure. An MCMC sample of length 20,000 for each stock was considered representative of the Bayes posterior distribution of the parameter estimates.

Evaluation of mortality effects requires a model that simulates the entire resource management system. Model inputs are the sub-components that quantify the population dynamics (*i.e.,* the Bayes posterior distributions), the assumed harvest and in-river mortality. Model outputs are the estimates of escapement and returns at each annual time step. The Bayesian approach for capturing parameter uncertainty and posterior sampling techniques, such as the MCMC approach of Gelman *et al.* (1995) used here, offer the advantage that complex parameter distributions can be readily incorporated into the analysis. To explicitly incorporate parameter uncertainty, a sub-sample of 250 SR parameter vectors θ were systematically sampled from the original 20,000 MCMC samples.

For each parameter vector sampled from the Bayes posterior distribution, the effect of mortality, including fishing and PSM, is simulated by generating future streams of escapement and returns. S_t is initialized using the last four years of data after accounting for PSM (see below). The simulation proceeds in annual time steps for years *t*=5, 6, 7,…, N where the harvest and PSM process in each year occurs by first generating recruitment from the spawner-recruitment curve. For example, recruits for the dynamic model (Equation 3.1) are generated according to:

$$R_t = g(S_{t-4},\theta)\exp(\eta_{t-4}) . \qquad \text{(Equation 3.11)}$$

In the simulations, η_{t-4} depends on σ and suitable autocorrelation ρ of the residuals at a lag of one year where:

$$\eta_{t-4} = \rho\varepsilon_{t-3}\sigma + \varepsilon_{t-4}\sigma . \qquad \text{(Equation 3.12)}$$

The variable ρ was computed using standard statistical methods and represents the degree that environmental effects on survival are correlated over time. For Cultus Lake the residuals are moderately autocorrelated. The autocorrelation at a lag of one year is statistically significant (P<0.05) at ρ = 0.24.

The escapement S_{t-4} results in simulated age-4 and age-5 recruits according to Equation 3.11 in years t and $t+1$, respectively. The mean values of age-4 and age-5 fish in the historical time series was used to partition recruits into age-4 and age-5 returns. Applying an assumed PSM rate *m* and harvest rate h_t results in subsequent escapement S_t according to:

$$S_t = (1-m)h_t R_t . \qquad \text{(Equation 3.13)}$$

The annual time step is then incremented and S_t is used to generate recruitment in the next generation according to Equation 3.11.

Mortality rates *m* of 40-90% were used to simulate their effects on escapement trends. For modelling future populations, we initialized the simulations with the estimated number of successful spawners for the last four years. Because potential spawners are enumerated as they migrate into Cultus Lake well in advance of spawning, the counts include mortalities among adults holding in the lake before spawning. Normally, such mortalities are included in the PSM estimate. In recent years when early migrations likely increased mortality among holding adults, however, the number of carcasses recovered in the lake have been insufficient to provide reliable estimates. We approximate recent PSM levels by comparing recent and historic relationships between spawners and subsequent smolts. The average number of smolts per adult spawner was 67 before 1991 and only 5 for the 1999-2000 brood years. We assumed the reduction in smolts per adult resulted from elevated mortality while holding in the lake. While reduced egg-to-smolt survival also may contribute to the smolt production per adult, especially if fry suffer depensatory mortality in the lake, we discount it as significant causal factor given the high PSM observed in other late run stocks. Furthermore, the failure to observe any spawners at Lindell Beach is consistent with our assumption of high mortality among sockeye holding in the lake. Consequently, we estimate the number of successful spawners in 1999 and 2000 by applying the ratio of smolts per adult in each year and the historical average smolts per adult to the respective total escapements (12,392 and 1,227). Our estimate of successful spawners was 920 adults (93% PSM) in 1999 and 83 adults (93% PSM) in 2000. To initialize the simulations, therefore, we assume that the number of successful spawners from 1998-2001 was 10% of the adults counted at the fence.

3.5. STOCK STATUS

COSEWIC is responsible for classifying species at risk in Canada. It uses a quantitative system (the *Red List*) developed by the World Conservation Union (IUCN) for classifying species at risk of extinction (IUCN 2001). The Red List criteria can be applied to any taxonomic unit at or below the species level, including populations such as Cultus sockeye, provided there is little genetic exchange with other populations. Categories are assigned based on the highest criterion that is met. Higher categories imply a higher expectation of extinction; over a specified period, more taxa listed in the higher categories are expected to go extinct than in lower categories. The IUCN acknowledges that the evaluation data are often estimated with uncertainty that may arises from natural variation or measurement error; they require the specification of a range in outcomes and the selection of a single category that is both precautionary and credible.

The Red List categories are extinct, extinct in the wild, threatened, near threatened, least concern and data deficient. The category of interest to the Cultus sockeye assessment is *threatened,* consisting of three subcategories: *critically endangered*, *endangered* and *vulnerable*. Each category has a number of evaluation criteria (described below) with variable applicability to the Cultus sockeye assessment. We acknowledge that the classification of species at risk is a COSEWIC responsibility, and that COSEWIC may consider evaluation criteria incremental to those used by the IUCN. Consequently, we do not provide a definitive categorization of Cultus sockeye in the current stock status report; instead, we report the results if the IUCN criteria were applied to past abundance trends and future abundance projections for Cultus sockeye. We use the following IUCN criteria: observed reduction in the number of mature individuals (adults); predicted reduction in the number of mature individuals; absolute size of the population of mature individuals; and the probability of extinction over specified time periods. Decline rates are estimated by fitting a linear regression to a three-generation window (12 years) in the time series of a one-generation smoothed trend (running four-year average) for the natural logarithm of adult spawner abundance. We use the term *extinction* rather than *extirpation* when categorizing the Cultus stock because, while the loss of sockeye from the system would mean that species was extirpated, the Cultus stock itself would be extinct.

3.5.1. IUCN Definition of Critically Endangered (CR)

Critically Endangered applies when the best available evidence shows an extremely high risk of extinction in the wild. It receives this classification if any of the following apply:

A. A reduction in population size based on any of the following:

1. A reduction of $\geq$90% over the last three generations where the causes are clearly reversible, understood, and have ceased;
2. A reduction of $\geq$80% over the last three generations where the causes may not be reversible or understood or may not have ceased;
3. A reduction of $\geq$80% projected over the next three generations;
4. A reduction of $\geq$80% over any three generation period that includes both past and future, and where the causes may not be reversible or understood or may not have ceased.

B. The geographic range has one of both of the following characteristics:
1. Extent of occurrence is estimated at less than 100 km^2 and at least two of the following apply: a) severely fragmented or known to exist at only a single location; b) continuing decline in the extent of occurrence, area of occupancy, area/extent/quality of habitat, number of sub-populations, or number of mature individuals; or c) extreme fluctuations in extent of occurrence, area of occupancy, number of locations or sub-populations, or number of mature individuals.
2. Area of occupancy estimated at less than 10 km^2 and at least two of the above apply.

C. The estimated population size is <250 mature individuals and either:
1. The population is projected to decline at least 25% in one generation; or
2. The number of mature individuals has or will continue to decline and at least one of the following applies: a) no sub-population contains >50 mature individuals or at least 90% of the mature individuals are in one sub-population; and b) there are extreme fluctuations in the number of mature individuals.

D. The estimated population size is <50 mature individuals.

E. Quantitative analysis shows the probability of extinction in the wild is at least 50% in three generations.

3.5.2. IUCN Definition of Endangered (EN)

Endangered applies when the best available evidence shows a very high risk of extinction in the wild. It receives this classification if any of the following apply:

A. A reduction in population size based on any of the following:
1. A reduction of $\geq$70% over the last three generations where the causes are clearly reversible, understood, and have ceased;
2. A reduction of $\geq$50% over the last three generations where the causes may not be reversible or understood or may not have ceased;
3. A reduction of $\geq$50% projected over the next three generations;
4. A reduction of $\geq$50% over any three generation period that includes both past and future, and where the causes may not be reversible or understood or may not have ceased.

B. The geographic range has one of both of the following characteristics:
1. Extent of occurrence is estimated at less than 5,000 km^2 and at least two of the following apply: a) severely fragmented or known to exist in no more than five locations; b) continuing decline in the extent of occurrence, area of occupancy, area/extent/quality of habitat, number of sub-populations, or number of mature individuals; or c) extreme fluctuations in extent of occurrence, area of occupancy, number of locations or sub-populations, or number of mature individuals;
2. Area of occupancy estimated at less than 500 km^2 and at least two of the above apply.

C. The estimated population size is <2,500 mature individuals and either:
1. The population is projected to decline at least 20% in two generation; or
2. The number of mature individuals has or will continue to decline and at least one of the following applies: a) no sub-population contains >250 mature individuals or at least 95% of the mature individuals are in one sub-population; and b) there are extreme fluctuations in the number of mature individuals.

D. The estimated population size is <250 mature individuals.

E. Quantitative analysis shows the probability of extinction in the wild is at least 20% in five generations.

3.5.2. IUCN Definition of Vulnerable (VU)

Vulnerable applies when the best available evidence shows a high risk of extinction in the wild. It receives this classification if any of the following apply:

A. A reduction in population size based on any of the following:
1. A reduction of $\geq$50% over the last three generations where the causes are clearly reversible, understood, and have ceased;
2. A reduction of $\geq$30% over the last three generations where the causes may not be reversible or understood or may not have ceased;
3. A reduction of $\geq$30% projected over the next three generations;
4. A reduction of $\geq$30% over any three generation period that includes both past and future, and where the causes may not be reversible or understood or may not have ceased.

B. The geographic range has one of both of the following characteristics:
1. Extent of occurrence is estimated at less than 20,000 km^2 and at least two of the following apply: a) severely fragmented or known to exist in no more than ten locations; b) continuing decline in the extent of occurrence, area of occupancy, area/extent/quality of habitat, number of sub-populations, or number of mature individuals; or c) extreme fluctuations in extent of occurrence, area of occupancy, number of locations or sub-populations, or number of mature individuals;
2. Area of occupancy estimated at less than 2,000 km^2 and at least two of the above apply.

C. The estimated population size is <10,000 mature individuals and either:
1. The population is projected to decline at least 10% in three generation; or
2. The number of mature individuals has or will continue to decline and at least one of the following applies: a) no sub-population contains >1,000 mature individuals or all mature individuals are in one sub-population; and b) there are extreme fluctuations in the number of mature individuals.

D. The estimated population is very small or either of the following apply:
1. The population size is <1,000 mature individuals; or
2. The population has a very restricted area of occupancy (<20 km^2) or number of locations (<5);

E. Quantitative analysis shows the probability of extinction in the wild is at least 10% in 100 years.

3.6. PROBABILITY OF EXTINCTION

Our quantitative analysis of the probability of extinction of Cultus sockeye uses the simulation model described in Section 3.4; it incorporates SR parameter uncertainties under a range of prespawn mortality and exploitation rate scenarios. Our simulation comprises 100 trials for each of 250 parameter sets, or 25,000 simulation trials. Two criteria were used to calculate the probability of extinction. In the first criteria, we define the stock to be extinct if there are fewer than 50 effective adult spawners in any consecutive four-year period (50 mature individuals conforms to *critically endangered,* the most stringent IUCN Red List criteria). Extinction probability is the fraction of the total simulation trials where the population conforms to our definition of extinction. Second, because our simulation model does not explicitly consider the potential for depensatory population dynamics that may increase the risk of extinction at low population sizes, we assessed extinction based on the probability of fewer than 100 effective spawners in any consecutive four-year period. Depensation may occur at low population densities as a result of “Allee effects” (*e.g.,* from an impaired ability to find mates, increased vulnerability to predators or competitors, impaired social behaviours such as schooling, impaired ability to favourably modify the environment as occurs, for example, in the displacement of watermilfoil by redd construction activities), demographic stochasticity (*i.e.,* random variation among individuals in their tendency to survive or reproduce as a result of chance fluctuations in birth rates, death rates or sex ratios), and inbreeding depression or random genetic effects. Although somewhat arbitrary, we believe a 100-fish threshold reasonably approximates the level below which irreversible harm is likely.

3.7. PRODUCTIVE CAPACITY

3.7.1. Spawner to Smolt Stock-Recruitment Method

We estimate productive capacity from the smolt production data by fitting the Ricker SR model to the total adult escapement and subsequent smolt production, both measured at the fence. The SR model was fitted using the methods described by Hilborn and Walters (1992). S_{max}, the spawning escapement that maximizes recruitment, is equivalent to the optimum adult escapement in the PR Model and is calculated by dividing the Ricker capacity parameter β by the productivity parameter α.

3.7.2. Photosynthetic Rate Method

The productive capacity of a stock at a given life history stage is largely dependent on the productive capacity of the rearing habitat for that stage. Hume *et al.* (1996) and Shortreed *et al.* (2000) developed a photosynthetic rate (PR) model for estimating the capacity of lakes to rear juvenile sockeye based on the lake's primary production. The PR model uses three primary equations:

Maximum smolt biomass (kg) = $45.5 \bullet PR_{total}$
Maximum smolt numbers = $10{,}120 \bullet PR_{total}$
Optimum adult escapement, $S_{max} = 187 \bullet PR_{total}$

where PR_{total} is the total seasonal (May-October) carbon production (metric tons) in a lake. The model is based on the observed relationships between the maximum smolt biomass produced and PR_{total} in Alaskan sockeye lakes as well as experimental stockings reported by Koenings and Burkett (1987) and Koenings *et al.* (1993) that showed adult production is maximized at spawner densities that produced 4.5 g smolts. Observed maximum juvenile biomass (smolts, fall fry) in Alaska and B.C. lakes is correlated (r= 0.95) with model predictions (Shortreed *et al.* (2000); however, lake capacity may be overestimated in lakes with substantial planktivores populations other than age-0 sockeye (including age-1 sockeye and kokanee). Assumptions and limitations of the PR model are discussed at length in Shortreed *et al.* (2000).

3.7.3. Spawner to Adult Stock-Recruitment Method

We estimate productive capacity using the SR methods described in Section 3.4.1. The capacity parameter β is defined in Equation 3.5; the spawning escapement that maximizes recruitment is $1/\beta$.

4.0. RESULTS

4.1. ESCAPEMENT

4.1.1. Abundance

Cultus sockeye escapements have been assessed using enumeration fences since 1925, a 77 year time series of consistent data collected using an accurate assessment tool. Daily estimates are available since 1941 (Appendix 1); annual estimates are available for the entire period (Appendix 2). Escapement trends (Fig. 4) can be broadly categorized into four periods: generally low but variable escapements during a period of large scale hatchery experimentation in the 1920's and 1930's; very large escapements in 1939-1942 following the removal of predators from the lake; strong but variable escapements from the early 1940's to the late 1960's; and generally declining escapements from the late 1960's to the present. Spawner abundances and escapement patterns differ by cycle (Fig. 5). Since 1925, adult escapements averaged 14,700 and 27,000 on the 1998 sub-dominant and 1999 dominant cycles, respectively, and 12,300 and 5,000 on the 2000 and 2001 off-cycles (Table 1). Cyclic dominance largely disappeared in the 1940's, 1950's and 1960's when abundance was similar on the 1998, 1999 and 2000 cycles, and relatively strong on the 2001 cycle. It re-emerged when off-cycle escapements collapsed in the early 1970's. Since the late 1960's, the sub-dominant cycle adult escapements have progressively declined while the dominant cycle has been trendless, although the last two cycle years have been weak. In contrast, off-cycle abundances have remained at very low levels (<2,000 spawners) since the early 1970's. The most recent escapements on all cycles have been among the lowest ever recorded for Cultus sockeye.

4.1.2. Timing

Cultus sockeye migrate through Sweltzer Creek and into the lake where they hold for up to two months before spawning. The migration into the lake typically begins in late September, peaks in late October to early November and is complete by mid-December (Fig. 6); spawning peaks from late November to early December (Appendix 3). Since 1996, the migration into the lake has become progressively earlier to the extent that, by 2001, the start and peak of the migration were almost two months earlier than the 1941-1995 average. We could not determine whether similar changes in spawning timing had occurred because, despite systematic surveys since 1999, sockeye have not been observed on the Lindell Beach spawning grounds (Snag Point and Mallard Bay are rarely surveyed). Other late run stocks affected by the early migration, however, spawn during the normal period.

The early migration into Sweltzer Creek exposes the fish to water temperatures as high as 23ºC (DFO, unpublished data). Exposure to such temperatures, even for short periods, increases metabolic rates and the growth of bacteria and fungi, reduces reproductive hormone synthesis and the energy available for migration and reproduction, decreases swimming performance and delays gonadal maturation, all of which can contribute to increased pre-spawning mortality and reduced spawning success (D. Patterson, DFO, pers. comm.). The temperature gradients between the Chilliwack River (12-16ºC), Sweltzer Creek (>20ºC) and the lake's hypolimnion (6.5ºC) may exacerbate these impacts. As well, upper Sweltzer Creek is heavily used for swimming and unstructured recreation in August and early September, activities that may delay migration, increasing the exposure to high temperatures and the stress on returning fish.

4.1.3. Pre-Spawning Mortality

Cultus sockeye carcasses recovered on the fence and the spawning grounds have been sampled for age, length, sex and spawning success since 1952. A failure in most years to record recovery location compromises these data for PSM assessment purposes because the fence nonrandomly samples carcasses (PSM levels are higher than average). Recovery location has been recorded since 1991, but few female carcasses have been recovered since 1996.

Before 1995, PSM averaged only 7% and was generally less than 10% in the years with available data. Since the onset of the early migration in 1995, there have been sharp increases in PSM, to 24% in 1995, 66% in 1996 and 38% in 1998. PSM could not be measured in 1997 and 1999-2001 because few if any carcasses were recovered. For 1999-2000, we estimated the level of PSM by comparing the number of smolts produced per adult spawner for those brood years (5 smolts/adult) with the average number in years before the start of the early migration (67 smolts/adult). This indicates a further increase to 93% in those years, a level consistent with those reported for other late run stocks such as Weaver (unpublished DFO files).

4.1.4. Sex, Age and Fecundity

Escapements by sex have been reported since 1925 (Appendix 2); however, estimation methods changed over that period: in the 1920-1930's, each fish was examined when dip netted from the trap; from the late 1930's until 1993, sex was estimated as fish swam past the fence; and since 1994, the sex ratio among carcasses has been applied to the adult fence count. In years with low carcass recoveries, the historic average is used. Over the period of record, females comprised 65% of the adult spawners (Appendix 2); however, that proportion progressively declined from 71% in the 1920-1930's to 54% since 1990.

The escapement of jacks, also reported since 1925, has been estimated visually over the entire period of record; because visual techniques cannot discriminate between jacks and small adults, there are some discrepancies between the escapement estimate (Appendix 2) and the numbers sampled (Appendix 4).

Over the period of record, jacks comprised the highest proportion of the total escapement on the 2001 off-cycle (24%) and the 1998 subdominant cycle (6%), and less than 3% on the 1999 and 2000 cycles.

Cultus sockeye age composition averages 1% age-3, 94% age-4 and 5% age-5 (Appendix 4). The age composition differs between cycles, with a larger age-5 component on the 2000 (8%) and 2001 (9%) off-cycles than on the 1998 subdominant (<1%) and 1999 dominant (2%) cycles. The 2001 age composition was atypical, with a very high proportion of the escapement composed of age-3 and age-5 sockeye.

Fecundity estimates are available for 14 years during the period 1925-1944 (Appendix 3). Annual fecundity averaged 4,191 (range: 3,722 to 4,500).

4.2. FRY

4.2.1. Abundance

Fall fry abundance estimates for the 1980's brood years ranged from 475,000 to 2.38 million (95% C.I. ± <12%) (Appendix 5). Abundances for the 1999 and 2000 broods were considerably lower at 250,000 ± 19% and 46,000 ± 38%, respectively; the latter was a record low abundance. Although there is a tendency for higher escapements to result in lower fall fry abundances, the relationship was not significant ($P>0.05$). The highest observed fall fry densities of 2,800 to 3,500 fry/ha are well with the range of observed densities in other sockeye lakes in B. C. (Shortreed *et al.* 2001).

4.2.2. Growth

Age-0 sockeye fry sampled in October and November averaged 3.7 g (range: 2.8-4.5 g) (Appendix 6), somewhat smaller than in other Fraser Valley lakes (*e.g.,* Harrison: 3.0-8.8 g; Pitt: 3.0-6.0 g; Chilliwack: 3.4-4.0 g). Extreme summer epilimnion temperatures may make a substantial portion of the zooplankton inaccessible to sockeye during July and August, resulting in slow summer growth and relatively small fall fry. Sampling bias by the midwater trawl is considered unlikely; there is no indication of bias from data on other lakes, and a study of similar trawls indicates that there should be no bias up to about 150 mm (Parkinson *et al.* 1994). Given the small size of fry in the fall, there is considerable growth in the late fall, winter and early spring as the fry nearly double in size by the time they emigrate as smolts (Fig. 7). Recent lake assessments are consistent with this observation; overwinter and early spring zooplankton abundances, in particular *Daphnia,* are higher in Cultus than in other Fraser lakes. Growth may also be density dependent as both fall fry and smolt are smaller in large escapement years (Fig. 7).

4.2.3. Relationship Between Acoustic and Smolt Estimates

In the four years where both fall hydroacoustic and spring smolt abundance estimates are available, fry-to-smolt survivals average 23% (range: 11-38%) (Table 5). Estimation error may result from the relatively high variance in the hydroacoustic estimates (95% CI: 8-20%) as well as smolt estimates that are likely minima because they may not capture the entire migration period. The fall acoustic estimates may also include kokanee; however, this is unlikely because an examination of strontium levels in the cores of 20 1999-brood otoliths indicate that all sampled *O. nerka* were sockeye (Volk *et al.* 2000). Low densities in the fall of 2001 resulted in the capture of only two *O. nerka* out of a total of ten fish. Although the sample size was inadequate to properly apportion the acoustic estimate, it did indicate that sockeye abundance was very low; the subsequent smolt count was a record low 5,700 (Appendix 7).

4.2.4. Lake Limnology

The limnological characteristics of Cultus Lake are summarized in Section 1.1.2 from data collected in 2001 and earlier. While some characteristics make the lake less than ideal as a sockeye nursery area (*e.g.,* warm epilimnion, predator abundance), with its productive zooplankton community and the high proportion of *Daphnia* in that community, Cultus Lake has abundant food resources for juvenile sockeye. The lake is deep enough to have a substantial, cool hypolimnion (some of which is within the euphotic zone) that provides a favourable rearing environment. While the warm summer epilimnion temperatures and the relatively small late fall fry suggests that a substantial proportion of the zooplankton community may not be accessible to juvenile sockeye, the relatively long growing season results in considerable overwinter growth as the fry almost double in size before smolting. While both fall fry and smolts show some density dependent growth (the largest smolts (12 g) are from the ultra-low density 1999 brood year and the smallest (<3 g) are from years when the escapement exceeded 50,000 females), given sufficient fry recruitment, the lake is believed capable of producing a large smolt population (see Section 4.9.2). Comparisons with limnological data collected in 2001 and those from earlier studies in the 1930's, 1960's and 1970's suggest that the lake's limnetic habitat has changed relatively little over the past 65 years.

4.3. SMOLTS

The smolt migration has been assessed intermittently using enumeration fences since 1926. Estimates are available in 46 of the 76 year time series (Appendix 8); daily estimates are available for most of those years (Appendix 7). The smolt migration typically begins in March, peaks in late April and is complete by June. Total abundance has averaged 1,004,500 over the entire time series, ranging from 5,700 in 2002 to 3,124,000 in 1937. Production was variable but strong through the 1960's (1,216,300 average), followed by declines in the 1970's (712,700 average) and very low average abundances since 1990 (73,600). The most recent assessments report the lowest abundances on record in 2002, 2001 1991 and 1990. Smolt production is cyclic, with an average of 1.1 million and 1.7 million on the sub-dominant and dominant cycles, respectively, and 0.7 million and 0.4 million on the 2000 and 2001 off cycles.

4.4. CATCH

The 1974-2001 estimated total catch of Cultus sockeye in all fisheries averaged 19,400 and ranges from 102 (2001) to 88,000 (1983) (Appendix 9). During this period, ER's averaged 68% and ranged from 10.4% (1999) to 94.5% (1997) (Appendix 10). In recent years, fisheries have been adjusted in response to concerns regarding the early migration of the late run; consequently, Cultus ER's have been reduced.

The 1974-2001 average annual catch of Cultus sockeye in US Panel waters is 5,200, 27% of the total harvest. This fraction was higher before 1986 when US was entitled to 50% of Fraser River sockeye harvested in Convention waters. In recent years, the reduction in the portion of the Cultus sockeye harvested in US waters reflects their reduced share of total catch allocated under the terms of the current Annex provisions of the Pacific Salmon Treaty. The catch of Cultus sockeye in US non-Panel waters has tended to be small, averaging only 1% of the total harvest.

The 1974-2001 average annual catch of Cultus sockeye in Canadian Panel waters is 4,800, 25% of the total. While the proportion fluctuates annually, there is no identifiable trend in the proportion of the total catch that occurs in Canadian Panel waters. In contrast, the average annual catch in Canadian non-Panel waters is 8,900 fish, or 46% of the total harvest. Most of this catch occurs in Johnstone Strait net fisheries. The relative portion of the catch in Johnstone Strait has increased since 1986 due largely to generally higher Johnstone Strait diversion rates in the 1980's and 1990's and the coincident increase in the total sockeye allocation to Canada since 1986.

The 1974-2001 average catch of Cultus sockeye in Fraser River First Nations and sport fisheries is 400, 2% of the total harvest. The proportion of the total Cultus sockeye harvested in these fisheries has increased in some recent years, reflecting a reduction in commercial harvest rather than an increase in the catch in the in-river fisheries.

4.5. ANNUAL TOTAL RETURN

The 1952-2000 annual total return of Cultus sockeye adults has averaged 43,900, and has ranged from 500 (1977) to 282,500 (1959) (Fig. 8; Table 6; Appendix 10). Average returns were highest in the 1950's (100,700), stabilized at about 45,600 in the 1960's and 1970's, then progressively declined in the 1980's (31,800) and 1990's (15,700); returns in the 2000's averaged only 1,300 adult sockeye.

Since 1954, the total adult return on the 1998 sub-dominant cycle averaged 39,700 and ranged from

2,300 (1998) to 101,700 (1954). Returns have been variable but with an overall decline of 8% per cycle. In contrast, pre-1998 ER's were relatively stable on this cycle (except during lower exploitation years in the 1960's), varying from 74% (1986) to 82% (1978, 1990). In 1998, the ER declined to 15% in response to fishery restrictions addressing early migration concerns. Catch and escapements were also variable, but showed a similar overall decline of 8% per year.

Since 1955, the 1999 dominant cycle total adult return averaged 99,700 and ranged from 13,800 (1999) to 282,500 (1959). Production has been more variable than the 1998 cycle, with lower returns in the 1960's, 1970's and 1990's; overall, returns declined by 7% per cycle since 1955. ER's generally fluctuated in the 60-90% range, with lower recent ER's of 47% (1995) and 10% (1999). While total production, catch and escapement have all declined over the period of record, this remains the largest producing cycle with a 1999 total return and adult escapement of 13,800 and 12,400, respectively.

Since 1952, the 2000 off-cycle total return averaged 25,100 and ranged from 2,000 (2000) to 70,900 (1968). The average total return was relatively strong through 1976 (41,500), but declined to only 5,900 in 1980-2000. The catch ranged from 800 (2000) to 45,500 (1968). ER's have been variable, averaging less than 60% in the 1950's and 1960's but over 80% in 1972-1992; ER's range from 30% (1996) to 91% (1988). Escapement has been low on this cycle, especially since 1980.

Since 1953, the 2001 off-cycle total return averaged 14,900 and ranged from 500 (1977) to 73,600 (1957). The cycle was relatively strong in the 1950's (57,100) and 1960's (18,900), but has experienced very low production (2,600) in most return years since 1977; overall returns have declined by 9% per cycle. The catch also has been small, ranging from 100 (2001) to 53,200 (1957). ER's have been high (except 1961, 1985, 2001) but variable; ER's averaged 67% in the 1950's and 1960's, increasing to 82% in the 1970's to 1990's. Overall, ER's averaged 70% and ranged from 17% (2001) to 95% (1997). Since 1973, escapements have been extremely low on this cycle, exceeding 1,000 fish only in 1993.

4.6. SURVIVAL

4.6.1. Freshwater Survival Index

The freshwater survival index was calculated for the 1925-2000 brood years when adult spawner (as counted at the fence) and subsequent smolt abundances were available (N=45; Fig. 9, Appendix 5). The long term freshwater survival index averaged 72 smolts/adult (range: 3-203), very similar to the Chilko Lake index (average 61 smolts/adult over a 49 year time series; range: 9-115), the only other wild sockeye smolt data for Fraser sockeye stocks (DFO, unpublished). The freshwater survival index decreases with spawner density (Fig. 10) in both lakes, but only significantly so in Chilko ($P < 0.05$), and shows no obvious long term trends (Fig. 9). In the 1988-1990 brood years, just prior to the current early return phenomenon, the freshwater index of about 100 smolts/adults is as high or higher than the long term average for Cultus Lake. Overall, there is no indication of any systematic changes in the survival index until the 1999-2000 brood years when the index was only five smolts/adult for both years (Fig. 9).

4.6.2. Marine Survival

Marine survivals were calculated for brood years between 1951-1990 when age-1 smolts and the resulting ages 4_2 and 5_2 adult recruits produced were available (N=24; Fig. 11; Appendix 11). Marine survivals averaged 8.5% (range 0.5-43.9%), with higher average survivals (15.3%) in the late 1980's. The mean marine survival for Chilko sockeye was only slightly higher at 9.1% (range: 1.3-22.2%). Marine survival for the 1951 Cultus brood year was exceptional at 43.9%, more than twice the next highest survival. If this point is removed, then the mean marine survival is reduced to 7.0% (range 0.5-20.3%), although still not significantly different from the Chilko mean (paired sample T-test, $t_{0.05,21}=1.80$, $p= 0.09$). As adult returns produced from the 1999 and 2000 brood years are as yet unknown (first returns will be in the fall of 2002), it is uncertain whether the recent early migration and PSM of adult spawners will also have a negative impact on marine survival rates. Given the large size of the smolts produced in the 1999 and 2000 broods, marine survival should be better than in most other years (Foerster 1954; Bradford *et al.* 2000).

4.6.3. Total Survival Index

The total survival index (returns-per-spawner) is highly variable, averaging 4.8 and ranging from <1 to 26 (Fig. 12; Appendix 12). Returns were low in the early and late 1960's and the 1990's, when the index dropped below the replacement line (Fig. 12; horizontal dashed line). The mean recruits per spawner (R/S) for Cultus (4.8) is less that other Fraser sockeye populations (Chilko 7.2; Shuswap 7.3), suggesting its productivity is lower (Fig. 13). The lower mean R/S for Cultus is also reflected in the mean productivity parameter h^*, (ER at maximum sustainable production); the h^* estimate for Cultus is 0.56 (*i.e.,* 56% ER), compared to greater than 0.76 for Chilko and 0.68 for the South Thompson (Adams) group.

4.7. EXPLOITATION RATE

The 1952-2001 Cultus sockeye ER's average 68%, and range from 10% (1999) to 95% (1997) (Table 6; Appendix 10). Generally, ER's have exceeded 75% except in the early 1960's and in the 1990's. Beginning in 1995, ER's decreased (with the notable exception of 1997) by over 40% to a mean of 36% as a result of conservation measures (*e.g.,* fishery restrictions) to protect all late run stocks. In 2001, the Fraser Panel and DFO managed fisheries to ensure late run (excluding Birkenhead) ER's would not exceed 17%. This trend in reduced ER's, along with the general decline in production and spawning escapements for Cultus Lake sockeye, is reflected in Table 6.

Because Cultus sockeye are not actively managed, the cycle-specific ER patterns differ depending on the target stock that triggers management actions. On the 1998 sub-dominant and 1999 dominant cycles, the fisheries are managed to meet harvest and escapement objectives for Adams sockeye; ER's averaged 72% and 77%, respectively (Table 6). Sub-dominant cycle ER's have been generally high and relatively trendless since 1954, while dominant cycle ER's have decreased slightly since 1971. On the 2000 and 2001 off-cycles, the fisheries are actively managed for Weaver sockeye, where the wild stock has been augmented with enhanced production since the spawning channel began operation in 1965. Off-cycle ER's are similar to those on the other cycles, averaging 67% (2000) and 70% (2001); however, the trends are considerably different. Before the first return of enhanced sockeye in 1969, ER's averaged 57% (2000 cycle) and 65% (2001 cycle). After enhancement and until fisheries were reduced to address concerns regarding the early migration, ER's increased to an average of 83% (2000 cycle) and 81% (2001 cycle) with slight increasing trends of 2.0% and 0.5% per cycle on the 2000 and 2001 cycles, respectively.

4.8. MARINE TIMING AND ESTUARINE DELAY

Early work by Foerster (1936b) provided evidence that Cultus sockeye were present in Juan de Fuca Strait from mid-July to the end of September, with the peak migration occurring from mid-August to early September (Table 4). This suggests a peak migration into the Strait of Georgia in late August or early September, similar to co-migrating stocks such as Adams sockeye. The Cultus sockeye migration past the Sweltzer Creek fence spans a period from late September through early December with a peak occurring in late October (Fig. 6). This suggests that the main body of Cultus sockeye delay in the Strait of Georgia from late August or early September until mid/late October, a period of seven to eight weeks. This is considerably longer than the typical delay of three to six weeks for other late run stocks such as Adams or Weaver. The implications of the additional delay relative to vulnerability to harvest or susceptibility to PSM in early migration years is unknown.

4.9. PRODUCTIVE CAPACITY

4.9.1. Spawner to Smolt Stock-Recruitment Method

As expected from the lack of a significant relationship between the freshwater survival index and adult spawners (Section 4.6.1), there is little evidence of decreasing smolt production at increasing adult escapements (Fig. 10). A linear relationship is highly significant (R^2_{adj} = 0.46, P<.001) and the fit of a Ricker curve to the data is very poor. The estimate of S_{max} is 115,300 adult spawners, almost 50% greater than any escapement observed during the 77 year period of record (Fig. 4).

4.9.2. Photosynthetic Rate Method

An assessment in 2001 estimated the total seasonal carbon production in Cultus Lake, PR_{total}, at 447.2 metric tons. Based on that estimate, the PR model predicts a maximum smolt production of 20.35 tonnes that is reached at a total spawner abundance, S_{max}, of about 84,000 adults. The estimated S_{max} lies outside the range of observed escapement data for which we also have estimates of subsequent recruitment. The largest escapement of 47,800 (1959) adults, however, also produced the largest recruitment at 282,500 (Table 6), and escapements without associated estimates of recruitment approached this value in 1927 (82,000), 1939 (71,000) and 1940 (74,000) (Table 1).

S_{max} is equivalent to about 4.5 million smolts for 4.5 g smolts (Fig. 10), the value that literature sources indicate should maximize adult returns (Koenings *et al.* 1993). If we use the Cultus-specific regression of smolt weight against adult escapement (Fig. 7), however, S_{max} would produce about 5.7 million smolts at an average size of 3.6 g. Applying the average marine survival rate of 7.0% to these values, we could expect 315 to 400 thousand returns at the PR predicted optimum escapement. This is also outside the range of observed return data, with only the 1959 brood return approaching the lower end of this range.

We have two concerns regarding the assessment of PR_{total}. First, the estimate is based on only one year of data collection, from May to October, 2001. Assessments in Shuswap Lake over six years show a variability of about twice the standard error, or 13% of the mean. Second, Cultus is a low elevation coastal lake where the growing season for both plankton and fish likely extends beyond the May to October assessment period; consequently, the total seasonal carbon production may be larger than indicated by the assessment. The lakes assessment group is continuing to monitor physical, chemical and biological limnological variables in order to refine the estimates of the growing season and interannual variation.

4.9.3. Spawner to Adult Stock-Recruitment Method

Uncertainty in the SR parameter estimates for Cultus sockeye (Fig. 14) indicate the uncertainty in optimal escapement S^* is large compared to the productivity parameter h^*. The posterior distribution P for S^* reveals a broad range of uncertainty where the upper range is poorly determined and is constrained by the prior imposed at the maximum observed spawning escapement (1948-1997). The productive capacity based on the SR analysis, therefore, is also badly determined. Using the mean of the Bayesian parameter estimates, the number of spawners S_{max} that produce the maximum recruitment is 56,000 adults. As noted for the other methods, this is beyond the maximum observed adult escapement of 47,800 (Fig. 15).

4.10. STOCK STATUS

4.10.1. Last Three Generations (1989-2001)

The number of sockeye adults entering Cultus Lake declined by 51% over the last three generations, a rate of 6.5% per year across all cycles (one-generation smoothed data, Fig. 16). The reduction in population size does not meet the IUCN *Critically Endangered* criteria ($\geq$80%, where the causes may not be reversible or may not have ceased) but exceeds the *Endangered* criteria ($\geq$50%, with the same qualifiers). The rate of decline in spawner abundance is a continuation of a longer term trend that began on most cycles in the late 1960's (Fig. 5).

The estimated rate of decline underestimates the population's loss of reproductive potential because it does not consider the recent increases in mortality suffered by the adults after entering the lake but before spawning. When the data are adjusted to reflect our best estimates of annual PSM levels (Appendix 2), we calculate a rate of decline of 93% (Fig. 17). This is consistent with the IUCN *Critically Endangered* criteria. This substantial change is largely attributable to the reduction in reproductive potential of the 1999 dominant cycle escapement. We note that, although there are weaknesses in the PSM data (averages are used for many pre-1995 and some post-1995 data points) because the 1999 dominant cycle estimate is derived from a direct assessment of the lake's smolt production in 2001, this analysis likely produces a realistic estimate of the real change in reproductive potential during the recent era of elevated PSM.

4.10.2. Three Generation Projections (2002-2013)

The three-generation spawner projections are yearly averages for all parameter sets and trials. We modelled scenarios in 10% increments of PSM's from 40-90%, and ER's from 0-50% (Table 7). Two results are notable. First, the population is projected to continue to decline if PSM remains above 80% even if harvest is restricted to low levels. For example, if PSM continues to exceed 90%, then the effective spawning population will decline by more than 75% in the absence of exploitation (one-generation smoothed trend), and by over 80% (a level associated with a *Critically Endangered* classification using the IUCN criteria) if the ER exceeds 10% (Fig. 18). Second, because the population is relatively unproductive and the current population is small, abundances will increase very slowly even at low levels of PSM and harvest. For example, at 40% PSM and 0% ER, the average abundance is not expected to approach even the lower part of the range in productive capacity estimates for at least 25 generations.

4.10.3. Probability of Extinction

We estimate the probability of extinction using quasi-extinction thresholds of 50 and 100 effective adult spawners in any consecutive four year period (one cycle) to avoid the need to explicitly consider the potential for depensatory population dynamics that may increase the risk of extinction at low population sizes. Although somewhat arbitrary, these demographic extinction thresholds probably approximate the level below which recovery is unlikely. Extinction probability is highly dependent on several factors, including the levels of PSM and ER, the time frame over which the projections are made, and the threshold of extinction used (Table 8). In this discussion, we limit consideration to the 100 fish quasi-extinction threshold because, although the lower threshold reduces the short-term probability of extinction, it has little impact over longer time frames. The probability of extinction increases with increasing PSM and exploitation. In general, the probability of extinction is negligible if PSM is less than 70% and harvest is constrained to moderate levels, but increases sharply at higher PSM levels. If PSM remains at 90% or more, even in the absence of fishing, the probability of extinction is 56% in three generations and 98-100% over longer periods of 10 and 25 generations, respectively. If the fishery ER exceeds approximately 15% and PSM remains at 90%, the probability of extinction exceeds 65%.

Our model may underestimate the probability of extinction of Cultus sockeye for two reasons. First, the extinction probability estimates reflect the persistence of a strong dominant cycle in the 1998-2001 brood year escapements that we use to initialize the model. The 1999 dominant cycle escapement of 12,400, after the adjustment for an assumed 90% PSM (Section 3.4.2), was 1,240 adults. This is about six times the next largest escapement (200 on the 1998 subdominant cycle) and 24 times the smallest escapement (52 on the 2001 off-cycle). The existence of a single large cycle results in lower estimates of the probability of extinction because it significantly reduces the probability that escapements will fall below 100 effective spawners in any four year period (Fig. 19). At an assumed 90% PSM in the absence of fishing, the probability that escapements on the 1999 dominant cycle will fall below 100 effective spawners within three generations is 43%. In contrast, the probability of extinction for the other three cycles exceeds 77% in the same time period, and is as high as 96% for the weak 2001 off-cycle. At a 90% PSM and a 15% ER, three of the four cycles have probabilities of extinction that exceed 85%; the 1999 dominant cycle has a probability of about 55%. Under conditions of high PSM, the population will be maintained increasingly by a single year-class. We acknowledge that five-year-old spawners from the dominant cycle can repopulate subsequent cycles; however, we are concerned that the genetic diversity of the population would likely be reduced and population resiliency compromised. Second, while our use of a quasi-extinction threshold is intended to compensate for Allee effects, demographic stochasticity and genetic effects, a higher level may be warranted given stock-specific considerations such as dense predator populations and the encroachment onto the spawning grounds by watermilfoil. Since the onset of the early migration, the fry population has declined by an order of magnitude below the previously observed range in abundance (the 2000 brood population of 46,000 compares to populations ranging from 0.475-2.38 million in the 1980's). We are concerned that such declines in abundance may be sufficiently extreme to permit the mortality rate caused by predators in Cultus Lake to increase to a level that inhibits recovery or even population replacement. The large predator population in Cultus Lake makes some level of depensatory mortality possible. Watermilfoil is also a concern because, at low spawner populations, the impact of redd construction activities may be insufficient to inhibit its encroachment onto the spawning grounds.

Our model did not explicitly consider potential differences in the spawning success of adults from different temporal components of the Cultus sockeye migration. Tagging studies on Weaver and Portage sockeye in 2001 show that spawning success is lower among fish tagged at the beginning of the study. If these fish were also the first to enter the Fraser River, then the affect of fisheries (which are expected to have a greater impact on the earlier part of the late run) on the number of effective adults may be overstated by the model. Given the uncertainty about whether the fish that were tagged first in terminal areas were from the earliest part of the migration into river, we used a precautionary assumption that all adults had an equal probability of spawning success. Given the low exploitation rates expected for Cultus sockeye in 2002, this assumption will not significantly impact our estimates of the probability of extinction as presented above. In 2002, a large scale marine tagging program directed at Adams River sockeye should provide data on the chronological order of movement of adults from marine waters to the terminal area, and on temporal trends in spawning success. This will be important in evaluating the impact of potential fisheries in the future.

4.10.4. IUCN Red List Categorization

There is strong evidence from current rates of decline and modelled population results that, should PSM and ER continue to exceed 90% and 10-20%, respectively, the status of the Cultus sockeye stock will be consistent with a *Critically Endangered (CR)* classification as defined by the IUCN. Under this scenario, the model suggests that escapements will decline at a rate greater than 80% (Criterion A4, Section 3.5.1) and the probability of extinction over the next three generations will be greater than 50% (Criterion E, Section 3.5.1).

5.0. CONCLUSIONS

1. **Population Genetics:** Cultus Lake supports a sockeye population that is genetically unique from other Fraser populations both at neutral loci such as microsatellites and at a locus under selection such as MHC. The population exhibits considerable evidence of evolutionary adaptations for survival in their local lake environment. Attempts to introduce non-native sockeye populations into the lake have failed. We conclude, therefore, that Cultus sockeye are evolutionarily distinct from other sockeye populations.

2. **Population Status:** Cultus sockeye escapements declined on all cycles since the 1950's, and by 51% or 6.5% per year over the last three generations. Fewer than 2,000 adult sockeye returned to Cultus Lake in three of the last four years. When we consider the impact of the elevated prespawn mortality in recent years, the rate of decline is more severe at 93% over the last three generations. The effective spawning population has declined to less than 4% of the long term average on each of the four cycles. There are three principle causes for the current status of the Cultus sockeye stock: exploitation rates that have exceeded the optimum rate associated with maximum sustainable yield (MSY) in most years between 1952 and 1995; low recruitment rates in the 1991 to 1996 brood years; and the extremely high prespawn mortality that has occurred since the onset of the early migration in 1995:

   Exploitation Rates: Our estimate of the mean exploitation rate at MSY for Cultus sockeye is 56%. Exploitation rates have far exceeded this level in most years and on all cycles: long-term cycle-specific average exploitation rates vary from 67-77%; annual exploitation rates have frequently exceeded 80% and sometimes 90%; and exploitation rates on the two off-cycles actually increased from about 60% in the 1960's to over 80% in subsequent decades as a result of increased fishing to harvest enhanced Weaver sockeye. It is likely that the sustained decline in escapements on three cycles results from the sub-optimal exploitation rates that have been applied to the stock almost continuously for over four decades. These declines have increased the vulnerability of the Cultus population to the recent environmental and behavioural changes that are associated with low recruitment and high prespawn mortality.

Low Recruitment: Recruitment was near or below the replacement level and considerably below the long-term average for most of the 1990's, a period coincident with the *El Nino* events of 1992-1993 and 1997-1998. Short term low recruitment compounded the long term effects of overexploitation and contributed to the sharp population declines in the 1990's.

Prespawn Mortality: Prespawn mortality increased in the late 1990's to a level that we estimate to be in excess of 90%. Based on information collected from Cultus and other late run stocks, we conclude that the elevated mortalities result directly from extended exposures to *Parvicapsula minibicornis*, and indirectly from the abnormally early migration into freshwater. Although considerable effort is being expended to identify the cause of the early migration, we are unable to predict either its occurrence or its likely severity. Its effect on Cultus sockeye has been an unsustainable loss of reproductive potential. To illustrate this point, at current marine survival (7%) and prespawn mortality (93%) levels, we estimate that each successful adult spawner must produce over 400 smolts to sustain the population. This is almost six times the level of smolt production that has been observed in the last two brood years. Under these conditions, even if exploitation is limited to the lowest possible levels, effective mitigation measures will be required to arrest the decline and maintain a viable stock. A recovery to higher abundances in the face of continued high prespawn mortality may not be possible.

3. **Threats to the Population:** The current low population abundances leaves Cultus sockeye vulnerable to a number of threats:

Environmental Stochastisity: The Cultus sockeye population is vulnerable to random changes in the freshwater and marine environments that otherwise might be benign for larger populations. For example, the recurrence of a series of *El Ninos* such as those of the 1990's could reduce marine survivals to levels that, even if the migration returned to normal and exploitation rates were limited to low levels, would pose a serious threat to this population.

Parasites: The copepod *Salmincola californiensis* is known to infect and cause mortality in juvenile sockeye salmon (Kabata and Cousens 1977). Foerster (1929c) reported a heavy infestation of the 1927 smolt migration; similar levels were observed in recent smolt migrations (K. Peters, DFO Stock Assessment, pers. comm) and among captive broodstock (S. Barnetson, DFO, Inch Creek Hatchery, pers. comm.). The impact of this parasite on the survival of fry and smolts is unknown; however, the level of infestation is sufficiently severe that it may present a threat to the population at current low abundances and may impact the success of emergency mitigation measures.

Predators: Relatively small fry populations are now entering into a predator-rich environment in Cultus Lake. Because predation is one mechanism in the depensatory population dynamics of collapsed stocks, the large predator population is probably an important threat to the recovery of this stock.

Eurasian Watermilfoil: The expanding Eurasian watermilfoil population provides habitat for predator species and encroaches on sockeye spawning habitat; it may pose a threat to sockeye recovery.

Habitat Alteration: The impact of recreational, residential and agricultural activities on the sockeye population is unclear. Comparisons of limnological information from 2001 with that collected in the 1930's and 1960's suggest that the lake's limnetic habitat has changed relatively little over 65 years. Little information is available, however, regarding changes in the quality and quantity of groundwater, the effect of siltation or pollutants on habitat quality, or the encroachment of lakeshore developments on spawning habitats.

4. **Prognosis:** Our simulations show that if the current conditions of high prespawn mortality continue, even in the absence of any fishing mortality, the prognosis for the stock over the next three generations is critical: the probability of falling to less than 100 adult spawners is very high (>90%) for three cycles and high (60%) for the remaining cycle; the probability of extinction, defined as the return of 100 or fewer effective spawners per year for four consecutive years, is 56%; and the rate of decline over three generations is predicted to be 76%. If moderate exploitation rates continue (modelled ER's exceeding 15% and PSM remaining at 90%), the prognosis is poorer; the probability of extinction over the next

three generations increases to more than 65%. We note that our prognosis may be optimistic for two reasons. First, our understanding of the dynamics of the population at low levels of abundance is poor. Depensatory effects that increase mortalities at low abundances (*e.g.,* predator pits) may exacerbate difficulties in maintaining or rebuilding this population. Second, while the persistence of the large dominant cycle reduces our estimate of the probability of extinction, the maintenance of the population by a single cycle likely reduces genetic diversity and compromises population resiliency. Considering all of these factors, we conclude that it is very unlikely that Cultus sockeye can avoid the conditions defined as *Critically Endangered* by the IUCN.

5. **Stock Productivity:** The productivity of a stock has implications to both its probability of extinction and its prospects for recovery, especially when managed and harvested with other more productive stocks in mixed stock fisheries. Our analyses indicate that the Cultus sockeye stock typically has been less productive than other Fraser stocks: the exploitation rate at MSY (56%) is lower than for Chilko (76%) and Adams (68%), two stocks with which Cultus co-migrates; the marine survival rate (7%) is lower than for the Chilko population (9%); and trends in abundance since the 1950's are consistent with the conclusion that the production of Cultus sockeye will decline from optimal levels in the absence of high prespawn mortalities if exploitation rates are in the 70-90% range. Furthermore, depensatory mortality could reduce the stock productivity when abundances are low, increasing the probability of extinction if exploitation rates return to high levels.

6. **Productive Capacity:** Productive capacity is a measure of the spawner abundance that produces the maximum sustainable numbers of recruits. While productivity is related to productive capacity, there can be stocks that are very productive but have a small productive capacity while the opposite can also be true. Point estimates of the productive capacity of Cultus sockeye (S_{max}) range from 56,000 to 115,300 effective spawners. These estimates are uncertain because they lie outside the range of the observed escapement data; however, they are consistent in suggesting that the stock's productive capacity is in the higher part of the range of the observed data or beyond. The mean observed escapements of 15,000 since 1925, 7,000 since 1975, and 4,000 since 1995 are much lower than any of our estimates of S_{max}. Since 1995, the mean escapement recorded at the fence is only 7% of the lowest estimate of S_{max}, while the mean number of effective spawners at 90% prespawn mortality is less than 1% of the low end of the S_{max} range. Regardless of the true value of S_{max}, we conclude that current escapements are a small fraction of the level that would utilize a substantial part of the stock's productive capacity.

7. **Mixed Stock Management:** Cultus sockeye are managed as part of a late run group that includes much larger and more productive stocks such as Adams and Weaver. The Department's management policy establishes fishery objectives and escapement targets for the dominant stocks in the group (either Weaver or Adams), resulting in sub-optimal exploitation rates on other stocks such as Cultus. The policy acknowledges that the less productive stocks may not achieve their productive capacity but assumes that they will stabilize at lower levels. We conclude that this assumption is likely invalid for Cultus sockeye because exploitation rates at the high end of the historic range have caused sustained declines in the size of the population. The recent increase in prespawn mortality has accelerated that decline.

   The already depressed state of the Cultus sockeye stock has made it more vulnerable to survival fluctuations such as that caused by the recent change in migratory behaviour; other as yet unassessed late run stocks may share a similar status. If the early migration persists, other late run stocks will decline to levels where the probability of extinction becomes significant; populations that are already small are most vulnerable.

6.0. RECOMMENDATIONS

1. **Risk Assessment Framework:** We recognize that various fisheries and recovery options have costs and benefits for Cultus sockeye and for other co-migrating stocks and the fisheries that harvest them. We recommend the formation of an inter-sectoral working group to develop a risk assessment framework that explicitly evaluates the risks of different fisheries and recovery options in terms of their cultural, ecological, economic and social values.

2. **Precaution:** Precautionary measures are required while a risk assessment framework is developed. We recommend that the risk assessment take into account the high level of uncertainty resulting from the inability to forecast either the occurrence of the early migration of Cultus sockeye or the severity of mortality associated with this abnormal behaviour. It should also recognize the likelihood that the early migration will continue and that prespawning mortalities will be high. Consequently, it would be precautionary for managers to minimize exploitation rates to reduce the near term probability of extinction and slow the rate of decline in adult spawner abundance.

3. **Recovery Plan:** Even if exploitation rates are negligible, Cultus sockeye will continue to decline if pre-spawn mortality remains high and will face a high probability of extinction. Because the current level of abundance is extremely low, Cultus sockeye are more susceptible to adverse conditions such as poor marine survival that, in themselves, would increase the probability of extinction and inhibit the recovery of the stock. Consequently, the Department should continue to support short term mitigation efforts, such as the captive brood stock project that began this year, while developing a comprehensive recovery plan that integrates options to improve freshwater survival (*e.g.,* enhancement, predator control, habitat improvement) with harvest control and other measures. Other measures that should be considered for immediate implementation are: a public education and awareness campaign to improve public awareness of the importance of the riparian zone and to address poor residential construction and home maintenance practices, and the illegal removal of sockeye from Sweltzer Creek; and restricting access to the day use area of upper Sweltzer Creek to minimize delaying by Cultus sockeye in thermally suboptimal environments.

4. **Assessment Data:** Our analyses are based on critical assumptions regarding run timing, exploitation rates, the temporal pattern of prespawn mortality, and freshwater survival. For example, if the stock actually migrates earlier than we assume (with the more heavily exploited summer run stocks), or if freshwater survival is lower than in the past, then the probability of extinction may actually be higher than reported here. Ongoing and planned studies provide information important to our understanding of the status of Cultus sockeye and to the development of a risk assessment framework and a comprehensive recovery plan. The following operational assessment projects must be implemented, or maintained and improved, if we are to adequately assess and document the status of the stock over the recovery period:

   - The spawner enumeration fence should continue to be used as the primary tool to enumerate Cultus sockeye escapements. Early installation is required to document the persistence of the early migration;
   - Frequent and systematic spawner surveys of the entire lake, beginning shortly after the first arrival of spawners at the fence, are required to better document spawning locations, the temporal pattern of mortality, and the prespawn mortality level;
   - The relationship between arrival time at Sweltzer Creek and subsequent prespawn mortality should be investigated, provided there is a minimal risk of incremental mortality among the test animals;
   - Underwater surveys (diver or remote video) are required to map substrate composition and groundwater flow and quantity, document the extent of available spawning habitat and its current level of utilization and map the distribution of watermilfoil to assess whether a control program is warranted;
   - The current status (amount, chemistry, oxygen, pH, heavy metals) of groundwater should be sampled in selected lake areas to assess potential impacts of upslope activities;

- Hydroacoustic assessments of fall fry abundance are required as early feedback regarding the actual level of prespawn mortality;
- Continued limnological assessments are required to evaluate and refine the estimate of total seasonal carbon production in Cultus Lake (PR_{total}) and the related estimate of S_{max};
- Our understanding of the interaction between northern pikeminnows and sockeye juveniles should be improved by: completing a comprehensive analysis of the effectiveness of previous control projects; conducting a mark-recapture project to determine the current abundances of piscivorous fish populations; and assess the potential benefits from a predator control project;
- The smolt enumeration fence should continue as a tool to assess freshwater and marine survivals;
- First Nations' traditional knowledge should be collected and documented through an interview process with Soowahlie First Nation elders and incorporated into the recovery plan;
- Past and future watershed uses should be mapped to evaluate ecosystem and stock impacts;
- The development of an effective recovery plan requires studies of ecosystem linkages in Cultus Lake, especially those that improve our understanding of predators effects at low sockeye fry abundance. Depensatory mortality, if present, will inhibit the recovery of Cultus sockeye and will increase the population's probability of extinction.

7.0. LITERATURE CITED

Aiken, S.G., Newroth, P.R., and Wile, I. 1979. The biology of Canadian Weeds 34: *Myriophyllum spicatum* L. Can. J. Plant Sci. 59: 201-215.

Alexander, C.A.D. 2001 First Nation catch estimates in the lower Fraser River and recommended improvements for future aerial-access creel surveys. Prepared for the Department of Fisheries and Oceans, Fraser River Division by ESSA Technologies Ltd. 46 p.

Aro, K.V. 1979. Transfers of eggs and young of Pacific Salmon within British Columbia. Fish. Mar. Serv. Tech. Rep. 861: 147 p.

Beverton, R.J.H., and Holt, S.J. 1957. On the dynamics of exploited fish populations. U.K. Min. Agr., Fish. and Food, Fish. Invest. (Ser. 2), 19: 1-533.

Bickham, J.W., Wood, C.C., and Patton, J.C. 1995. Biogeographic implications of cytochrome *b* sequences and allozymes in sockeye (*Oncorhynchus nerka*). J. Hered. 86: 140-144.

Bradford, M.J., Pyper, B., and Shortreed, K.S. 2000. Biological responses of sockeye salmon to the fertilization of Chilko Lake, a large lake in the interior of British Columbia. N. Am. J. Fish Manage. 20: 661-671.

Brannon, E.L. 1967. Genetic control of migration behavior of newly emerged sockeye salmon fry. International Pacific Salmon Fisheries Commission Progress Report No. 16: 31p.

Burczynski, J. J., and Johnson, R. L. 1986. Application of dual-beam acoustic survey techniques to limnetic populations of juvenile sockeye salmon (*Oncorhynchus nerka*). Can. J. Fish. Aquat. Sci. 43: 1776-1788.

Cannings, S.G., and Ptolemy, J. 1998. Rare freshwater fish of British Columbia. Ministry of Environment, Lands and Parks, Victoria, B.C. 214 pp.

Cannings, S.G., Fraser, D., and Munro, W.T. 1998. Provincial lists of species at risk. Pp. 16-23 *In:* Biodiversity in British Columbia. Harding, L.E., and McCullum, E. (eds.), Canadian Wildlife Service, Delta, B.C.

Cass, A.J. 1989. Stock status of Fraser River sockeye. Can. Tech. Rep. Fish. Aquat. Sci: 1674. 106 p.

Cass, A. 2000. Pre-season run size forecasts for Fraser River sockeye in 2000. Canadian Stock Assessment Secretariat. Research Document 99/129.

Cass, A. 2001. Pre-season run size forecasts for Fraser River sockeye and pink salmon in 2001. Canadian Stock Assessment Secretariat. Research Document 2001/063.

Clutter, R.I., and Whitesel, L.E. 1956. Collection and interpretation of sockeye salmon scales. Int. Pac. Salmon Fish. Comm. Bull. 9: 159 p.

Collie, J.S., and Walters, C.J. 1987. Alternative recruitment models of Adams River sockeye salmon, *Oncorhynchus nerka*. Can. J. Fish. Aquat. Sci. 44: 1551-1561.

Cook, R.C., and Lord, G.E. 1978. Identification of stocks of Bristol Bay sockeye salmon *(Oncorhynchus nerka)* by evaluating scale patterns with a polynomial discriminant method. Fish. Bull., U.S. 76: 415-423.

Cooper, A.C. 1952. Downstream migrant study Cultus Lake. Int. Pac. Salmon Fish. Comm., unpublished. 12 p.

Deriso, R.B. 1980. Risk averse harvesting strategies, p. 65-73 *In:* M. Mangel (ed). Resource management, Proceedings of the second Ralf Yorque Workshop (Springer-Verlag Lecture Notes in Biomathematics No. 61). Berlin: Spinger.

Enzenhofer, H. J., and Hume, J. M. B. 1989. Simple closing midwater trawl for small boats. N. Am. J. Fish Manage. 9: 372-377.

Foerster, R.E. 1929a. An investigation of the life history and propagation of the sockeye salmon *(Oncorhynchus nerka)* at Cultus Lake, British Columbia. No. 1. Introduction and the run of 1925. Contributions to Canadian Biology and Fisheries 5 (1): 3-35.

Foerster, R.E. 1929b. An investigation of the life history and propagation of the sockeye salmon (*Oncorhynchus nerka)* at Cultus Lake, British Columbia. No. 2. The run of 1926. Contributions to Canadian Biology and Fisheries 5 (2): 39-53.

Foerster, R.E. 1929c. An investigation of the life history and propagation of the sockeye salmon *(Oncorhynchus nerka)* at Cultus Lake, British Columbia. No. 3. The downstream migration of the young in 1926 and 1927. Contributions to Canadian Biology and Fisheries 5 (3): 57-82.

Foerster, R.E. 1934. An investigation of the life history and propagation of the sockeye salmon *(Oncorhynchus nerka)* at Cultus Lake, British Columbia. No. 4. The life history cycle of the 1925 year class with natural propagation. Contributions to Canadian Biology and Fisheries 8 (27): 345-355.

Foerster, R.E. 1936a. An investigation of the life history and propagation of the sockeye salmon *(Oncorhynchus nerka)* at Cultus Lake, British Columbia. No. 5. The life history cycle of the 1926 year class with artificial propagation involving the liberation of free-swimming fry. J. Biol. Bd. Can. 2 (3): 311-333.

Foerster, R.E. 1936b The return from the sea of sockeye salmon *(Oncorhynchus nerka)* with special reference to percentage survival, sex proportions and progress of migration. J. Biol. Bd. Can. 3 (1): 26-42.

Foerster, R.E. 1938. An investigation of the relative efficiencies of natural and artificial propagation of sockeye salmon (*Oncorhynchus nerka*) at Cultus Lake, British Columbia. J. Fish. Res. Bd. Can. 4 (3): 151-161.

Foerster, R.E. 1946. Restocking depleted sockeye salmon areas by transfer of eggs. J. Fish. Res. Bd. Can. 6 (7): 483-490.

Foerster, R.E. 1947. Experiment to develop sea-run from land-locked sockeye salmon (*Oncorhynchus nerka kennerlyi)*. J. Fish. Res. Bd. Can. 7 (2): 88-93.

Foerster, R.E. 1954. On the relation of adult sockeye salmon returns to known seaward migrations. J. Fish. Res. Bd. Can. 11:339-350.

Foerster, R.E. 1968. The sockeye salmon, *Oncorhynchus nerka.* Fish. Res. Board Can. Bull. 162. Ottawa.

Foerster, R.E., and Ricker, W.E. 1941. The effect of reduction of predaceous fish on survival of young sockeye salmon a Cultus Lake. J. Fish. Res. Bd. Can. 5 (4): 315-336.

Foerster, R.E., and Ricker, W.E. 1953a. The coho salmon of Cultus Lake and Sweltzer Creek. J. Fish. Res. Bd. Can. 10: 293-319.

Foerster, R.E., and Ricker, W.E. 1953b. Predator control and sockeye salmon production. Fisheries Research Board of Canada, Confidential Manuscript, 18 p.

Friesen, T.A., and D.L. Ward. 1999. Management of northern pikeminnow and implications for juvenile salmonid survival in the lower Columbia and Snake rivers. N. Am. J. Fish. Manage. 19: 406-420.

Gable, J.H., and Cox-Rogers. S.F. 1993. Stock identification of Fraser River sockeye salmon: methodology and management application. Pacific Salmon Comm. Tech. Rep. 5: 36 p.

Gelman, A., Carlin, J.B., Stern, H.S., and Rubin, D.B. 1995. Bayesian data analysis. Chapman and Hall, London, U.K.

Gilhousen, P. 1960. Migratory behavior of adult Fraser River sockeye. Int. Pac. Salmon Fish. Comm. Progress Report 7: 78 p.

Goodlad, J.C., Gjernes, T.W., and Brannon, E.L. 1974. Factors affecting sockeye salmon (*Oncorhynchus nerka*) growth in four lakes of the Fraser River system. J. Fish. Res. Bd. Can. 31: 871-892.

Hall, D.L. 1992. Summary of the 1991 and 1992 squawfish removal program, Cultus Lake British Columbia. Unpublished manuscript. 30 p.

Healey, M.C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. *In:* Salmonid ecosystems of the North Pacific. McNeil, W.J., and D.C. Himsworth (eds.). Oregon State University Press.

Henry, K.A. 1961. Racial identification of Fraser River sockeye salmon by means of scales and its application to salmon management. Int. Pac. Salmon Fish. Comm. Bull. XII: 97 p.

Hilborn, R., and Walters, C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall. New York. 570p.

Howard, G.V. 1948. A study of the tagging method in the enumeration of sockeye salmon populations, p. 9-66 *In:* Problems in enumeration of populations of spawning sockeye salmon. International Pacific Salmon Fisheries Commission, Bulletin II.

Hume, J.B., Shortreed, K.S., and Morton, K.F. 1996. Juvenile sockeye rearing capacity of three lakes in the Fraser River system. Can. J. Fish. Aquat. Sci. 53: 719-733.

IUCN 2001. IUCN Red List categories and criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. 30 p.

Jeppson, P.A., and Platts, W.S. 1959. Ecology and control of Columbia squawfish in northern Idaho lakes. Trans. Amer. Fish. Soc. 88: 197-202.

Kabata, Z., and Cousens, B. 1977. Host-parasite relationships between sockeye salmon, *Oncorhynchus nerka*, and *Salmincola californiensis* (Copepoda: Lernaeopodidae). J. Fish. Res. Bd. Can. 34: 191-202.

Keasts, A. 1984. The introduced aquatic macrophyte *Myriophyllum spicatum*, as habitat for fish and their invertebrate prey. Can. J. Zool. 62: 1289-1303.

Koenings, J.P., and Burkett, R.D. 1987. Population characteristics of sockeye salmon (*Oncorhynchus nerka*) smolts relative to temperature regimes, euphotic volume, fry density and forage base within Alaskan lakes, p. 216-234 *In:* H.D. Smith, L. Margolis, and C.C. Wood [ed.] Sockeye salmon (Oncorhynchus nerka) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Koenings, J.P., H.J. Geiger, and Hasbrouck, J.J. 1993. Smolt-to-adult survival patterns of sockeye salmon (*Oncorhynchus nerka*): effects of smolt length and geographic latitude when entering the sea. Can. J. Fish Aquat. Sci. 50: 600-611.

Levy, D.A. 1990a. Feasibility of selective squawfish removal for sockeye salmon enhancement in Cultus Lake, British Columbia. Unpublished manuscript. 31 p.

Levy, D. A. 1990b. Reciprocal diel vertical migration behavior in planktivores and zooplankton in British Columbia lakes. Can. J. Fish. Aquat. Sci. 47:1755-1764.

Lewis, P. O., and Zaykin, D. 2001. Genetic Data Analysis: Computer program for the analysis of allelic data. Version 1.0 (d16c). Free internet program from http://lewis.eeb.uconn.edu/lewishome/software.html.

McDonald, J., and Hume, J. M. B. 1984. Babine Lake sockeye salmon (*Oncorhynchus nerka*) enhancement program: testing some major assumptions. Can. J. Fish. Aquat. Sci. 41: 70 92.

McPhail, J.D., and Lindsey, C.C. 1986. Zoogeography of the freshwater fishes of Cascadia (the Columbia system and rivers north to the Stikine), p 615-637 *In:* Hocutt, C.H., and Wiley, E.O. (eds.). Zoogeography of North American Freshwater Fishes. Wiley and Sons, New York.

Miller, K.M., Kaukinen, K.H., Beacham, T.D., and Withler, R.E. 2001. Geographic heterogeneity in natural selection of an MHC locus in sockeye salmon. Genetica 111: 237-257.

Mueller, C.W., and Enzenhofer, H.J. 1991. Trawl catch statistics in sockeye rearing lakes of the Fraser River drainage basin: 1975-1985. Can. Data Rep. Fish. Aquat. Sci. No. 825.

Newroth, P.R. 1993. Application of aquatic vegetation identification, documentation, and mapping in Eurasian watermilfoil control projects. Lake and Reserv. Manage. 7: 185-196.

Northcote, T.G., and Larkin, P.A. 1989. The Fraser River: a major salmonine production system, p. 172-204. *In:* D.P. Dodge (ed.) Proceedings of the International Large River Symposium (LARS). Can. Spec. Publ. Fish. Aquat. Sci. 106: 629 p.

PSC. 2001. Report of the Fraser River Panel to the Pacific Salmon Commission on the 1999 Fraser River sockeye fishing season. Pacific Salmon Commission, Vancouver, B.C.

Parkinson, E.P., Rieman, B.E., and Rudstam, L.G. 1994. A comparison of acoustic and trawl methods for estimating density and age structure in kokanee. Trans. Am. Fish. Soc. 123: 841-854.

Peterman, R.M. 1981. Form of random variation in salmon smolt-to-adult relations and its influence on production estimates. Can. J. Fish. Aquat. Sci. 38(9): 1113-1119.

Ricker, W.E. 1933. Destruction of sockeye salmon by predatory fishes. Biol Bd. Canada, Pacific Prog. Rept. No. 18, 3-4.

Ricker, W.E. 1935. Studies of the limnological factors affecting the propagation and survival of the sockeye salmon (*Oncorhynchus nerka*) in Cultus Lake, British Columbia. PhD. Thesis, University of Toronto.

Ricker, W.E. 1937. Physical and chemical characteristics of Cultus Lake, British Columbia. J. Biol. Bd. Can. 3 (4): 363-402.

Ricker, W.E. 1938a. A comparison of seasonal growth rates of young sockeye salmon and young squawfish in Cultus Lake. Fisheries Research Board of Canada. Progress Reports of the Pacific Biological Station 36: 3-5.

Ricker, W.E. 1938b. Seasonal and annual variations in quantity of pelagic net plankton, Cultus Lake, British Columbia. J. Fish. Res. Bd. Can. 4: 33-47.

Ricker, W.E. 1938c. "Residual" and kokanee salmon in Cultus Lake. J. Fish. Res. Bd. Can. 4 (3): 192-218.

Ricker, W.E. 1941. The consumption of young sockeye salmon by predaceous fish. J. Fish. Res. Bd. Can. 5: 293-313.

Ricker, W.E. 1952. Numerical relations between abundance of predators and survival of prey. Can. Fish. Culturist No. 13: 5-9.

Ricker, W.E. 1954. Stock and Recruitment. J. Fish. Res. Board Can. 11: 559-623.

Ricker, W.E. 1960. A population of dwarf coastrange sculpins (*Cottus aleuticus*). J. Fish. Res. Bd. Can. 17: 929-932.

Schnute, J. 1985. A general theory for the analysis of catch and effort data. Can. J. Aquat. Sci. 42: 414-429.

Schnute, J.T., and Kronlund, A.R. 1996. A management oriented approach to stock recruitment analysis. Can. J. Fish. Aquat. Sci. 53: 1281-1293.

Schnute, J.T., and Kronlund, A.R. 2002. Estimating salmon stock-recruitment relationships from catch and escapement data. Can. J. Fish. Aquat. Sci. 59: 433-449

Schnute, J.T., Cass, A.J., and Richards, L.J. 2000. A Bayesian decision analysis to set escapement goals for Fraser River sockeye salmon. Can. J. Aquat. Sci. 57: 962-979.

Schubert, N.D. 1992. Angler effort and catch in the 1985-1988 lower Fraser River sport fishery. Can. Manuscr. Rep. Fish. Aquat. Sci. 2170: 140 p.

Schubert, N.D. 1998. The 1994 Fraser River sockeye salmon (*Oncorhynchus nerka*) escapement. Can. Tech. Rep. Fish. Aquat. Sci. 2201: 62 p.

Shortreed, K.S., K.F. Morton, K. Malange, and Hume, J.M.B. 2001. Factors limiting juvenile sockeye production and enhancement potential for selected B.C. nursery lakes. Can. Stock. Ass. Sec. Res. Doc. 098.

Shortreed, K.S., Hume, J.M.B., and Stockner, J.G. 2000. Using photosynthetic rates to estimate the juvenile sockeye salmon rearing capacity of British Columbia lakes, p. 505-521 *In:* Knudsen, E.E., Steward, C.R., MacDonald, D.D., Williams, J.E., and D.W. Reiser (eds). Sustainable fisheries management: Pacific salmon. CRC Press LLC.

Sloey, D., Schenck, T., and Narf, R. 1997. Distribution of aquatic invertebrates within a dense bed of Eurasian milfoil (*Myriophyllum spicatum L*.). J. Freshwat. Ecol. 12: 303-313.

St-Hilaire, S., Burrows, S.M., Higgins, M., Barnes, D., Devlin, R., Withler, R., Khattra, J., Jones, S., and Kieser, D. 2001. Epidemiology of *Parvicapsula minibicornis* in Fraser River sockeye salmon. Unpublished.

Thorne, R.E. 1988. An empirical evaluation of the duration-in-beam technique for hydroacoustic estimation. Can. J. Fish. Aquat. Sci. 45: 1244-1248.

Truelson, R.L. 1992. Control of Eurasian watermilfoil in Cultus Lake 1991. B.C. Ministry of Environment. Unpublished manuscript.

Unmuth, J.M.L., Lillie, R.A., Dreikosen, D.S., and Marshall, D.W. 2000. Influence of dense growth of Eurasian watermilfoil on lake temperature and dissolved oxygen. J. Freshwat. Ecol. 15: 497-504.

Verhoeven, L.A., and Davidoff, E.B. 1962. Marine tagging of Fraser River sockeye salmon. Int. Pac. Salmon Fish. Comm. Bull. XIII: 132 p.

Volk E.C., Blakley, A., Schroder, S.L., and Kuehner, S.M. 2000. Otolith chemistry reflects migratory characteristics of Pacific salmonids: Using otolith core chemistry to distinguish maternal associations with sea and freshwaters. Fish. Res. 46: 251-266.

Ward, F.J. 1953. A discussion of the sockeye salmon predator control experiment in Cultus Lake. International Pacific Salmon Fisheries Commission, unpublished. 25 p.

Withler, R.E., Le, K.D., Nelson, J. Miller, K.M., and Beacham, T.D. 2000. Intact genetic structure and high levels of genetic diversity in bottlenecked sockeye salmon (*Oncorhynchus nerka*) populations of the Fraser River, British Columbia, Canada. Can. J. Fish. Aquat. Sci. 57: 1985-1998.

Wood, C.C. 1995. Life history variation and population structure in sockeye salmon. Am. Fish. Soc. Symp. 17: 195-216.

Wood, C.C., Riddell, B.E., Rutherford, D.T., and Withler, R.E. 1994. Biochemical genetic survey of sockeye salmon (*Oncorhynchus nerka*) in Canada. Can. J. Fish. Aquat. Sci. 51 (Supl. 1): 114-131.

Woodey, J.C. 1987. In-season management of Fraser River sockeye salmon (*Oncorhynchus nerka*): meeting multiple objectives, p. 367-374 *In:* H.D. Smith, L. Margolis and C.C. Wood (eds.). Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

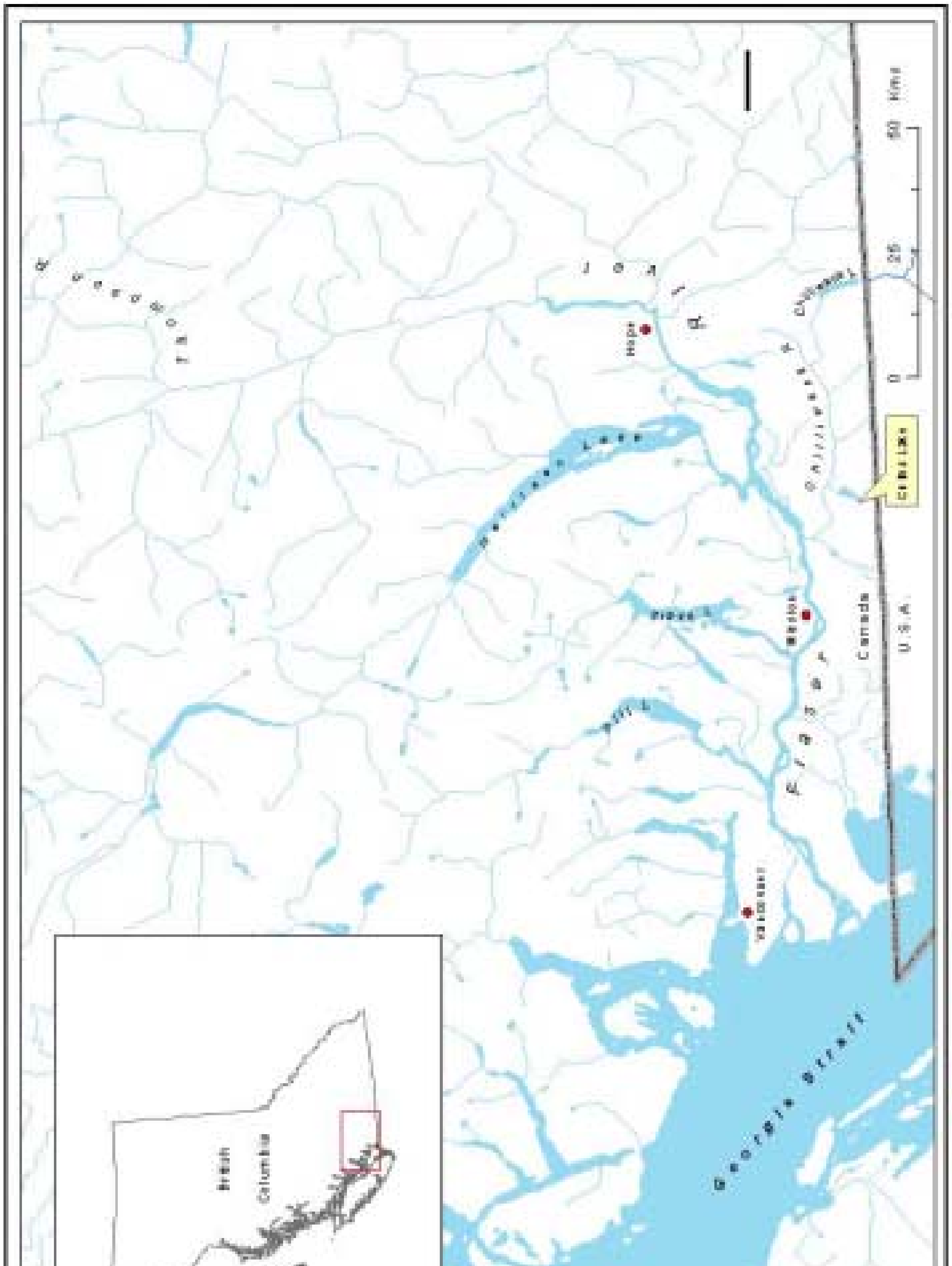

Figure 1. Location of Cultus Lake in the Lower Fraser Valley, B.C.

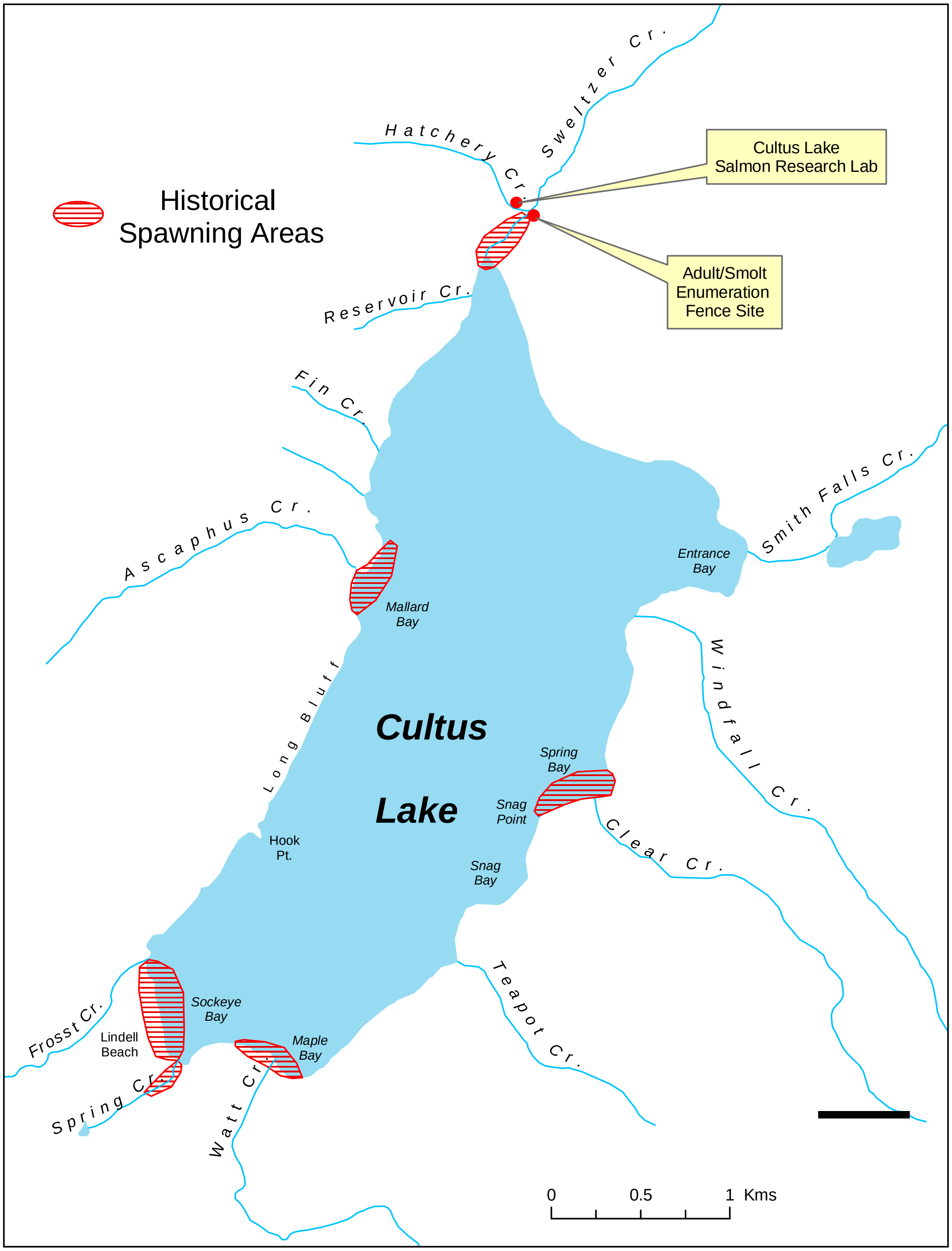

Figure 2. Cultus Lake and its tributaries, including the location of lake spawning areas.

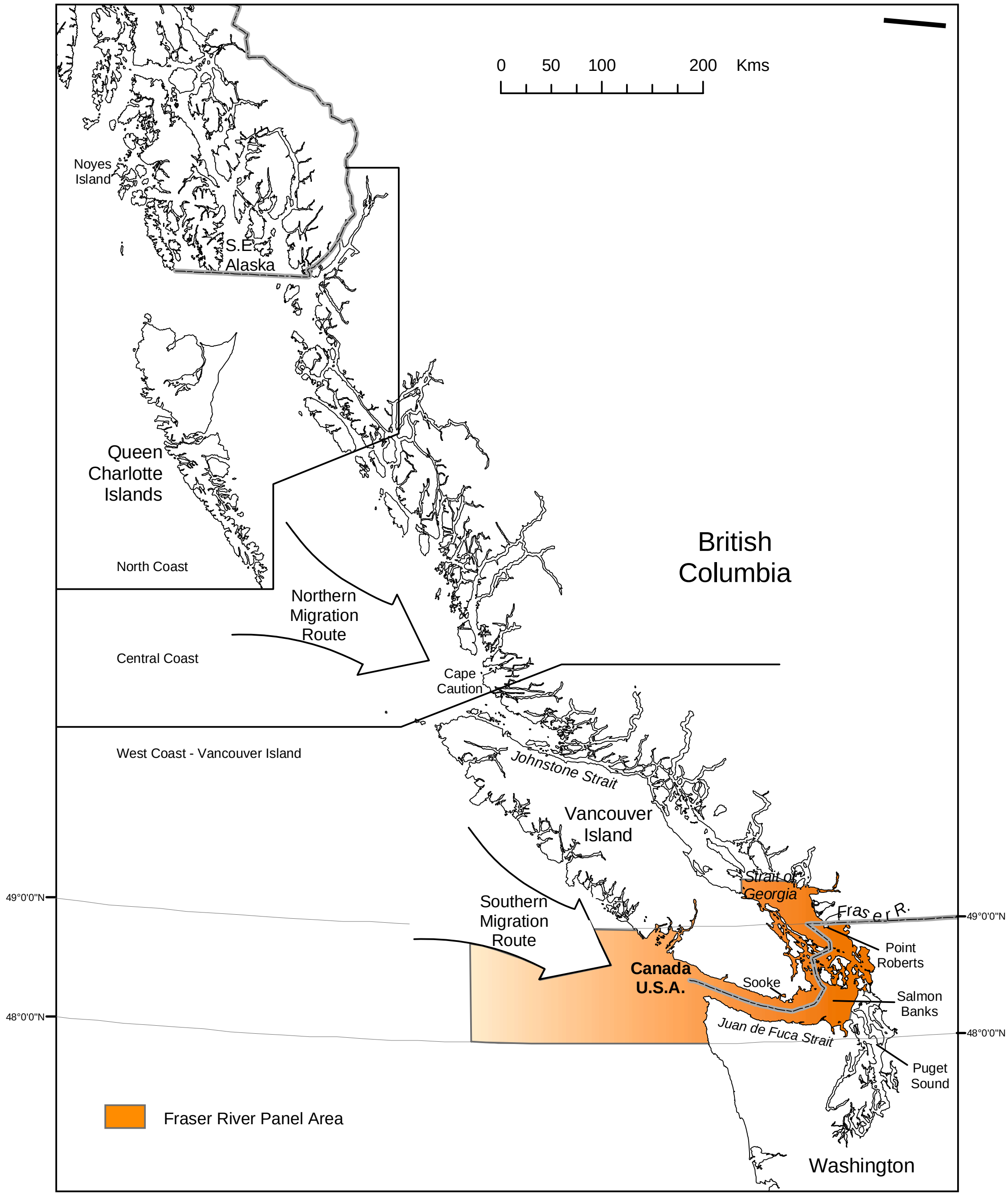

Figure 3. Migration routes and fishery locations in coastal B.C. waters and U.S. waters.

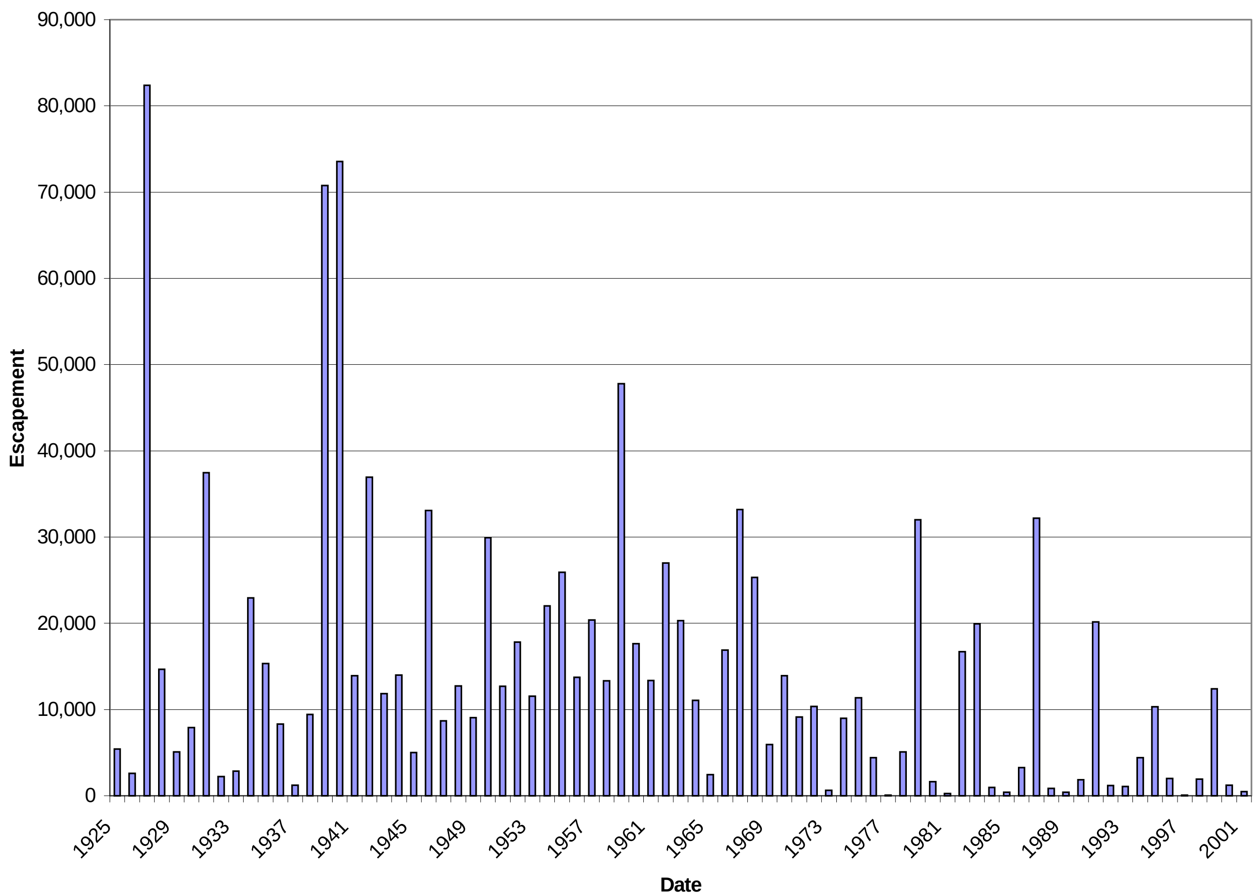

Figure 4. Annual escapements of Cultus sockeye adults, 1925 to 2001.

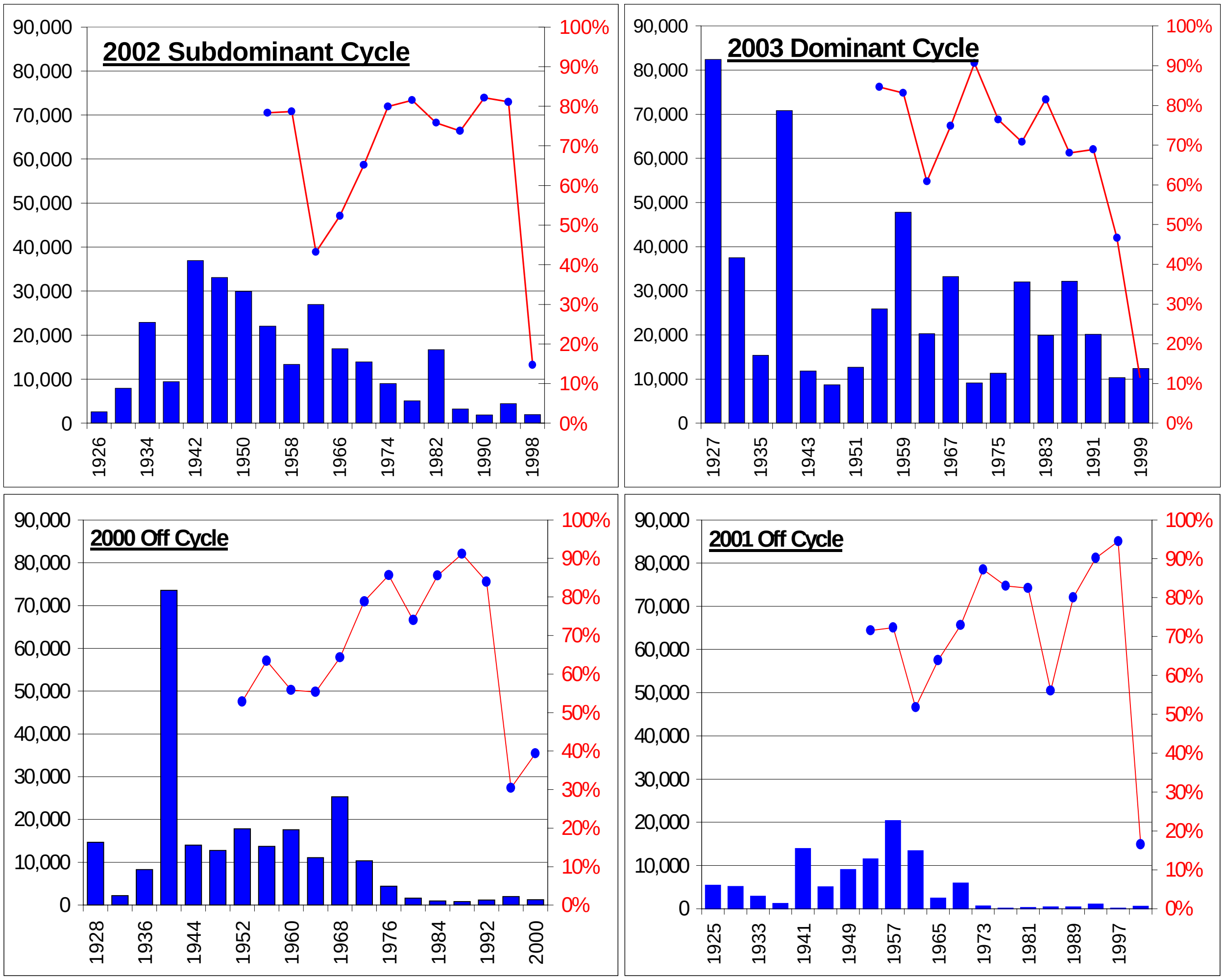

Figure 5. Annual escapement of Cultus sockeye adults for the 1998, 1999, 2000 and 2001 cycles.

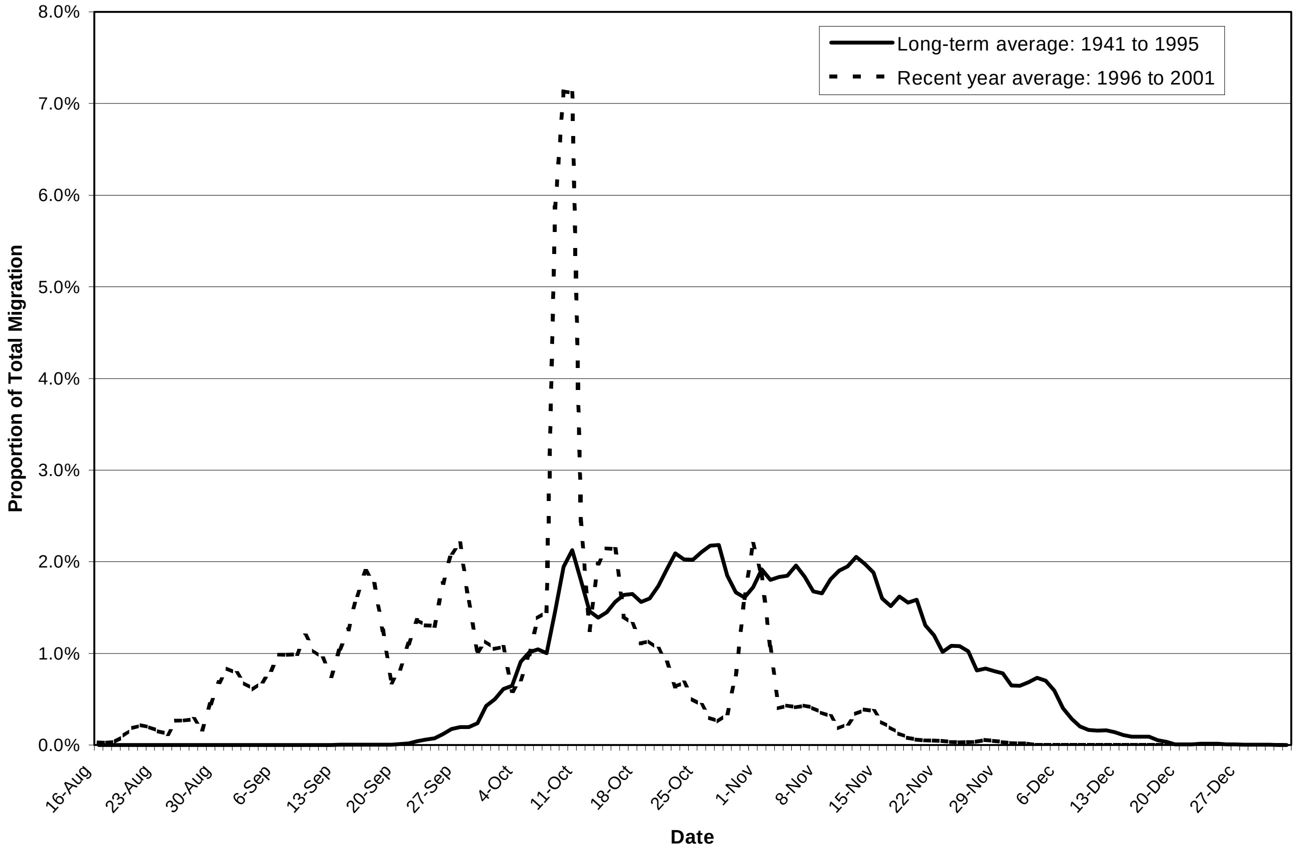

Figure 6. Average timing (with 3-day smoothing) of the migration of sockeye spawners into Cultus Lake: a comparison of the long-term average (1941-1995) and the pattern in recent years (1996-2001).

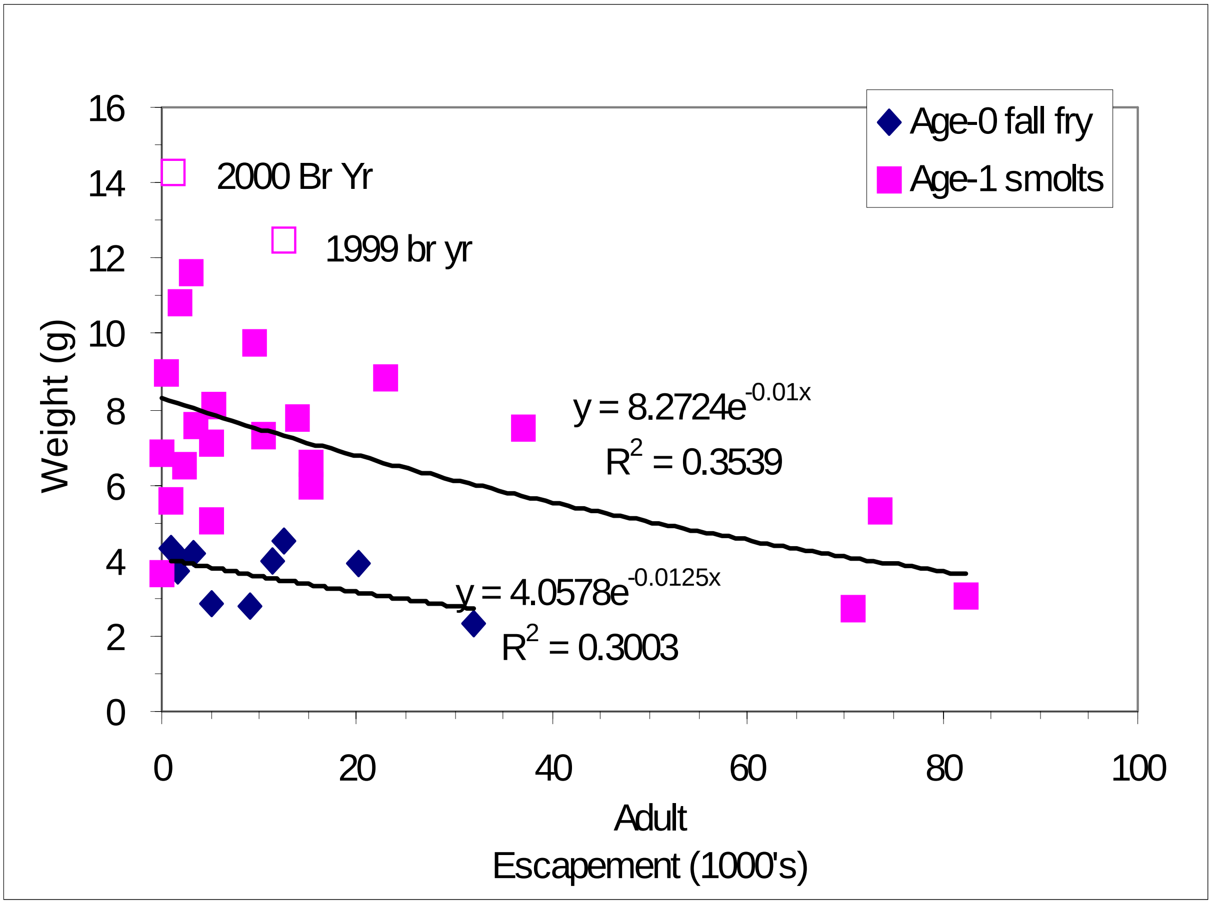

Figure 7. Relationship between Cultus adult spawner abundance and the weight of subsequent fall fry and one year old smolts.

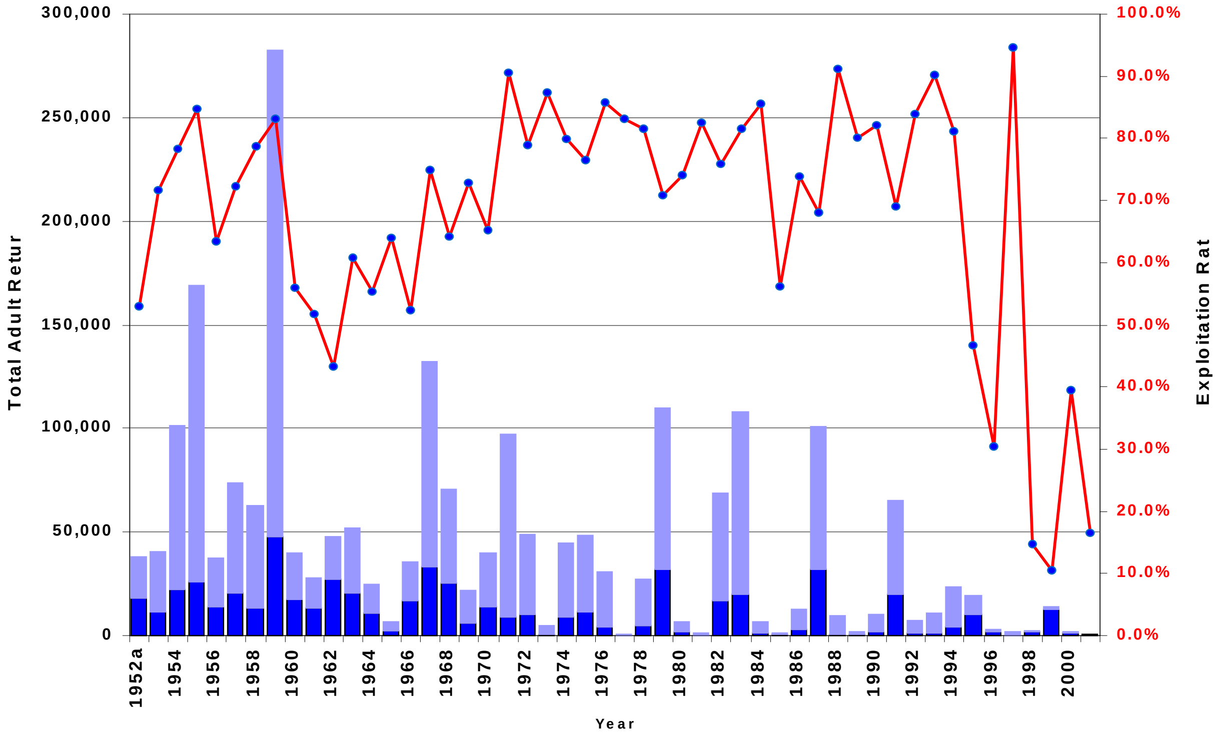

Figure 8. Total return, catch, escapement and exploitation rate for Cultus sockeye salmon, 1952 to 2001.

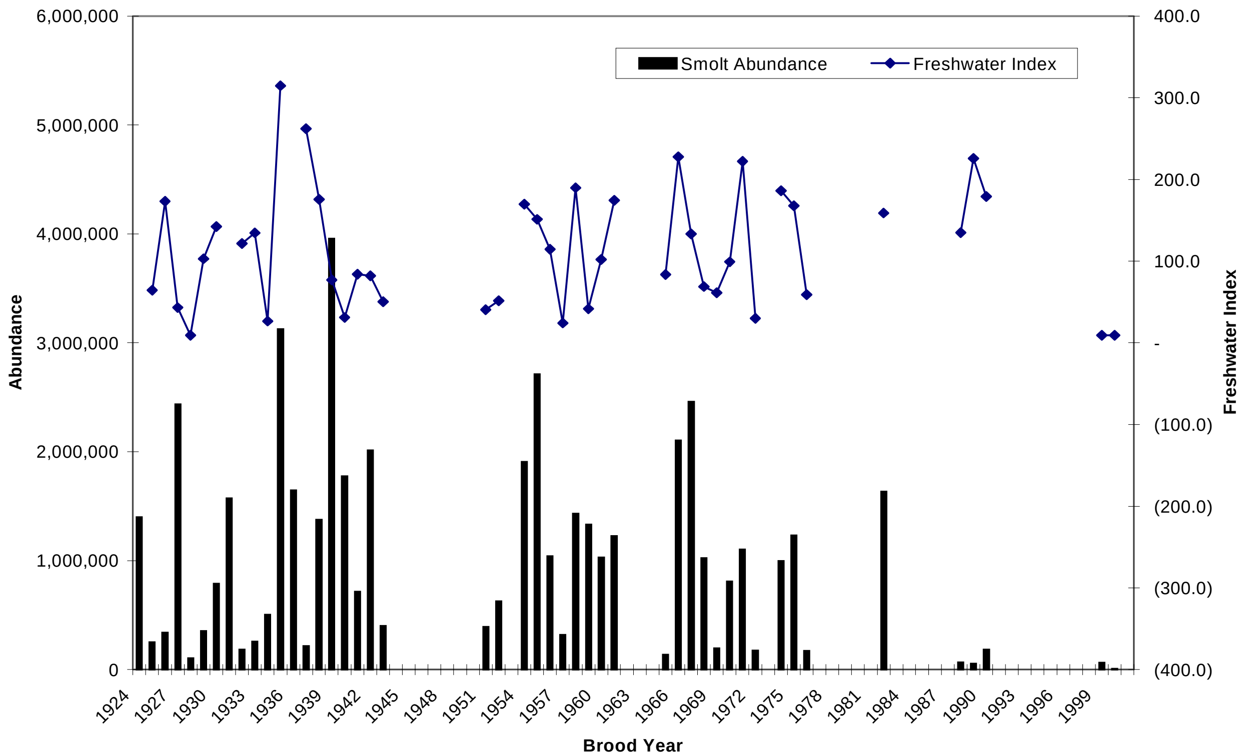

Figure 9. Cultus sockeye smolt abundance and the index of freshwater survival, 1924 to 2001.

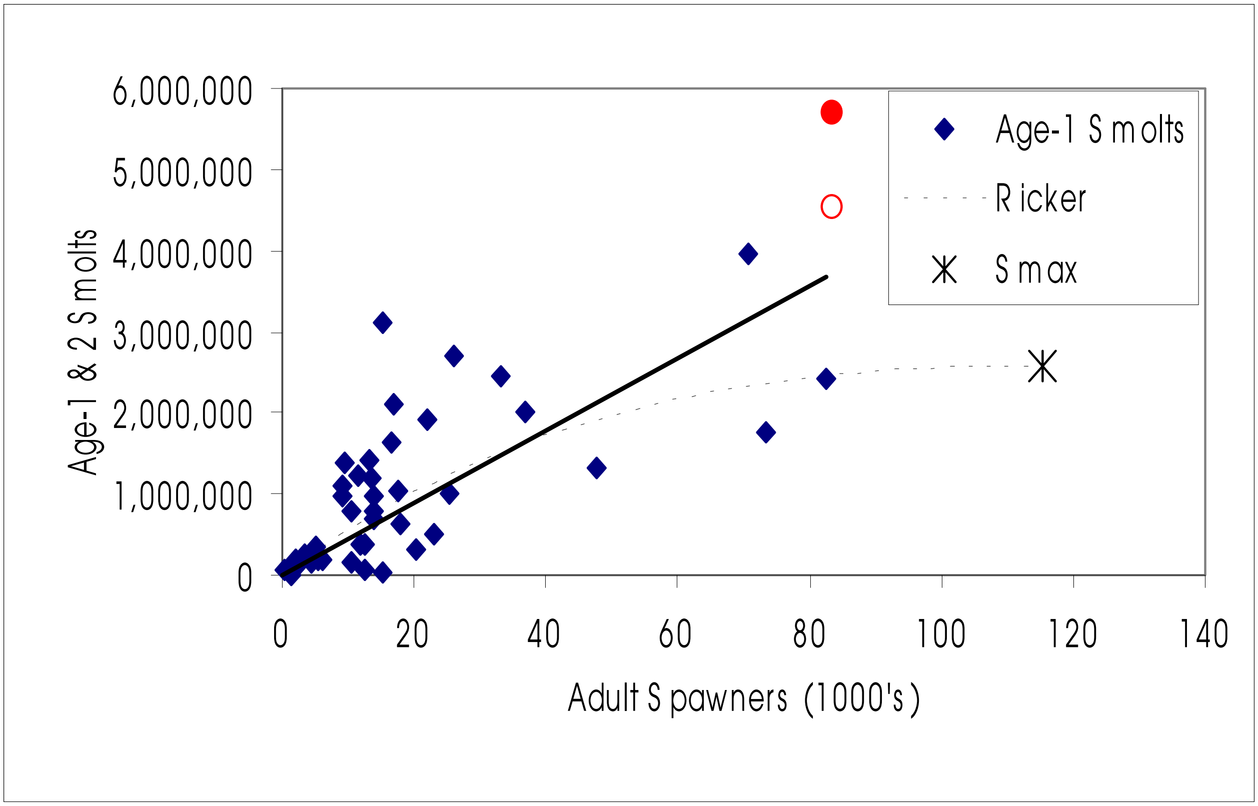

Figure 10. Relationship of smolt abundance to total escapement at Sweltzer Creek. The dotted line is a Ricker curve fitted to the data with Ricker's S_{max} shown (asterisk). The solid line is a linear fit through 0. The PR estimate of smolt production is shown using a mean smolt size of 4.5 g (open circle) and of 3.6 g (solid circle) (see Section 4.9).

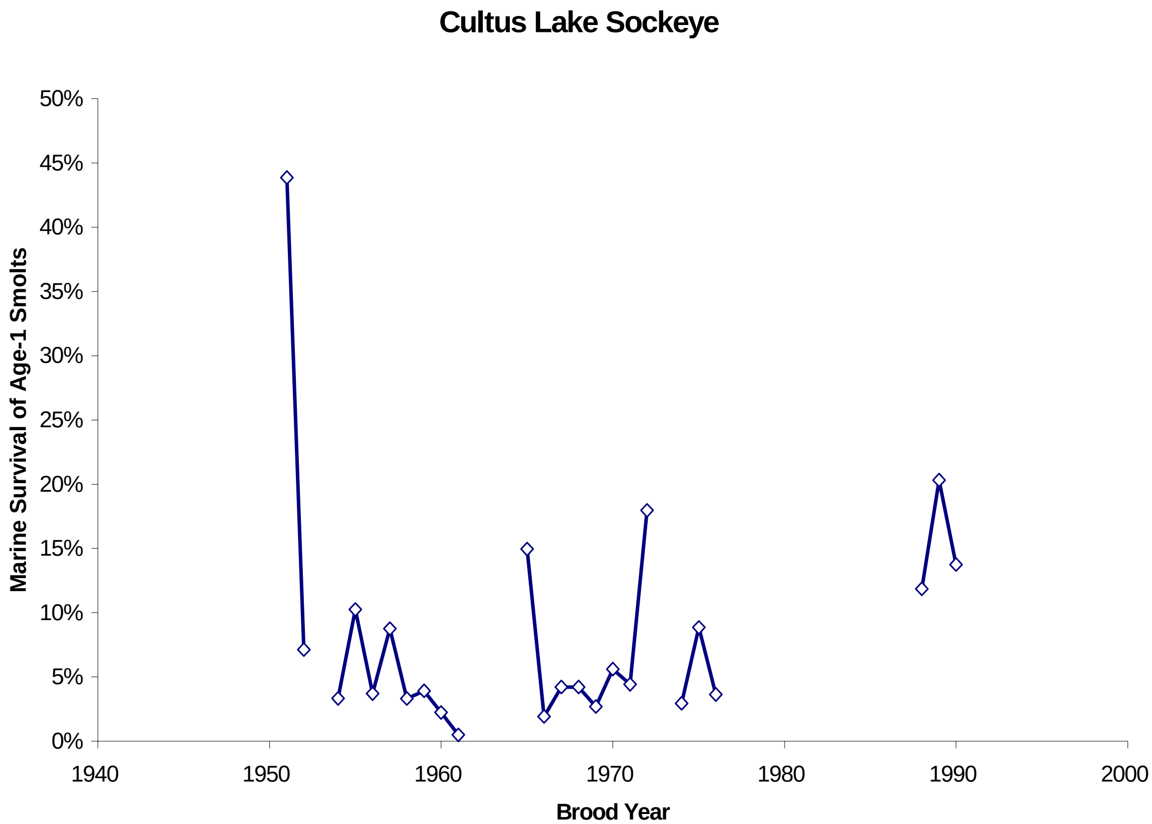

Figure 11. Cultus sockeye marine survival rates (age-1 smolts to age 4_2 and 5_2 adults) by brood year, 1951 to 1990.

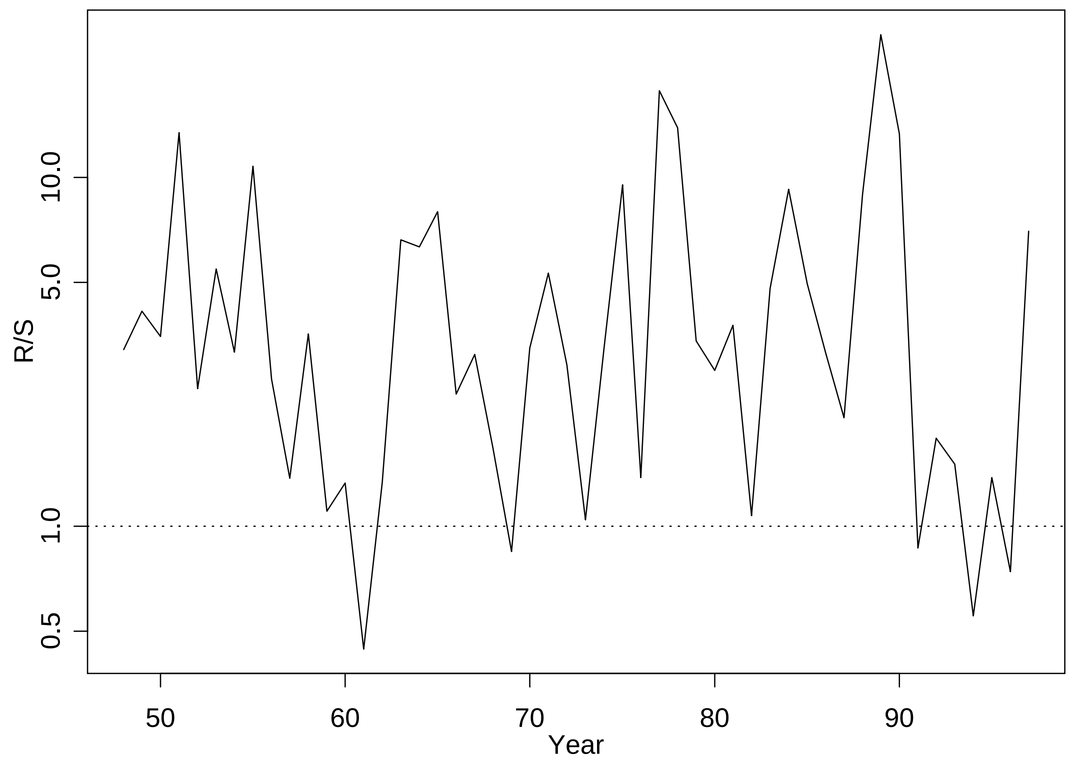

Figure 12. Time series of recruits-per-spawner (R/S) for Cultus sockeye. The horizontal broken line is the replacement line.

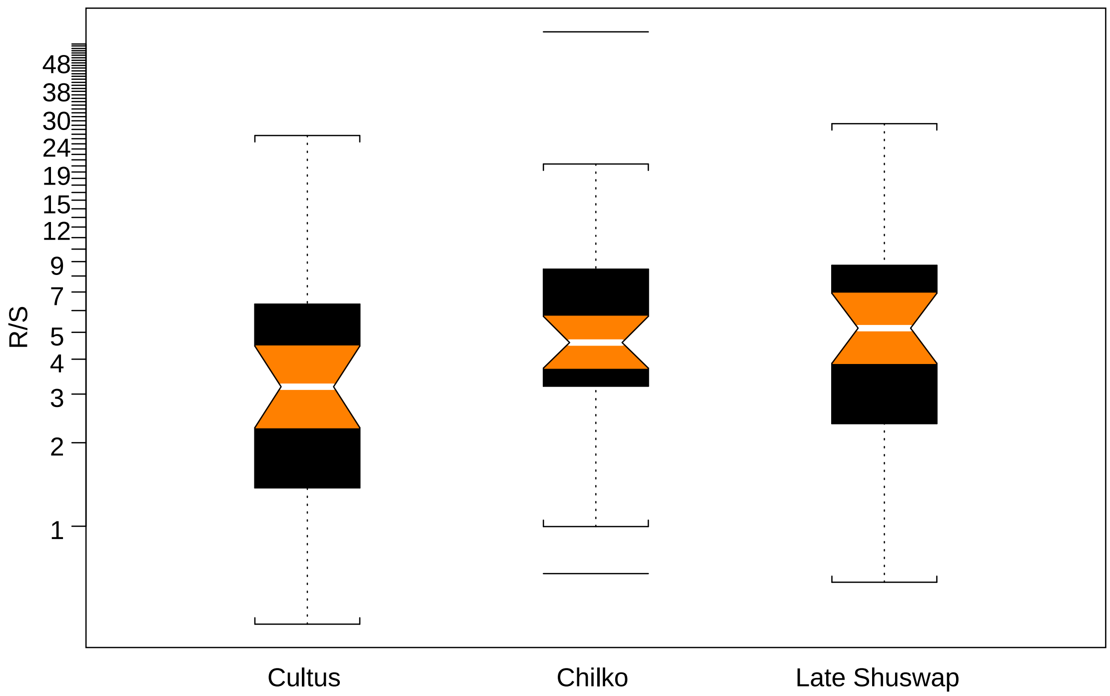

Figure 13. Boxplots of the distribution of recruits-per-spawner for three Fraser River sockeye stocks. The shaded notched regions represent the 95% confidence intervals for the median value. The dark rectangular regions represent the upper and lower quartiles. The whiskers are 1.5 times (inter-quartile range). Note the scale is in the $\log_e$ domain.

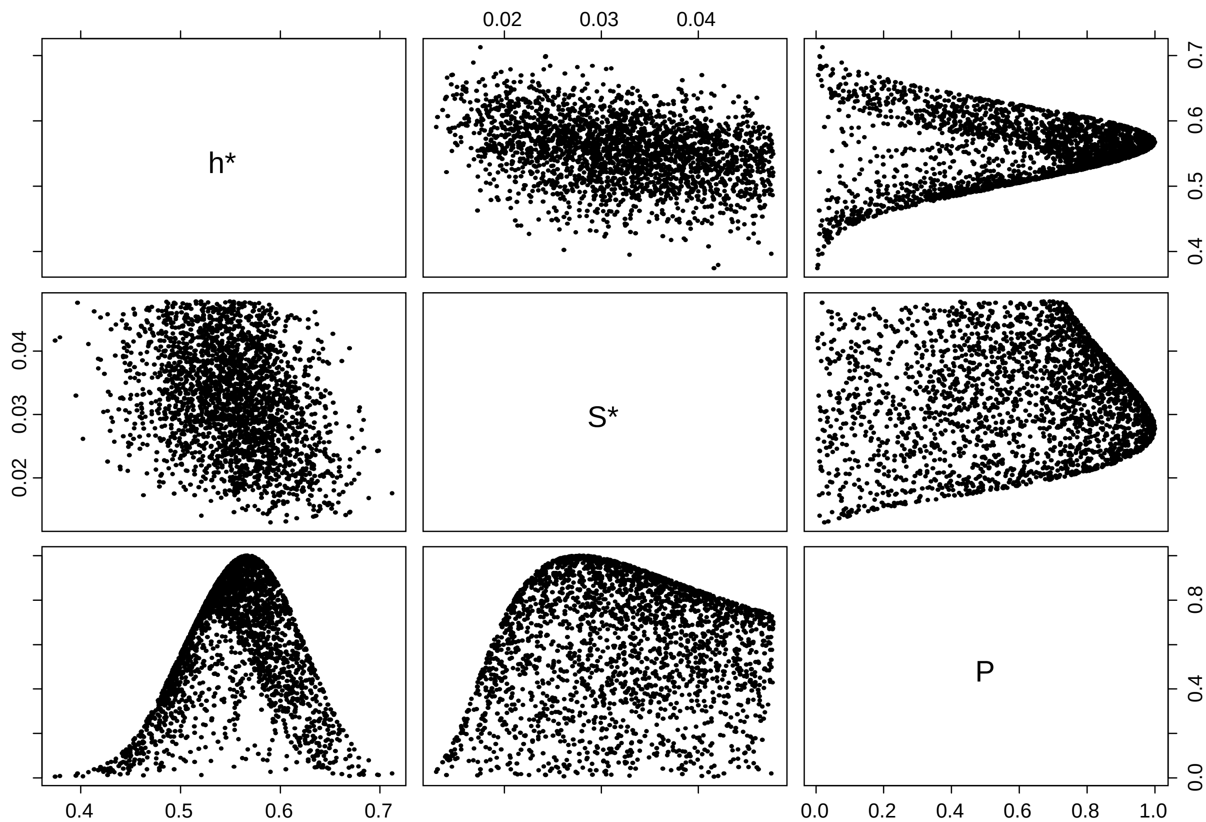

Figure 14. Pairs plot showing uncertainty in joint *h**-*S** stock-recruitment parameter estimates for the Ricker curve. *P* represents the posterior distribution.

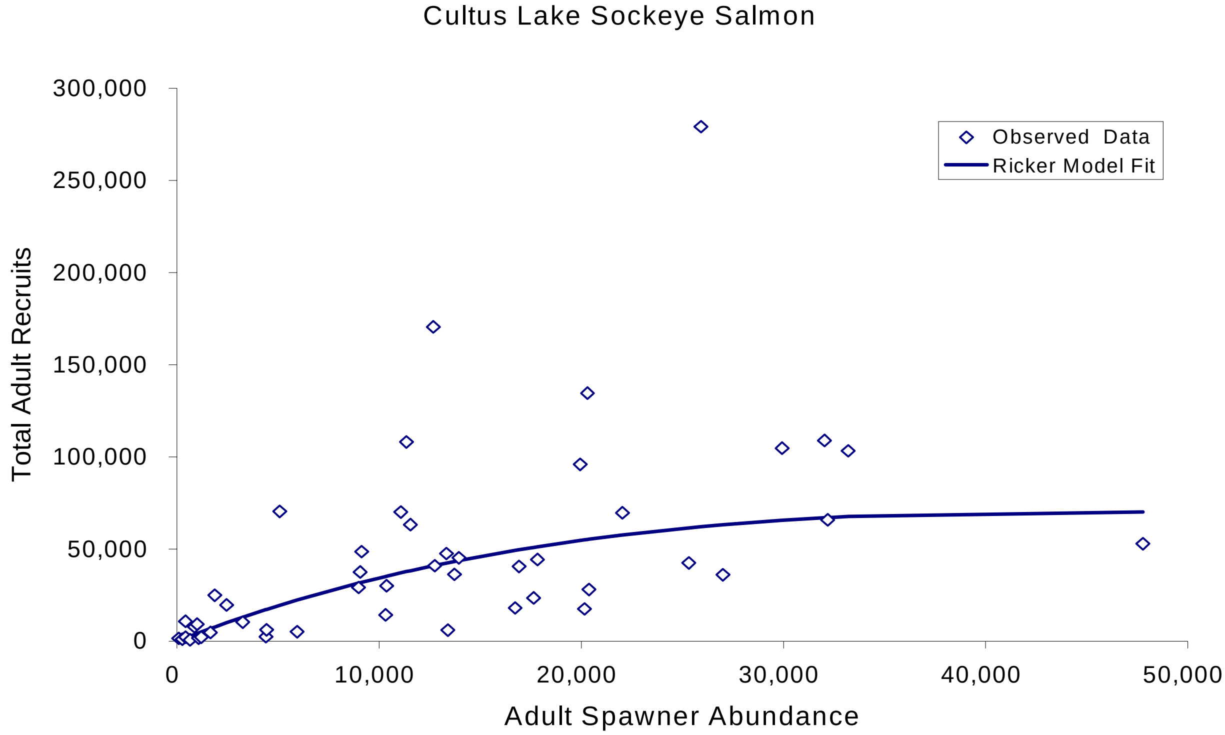

Figure 15. Relationship of total adult return to total adult escapement at Sweltzer Creek.

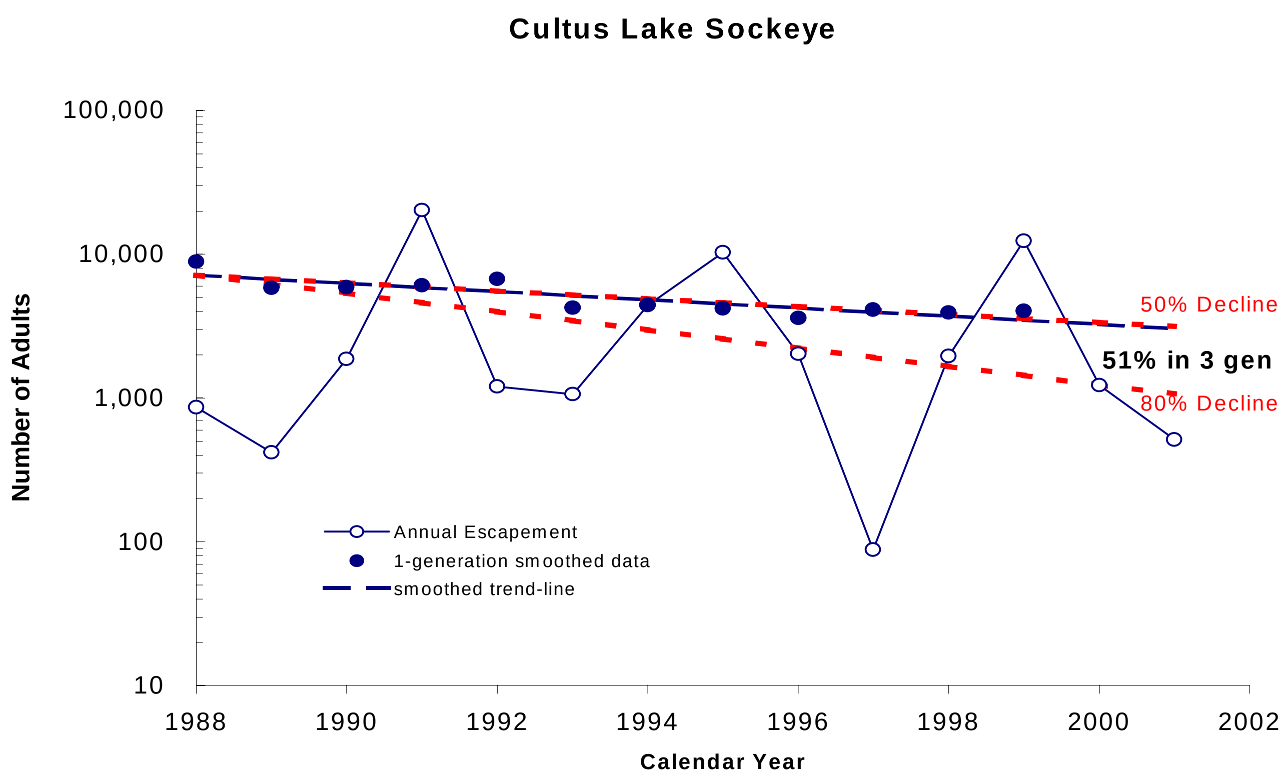

Figure 16. Annual and one-generation smoothed adult escapements, measured at the Sweltzer Creek enumeration fence, in relation to 50% and 80% decline thresholds that coincide with the IUCN categories of *endangered* and *critically endangered*, respectively. Numbers of adults are plotted on a log scale.

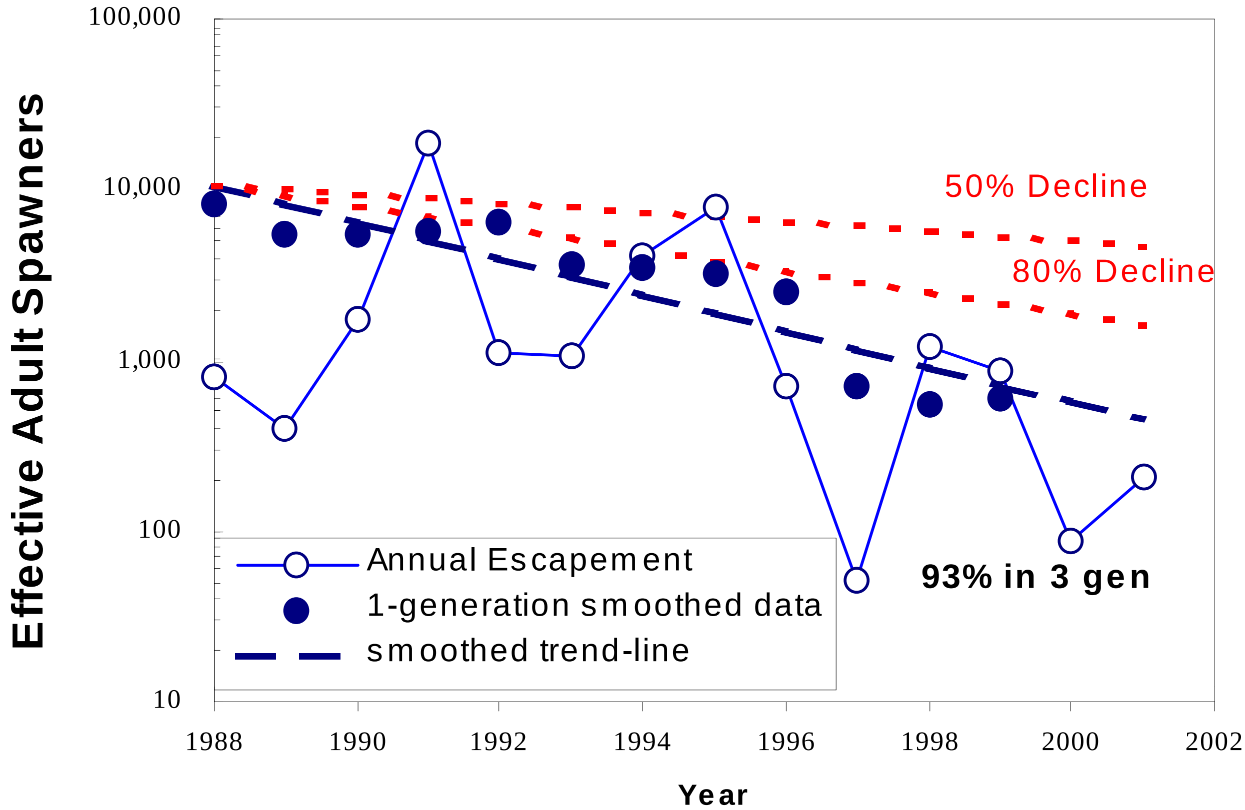

Figure 17. Annual and one-generation smoothed adult escapements, adjusted to reflect estimated levels of prespawn mortality, in relation to 50% and 80% decline thresholds that coincide with the IUCN categories of *endangered* and *critically endangered*, respectively. Numbers of adults are plotted on a log scale.

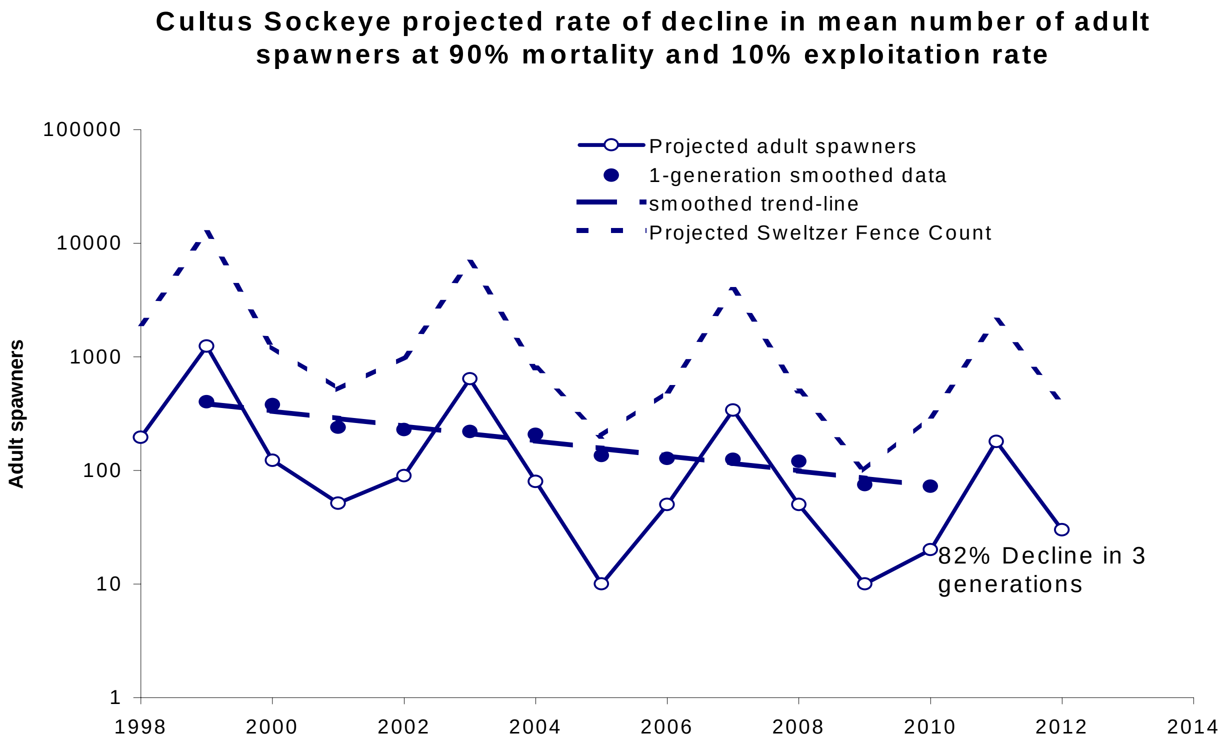

Figure 18. Projected rate of decline of Cultus sockeye escapements (mean number of adult spawners) when prespawn mortality is 90% and the exploitation rate is 10%. Note: adult spawner estimates are adjusted to reflect 90% PSM; observed fence counts at Sweltzer Creek will be ten times higher than the figures reported here.

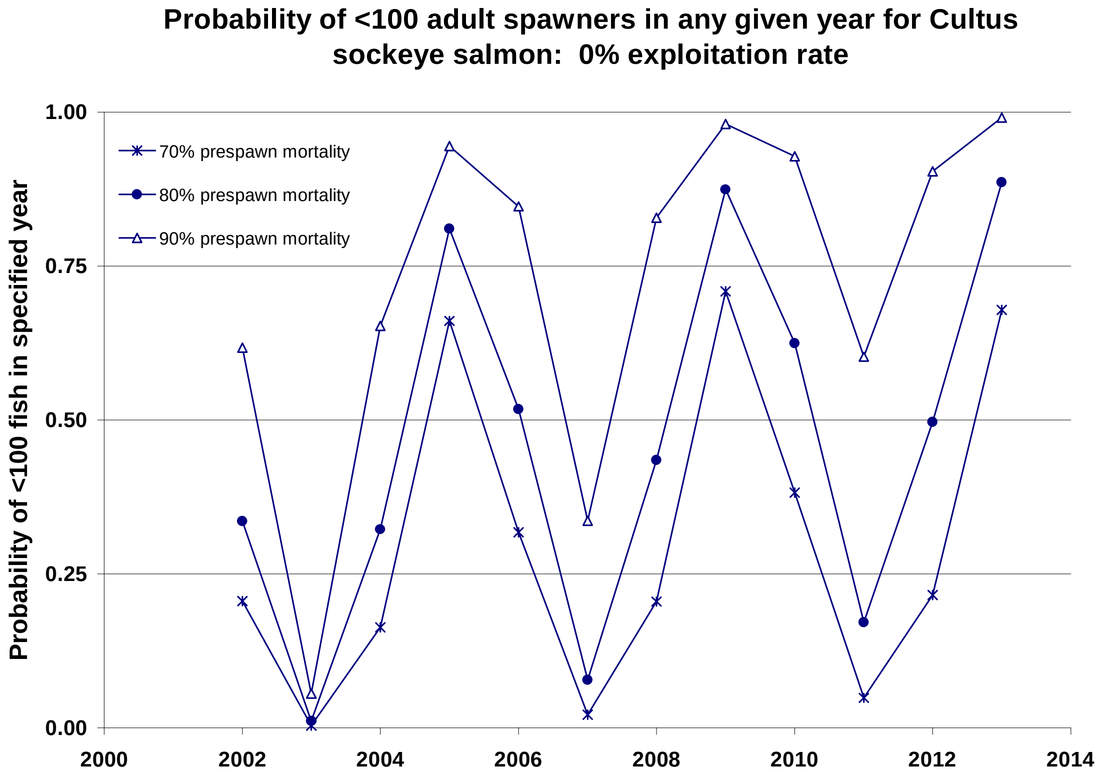

Figure 19. Probability that the escapement of Cultus sockeye will be less than 100 spawners in any given year when the exploitation rate is 0% and prespawn mortality varies from 70% to 90%. Note: adult spawner estimates are adjusted to reflect the assumed PSM level; observed fence counts at Sweltzer Creek will be higher than the figures reported here.

Table 1. Total adult escapement by cycle year for Cultus sockeye, 1925 to 2001.

1998 Subdominant Cycle		1999 Dominant Cycle		2000 Off Cycle		2001 Off Cycle	
Year	Escapement	Year	Escapement	Year	Escapement	Year	Escapement
						1925	5,423
1926	2,622	1927	82,426	1928	14,661	1929	5,084
1930	7,946	1931	37,473	1932	2,231	1933	2,864
1934	22,940	1935	15,339	1936	8,322	1937	1,227
1938	9,434	1939	70,789	1940	73,536	1941	13,950
1942	36,959	1943	11,822	1944	14,002	1945	5,030
1946	33,068	1947	8,699	1948	12,746	1949	9,055
1950	29,928	1951	12,677	1952	17,833	1953	11,543
1954	22,036	1955	25,922	1956	13,718	1957	20,375
1958	13,324	1959	47,779	1960	17,640	1961	13,396
1962	26,997	1963	20,303	1964	11,067	1965	2,455
1966	16,919	1967	33,198	1968	25,314	1969	5,942
1970	13,941	1971	9,128	1972	10,366	1973	641
1974	8,984	1975	11,349	1976	4,435	1977	82
1978	5,076	1979	32,031	1980	1,657	1981	256
1982	16,725	1983	19,944	1984	994	1985	424
1986	3,256	1987	32,184	1988	861	1989	418
1990	1,860	1991	20,157	1992	1,203	1993	1,063
1994	4,399	1995	10,316	1996	2,022	1997	88
1998	1,959	1999	12,392	2000	1,227	2001	515
Average		Average		Average		Average	
1926-1938	10,736	1927-1939	51,507	1928-1936	8,405	1925-1937	3,650
1942-1966	25,604	1943-1967	22,914	1940-1968	23,232	1941-1969	10,218
1970-1986	9,596	1971-1987	20,927	1972-1988	3,663	1973-1989	364
1990-1998	2,739	1991-1999	14,288	1992-2000	1,484	1993-2001	555
All years	14,651	All years	27,049	All years	12,307	All years	4,992

Table 2. F_{ST} values for 14 microsatellite loci (95% confidence limits in parentheses) and one MHC locus between the Cultus sockeye population and populations in 45 other locations in the Fraser River system (data from T. Beacham).

Stock Group	Population	Microsatellites	MHC
Early Stuart	Kynock Creek	0.1096 (0.0705,0.1567)	0.6456
	Gluskie Creek	0.1107 (0.0716, 0.1620)	0.5719
	Forfar Creek	0.1092 (0.0687, 0.1588)	0.5489
	Dust Creek	0.1073 (0.0638, 0.1599)	0.6299
	Porter Creek	0.1136 (0.0690, 0.1731)	0.5772
	Hudson Bay Creek	0.1153 (0.0726, 0.1668)	0.5748
	Blackwater Creek	0.1306 (0.0858, 0.1910)	0.5930
Late Stuart and Stellako	Stellako River	0.1069 (0.0687, 0.1434)	0.5850
	Middle River	0.1039 (0.0646, 0.1489)	0.6042
	Nadina River	0.1060 (0.0638, 0.1522)	0.5904
	Pinchi Creek	0.1105 (0.0660, 0.1635)	0.5474
	Tachie River	0.1044 (0.0686, 0.1415)	0.5812
	Kuzkwa River	0.1076 (0.0691, 0.1570)	0.5596
Upper Mid-Fraser	Bowron River	0.1086 (0.0688, 0.1563)	0.4427
	Chilko River	0.0994 (0.0623, 0.1401)	0.3442
	Chilko Lake (south)	0.1162 (0.0731, 0.1641)	0.3413
	Horsefly River (mixed)	0.1131 (0.0699, 0.1617)	0.2318
	Lower Horsefly River	0.1148 (0.0700, 0.1689)	0.2782
	Middle Horsefly River	0.1197 (0.0733, 0.1762)	0.2435
	Upper Horsefly River	0.1163 (0.0720, 0.1660)	0.2454
	Roaring River	0.1161 (0.0772, 0.1644)	0.1534
	Wasko Creek	0.1170 (0.0768, 0.1671)	0.1369
	Blue Lead Creek	0.1215 (0.0826, 0.1738)	0.1448
	McKinley Creek	0.1221 (0.0732, 0.1829)	0.2653
	Mitchell River	0.1361 (0.1000, 0.1700)	0.1276
Lower Mid-Fraser	Portage Creek	0.1066 (0.0650, 0.1500)	0.3834
	Gates Creek	0.1611 (0.1161, 0.2034)	0.1871
	Nahatlatch River	0.1153 (0.0740, 0.1649)	0.4294
Lower Fraser, north side	Birkenhead River	0.1116 (0.0615, 0.1777)	0.0074
	Weaver Creek	0.0981 (0.0641, 0.1359)	0.0109
	Big Silver Creek	0.1295 (0.0839, 0.1911)	0.0926
	Harrison River	0.1137 (0.0683, 0.1690)	0.3138
	Pitt River	0.1133 (0.0674, 0.1657)	0.0056
Lower Fraser, south side	Chilliwack River	0.0945 (0.0655, 0.1277)	0.2007
South Thompson	Lower Adams	0.1034 (0.0660, 0.1446)	0.3151
	Upper Adams	0.1415 (0.0964, 0.2025)	0.1554
	Cayenne Creek	0.1912 (0.1271, 0.2752)	0.1350
	Lower Shuswap	0.0943 (0.0643, 0.1275)	0.2829
	Middle Shuswap	0.0969 (0.0654, 0.1382)	0.3178
	Little Shuswap	0.1111 (0.0763, 0.1508)	0.3018
	Scotch Creek	0.1057 (0.0708, 0.1407)	0.2572
	Seymour River	0.1057 (0.0709, 0.1420)	0.2475
	Eagle River	0.1073 (0.0692, 0.1507)	0.3347
North Thompson	Fennell Creek	0.1053 (0.0801, 0.1349)	0.3319
	Raft River	0.1027 (0.0709, 0.1381)	0.3864

Table 3. Annual removals by species from Cultus Lake by predator control projects conducted in 1932-1942 and 1990-1992.

Date	Northern Pike-minnow	Trout	Char	Coho [a]	Sucker	Sockeye	White-fish	Chub	Sculpin	Shiner	Stickle-back	Total (all species)
Gillnet techniques												
1932	317	1	87	2	47	71	3	4	8	0	0	540
1933	109	4	22	0	7	6	1	1	1	0	0	151
1934	48	9	68	10	38	67	1	0	6	0	0	247
1935 [b]	2,046	225	232	44	853	72	17	8	42	0	0	3,539
1936 [c]	4,573	720	258	239	1,098	954	11	13	14	0	0	7,880
1937	1,783	764	177	268	900	21	4	1	227	0	0	4,145
1938	1,726	587	91	167	807	7	16	0	129	0	0	3,530
1939	1,338	648	117	351	618	na	na	na	na	0	0	3,072
1940	2,162	822	67	23	1,076	na	na	na	na	0	0	4,150
1941	4,647	397	28	643	847	na	na	na	na	0	0	6,562
1942	3,065	390	54	304	1,152	na	na	na	na	0	0	4,965
1992[e]	686	-	-	-	-	-	-	-	-	-	-	686
Seine net techniques[d]												
1935	3,824	na	0	na	0	0	0	0	na	na	na	3,824
1936	8,658	na	0	na	0	0	0	0	na	na	na	8,658
1937	6,416	na	0	na	0	0	0	0	na	na	na	6,416
1990[f]	7,448	-	-	-	-	-	-	-	-	-	-	7,448
1991[g]	3,326	-	-	-	-	-	-	-	-	-	-	3,326
Bait lines and trapping techniques												
1935-37	200	0	0	0	0	0	0	0	400	0	0	600

a. Adult coho were counted into Cultus Lake through the Sweltzer Creek fence in 1934-1935 was 140. The normal escapement is 300-800 adult coho.

b. Thirteen kokanee were caught by gillnet techniques in 1935.

c. Two kokanee were caught by gill-net techniques in 1936.

d. Approximately 300 trout and coho were captured using seine techniques in 1935-1937.

e. Of the 686 Northern Pikeminows captured in 1992, 613 were captured by gillnet and 73 by trap net.

f. Of the 7,448 Northern Pikeminow captured in 1990, the majority were catured by purse seine with smaller catches using trap netting.

g. Of the 3,326 Northern Pikeminow captured in 1991, 2,578 were by purse seine, 116 by beach seine, 574 by trap net, 46 by gill net and 12 by other methods.

Table 4. Summary of Cultus sockeye marine distribution and timing information from fry fin clipping studies conducted in 1930, 1932, 1933 and 1938, and marine adult tagging studies conducted in 1938-1948 (after Verhoeven and Davidoff (1962)) .

			Period present				
					Proportion of tags recovered by date		
Recovery area	Year	Number recovered	Range		25%	50%	75%
Sooke	1930	9 [a]	8/20-27	9/13-20	8/28 - 9/4	9/5-12	9/5-12
	1932	229 [b]	7/24-30	9/18-24	8/14-20	8/21-27	8/28 - 9/3
	1933	1864 [b]	7/10-16	9/25 -10/1	8/14-20	8/28 - 9/3	8/28 - 9/3
	1938	220 [c]	8/15	9/19	8/22	8/26	8/29
	1938-48	9	8/22	8/29	8/24	8/25	8/27
Salmon Banks	1930	23 [d]	7/28-31	9/21-29	7/28-31	8/12-19	828 - 9/4
	1932	365	7/24-30	9/4-10	8/7-13	8/14-20	8/21-27
	1933	3817	7/10-16	10/2-8	8/21-27	8/28 - 9/3	9/4-10
	1938	763 [e]	7/25	9/5	8/17	8/22	8/24
	1938-48	13	8/9	9/1	8/13	8/15	8/27
Lumi Island	1930	225 [f]	5/29	10/1-4	7/28-31	8/12-19	8/28 - 9/4
	1932	248 [g]	7/31 - 8/6	9/4-10	8/14-20	8/21-27	8/28 - 9/3
	1933	620	7/31 - 8/6	9/4-10	8/14-20	8/21-27	8/28 - 9/3
	1938	-	-	-	-	-	-
Point Roberts	1930	92 [h]	8/4-11	10/14	8/20-27	8/28 - 9/3	9/21-29
	1932	289	7/24-30	9/4-10	8/7-13	8/21-27	8/21-27
	1933	972	7/10-16	9/25 - 10/1	8/21-27	8/21-27	9/4-10
	1938	499	7/31	9/9	8/23	8/29	9/3
Sand Heads	1938-48	21	9/1	9/25	9/11	9/16	9/25
Fraser River and vicinity	1930	5	8/12-19	11/22	11/13	11/13	11/14
	1932	819	8/14-20	11/20-26	9/4-10	9/18-24	9/25 - 10/1
	1933	1673	7/17-23	11/6-12	9/11-17	9/18-24	10/2-8
	1938	2037	7/27	11/8	8/30	9/10	10/13

a. Foerster, 1936a.

b. Foerster, 1936b.

c. IPFSC, no observer at Sooke until 8/15.

d. Includes recoveries in West Beach and all San Juan Isl. areas, except Lumi Island.

e. Includes recoveries in all US areas, except Swiftsure / Pt. Roberts.

f. Includes Gulf of Georgia and Cherry Pt.

g. Includes Birch Bay.

h. Includes Boundary Bay.

Table 5. Estimated freshwater survival of juvenile sockeye from fall hydroacoustic surveys to the subsequent spring smolt estimates.

Brood year	Age-0 fall fry Estimate	Age-0 fall fry 95% CL	Age-1 smolts	Fry to smolt survival
1988	580,361	46,174	65,184	11%
1990	474,623	44,312	178,357	38%
1999	249,590	48,073	62,564	25%
2000	46,327	17,559	5,677	12%
Mean:	337,725	-	77,946	23%

Table 6. Annual total adult return, catch, escapement and exploitation rate by cycle for Cultus sockeye, 1952-2001.

1998 Sub-dominant Cycle					1999 Dominant Cycle				
Return Year	Catch	Adult Escapement	Total Return	Exploitation rate	Return Year	Catch	Adult Escapement	Total Return	Exploitation rate
1954	79,628	22,036	101,664	78%	1955	143,195	25,922	169,117	85%
1958	49,162	13,324	62,486	79%	1959	234,701	47,779	282,480	83%
1962	20,536	26,997	47,533	43%	1963	31,541	20,303	51,844	61%
1966	18,564	16,919	35,483	52%	1967	98,802	33,198	132,000	75%
1970	26,138	13,941	40,079	65%	1971	87,978	9,128	97,106	91%
1974	35,813	8,984	44,797	80%	1975	36,735	11,349	48,084	76%
1978	22,364	5,076	27,440	82%	1979	77,620	32,031	109,651	71%
1982	52,386	16,725	69,111	76%	1983	87,952	19,944	107,896	82%
1986	9,163	3,256	12,419	74%	1987	68,537	32,184	100,721	68%
1990	8,540	1,860	10,400	82%	1991	44,762	20,157	64,919	69%
1994	18,844	4,399	23,243	81%	1995	9,026	10,316	19,342	47%
1998	338	1,959	2,297	15%	1999	1,436	12,392	13,828	10%
Averages					Averages				
1950's	64,395	17,680	82,075	78%	1950's	188,948	36,851	225,799	84%
1960's	19,550	21,958	41,508	47%	1960's	65,172	26,751	91,922	71%
1970's	28,105	9,334	37,439	75%	1970's	67,444	17,503	84,947	79%
1980's	30,775	9,991	40,765	75%	1980's	78,245	26,064	104,309	75%
1990's	9,241	2,739	11,980	77%	1990's	18,408	14,288	32,696	56%
Total	28,456	11,290	39,746	72%	Total	76,857	22,892	99,749	77%

2000 Off-Cycle					2001 Off-Cycle				
Return Year	Catch	Adult Escapement	Total Return	Exploitation rate	Return Year	Catch	Adult Escapement	Total Return	Exploitation rate
1952	19,987	17,833	37,820	53%	1953	29,029	11,543	40,572	72%
1956	23,808	13,718	37,526	63%	1957	53,208	20,375	73,583	72%
1960	22,304	17,640	39,944	56%	1961	14,395	13,396	27,791	52%
1964	13,722	11,067	24,789	55%	1965	4,349	2,455	6,804	64%
1968	45,539	25,314	70,853	64%	1969	16,011	5,942	21,953	73%
1972	38,639	10,366	49,005	79%	1973	4,390	641	5,031	87%
1976	26,410	4,435	30,845	86%	1977	401	82	483	83%
1980	4,719	1,657	6,376	74%	1981	1,201	256	1,457	82%
1984	5,882	994	6,876	86%	1985	541	424	965	56%
1988	8,924	861	9,785	91%	1989	1,679	418	2,097	80%
1992	6,298	1,203	7,501	84%	1993	9,808	1,063	10,871	90%
1996	885	2,022	2,907	30%	1997	1,512	88	1,600	95%
2000	797	1,227	2,024	39%	2001	102	515	617	17%
Averages					Averages				
1950's	21,898	15,776	37,673	58%	1950's	41,119	15,959	57,078	72%
1960's	27,188	18,007	45,195	60%	1960's	11,585	7,264	18,849	61%
1970's	32,525	7,401	39,925	81%	1970's	2,396	362	2,757	87%
1980's	6,508	1,171	7,679	85%	1980's	1,140	366	1,506	76%
1990's	2,660	1,484	4,144	64%	1990's	3,807	555	4,363	87%
Total	16,763	8,334	25,096	67%	Total	10,510	4,400	14,910	70%

Table 7. Predicted number of Cultus sockeye adults entering Cultus Lake at different levels of prespawn mortality (PSM) and exploitation rates (ER). Predictions are averaged across four years for 3, 5, 10 and 25 generations from the present (1998-2001) brood years. Note that, for 1998-2001, PSM averaged 82% and ER averaged 20%.

Prespawn mortality (PSM)	Exploitation rate (ER)	Average future escapement in: Three generations	Five generations	Ten generations	Twenty-five generations
40%	0%	12,100	30,600	49,900	52,200
	10%	9,700	23,500	42,500	45,900
	20%	7,200	17,700	33,900	38,700
	30%	5,400	12,000	24,900	30,900
	40%	3,600	7,700	15,900	21,900
	50%	2,300	4,200	8,200	12,000
50%	0%	8,000	19,200	36,500	41,000
	10%	6,300	14,500	29,400	34,800
	20%	4,600	10,300	21,500	27,800
	30%	3,400	6,900	14,400	20,200
	40%	2,200	4,100	8,000	12,000
	50%	1,400	2,200	3,700	5,000
60%	0%	4,600	10,500	21,600	27,700
	10%	3,500	7,600	15,900	21,800
	20%	2,600	5,300	10,500	15,200
	30%	1,900	3,300	6,200	9,000
	40%	1,200	1,900	3,000	3,900
	50%	750	953	1,153	1,103
70%	0%	2,300	4,100	8,200	12,100
	10%	1,700	2,900	5,200	7,600
	20%	1,300	1,900	3,000	3,900
	30%	870	1,120	1,485	1,625
	40%	570	615	613	438
	50%	340	280	188	85
80%	0%	753	998	1,128	1,110
	10%	575	620	603	468
	20%	400	408	293	153
	30%	280	213	118	48
	40%	175	120	38	8
	50%	103	48	10	0
90%	0%	115	45	10	0
	10%	73	25	3	0
	20%	55	15	0	0
	30%	30	5	0	0
	40%	25	3	0	0
	50%	8	0	0	0

Table 8. Mean probability of demographic extinction for Cultus sockeye at different levels of prespawn mortality (PSM) and exploitation rates (ER) after 3, 5, 10 and 25 generations. Quasi-extinction is defined as the probability that spawner abundance will be less than 50 or 100 adult spawners in four successive years based on a forward simulation in Population Viability Analysis.

		<50 spawners in 4 sucessive years				<100 spawners in 4 successive years			
		Generations from present				Generations from present			
PSM	**ER**	**3**	**5**	**10**	**25**	**3**	**5**	**10**	**25**
0.4	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	0.3	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
	0.4	0.00	0.00	0.01	0.02	0.01	0.02	0.04	0.05
	0.5	0.00	0.01	0.04	0.09	0.02	0.05	0.10	0.17
0.5	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.1	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
	0.2	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.02
	0.3	0.00	0.01	0.01	0.03	0.01	0.02	0.04	0.06
	0.4	0.00	0.01	0.04	0.09	0.02	0.05	0.10	0.17
	0.5	0.01	0.04	0.13	0.29	0.05	0.11	0.24	0.42
0.6	0	0.00	0.00	0.01	0.01	0.00	0.01	0.02	0.02
	0.1	0.00	0.00	0.01	0.02	0.01	0.02	0.03	0.05
	0.2	0.00	0.01	0.03	0.06	0.02	0.04	0.07	0.12
	0.3	0.01	0.02	0.06	0.15	0.03	0.07	0.15	0.25
	0.4	0.02	0.05	0.16	0.35	0.06	0.13	0.28	0.48
	0.5	0.03	0.12	0.35	0.65	0.11	0.25	0.51	0.76
0.7	0	0.00	0.01	0.04	0.09	0.02	0.05	0.11	0.18
	0.1	0.01	0.03	0.09	0.19	0.03	0.08	0.18	0.30
	0.2	0.01	0.05	0.16	0.36	0.06	0.13	0.29	0.49
	0.3	0.03	0.10	0.30	0.58	0.09	0.22	0.44	0.70
	0.4	0.06	0.19	0.49	0.80	0.16	0.35	0.64	0.87
	0.5	0.11	0.34	0.72	0.94	0.26	0.52	0.82	0.97
0.8	0	0.04	0.12	0.35	0.66	0.11	0.25	0.51	0.76
	0.1	0.06	0.19	0.49	0.80	0.16	0.35	0.64	0.87
	0.2	0.09	0.28	0.65	0.91	0.22	0.46	0.76	0.95
	0.3	0.14	0.41	0.78	0.97	0.31	0.58	0.87	0.98
	0.4	0.23	0.56	0.89	0.99	0.41	0.72	0.94	1.00
	0.5	0.36	0.72	0.96	1.00	0.55	0.84	0.98	1.00
0.9	0	0.36	0.72	0.96	1.00	0.56	0.84	0.98	1.00
	0.1	0.44	0.80	0.98	1.00	0.64	0.89	0.99	1.00
	0.2	0.53	0.87	0.99	1.00	0.71	0.93	1.00	1.00
	0.3	0.63	0.92	1.00	1.00	0.79	0.96	1.00	1.00
	0.4	0.73	0.96	1.00	1.00	0.86	0.98	1.00	1.00
	0.5	0.83	0.98	1.00	1.00	0.92	0.99	1.00	1.00

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001.

Date	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953 [a]
16-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
21-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
24-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
25-Aug	-	-	1	-	-	-	-	-	-	-	-	-	-
26-Aug	-	-	0	-	-	-	-	-	-	-	-	-	-
27-Aug	-	-	0	-	-	-	-	-	-	-	-	-	-
28-Aug	-	-	0	-	-	-	-	-	-	-	-	-	-
29-Aug	-	-	0	-	-	-	-	-	-	-	-	-	-
30-Aug	-	-	0	10	-	-	-	-	-	-	-	-	-
31-Aug	-	-	0	2	-	-	-	-	-	-	-	-	-
1-Sep	-	-	0	6	-	-	-	-	-	-	-	-	-
2-Sep	-	-	0	7	-	-	-	-	-	-	-	-	-
3-Sep	-	-	0	4	-	-	-	-	-	-	-	-	-
4-Sep	-	-	0	3	-	-	-	-	-	-	-	-	-
5-Sep	-	-	0	2	-	-	-	-	-	-	-	-	-
6-Sep	-	-	0	3	-	-	-	-	-	-	-	-	-
7-Sep	-	-	0	6	-	-	-	-	-	-	-	-	-
8-Sep	-	-	0	1	-	-	-	-	-	-	-	-	-
9-Sep	2	-	0	4	-	-	-	-	-	-	-	-	-
10-Sep	0	-	0	2	-	-	-	-	-	-	-	-	-
11-Sep	0	-	2	5	-	-	-	-	-	-	-	-	-
12-Sep	0	-	0	12	-	-	-	-	-	-	-	-	-
13-Sep	0	-	0	5	-	-	-	-	-	-	-	-	-
14-Sep	0	-	0	2	-	-	-	-	-	-	-	-	-
15-Sep	0	-	0	9	-	-	-	-	-	-	-	-	-
16-Sep	17	-	0	3	-	-	-	-	-	-	-	-	-
17-Sep	0	-	0	1	-	-	-	-	-	-	-	-	-
18-Sep	0	-	1	14	-	-	-	-	-	-	-	-	-
19-Sep	47	3	0	4	-	-	-	-	-	-	-	-	-
20-Sep	0	2	0	3	-	-	-	-	-	-	-	-	9
21-Sep	0	2	0	4	-	-	-	-	-	-	23	-	10
22-Sep	0	3	0	6	-	8	-	-	-	-	37	-	3
23-Sep	0	6	2	23	-	3	-	-	-	-	38	-	3
24-Sep	0	15	1	25	-	3	-	-	-	-	18	-	24
25-Sep	56	15	1	34	-	0	-	7	-	-	5	-	28
26-Sep	0	11	0	17	-	0	10	7	-	88	0	-	37
27-Sep	0	0	6	29	-	0	0	5	-	62	0	-	30
28-Sep	0	0	0	35	-	56	10	0	-	173	0	-	172
29-Sep	40	0	11	55	11	0	0	10	-	420	0	-	117
30-Sep	35	11	29	71	22	109	6	19	-	108	0	-	86
1-Oct	0	10	44	38	63	33	5	30	0	165	0	0	5
2-Oct	39	192	17	104	7	53	158	48	0	109	0	0	7
3-Oct	69	28	20	27	45	48	27	65	0	105	534	0	95
4-Oct	141	16	26	458	68	46	118	53	45	223	1,045	19	385
5-Oct	0	0	70	295	39	48	36	75	9	581	479	0	309
6-Oct	42	49	48	230	0	0	24	31	26	1,115	295	25	494
7-Oct	61	25	5	120	0	0	14	48	34	676	158	37	527
8-Oct	54	148	10	63	0	656	30	122	16	4,965	190	65	799
9-Oct	0	141	5	32	4	203	53	195	173	1,437	511	327	739
10-Oct	478	87	12	58	273	169	38	276	718	1,129	348	108	437
11-Oct	178	203	24	48	25	20	43	244	493	262	1,026	125	267
12-Oct	231	200	81	46	106	11	22	611	463	456	818	318	472

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953 [a]
13-Oct	256	151	76	39	98	73	73	588	155	736	339	336	402
14-Oct	551	57	32	70	133	85	78	656	186	719	652	350	272
15-Oct	317	48	17	105	112	65	88	449	515	520	489	195	454
16-Oct	1,120	96	124	95	79	543	363	159	80	355	219	265	434
17-Oct	191	110	84	42	73	239	482	258	426	284	180	408	482
18-Oct	114	205	526	50	25	142	156	526	0	0	325	376	189
19-Oct	0	61	28	34	20	139	184	563	233	1,502	185	311	661
20-Oct	1,346	91	53	56	10	372	118	386	0	509	945	397	535
21-Oct	1,146	194	23	97	17	1,377	53	273	0	431	540	388	241
22-Oct	696	520	34	156	8	1,938	202	239	111	271	353	401	78
23-Oct	848	381	4	623	6	999	143	275	0	233	219	225	212
24-Oct	653	231	61	282	257	1,204	189	627	311	241	164	1,889	110
25-Oct	375	205	64	227	765	1,915	122	398	203	868	130	2,202	130
26-Oct	343	213	159	202	104	846	329	217	538	892	154	209	135
27-Oct	788	59	110	127	231	1,051	97	327	146	891	66	142	166
28-Oct	744	253	150	274	196	734	170	171	383	235	89	259	113
29-Oct	265	335	80	366	523	531	125	349	132	230	299	306	94
30-Oct	164	181	59	327	436	296	202	529	310	278	243	580	81
31-Oct	251	249	47	770	374	1,226	173	520	420	152	166	686	172
1-Nov	193	1,068	47	320	199	2,203	169	249	162	235	86	122	0
2-Nov	185	658	19	429	225	302	174	157	163	198	52	73	196
3-Nov	285	1,749	204	373	210	398	24	588	23	290	69	54	115
4-Nov	315	632	82	226	204	223	285	118	91	320	83	315	255
5-Nov	893	374	68	310	311	145	222	206	153	528	96	645	112
6-Nov	440	586	108	215	118	1,042	235	43	74	125	59	245	83
7-Nov	316	227	49	218	89	142	198	244	103	321	69	84	46
8-Nov	159	355	52	255	85	152	283	106	251	197	53	95	55
9-Nov	131	331	83	670	24	249	207	107	137	427	56	70	157
10-Nov	146	458	110	314	26	346	262	83	60	381	58	246	63
11-Nov	304	301	244	339	67	584	157	117	361	406	82	1,033	0
12-Nov	240	358	261	142	96	384	180	87	63	487	34	681	5
13-Nov	475	182	293	299	129	387	320	80	56	267	34	252	2
14-Nov	946	442	319	318	555	74	180	145	141	246	48	100	5
15-Nov	483	960	289	377	177	751	124	95	134	199	62	117	56
16-Nov	110	298	227	431	149	656	82	65	162	338	49	89	0
17-Nov	113	420	2,792	347	221	930	217	33	107	307	0	123	1
18-Nov	108	526	261	368	272	286	187	14	70	207	59	120	5
19-Nov	54	655	68	211	112	246	72	38	62	98	35	306	53
20-Nov	51	588	43	267	63	59	133	39	75	719	45	409	45
21-Nov	66	557	109	127	93	220	102	48	85	456	41	184	5
22-Nov	21	828	67	113	174	264	86	109	152	531	17	104	123
23-Nov	14	1,260	76	498	120	1,367	77	88	92	194	11	130	42
24-Nov	13	1,233	60	232	116	536	93	140	26	220	34	69	41
25-Nov	68	385	120	50	81	946	147	159	185	173	27	74	1
26-Nov	74	538	50	120	79	280	115	119	0	225	171	93	3
27-Nov	32	628	246	88	229	1,993	69	67	0	638	86	96	0
28-Nov	20	592	152	32	209	220	65	96	0	129	109	76	31
29-Nov	36	413	222	20	107	290	20	22	12	133	219	50	5
30-Nov	0	833	301	75	79	305	60	40	26	29	8	95	-
1-Dec	33	773	358	13	34	189	75	23	33	29	0	867	-
2-Dec	114	1,085	674	73	62	409	55	24	24	14	0	140	-
3-Dec	0	1,109	1,068	33	70	285	15	18	13	16	0	153	-
4-Dec	15	1,312	118	130	30	242	17	44	7	7	0	106	-
5-Dec	15	951	37	35	59	273	24	43	12	27	9	349	-
6-Dec	4	902	26	14	54	40	27	11	4	23	-	67	-
7-Dec	0	943	12	5	28	51	32	13	4	7	-	55	-
8-Dec	3	868	4	6	13	47	8	10	17	5	-	48	-
9-Dec	12	649	66	63	0	27	10	14	17	23	-	26	-

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953 [a]
10-Dec	10	1,026	42	38	0	247	27	10	0	-	-	-	-
11-Dec	5	1,025	51	45	6	34	22	12	18	-	-	-	-
12-Dec	0	407	62	18	40	11	7	4	-	-	-	-	-
13-Dec	1	524	34	16	22	15	48	1	-	-	-	-	-
14-Dec	-	768	21	16	27	8	22	1	-	-	-	-	-
15-Dec	-	491	7	4	18	9	3	-	-	-	-	-	-
16-Dec	-	626	7	4	10	4	9	-	-	-	-	-	-
17-Dec	-	27	7	9	9	20	2	-	-	-	-	-	-
18-Dec	-	41	2	4	4	16	1	-	-	-	-	-	-
19-Dec	-	22	1	3	2	9	2	-	-	-	-	-	-
20-Dec	-	42	1	7	2	11	0	-	-	-	-	-	-
21-Dec	-	27	1	2	1	16	1	-	-	-	-	-	-
22-Dec	-	167	0	3	-	-	0	-	-	-	-	-	-
23-Dec	-	49	2	0	-	-	0	-	-	-	-	-	-
24-Dec	-	60	0	0	-	-	1	-	-	-	-	-	-
25-Dec	-	67	2	0	-	-	0	-	-	-	-	-	-
26-Dec	-	23	0	3	-	-	0	-	-	-	-	-	-
27-Dec	-	26	2	0	-	-	2	-	-	-	-	-	-
28-Dec	-	17	0	0	-	-	2	-	-	-	-	-	-
29-Dec	-	10	0	1	-	-	1	-	-	-	-	-	-
30-Dec	-	11	0	-	-	-	-	-	-	-	-	-	-
31-Dec	-	6	0	-	-	-	-	-	-	-	-	-	-
1-Jan	-	-	1	-	-	-	-	-	-	-	-	-	-
"Misc."	-	-	-	-	-	-	-	-	-	-	-	-	22
Total	18,161	37,296	11,775	14,197	9,240	33,184	8,899	13,086	9,301	30,596	13,143	18,910	11,543
Final escapement estimates [b]													
Adults	13,950	36,959	11,822	14,002	5,030	33,068	8,699	12,746	9,055	29,928	12,677	17,833	11,543
Jacks	4,214	346	53	198	4,197	216	199	340	246	667	466	1,077	1,457
Total	18,164	37,305	11,875	14,200	9,227	33,284	8,898	13,086	9,301	30,595	13,143	18,910	13,000

[a.] Adults only

[b.] Final escapement estimates corrected for age, observer error at fence, or brood stock and experimental removals upstream of Sweltzer fence.

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
16-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
21-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
24-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
25-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
26-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
27-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
28-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
29-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
30-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
31-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
1-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
3-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
5-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
6-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
7-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
8-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
9-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
10-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
11-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
12-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
13-Sep	-	-	13	-	-	-	-	-	-	-	-	-	-
14-Sep	-	-	10	-	-	-	-	-	-	-	-	-	-
15-Sep	-	-	0	-	-	-	-	-	-	-	-	-	-
16-Sep	-	-	12	-	-	-	-	-	-	-	-	-	-
17-Sep	-	-	5	-	-	-	-	-	-	-	-	-	-
18-Sep	-	-	10	-	-	-	-	-	-	-	-	-	-
19-Sep	-	-	7	7	-	-	-	7	-	-	-	-	-
20-Sep	-	-	47	9	-	-	-	37	3	-	-	-	-
21-Sep	-	-	147	14	-	-	-	39	3	-	-	-	-
22-Sep	-	-	288	33	-	-	-	194	4	-	-	-	-
23-Sep	-	-	250	53	-	-	-	82	7	-	-	-	-
24-Sep	-	-	207	36	-	2	-	288	3	-	-	-	-
25-Sep	-	-	844	18	1	5	-	377	8	4	74	-	-
26-Sep	-	-	1,094	19	0	0	-	249	3	2	68	-	-
27-Sep	-	-	682	37	0	6	38	30	9	1	0	-	-
28-Sep	-	-	441	5	0	10	103	89	14	28	43	-	-
29-Sep	23	182	747	78	0	4	108	180	79	37	63	-	-
30-Sep	381	75	1,269	42	1	11	76	667	149	27	377	-	-
1-Oct	449	342	745	16	3	12	50	446	223	34	28	-	-
2-Oct	796	1,215	284	22	2	13	25	388	311	19	34	-	-
3-Oct	478	876	146	0	8	21	39	396	268	73	28	-	-
4-Oct	405	1,027	186	86	7	12	42	312	602	48	16	-	1,209
5-Oct	476	1,805	192	272	4	40	24	131	527	83	23	88	74
6-Oct	418	678	123	610	18	46	23	569	31	44	38	1,103	94
7-Oct	681	713	97	618	44	22	507	379	489	70	40	117	423
8-Oct	5,089	809	167	414	380	98	268	200	410	112	57	48	1,156
9-Oct	3,619	1,404	207	701	747	181	170	187	257	108	87	61	4,560
10-Oct	689	621	144	1,056	230	183	55	271	645	87	80	32	882
11-Oct	986	779	206	635	9	198	37	295	302	47	107	23	268
12-Oct	562	636	247	679	23	415	81	347	113	143	59	14	89

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
13-Oct	227	725	278	813	7	498	342	317	253	167	78	44	27
14-Oct	249	681	75	936	33	568	857	202	482	393	117	22	87
15-Oct	398	1,057	1,066	261	17	222	998	276	579	344	146	26	55
16-Oct	631	490	411	67	17	300	1,302	354	520	332	62	3	84
17-Oct	671	377	258	37	7	269	1,626	191	229	257	112	9	69
18-Oct	540	572	59	74	3	480	1,005	156	192	157	268	2	83
19-Oct	296	455	174	221	8	459	1,434	130	147	110	483	0	1,642
20-Oct	248	622	30	171	73	333	902	97	176	89	604	5	2,354
21-Oct	349	344	15	262	166	304	585	43	137	615	641	12	250
22-Oct	205	246	52	410	94	444	227	395	101	495	338	5	145
23-Oct	81	180	47	122	60	149	240	347	285	460	159	3	994
24-Oct	92	1,234	24	180	144	706	245	273	275	508	212	7	290
25-Oct	124	621	25	708	224	92	358	758	473	704	167	6	54
26-Oct	98	131	93	722	290	68	523	553	460	792	311	3	164
27-Oct	108	273	166	446	374	135	577	681	515	1,104	394	2	62
28-Oct	177	154	64	179	435	337	211	810	333	403	277	3	173
29-Oct	138	386	75	153	425	241	105	464	288	299	339	264	337
30-Oct	139	401	101	1,831	570	435	77	539	193	599	278	247	114
31-Oct	105	255	102	588	456	512	282	383	348	631	491	6	23
1-Nov	115	296	48	700	812	684	353	510	201	803	772	18	129
2-Nov	152	140	29	283	668	1,247	217	233	197	451	329	25	158
3-Nov	242	320	60	97	703	2,047	373	205	149	1,127	125	34	183
4-Nov	241	[c]	67	171	807	1,771	443	121	347	649	1,203	19	68
5-Nov	1,145	2	67	181	560	1,092	78	154	446	412	198	31	71
6-Nov	308	31	100	97	581	1,168	61	241	540	224	102	8	68
7-Nov	136	116	41	124	720	1,598	71	89	612	717	147	7	77
8-Nov	90	375	45	55	724	2,097	103	126	793	645	60	11	31
9-Nov	111	613	1	362	714	2,095	44	135	1,185	441	61	4	34
10-Nov	118	550	192	217	502	2,304	148	69	1,274	327	40	5	125
11-Nov	74	[c]	90	239	355	1,716	286	49	836	567	82	3	134
12-Nov	44	138	43	200	477	1,020	79	31	586	848	86	0	130
13-Nov	64	104	27	907	239	1,128	94	140	479	598	88	4	54
14-Nov	107	103	45	174	343	932	40	58	303	276	84	3	97
15-Nov	52	132	29	122	245	645	39	39	1,767	213	64	2	69
16-Nov	47	58	45	153	272	502	82	12	1,114	104	22	4	66
17-Nov	88	182	480	163	17	757	290	38	1,126	443	50	12	48
18-Nov	277	168	34	93	49	1,559	417	10	825	212	50	6	26
19-Nov	405	188	34	386	64	2,879	157	13	391	174	26	5	10
20-Nov	78	296	32	180	43	1,292	139	8	11	190	31	8	23
21-Nov	71	193	6	113	26	1,206	67	9	4	243	33	-	-
22-Nov	32	133	10	97	42	1,450	260	2	10	225	41	-	-
23-Nov	0	142	20	405	28	720	40	1	59	158	66	-	-
24-Nov	16	157	31	181	21	414	12	3	267	182	78	-	-
25-Nov	19	74	26	72	10	202	42	2	493	352	13	-	-
26-Nov	-	91	39	146	35	503	41	0	478	296	20	-	-
27-Nov	-	27	22	254	25	1,705	34	0	218	151	4	-	-
28-Nov	-	76	45	33	15	907	46	1	528	32	3	-	-
29-Nov	-	39	15	3	26	1,129	20	0	413	23	4	-	-
30-Nov	-	39	25	0	8	961	8	-	285	20	-	-	-
1-Dec	-	28	27	2	21	796	14	-	196	14	-	-	-
2-Dec	-	10	30	0	24	667	12	-	137	9	-	-	-
3-Dec	-	8	228	16	6	422	11	-	108	10	-	-	-
4-Dec	-	0	15	-	6	316	14	-	75	4	-	-	-
5-Dec	-	-	3	-	12	306	12	-	116	4	-	-	-
6-Dec	-	-	-	-	5	147	-	-	48	-	-	-	-
7-Dec	-	-	-	-	-	67	-	-	7	-	-	-	-
8-Dec	-	-	-	-	-	56	-	-	-	-	-	-	-
9-Dec	-	-	-	-	-	51	-	-	-	-	-	-	-

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
10-Dec	-	-	-	-	-	35	-	-	-	-	-	-	-
11-Dec	-	-	-	-	-	15	-	-	-	-	-	-	-
12-Dec	-	-	-	-	-	7	-	-	-	-	-	-	-
13-Dec	-	-	-	-	-	9	-	-	-	-	-	-	-
14-Dec	-	-	-	-	-	6	-	-	-	-	-	-	-
15-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
16-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
21-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
24-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
25-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
26-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
27-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
28-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
29-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
30-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
31-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
1-Jan	-	-	-	-	-	-	-	-	-	-	-	-	-
"Misc."	-	-	-	-	-	-	-	-	-	-	552	168	651
Total	23,960	25,195	13,983	19,867	14,085	48,461	17,689	15,428	27,070	20,570	11,133	2,532	18,014
Final escapement estimates [b]													
Adults	22,036	25,922	13,718	20,375	13,324	47,779	17,640	13,396	26,997	20,303	11,067	2,455	16,919
Jacks	2,114	78	415	272	773	682	49	2,032	73	268	76	77	545
Total	24,150	26,000	14,133	20,647	14,097	48,461	17,689	15,428	27,070	20,571	11,143	2,532	17,464

[b.] Final escapement estimates corrected for age, observer error at fence, or brood stock and experimental removals upstream of Sweltzer fence.

[c.] Fence out due to high water.

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
16-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
21-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
24-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
25-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
26-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
27-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
28-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
29-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
30-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
31-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
1-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
3-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
5-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
6-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
7-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
8-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
9-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
10-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
11-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
12-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
13-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
14-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
15-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
16-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Sep	-	-	-	-	-	-	-	-	-	-	-	-	2
21-Sep	-	-	-	-	-	-	-	-	-	-	-	-	3
22-Sep	-	-	-	-	-	-	-	-	-	-	-	-	5
23-Sep	32	-	2	-	-	-	-	-	-	-	-	-	0
24-Sep	22	-	3	-	-	-	-	-	-	-	-	-	2
25-Sep	94	34	1	-	-	-	-	2	5	-	-	-	1
26-Sep	78	43	2	-	-	-	-	9	3	-	-	-	7
27-Sep	105	44	1	-	-	-	-	2	1	-	-	-	5
28-Sep	44	43	3	-	-	-	3	1	0	-	-	-	272
29-Sep	71	13	5	-	-	2	0	2	0	-	-	-	14
30-Sep	158	28	8	-	50	4	9	0	5	-	-	-	2
1-Oct	62	40	23	-	95	4	3	2	15	-	-	-	7
2-Oct	1,032	20	16	-	54	6	3	15	6	-	-	-	3
3-Oct	157	41	22	-	46	11	3	14	6	-	-	8	4
4-Oct	308	50	26	-	540	13	5	55	42	-	-	5	12
5-Oct	153	52	23	-	152	11	2	9	1,162	-	-	23	8
6-Oct	72	53	145	-	19	44	2	1	268	-	-	9	4
7-Oct	1,288	71	105	2	40	18	10	7	29	28	-	6	2
8-Oct	409	69	192	10	19	54	16	4	4	7	3	0	13
9-Oct	345	54	184	325	22	128	6	6	2	45	13	9	3
10-Oct	194	87	89	253	43	86	2	26	15	415	22	222	4
11-Oct	400	125	92	51	81	123	1	46	18	435	3	405	4
12-Oct	160	130	120	17	43	316	0	29	18	360	9	311	5

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
13-Oct	87	174	145	52	408	392	94	23	41	372	7	100	10
14-Oct	198	127	137	37	128	568	10	51	93	233	12	35	34
15-Oct	531	131	130	30	53	474	18	75	1,043	124	7	36	88
16-Oct	895	157	174	110	29	275	3	50	241	54	7	42	21
17-Oct	643	83	193	74	20	164	7	47	511	79	35	111	52
18-Oct	696	148	165	166	28	280	8	68	409	134	27	525	16
19-Oct	636	100	183	99	27	242	24	275	288	126	11	318	88
20-Oct	462	128	486	99	56	266	17	221	327	154	44	432	69
21-Oct	393	114	584	435	60	252	62	407	201	189	9	489	70
22-Oct	803	230	423	184	47	343	39	202	312	136	8	329	147
23-Oct	442	390	226	157	19	240	71	263	276	119	4	661	647
24-Oct	376	1,031	220	199	37	194	33	156	295	117	15	378	475
25-Oct	240	1,203	319	112	67	141	27	166	250	138	29	365	2,540
26-Oct	351	919	332	96	142	510	46	286	423	72	4	202	1,198
27-Oct	916	736	101	94	103	141	24	382	373	39	13	352	1,101
28-Oct	373	895	96	208	50	137	25	482	229	26	26	420	370
29-Oct	473	802	159	106	39	122	16	181	338	64	5	233	378
30-Oct	764	1,390	137	123	44	97	40	95	351	25	12	121	385
31-Oct	476	1,134	129	204	97	137	30	28	394	20	2	106	293
1-Nov	90	631	164	211	90	184	41	476	193	189	5	99	84
2-Nov	112	1,143	68	253	133	517	42	151	348	50	6	118	164
3-Nov	297	1,590	59	90	428	334	33	138	203	27	2	137	497
4-Nov	403	1,297	740	236	55	471	15	71	308	24	-	394	525
5-Nov	467	1,028	51	511	282	266	0	230	234	43	-	4	435
6-Nov	743	899	33	526	132	176	1	294	209	20	-	12	614
7-Nov	1,206	659	46	687	197	182	1	572	166	16	-	207	211
8-Nov	1,584	1,233	31	540	254	194	0	339	154	8	-	24	269
9-Nov	1,161	1,509	23	2,513	198	235	1	311	117	14	-	3	171
10-Nov	1,060	707	29	676	386	124	3	355	129	16	-	3	273
11-Nov	525	866	29	202	379	192	3	72	190	50	-	4	631
12-Nov	535	504	26	901	310	242	0	1,669	172	25	-	3	734
13-Nov	763	473	1	965	276	174	0	154	210	22	-	3	515
14-Nov	1,211	302	11	399	237	63	3	198	309	32	-	1	475
15-Nov	1,528	275	2	329	350	121	7	103	160	29	-	-	481
16-Nov	1,916	172	-	1,051	412	50	1	61	80	21	-	-	711
17-Nov	937	147	-	233	223	54	-	121	-	235	-	-	1,924
18-Nov	623	231	-	170	299	49	-	139	-	59	-	-	1,451
19-Nov	590	233	-	119	280	38	-	59	-	14	-	-	781
20-Nov	425	259	-	150	220	47	-	93	-	13	-	-	636
21-Nov	269	222	-	43	151	36	-	295	-	15	-	-	329
22-Nov	445	101	-	10	74	58	-	47	-	17	-	-	165
23-Nov	331	72	-	94	171	102	-	29	-	-	-	-	1,805
24-Nov	462	53	-	531	206	15	-	46	-	-	-	-	1,290
25-Nov	189	40	-	35	180	55	-	46	-	-	-	-	703
26-Nov	117	21	-	54	156	-	-	27	-	-	-	-	647
27-Nov	82	15	-	63	88	-	-	25	-	-	-	-	431
28-Nov	85	21	-	9	40	-	-	5	-	-	-	-	395
29-Nov	37	8	-	-	110	-	-	-	-	-	-	-	552
30-Nov	-	-	-	-	68	-	-	-	-	-	-	-	1,073
1-Dec	-	-	-	-	28	-	-	-	-	-	-	-	662
2-Dec	-	-	-	-	5	-	-	-	-	-	-	-	1,008
3-Dec	-	-	-	-	0	-	-	-	-	-	-	-	526
4-Dec	-	-	-	-	-	-	-	-	-	-	-	-	1,342
5-Dec	-	-	-	-	-	-	-	-	-	-	-	-	590
6-Dec	-	-	-	-	-	-	-	-	-	-	-	-	424
7-Dec	-	-	-	-	-	-	-	-	-	-	-	-	83
8-Dec	-	-	-	-	-	-	-	-	-	-	-	-	60
9-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
10-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
11-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
12-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
13-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
14-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
15-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
16-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
21-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
24-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
25-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
26-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
27-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
28-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
29-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
30-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
31-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
1-Jan	-	-	-	-	-	-	-	-	-	-	-	-	-
"Misc."	370	150	25	200	69	10	50	-	-	-	13	-	-
Total	33,502	25,750	6,739	15,044	9,145	9,784	860	9,814	11,176	4,450	353	7,265	32,031
Final escapement estimates [b]													
Adults	33,198	25,314	5,942	13,941	9,128	10,366	641	8,984	11,349	4,435	82	5,076	32,031
Jacks	294	422	797	1,208	17	294	217	830	129	15	271	2,189	14
Total	33,492	25,736	6,739	15,149	9,145	10,660	858	9,814	11,478	4,450	353	7,265	32,045

[b.] Final escapement estimates corrected for age, observer error at fence, or brood stock and experimental removals upstream of Sweltzer fence.

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
16-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
21-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
24-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
25-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
26-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
27-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
28-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
29-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
30-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
31-Aug	-	-	-	-	-	-	-	-	-	-	-	-	-
1-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
3-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
4-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
5-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
6-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
7-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
8-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
9-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
10-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
11-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
12-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
13-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
14-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
15-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
16-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
21-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
24-Sep	-	-	-	-	-	-	-	-	-	-	-	-	-
25-Sep	-	-	-	-	0	-	-	-	-	-	-	-	-
26-Sep	-	-	-	-	1	-	-	-	-	-	-	0	-
27-Sep	-	-	-	13	4	5	-	-	-	-	-	26	-
28-Sep	1	-	-	22	0	3	-	-	-	-	-	49	-
29-Sep	1	-	-	31	2	3	-	-	-	-	-	364	-
30-Sep	0	-	-	22	3	2	-	3	-	-	-	241	-
1-Oct	2	-	-	88	5	2	3	33	-	-	-	83	-
2-Oct	7	-	-	86	13	5	20	16	-	-	-	14	-
3-Oct	5	-	-	138	15	6	11	34	-	-	-	59	-
4-Oct	1	-	19	17	11	1	2	20	-	-	-	113	-
5-Oct	4	-	46	15	9	2	14	26	-	4	-	149	7
6-Oct	3	5	29	19	6	5	36	17	-	0	-	154	5
7-Oct	2	27	124	31	2	15	52	69	-	0	-	158	3
8-Oct	4	28	247	42	4	8	64	47	-	6	-	180	5
9-Oct	1	20	334	186	6	2	56	39	-	2	-	112	2
10-Oct	0	23	389	293	26	4	62	75	-	2	-	186	4
11-Oct	2	22	209	444	18	9	77	88	-	3	34	239	4
12-Oct	7	35	293	408	23	14	122	109	-	19	61	131	0

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
13-Oct	5	5	136	751	22	4	150	272	-	6	2	74	26
14-Oct	4	98	172	490	23	1	165	141	-	6	1	85	4
15-Oct	6	84	125	500	22	1	126	148	-	5	44	117	3
16-Oct	6	112	193	567	20	0	46	290	-	11	0	470	2
17-Oct	9	62	479	1,035	38	0	57	242	-	16	73	211	5
18-Oct	8	70	217	1,159	44	4	7	410	-	20	4	101	41
19-Oct	25	122	142	335	29	27	73	414	-	37	39	21	119
20-Oct	29	110	128	668	19	42	23	281	-	5	12	154	173
21-Oct	36	61	83	1,416	25	13	83	482	-	0	9	516	86
22-Oct	30	56	630	3,746	30	37	62	328	-	6	52	307	42
23-Oct	24	15	300	1,900	25	28	28	192	-	0	13	90	47
24-Oct	23	26	209	576	24	7	20	339	117	3	51	41	38
25-Oct	59	17	240	264	20	24	38	326	49	3	818	51	17
26-Oct	132	39	154	207	19	12	514	946	38	7	10	61	10
27-Oct	109	50	282	331	28	17	649	435	26	1	78	43	11
28-Oct	38	36	227	299	24	6	117	323	21	20	34	39	7
29-Oct	33	13	274	92	10	8	4	503	16	12	18	21	7
30-Oct	34	1	382	124	18	5	62	626	99	15	37	12	18
31-Oct	41	0	240	887	9	4	55	567	58	14	19	31	3
1-Nov	84	0	261	691	3	5	17	1,308	15	12	81	29	77
2-Nov	105	2	320	283	4	2	45	649	12	12	80	41	8
3-Nov	51	2	123	439	5	4	18	464	57	14	33	85	8
4-Nov	59	2	1,140	114	4	10	17	432	8	34	30	127	8
5-Nov	128	0	786	128	0	6	83	274	23	69	119	477	5
6-Nov	75	3	688	128	21	4	7	131	400	96	38	221	9
7-Nov	56	0	378	184	0	1	13	52	-	76	55	324	214
8-Nov	28	0	280	195	0	1	14	449	-	14	25	634	9
9-Nov	17	0	289	49	0	4	10	469	-	18	-	343	5
10-Nov	32	9	306	14	15	4	7	483	-	-	-	1,211	4
11-Nov	6	0	150	13	8	5	8	577	-	-	-	2,078	1
12-Nov	7	1	82	12	4	16	34	5,148	-	-	-	1,264	1
13-Nov	5	1	147	11	5	28	43	942	-	-	-	1,020	0
14-Nov	8	0	211	10	3	46	33	913	-	-	-	1,952	5
15-Nov	15	0	238	48	0	32	48	307	25	-	-	178	3
16-Nov	16	0	421	94	3	23	37	198	-	-	-	198	1
17-Nov	13	2	537	74	2	45	115	230	-	-	-	754	13
18-Nov	15	0	557	77	7	6	12	107	-	-	-	188	11
19-Nov	41	0	581	52	2	1	35	476	-	-	-	941	9
20-Nov	10	-	221	27	0	2	36	660	-	-	-	428	7
21-Nov	92	-	411	2	2	0	32	1,033	-	-	-	435	4
22-Nov	12	-	16	7	0	-	0	897	-	-	-	348	31
23-Nov	5	-	170	20	4	-	0	1,471	-	-	-	161	4
24-Nov	4	-	104	12	5	-	0	552	-	-	-	200	9
25-Nov	3	-	136	5	4	-	0	662	-	-	-	106	1
26-Nov	1	-	192	5	4	-	7	303	-	-	-	150	1
27-Nov	38	-	436	3	4	-	9	115	-	-	-	151	51
28-Nov	1	-	406	0	15	-	3	89	-	-	-	682	3
29-Nov	13	-	484	6	32	-	1	77	-	-	-	78	3
30-Nov	6	-	307	-	35	-	1	160	-	-	-	23	11
1-Dec	2	-	198	-	21	-	0	561	-	-	-	59	-
2-Dec	12	-	88	-	24	-	-	734	-	-	-	41	-
3-Dec	1	-	46	-	19	-	-	1,976	-	-	-	24	-
4-Dec	0	-	3	-	14	-	-	428	-	-	-	33	-
5-Dec	-	-	31	-	-	-	-	88	-	-	-	101	-
6-Dec	-	-	22	-	-	-	-	10	-	-	-	128	-
7-Dec	-	-	33	-	-	-	-	1	-	-	-	276	-
8-Dec	-	-	18	-	-	-	-	15	-	-	-	0	-
9-Dec	-	-	15	-	-	-	-	51	-	-	-	-	-

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
10-Dec	-	-	-	-	-	-	-	3	-	-	-	-	-
11-Dec	-	-	-	-	-	-	-	7	-	-	-	-	-
12-Dec	-	-	-	-	-	-	-	0	-	-	-	-	-
13-Dec	-	-	-	-	-	-	-	0	-	-	-	-	-
14-Dec	-	-	-	-	-	-	-	0	-	-	-	-	-
15-Dec	-	-	-	-	-	-	-	0	-	-	-	-	-
16-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
17-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
18-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
19-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
20-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
21-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
22-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
23-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
24-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
25-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
26-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
27-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
28-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
29-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
30-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
31-Dec	-	-	-	-	-	-	-	-	-	-	-	-	-
1-Jan	-	-	-	-	-	-	-	-	-	-	-	-	-
"Misc."	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1,652	1,159	17,135	19,905	866	571	3,483	31,343	964	568	1,870	20,192	1,205
Final escapement estimates [b]													
Adults	1,657	256	16,725	19,944	994	424	3,256	32,184	861	418	1,860	20,157	1,203
Jacks	30	903	497	8	153	147	277	152	103	150	10	34	2
Total	1,687	1,159	17,222	19,952	1,147	571	3,533	32,336	964	568	1,870	20,191	1,205

[b.] Final escapement estimates corrected for age, observer error at fence, or brood stock and experimental removals upstream of Sweltzer fence.

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1993	1994	1995	1996	1997	1998	1999	2000	2001
16-Aug	-	-	-	-	-	-	-	-	5
17-Aug	-	-	-	-	-	-	-	-	4
18-Aug	-	-	-	-	-	-	-	-	12
19-Aug	-	-	-	-	-	-	-	28	14
20-Aug	-	-	-	-	-	-	-	32	17
21-Aug	-	-	-	-	-	-	-	6	23
22-Aug	-	-	-	-	-	-	-	18	12
23-Aug	-	-	-	-	-	-	-	10	14
24-Aug	-	-	-	-	-	-	-	4	9
25-Aug	-	-	-	-	-	-	-	77	33
26-Aug	-	-	-	-	-	-	-	14	12
27-Aug	-	-	-	-	-	-	1	3	16
28-Aug	-	-	-	-	-	-	5	28	15
29-Aug	-	-	-	-	-	-	128	23	34
30-Aug	-	-	-	-	-	-	115	13	21
31-Aug	-	-	-	-	-	-	96	14	19
1-Sep	-	-	-	-	-	-	114	30	13
2-Sep	-	-	-	-	-	-	46	18	26
3-Sep	-	-	-	-	-	-	63	14	14
4-Sep	-	-	-	-	-	-	167	38	0
5-Sep	-	-	-	-	-	-	135	24	1
6-Sep	-	-	-	-	-	-	142	16	26
7-Sep	-	-	-	-	-	-	175	20	8
8-Sep	-	-	-	-	-	-	152	12	1
9-Sep	-	-	-	-	-	-	220	65	11
10-Sep	-	-	-	-	-	-	53	38	22
11-Sep	-	-	-	-	-	-	28	48	41
12-Sep	-	-	-	-	-	-	151	25	12
13-Sep	-	-	-	-	-	-	229	43	7
14-Sep	-	-	-	32	-	6	151	23	22
15-Sep	-	-	-	96	-	2	140	149	8
16-Sep	-	-	-	285	-	3	79	47	11
17-Sep	-	-	-	40	-	3	89	17	7
18-Sep	-	-	-	33	-	2	46	28	4
19-Sep	-	-	-	19	-	3	55	32	2
20-Sep	-	-	-	38	-	7	172	20	1
21-Sep	-	-	-	15	-	19	226	2	4
22-Sep	-	-	-	28	-	7	210	3	7
23-Sep	-	-	-	21	1	9	163	0	11
24-Sep	-	-	-	35	5	7	204	0	12
25-Sep	-	-	-	30	2	11	446	19	6
26-Sep	-	-	-	47	13	21	302	5	2
27-Sep	-	-	-	19	9	62	225	3	1
28-Sep	-	-	-	2	4	13	122	18	0
29-Sep	-	-	81	38	0	6	42	5	1
30-Sep	-	-	1,375	132	1	6	218	20	1
1-Oct	-	-	116	6	0	22	84	1	0
2-Oct	-	-	199	52	0	10	30	13	0
3-Oct	-	-	2,342	38	2	7	42	20	0
4-Oct	-	0	1,512	86	0	6	78	13	0
5-Oct	-	0	227	173	0	7	77	1	0
6-Oct	-	1	34	72	0	6	248	2	0
7-Oct	-	0	25	25	5	18	171	7	0
8-Oct	-	18	0	8	2	6	2,681	9	1
9-Oct	-	231	77	4	1	7	1,015	8	0
10-Oct	-	90	575	26	2	16	169	1	0
11-Oct	-	130	449	9	0	3	100	0	1
12-Oct	-	90	478	16	1	9	336	4	6

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1993	1994	1995	1996	1997	1998	1999	2000	2001
13-Oct	-	53	215	4	0	11	593	0	9
14-Oct	-	48	202	34	1	129	26	0	14
15-Oct	-	33	327	37	2	279	43	2	5
16-Oct	-	17	168	10	0	160	40	1	0
17-Oct	-	8	258	13	0	14	125	0	3
18-Oct	-	12	143	1	1	167	73	5	3
19-Oct	-	4	55	3	1	134	70	15	2
20-Oct	-	5	86	12	1	63	16	14	1
21-Oct	-	653	71	9	1	116	21	16	5
22-Oct	-	547	28	4	0	62	11	1	2
23-Oct	-	27	61	24	0	84	19	2	1
24-Oct	-	18	29	4	2	25	27	2	9
25-Oct	31	9	66	17	0	15	7	3	1
26-Oct	15	33	104	1	0	22	24	0	5
27-Oct	12	84	25	2	1	24	19	0	2
28-Oct	9	2	7	23	0	33	32	0	3
29-Oct	36	5	24	41	0	50	194	0	3
30-Oct	40	25	37	14	21	27	447	0	4
31-Oct	32	45	32	4	3	35	374	0	4
1-Nov	23	60	1	23	0	17	56	2	2
2-Nov	15	14	6	18	0	30	24	0	2
3-Nov	7	0	3	9	0	21	17	0	2
4-Nov	20	4	31	3	0	23	74	14	3
5-Nov	11	8	68	15	2	19	24	1	1
6-Nov	1	3	28	23	0	20	14	1	3
7-Nov	6	1	133	22	1	58	18	4	0
8-Nov	16	73	134	7	0	11	7	7	1
9-Nov	17	26	19	21	0	8	8	1	1
10-Nov	17	16	48	20	-	8	0	0	1
11-Nov	0	62	46	34	-	10	16	0	1
12-Nov	6	11	53	25	-	33	40	0	1
13-Nov	5	24	117	16	-	38	0	0	1
14-Nov	9	61	31	26	-	25	0	0	1
15-Nov	107	215	15	10	-	22	0	0	1
16-Nov	37	31	8	7	-	10	3	0	2
17-Nov	7	53	29	0	-	11	-	1	2
18-Nov	24	10	17	0	-	7	-	0	2
19-Nov	26	396	16	5	-	5	-	0	0
20-Nov	14	477	27	6	-	3	-	0	1
21-Nov	170	87	17	6	-	1	-	0	0
22-Nov	18	43	16	7	-	0	-	0	1
23-Nov	0	58	9	1	-	0	-	1	1
24-Nov	3	26	10	3	-	-	-	2	0
25-Nov	13	34	10	9	-	-	-	0	0
26-Nov	8	4	9	6	-	-	-	0	0
27-Nov	1	67	6	16	-	-	-	0	0
28-Nov	5	51	6	3	-	-	-	0	0
29-Nov	37	69	5	0	-	-	-	0	0
30-Nov	49	195	0	7	-	-	-	1	0
1-Dec	13	24	2	-	-	-	-	0	0
2-Dec	98	10	0	-	-	-	-	0	0
3-Dec	172	6	0	-	-	-	-	0	0
4-Dec	0	4	1	-	-	-	-	0	0
5-Dec	1	-	0	-	-	-	-	-	0
6-Dec	0	-	0	-	-	-	-	-	0
7-Dec	0	-	-	-	-	-	-	-	0
8-Dec	0	-	-	-	-	-	-	-	-
9-Dec	-	-	-	-	-	-	-	-	-

Continued

Appendix 1. Daily total sockeye escapement (adults plus jacks) counted at the Sweltzer Creek enumeration fence, 1941-2001 continued.

Date	1993	1994	1995	1996	1997	1998	1999	2000	2001
10-Dec	-	-	-	-	-	-	-	-	-
11-Dec	-	-	-	-	-	-	-	-	-
12-Dec	-	-	-	-	-	-	-	-	-
13-Dec	-	-	-	-	-	-	-	-	-
14-Dec	-	-	-	-	-	-	-	-	-
15-Dec	-	-	-	-	-	-	-	-	-
16-Dec	-	-	-	-	-	-	-	-	-
17-Dec	-	-	-	-	-	-	-	-	-
18-Dec	-	-	-	-	-	-	-	-	-
19-Dec	-	-	-	-	-	-	-	-	-
20-Dec	-	-	-	-	-	-	-	-	-
21-Dec	-	-	-	-	-	-	-	-	-
22-Dec	-	-	-	-	-	-	-	-	-
23-Dec	-	-	-	-	-	-	-	-	-
24-Dec	-	-	-	-	-	-	-	-	-
25-Dec	-	-	-	-	-	-	-	-	-
26-Dec	-	-	-	-	-	-	-	-	-
27-Dec	-	-	-	-	-	-	-	-	-
28-Dec	-	-	-	-	-	-	-	-	-
29-Dec	-	-	-	-	-	-	-	-	-
30-Dec	-	-	-	-	-	-	-	-	-
31-Dec	-	-	-	-	-	-	-	-	-
1-Jan	-	-	-	-	-	-	-	-	-
"Misc."	-	-	-	-	-	-	-	-	-
Total	1,131	4,411	10,349	2,030	85	2,134	12,403	1,227	656
Final escapement estimates [b]									
Adults	1,063	4,399	10,316	2,022	88	1,959	12,392	1,227	515
Jacks	68	23	33	8	3	207	11	0	160
Total	1,131	4,422	10,349	2,030	91	2,166	12,403	1,227	675

[b.] Final escapement estimates corrected for age, observer error at fence, or brood stock and experimental removals upstream of Sweltzer fence.

Appendix 2. Annual escapement of adults by sex and jacks, and female spawning success of Cultus sockeye salmon, 1925 to 2001. ("na" indicates data are unavailable)

	Escapement							
			Adults			Female	Female	Estimated
	Total					carcasses	spawning	prespawn
Year	population	Jacks	Total	Males	Females	recovered	success	mortality [c]
1925	5,423	0	5,423	1,540	3,883	-	-	-
1926	5,071 [a]	2,449	2,622	1,122	1,500	-	-	-
1927	82,426	0	82,426	26,050	56,376	-	-	-
1928	15,339 [b]	678	14,661	3,700	10,961	-	-	-
1929	5,084 [a]	0	5,084	1,645	3,439	-	-	-
1930	10,395	2,449	7,946	2,404	5,542	-	-	-
1931	37,473	0	37,473	10,368	27,105	-	-	-
1932	2,259 [a]	28	2,231	713	1,518	-	-	-
1933	3,471 [b]	607	2,864	1,027	1,837	-	-	-
1934	23,026	86	22,940	3,966	18,974	-	-	-
1935	15,339	na	15,339	5,412	9,927	-	-	-
1936	8,378	56	8,322	3,261	5,061	-	-	-
1937	3,061	1,834	1,227	513	714	-	-	-
1938	13,342	3,908	9,434	1,603	7,831	-	-	-
1939	73,189	2,400	70,789	19,224	51,565	-	-	-
1940	74,121	585	73,536	16,089	57,447	-	-	-
1941	18,164	4,214	13,950	5,413	8,537	-	-	-
1942	37,305	346	36,959	12,396	24,563	-	-	-
1943	11,875	53	11,822	3,881	7,941	-	-	-
1944	14,200	198	14,002	4,701	9,301	-	-	-
1945	9,227	4,197	5,030	1,780	3,250	75	79.0%	21.0%
1946	33,284	216	33,068	11,911	21,157	434	91.9%	8.1%
1947	8,898	199	8,699	2,869	5,830	-	-	-
1948	13,086	340	12,746	5,601	7,145	-	-	-
1949	9,301	246	9,055	3,039	6,016	-	-	-
1950	30,595	667	29,928	10,027	19,901	-	-	-
1951	13,143	466	12,677	3,002	9,675	-	-	-
1952	18,910	1,077	17,833	5,698	12,135	-	-	-
1953	13,000	1,457	11,543	6,253	5,290	-	-	-
1954	24,150	2,114	22,036	10,795	11,241	-	-	-
1955	26,000	78	25,922	7,990	17,932	-	-	-
1956	14,133	415	13,718	4,630	9,088	-	-	-
1957	20,647	272	20,375	7,245	13,130	-	-	-
1958	14,097	773	13,324	5,794	7,530	-	-	-
1959	48,461	682	47,779	15,753	32,026	-	-	-
1960	17,689	49	17,640	7,520	10,120	-	-	-
1961	15,428	2,032	13,396	6,363	7,033	-	-	-
1962	27,070	73	26,997	9,450	17,547	-	-	-
1963	20,571	268	20,303	9,032	11,271	-	-	-
1964	11,143	76	11,067	4,857	6,210	-	-	-
1965	2,532	77	2,455	832	1,623	-	-	-
1966	17,464	545	16,919	7,676	9,243	-	-	-
1967	33,492	294	33,198	14,767	18,431	-	-	-
1968	25,736	422	25,314	10,439	14,875	-	-	-
1969	6,739	797	5,942	2,761	3,181	-	-	-
1970	15,149	1,208	13,941	5,778	8,163	-	-	-
1971	9,145	17	9,128	4,161	4,967	-	-	-
1972	10,660	294	10,366	4,572	5,794	-	-	-
1973	858	217	641	318	323	-	-	-
1974	9,814	830	8,984	3,630	5,354	-	-	-
1975	11,478	129	11,349	4,006	7,343	-	-	-
1976	4,450	15	4,435	1,551	2,884	-	-	-
1977	353	271	82	41	41	-	-	-

Continued

Appendix 2. Annual escapement of adults by sex and jacks, and female spawning success of Cultus sockeye salmon, 1925 to 2001 continued. ("na" indicates data are unavailable)

	Escapement								
			Adults			Female	Female	Estimated	
Year	Total population	Jacks	Total	Males	Females	carcasses recovered	spawning success	prespawn mortality	
1978	7,265	2,189	5,076	1,920	3,156	-	-	-	
1979	32,045	14	32,031	11,736	20,295	-	-	-	
1980	1,687	30	1,657	693	964	-	-	-	
1981	1,159	903	256	112	144	-	-	-	
1982	17,222	497	16,725	6,445	10,280	-	-	-	
1983	19,952	8	19,944	8,454	11,490	35	100.0%	0.0%	
1984	1,147	153	994	449	545	-	-	-	
1985	571	147	424	215	209	-	-	-	
1986	3,533	277	3,256	1,062	2,194	-	-	-	
1987	32,336	152	32,184	14,800	17,384	-	-	-	
1988	964	103	861	374	487	-	-	6.6%	d
1989	568	150	418	182	236	-	-	6.6%	d
1990	1,870	10	1,860	849	1,011	-	-	6.6%	d
1991	20,191	34	20,157	9,690	10,467	246	94.1%	5.9%	
1992	1,205	2	1,203	455	748	-	-	6.6%	d
1993	1,131	68	1,063	492	571	71	100.0%	0.0%	
1994	4,422	23	4,399	1,749	2,650	115	95.2%	4.8%	
1995	10,349	33	10,316	4,744	5,572	28	76.5%	23.5%	
1996	2,030	8	2,022	908	1,114	10	34.4%	65.6%	
1997	91	3	88	45	43	0	-	51.6%	e
1998	2,166	207	1,959	928	1,031	9	62.5%	37.5%	
1999	12,403	11	12,392	5,576	6,816	0	-	93.0%	f
2000	1,227	0	1,227	613	614	0	-	93.0%	f
2001	675	160	515	257	258	1	0.0%	62.5%	g

[a.] No natural spawning; all eggs stripped from females for hatchery incubation and subsequent fry liberation into lake.
[b.] No natural spawning; all eggs stripped from females for egg plants in tributaries to Cultus Lake.
[c.] Directly estimated from female carcass recovery, unless otherwise noted.
[d.] Direct estimate unavailable; 1925-1994 average used for three generation projection.
[e.] Direct estimate unavailable; 1996 and 1998 average used for three generation projection.
[f.] Direct estimate unavailable; estimated from ratio of smolts/adult for brood with 1925-1994 (pre-early migration) average.
[g.] Direct estimate unavailable; 1995, 1996, 1998, 1999 and 2000 average used for three generation projection.

Appendix 3. Annual Cultus sockeye migration timing through the Sweltzer Creek enumeration fence, peak of spawning period and average female fecundity, 1925-2001.

	Date at Sweltzer fence				Fecundity sample		
Year	Fence installed[a]	50% migration	Fence removed[b]	Period of peak spawning	N	Mean S. Length	Mean fecundity
1925	-	-	-	-	-	-	4,500
1926	-	-	-	-	-	-	-
1927	-	-	-	-	-	-	4,500
1928	-	-	-	-	-	-	-
1929	-	-	-	-	-	-	-
1930	-	-	-	-	-	-	4,500
1931	-	-	-	-	46	53.11	-
1932	-	-	-	-	47	51.22	4,310
1933	-	-	-	-	-	-	3,796
1934	-	-	-	-	55	53.56	-
1935	-	-	-	-	-	-	4,067
1936	-	-	-	-	40	49.85	-
1937	-	-	-	-	61	51.00	3,764
1938	27-Sep	-	-	12-Nov to 19-Nov	-	-	4,237
1939	10-Oct	-	-	20-Nov to 26-Nov	-	-	4,273
1940	20-Sep	-	-	23-Nov to 28-Nov	-	-	4,300
1941	9-Sep	27-Oct	13-Dec	-	-	-	4,300
1942	19-Sep	23-Nov	31-Dec	-	56	50.23	4,300
1943	25-Aug	18-Nov	1-Jan	-	40	52.12	3,722
1944	30-Aug	5-Nov	30-Dec	-	-	-	4,103
1945	29-Sep	4-Nov	22-Dec	23-Nov to 28-Nov	-	-	-
1946	22-Sep	2-Nov	22-Dec	23-Nov to 28-Nov	-	-	-
1947	26-Sep	5-Nov	30-Dec	-	-	-	-
1948	25-Sep	25-Oct	15-Dec	-	-	-	-
1949	4-Oct	27-Oct	12-Dec	23-Nov to 28-Nov	-	-	-
1950	26-Sep	20-Oct	10-Dec	23-Nov to 30-Nov	-	-	-
1951	21-Sep	16-Oct	6-Dec	21-Nov to 26-Nov	-	-	-
1952	4-Oct	30-Oct	10-Dec	23-Nov to 01-Dec	-	-	-
1953	20-Sep	16-Oct	30-Nov	18-Nov to 26-Nov	-	-	-
1954	29-Sep	10-Oct	20-Nov	18-Nov to 21-Nov	-	-	-
1955	29-Sep	16-Oct	4-Nov	20-Nov to 25-Nov	-	-	-
1956	14-Sep	3-Oct	6-Dec	18-Nov to 21-Nov	-	-	-
1957	19-Sep	27-Oct	4-Dec	18-Nov to 26-Nov	-	-	-
1958	25-Sep	4-Nov	7-Dec	25-Nov to 01-Dec	-	-	-
1959	24-Sep	16-Oct	15-Dec	01-Dec to 05-Dec	-	-	-
1960	27-Sep	20-Oct	6-Dec	16-Nov to 20-Nov	-	-	-
1961	19-Sep	20-Oct	30-Nov	25-Nov to 28-Nov	-	-	-
1962	20-Sep	9-Nov	8-Dec	20-Nov to 25-Nov	-	-	-
1963	25-Sep	3-Nov	6-Dec	03-Dec to 07-Dec	-	-	-
1964	25-Sep	29-Oct	30-Nov	-	-	-	-
1965	5-Oct	8-Oct	21-Nov	24-Nov to 30-Nov	-	-	-
1966	4-Oct	18-Oct	21-Nov	17-Nov to 22-Nov	-	-	-
1967	23-Sep	7-Nov	30-Nov	15-Nov to 20-Nov	-	-	-
1968	25-Sep	4-Nov	30-Nov	20-Nov to 26-Nov	-	-	-
1969	23-Sep	23-Oct	16-Nov	-	-	-	-
1970	7-Oct	10-Nov	29-Nov	15-Nov to 20-Nov	-	-	-
1971	30-Sep	11-Nov	4-Dec	22-Nov to 26-Nov	-	-	-
1972	29-Sep	27-Oct	26-Nov	15-Nov to 18-Nov	-	-	-
1973	28-Sep	25-Oct	17-Nov	01-Dec to 04-Dec	-	-	-
1974	25-Sep	7-Nov	29-Nov	20-Nov to 25-Nov	-	-	-
1975	25-Sep	25-Oct	17-Nov	25-Nov to 30-Nov	-	-	-
1976	7-Oct	19-Oct	23-Nov	15-Nov to 20-Nov	-	-	-

Continued

Appendix 3. Annual Cultus sockeye migration timing through the Sweltzer Creek enumeration fence, peak of spawning period and average female fecundity, 1925-2001 continued.

	Date at Sweltzer fence				Fecundity sample		
Year	Fence installed[a]	50% migration	Fence removed[b]	Period of peak spawning	N	Mean S. Length	Mean fecundity
1977	8-Oct	21-Oct	4-Nov	15-Nov to 20-Nov	-	-	-
1978	3-Oct	24-Oct	15-Nov	Mid Nov	-	-	-
1979	20-Sep	18-Nov	9-Dec	29-Nov to 05-Dec	-	-	-
1980	28-Sep	19-Oct	5-Dec	Mid Nov	-	-	-
1981	1-Oct	3-Nov	20-Nov	Mid Nov	-	-	-
1982	1-Oct	6-Nov	10-Dec	Mid Nov	-	-	-
1983	27-Sep	23-Oct	30-Nov	Early Nov	-	-	-
1984	26-Sep	24-Oct	5-Dec	Early Nov	-	-	-
1985	27-Sep	27-Oct	22-Nov	Late Nov	-	-	-
1986	1-Oct	27-Oct	2-Dec	Late Nov	-	-	-
1987	30-Oct	13-Nov	16-Dec	Late Nov to Early Dec	-	-	-
1988	24-Oct	4-Nov	7-Nov	Late Nov to Early Dec	-	-	-
1989	5-Oct	5-Nov	10-Nov	23-Nov to 05-Dec	-	-	-
1990	11-Oct	26-Oct	9-Nov	-	-	-	-
1991	27-Sep	12-Nov	9-Dec	-	-	-	-
1992	5-Oct	25-Oct	30-Nov	-	-	-	-
1993	25-Oct	22-Nov	9-Dec	10-Dec to 20-Dec	-	-	-
1994	6-Oct	2-Nov	5-Dec	Early Dec	-	-	-
1995	29-Sep	5-Oct	7-Dec	c	-	-	-
1996	14-Sep	5-Oct	1-Dec	c	-	-	-
1997	23-Sep	9-Oct	10-Nov	c	-	-	-
1998	14-Sep	20-Oct	24-Nov	c	-	-	-
1999	27-Aug	9-Oct	17-Nov	c	-	-	-
2000	19-Aug	13-Sep	5-Dec	c	-	-	-
2001	16-Aug	7-Sep	8-Dec	c	-	-	-
Average							
1941-1995	27-Sep	28-Oct	25-Nov	Late-Nov. to early Dec.	49	51.58	4,191
1996-2001	3-Sep	30-Sep	25-Nov	-	-	-	-

[a.] Fence installation date is based on historical timing information and the first observation of migrating adult sockeye.

[b.] Fence removal date is based on historical timing information and the last observations of migrating adult sockeye.

[c.] Spawning ground surveys were conducted in Cultus Lake, however, no sockeye spawning was observed.

Appendix 4. Annual age composition and mean standard length by age and sex for sockeye carcasses recovered on the Cultus Lake spawning grounds and at the Sweltzer Creek enumeration fence, 1965 to 2001.

	Mean lengths by age class																
	3_2		4_2				5_2				5_3				Adult percent at age		
	Jack		Male		Female		Male		Female		Male		Female				
Year	N	Length	N	Length	N	Length	N	Length	N	Length	N	Length	N	Length	4_2	5_2	5_3
1965	29	42.77	40	56.67	45	53.75	0	-	3	52.48	0	-	2	49.50	94.4%	3.3%	2.2%
1966	93	43.81	32	58.72	36	52.22	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1967	26	46.50	227	60.17	217	55.40	0	-	0	-	0	-	1	57.00	99.8%	0.0%	0.2%
1968	95	44.27	65	56.11	118	50.83	3	59.67	3	53.33	0	-	0	-	96.8%	3.2%	0.0%
1969	183	44.73	74	55.89	106	51.75	12	58.92	8	53.63	0	-	2	51.00	89.1%	9.9%	1.0%
1970	101	43.45	112	54.28	116	49.71	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1971	0	-	28	58.96	86	55.13	0	-	1	59.00	0	-	0	-	99.1%	0.9%	0.0%
1972	6	43.17	37	55.11	105	50.67	8	59.50	14	53.79	0	-	0	-	86.6%	13.4%	0.0%
1973	97	42.07	4	54.37	5	52.78	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1974	31	44.29	61	56.13	97	51.51	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1975	94	43.40	104	54.63	120	50.09	1	57.00	0	-	1	52.00	0	-	99.1%	0.4%	0.4%
1976	3	43.00	27	56.37	47	50.83	2	58.00	1	52.00	2	52.00	1	50.00	92.5%	3.8%	3.8%
1977	121	42.01	0	-	0	-	0	-	0	-	0	-	0	-	na	na	na
1978	210	41.69	119	55.22	114	50.71	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1979	0	-	117	55.91	119	50.60	3	61.00	1	54.00	0	-	0	-	98.3%	1.7%	0.0%
1980	25	40.76	59	53.12	97	48.52	9	58.33	4	51.50	0	-	0	-	92.3%	7.7%	0.0%
1981	115	42.65	0	-	0	-	0	-	0	-	0	-	0	-	na	na	na
1982	164	41.10	37	54.30	93	50.45	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1983	0	-	60	55.29	59	50.20	0	-	0	-	0	-	1	49.00	99.2%	0.0%	0.8%
1984	143	41.92	25	53.08	42	48.83	24	59.25	14	54.79	1	52.00	1	50.00	62.6%	35.5%	1.9%
1985	6	38.00	0	-	0	-	0	-	0	-	0	-	0	-	na	na	na
1986	96	40.23	2	52.50	6	47.83	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1987	56	41.20	56	56.79	58	50.93	6	60.83	2	54.50	0	-	0	-	93.4%	6.6%	0.0%
1988	55	41.49	16	54.59	39	50.91	5	65.80	1	56.00	0	-	0	-	90.2%	9.8%	0.0%
1989	110	41.74	35	53.77	59	48.90	1	62.00	0	-	0	-	1	54.00	97.9%	1.0%	1.0%
1990	6	42.67	26	53.23	34	48.35	1	59.00	0	-	0	-	0	-	98.4%	1.6%	0.0%
1991	6	39.33	119	52.43	120	48.18	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1992	8	41.13	16	51.88	35	47.26	6	57.00	0	-	0	-	0	-	89.5%	10.5%	0.0%
1993	24	41.25	39	51.82	16	47.56	1	60.00	1	54.00	0	-	0	-	96.5%	3.5%	0.0%
1994	14	40.40	71	54.49	114	49.46	2	58.50	0	-	0	-	0	-	98.9%	1.1%	0.0%
1995	9	42.56	79	53.32	72	48.51	12	59.00	1	52.00	0	-	1	46.40	91.5%	7.9%	0.6%
1996	3	40.67	32	56.72	53	51.58	23	60.43	6	52.17	0	-	1	48.70	73.9%	25.2%	0.9%
1997	3	40.73	1	55.00	6	46.83	0	-	1	56.00	0	-	0	-	87.5%	12.5%	0.0%
1998	44	41.73	15	55.73	19	49.42	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
1999	2	40.50	47	54.57	58	49.62	0	-	0	-	0	-	0	-	100.0%	0.0%	0.0%
2000	0	-	14	56.57	26	50.65	6	58.67	2	55.00	0	-	0	-	83.3%	16.7%	0.0%
2001	14	40.79	3	56.00	7	50.14	8	59.63	11	53.09	0	-	0	-	34.5%	65.5%	0.0%
Average																	
1941-1995		42.20		54.97		50.42		59.61		53.92		52.00		50.86	95.9%	3.7%	0.3%
1996-2001		40.88		55.77		49.71		59.58		54.07		na		48.70	82.9%	16.8%	0.3%

Appendix 5. Brood year adult escapement in year *n* , fall fry population estimate in year *n+1* , smolt population estimates in years *n+2* and *n+3,* and freshwater survival indicies for Cultus sockeye, 1926-2000.

Brood year	Adult escapement	Fry population Date	Fry population Estimates	Smolt population Age-1	Smolt population Age-2	Smolt population Total	Fry to smolt survival	Smolts per adult spawner
1923	-	-	-	na	13,980	na	-	-
1924	-	-	-	1,384,020	66,500	1,450,520	-	-
1925	5,423	-	-	183,400	1,700	185,100	-	34.13
1926	2,622	-	-	336,200	8,300	344,500	-	131.39
1927	82,426	-	-	2,426,200	66,600	2,492,800	-	30.24
1928	14,661	-	-	38,600	5,200	43,800	-	2.99
1929	5,084	-	-	349,000	200	349,200	-	68.69
1930	7,946	-	-	788,400	0	788,400	-	99.22
1931	37,473	-	-	1,571,000	63,300	1,634,300	-	43.61
1932	2,231	-	-	121,200	14,200	135,400	-	60.69
1933	2,864	-	-	242,500	1,400	243,900	-	85.16
1934	22,940	-	-	501,600	23,000	524,600	-	22.87
1935	15,339	-	-	3,101,000	20,000	3,121,000	-	203.47
1936	8,322	-	-	1,627,000	20,415	1,647,415	-	197.96
1937	1,227	-	-	196,255	138	196,393	-	160.06
1938	9,434	-	-	1,374,800	953	1,375,753	-	145.83
1939	70,789	-	-	3,955,502	20,705	3,976,207	-	56.17
1940	73,536	-	-	1,752,551	12,879	1,765,430	-	24.01
1941	13,950	-	-	702,980	2,730	705,710	-	50.59
1942	36,959	-	-	2,009,186	9,698	2,018,884	-	54.62
1943	11,822	-	-	390,064	na	390,064	-	32.99
1944	14,002	-	-	-	-	-	-	-
1945	5,030	-	-	-	-	-	-	-
1946	33,068	-	-	-	-	-	-	-
1947	8,699	-	-	-	-	-	-	-
1948	12,746	-	-	-	-	-	-	-
1949	9,055	-	-	-	-	-	-	-
1950	29,928	-	-	na	3,928	na	-	-
1951	12,677	-	-	388,873	6,265	395,138	-	31.17
1952	17,833	-	-	620,213	-	620,213	-	34.78
1953	11,543	-	-	na	4,759	na	-	-
1954	22,036	-	-	1,903,296	23,589	1,926,885	-	87.44
1955	25,922	-	-	2,688,063	64,512	2,752,575	-	106.19
1956	13,718	-	-	976,120	184	976,304	-	71.17
1957	20,375	-	-	319,495	1,480	320,975	-	15.75
1958	13,324	-	-	1,427,228	2,215	1,429,443	-	107.28
1959	47,779	-	-	1,327,842	4,438	1,332,280	-	27.88
1960	17,640	-	-	1,025,404	24,859	1,050,263	-	59.54
1961	13,396	-	-	1,200,498	-	1,200,498	-	89.62
1962	26,997	-	-	-	-	-	-	-
1963	20,303	-	-	-	-	-	-	-
1964	11,067	-	-	na	4,682	na	-	-
1965	2,455	-	-	131,106	822	131,928	-	53.74
1966	16,919	-	-	2,101,506	17,446	2,118,952	-	125.24
1967	33,198	-	-	2,441,694	17,582	2,459,276	-	74.08
1968	25,314	-	-	1,005,291	7,652	1,012,943	-	40.02
1969	5,942	-	-	186,787	8,080	194,867	-	32.79
1970	13,941	-	-	799,934	17,335	817,269	-	58.62
1971	9,128	-	-	1,086,016	6,505	1,092,521	-	119.69
1972	10,366	-	-	167,111	na	167,111	-	16.12
1973	641	-	-	na	9,963	na	-	-
1974	8,984	-	-	986,300	12,315	998,615	-	111.15
1975	11,349	-	-	1,219,211	1,697	1,220,908	-	107.58

Continued

Appendix 5. Brood year adult escapement in year *n* , fall fry population estimate in year *n+1* , smolt population estimates i
years *n+2* and *n+3,* and freshwater survival indicies for Cultus sockeye, 1926-2000.

Brood year	Adult escapement	Fry population		Smolt population			Fry to smolt survival	Smolts per adult spawner
		Date	Estimates	Age-1	Age-2	Total		
1976	4,435	-	-	167,982	na	167,982	-	37.88
1977	82	-	-	-	-	-	-	-
1978	5,076	-	-	-	-	-	-	-
1979	32,031	-	-	-	-	-	-	-
1980	1,657	-	-	-	-	-	-	-
1981	256	-	-	-	-	-	-	-
1982	16,725	-	-	-	-	-	-	-
1983	19,944	-	-	-	-	-	-	-
1984	994	-	-	-	-	-	-	-
1985	424	-	-	-	-	-	-	-
1986	3,256	17-Nov	2,379,300	-	-	-	-	-
1987	32,184	-	-	na	459	na	-	-
1988	861	27-Nov	580,361	65,184	372	65,556	11%	76.14
1989	418			52,865	2,716	55,581	-	132.97
1990	1,860	27-Nov	474,623	178,357	na	178,357	38%	95.89
1991	20,157	13-Nov	1,850,963	-	-	-	-	-
1992	1,203	-	-	-	-	-	-	-
1993	1,063	-	-	-	-	-	-	-
1994	4,399	-	-	-	-	-	-	-
1995	10,316	-	-	-	-	-	-	-
1996	2,022	-	-	-	-	-	-	-
1997	88	-	-	-	-	-	-	-
1998	1,959	-	-	na	70	na	-	-
1999	12,392	30-Oct	249,590	62,564	na	62,564	25%	5.05
2000	1,227	15-Oct	46,327	5,681	na	5,681	12%	4.63

Appendix 6a. Average weight, lengths and abundance estimates with 95% confidence limits, of Cultus sockeye fry sampled during fall hydroacoustic and trawl surveys, 1974 to 2000.

			Weight (g)				Length (mm)				Acoustic survey	
Brood year	Sample date	Sample size	Min.	Mean	Max.	95% C.I.	Min.	Mean	Max.	95% C.I.	Abundance estimate	95% C.I.
1974	12-Nov-75	56	0.6	2.8	5.1	0.3	38	64	79	2.4	-	-
1975	8-Nov-76	208	0.6	4.0	8.8	0.2	40	71	94	1.1	-	-
1978	15-Nov-79	205	0.4	2.9	8.3	0.2	33	63	94	1.5	-	-
1979	30-Oct-80	265	0.3	2.3	8.7	0.1	34	60	85	1.2	-	-
1980	26-Nov-81	19	1.5	3.7	6.0	0.5	49	69	82	3.7	-	-
1986	17-Nov-87	31	2.3	4.2	7.0	0.4	59	72	85	2.3	2,379,300	211,585
1988	27-Nov-89	29	1.2	4.3	7.9	0.6	47	70	91	3.6	580,361	46,174
1990	27-Nov-91	51	1.6	4.1	7.6	0.4	54	71	86	2.4	474,623	44,312
1991	13-Nov-92	204	0.4	3.9	6.9	0.2	35	71	87	1.1	1,850,963	
1999	30-Oct-00	49	1.5	4.5	8.8	0.1	52	76	95	3.0	249,590	48,073
2000	15-Oct-00	2	na	na	na	na	75	75	75	na	46,327	17,559
Average	-	-	1.0	3.7	7.5	0.3	47	69	87	2.3	-	-

Appendix 6b. Average weight and lengths with standard deviations by age class, of Cultus sockeye smolts sampled at the Sweltzer Creek enumeration fence, 1956 to 2001. [a]

	Age-1					Age-2				
		Weight (g)		Length (mm)			Weight (g)		Length (mm)	
Year	Sample size	Mean	S.D.	Mean	S.D.	Sample size	Mean	S.D.	Mean	S.D.
1956	343	4.5	1.2	79	6.4	0	-	-	-	-
1957	107	4.4	1.3	77	6.8	36	21.0	8.4	126	16.5
1958	122	2.9	0.2	63	1.5	105	20.6	6.0	124	11.0
1959	100	5.9	1.2	83	5.6	0	-	-	-	-
1960	0	-	-	-	-	35	30.4	8.5	146	13.2
1961	50	4.6	0.5	68	3.3	8	25.1	3.7	136	5.0
1962	56	5.0	0.5	80	5.5	7	19.8	8.8	124	11.9
1963	48	8.6	1.7	94	5.7	9	28.5	5.2	139	8.7
1965	115	5.4	1.1	84	5.1	6	15.5	3.8	122	8.0
1966	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	-	-	-
1968	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-	-	-
Average	-	5.2	1.0	78	5.0	-	23.0	6.3	131	10.6

[a.] Data from subsequent years is being retrieved from archives and will be included in subsequent reports.

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002.

Date	1928	1937	1938	1939	1940[a]	1941[b]	1942	1943	1944	1945[c]	1953
Pre-Mar	-	-	-	-	34	28,086	-	-	-	-	-
1-Mar	-	-	-	-	2	0	-	-	-	-	-
2-Mar	-	-	-	-	13	0	-	-	-	-	-
3-Mar	-	-	-	-	24	24	-	-	-	11	-
4-Mar	-	-	-	-	13	58	-	-	-	79	-
5-Mar	-	-	-	-	62	64	-	-	-	31	-
6-Mar	-	-	-	-	55	23	-	-	-	38	-
7-Mar	-	-	-	-	31	15	-	-	-	42	-
8-Mar	-	-	-	-	440	75	-	-	-	10	-
9-Mar	-	-	-	-	220	9	-	-	-	57	-
10-Mar	-	-	-	-	102	30	-	-	-	168	-
11-Mar	-	-	-	-	57	6	-	-	-	172	-
12-Mar	-	-	-	-	102	17	-	-	-	226	-
13-Mar	-	-	-	-	203	24	-	-	-	112	-
14-Mar	-	-	-	2	127	9	-	-	-	20	-
15-Mar	-	-	-	0	148	19	-	-	-	156	-
16-Mar	-	-	13	0	523	0	-	-	233	175	-
17-Mar	-	-	83	0	603	0	-	-	364	120	-
18-Mar	-	-	16	4	725	0	-	-	314	16	-
19-Mar	12	-	104	7	1,076	0	-	-	214	13	-
20-Mar	0	-	134	0	826	96	-	-	3,785	517	-
21-Mar	4	-	32	0	561	34	-	-	942	1,631	-
22-Mar	12	-	15	2	275	126	-	-	210	599	-
23-Mar	14	-	16	6	161	105	-	-	4,540	704	-
24-Mar	31	-	0	6	447	1,327	-	-	3,423	2,099	-
25-Mar	53	-	55	327	2,376	806	1	8	1,609	568	-
26-Mar	73	-	7	383	3,830	1,735	3	24	3,073	573	-
27-Mar	1	27	6	367	5,635	912	5	79	521	1,267	-
28-Mar	85	0	1,314	104	8,513	3,482	7	107	604	308	-
29-Mar	3	1	145	34	37,390	1,758	10	342	1,442	2,874	-
30-Mar	4	6	103	29	3,005	1,332	46	2,050	1,038	146	-
31-Mar	5	15	255	20	26,305	1,436	11	456	634	11,081	-
1-Apr	2	71	173	76	37,804	2,247	58	97	837	3,405	-
2-Apr	42	51	132	156	43,705	10,017	230	473	6,489	10,072	-
3-Apr	40	55	173	31	100,602	10,200	1,184	8,073	320	2,755	-
4-Apr	47	154	21	605	103,074	11,183	4,073	3,500	307	2,650	-
5-Apr	43	70	146	646	20,902	2,200	5,612	2,325	181	2,379	-
6-Apr	493	126	95	114	29,001	503	1,879	2,740	1,505	4,426	300
7-Apr	475	146	75	282	44,000	1,163	3,435	1,723	713	5,265	0
8-Apr	2,606	116	7	244	17,003	4,543	1,337	4,263	2,455	1,578	500
9-Apr	1,657	169	49	1,408	108,605	3,757	3,575	7,302	15,925	28,665	10,000
10-Apr	1,275	182	7	244	166,505	2,289	7,324	32,483	45,291	3,170	3,000
11-Apr	1,616	370	0	4,554	72,503	8,303	7,978	38,056	40,248	1,691	0
12-Apr	1,315	225	5	1,964	125,503	38,275	7,019	12,711	81,138	19,929	0
13-Apr	7,472	1,217	1	111	95,106	416,652	8,845	10,091	16,448	49,982	10,000
14-Apr	1,912	6,044	1,453	1,426	53,906	104,417	8,311	11,687	63,607	17,838	453
15-Apr	9,214	31,860	3,303	3,912	82,519	134,954	6,591	13,978	32,330	4,136	14,560
16-Apr	5,167	89,000	1,573	5,887	45,503	465,627	13,759	15,438	81,050	12,680	10,726
17-Apr	6,685	53,813	9,622	6,198	4,801	260,321	27,191	9,779	163,054	53,712	38,162
18-Apr	3,538	50,206	60,810	9,209	10,901	193,715	12,386	3,096	130,022	3,585	93,823
19-Apr	8,131	11,414	101,700	14,280	31,104	242,272	67,474	11,236	21,618	2,577	30,575
20-Apr	17,172	32,817	131,260	9,307	11,100	273,170	88,700	62,748	68,049	94,762	53,129
21-Apr	33,856	209,275	87,937	23,658	14,002	162,951	199,889	53,345	10,673	3,712	3,891
22-Apr	8,411	284,231	59,920	13,625	20,501	174,178	177,552	44,744	205,070	28,473	5,274
23-Apr	30,919	437,736	81,930	4,564	11,002	111,461	91,245	27,362	158,965	18,507	11,216
24-Apr	6,899	342,411	167,800	5,473	1,700	148,706	9,410	36,862	169,582	-	44,958
25-Apr	5,960	47,003	112,860	3,500	2,174	149,291	18,768	66,957	104,963	-	450
26-Apr	25,377	487,416	76,020	6,000	4,662	98,678	99,816	35,281	130,530	-	3,200
27-Apr	13,603	115,007	153,470	6,000	3,080	76,524	34,274	28,358	55,648	-	5,000

Continued

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1928	1937	1938	1939	1940[a]	1941[b]	1942	1943	1944	1945[c]	1953
28-Apr	11,478	254,892	196,640	14,500	751	99,779	51,003	10,526	135,820	-	5,541
29-Apr	55,488	115,503	69,290	13,621	684	119,998	218,965	6,186	71,165	-	1,945
30-Apr	13,550	101,500	88,050	8,632	1,217	147,350	57,232	16,013	9,952	-	11,808
1-May	749	114,068	45,260	6,874	329	36,969	36,175	25,615	37,967	-	11,018
2-May	5,644	89,001	26,680	4,422	1,117	74,135	194,759	19,575	28,944	-	5,070
3-May	13,965	38,004	17,639	1,317	1,647	23,344	156,707	22,269	17,335	-	350
4-May	6,907	42,002	25,653	8,214	1,900	57,914	38,964	10,409	24,498	-	496
5-May	17,726	36,503	28,150	5,185	450	21,270	26,275	7,767	12,170	-	2,015
6-May	6,679	31,005	29,610	3,993	1,012	18,244	27,268	2,019	8,897	-	8,252
7-May	2,000	8,000	18,310	1,254	1,472	24,193	17,483	8,647	4,627	-	2,564
8-May	813	3,600	8,520	3,071	750	21,906	4,607	4,976	5,719	-	1,000
9-May	682	3,901	6,030	3,269	535	26,694	4,256	3,688	990	-	1,000
10-May	642	3,701	2,550	2,497	1,095	28,848	3,669	3,456	2,292	-	500
11-May	200	4,000	300	1,499	283	24,791	2,431	1,461	2,662	-	1,000
12-May	117	6,800	1,830	1,021	540	5,726	2,189	1,031	934	-	0
13-May	340	3,600	4,430	1,433	1,149	10,226	1,285	2,539	706	-	1,000
14-May	827	4,300	5,950	1,549	700	6,500	532	809	371	-	25
15-May	214	5,100	2,530	569	244	5,200	1,254	1,773	331	-	-
16-May	54	3,000	2,330	1,089	639	1,714	3,061	1,000	110	-	-
17-May	94	901	700	1,565	858	4,600	4,170	2,016	657	-	-
18-May	100	1,400	1,300	582	300	1,001	2,891	726	484	-	-
19-May	149	1,800	200	385	234	7,143	1,140	707	115	-	-
20-May	123	1,500	700	1,268	260	4,432	1,505	284	470	-	-
21-May	246	1,400	201	673	482	4,126	517	238	868	-	-
22-May	55	600	100	214	256	3,900	1,259	69	1,966	-	-
23-May	269	700	300	338	77	3,043	513	333	597	-	-
24-May	355	700	80	460	142	3,600	275	483	416	-	-
25-May	174	600	201	534	46	4,680	431	214	306	-	-
26-May	282	200	200	23	52	1,650	382	314	645	-	-
27-May	43	800	210	543	316	2,500	1,255	46	2,006	-	-
28-May	55	700	88	140	126	1,654	683	45	784	-	-
29-May	108	1,000	36	263	32	854	117	24	662	-	-
30-May	51	1,600	176	465	12	0	201	0	680	-	-
31-May	172	1,700	625	256	18	1,029	408	0	805	-	-
1-Jun	5	700	242	108	11	665	240	0	27	-	-
2-Jun	0	300	128	30	6	800	482	41	171	-	-
3-Jun	16	500	222	22	8	1,478	121	-	564	-	-
4-Jun	46	1,000	63	4	12	750	40	-	1,177	-	-
5-Jun	17	200	74	3	5	675	0	-	285	-	-
6-Jun	10	300	430	2	9	412	0	-	327	-	-
7-Jun	0	200	211	3	2	240	0	-	493	-	-
8-Jun	21	0	246	5	5	202	0	-	376	-	-
9-Jun	0	100	234	0	2	350	181	-	1,130	-	-
10-Jun	15	27	204	0	1	820	0	-	356	-	-
11-Jun	4	44	58	4	-	518	45	-	53	-	-
12-Jun	-	85	26	0	-	210	77	-	26	-	-
13-Jun	-	29	9	0	-	130	0	-	0	-	-
14-Jun	-	2	8	0	-	54	0	-	8	-	-
15-Jun	-	8	9	0	-	41	0	-	6	-	-
16-Jun	-	1	4	2	-	176	160	-	2	-	-
17-Jun	-	0	4	0	-	109	0	-	-	-	-
18-Jun	-	1	3	0	-	27	32	-	-	-	-
19-Jun	-	-	2	0	-	12	0	-	-	-	-
20-Jun	-	-	11	1	-	4	0	-	-	-	-
21-Jun	-	-	1	0	-	14	18	-	-	-	-
22-Jun	-	-	0	1	-	209	-	-	-	-	-

Continued

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1928	1937	1938	1939	1940[a]	1941[b]	1942	1943	1944	1945[c]	1953
23-Jun	-	-	1	0	-	100	-	-	-	-	-
24-Jun	-	-	0	0	-	84	-	-	-	-	-
25-Jun	-	-	0	2	-	52	-	-	-	-	-
26-Jun	-	-	1	-	-	18	-	-	-	-	-
27-Jun	-	-	-	-	-	40	-	-	-	-	-
28-Jun	-	-	-	-	-	25	-	-	-	-	-
29-Jun	-	-	-	-	-	19	-	-	-	-	-
30-Jun	-	-	-	-	-	3	-	-	-	-	-
Other [d]	-	6,422	7,083	133	1,798	8,979	4,708	12,786	3,263	659	-
Total	334,709	3,095,234	1,646,983	216,803	1,376,736	3,965,434	1,777,964	715,859	2,015,179	400,421	392,801

[a.] Pre-March counts include all counts conducted in February.

[b.] Fence installed January 3; pre-March counts include all counts conducted in January and February.

[c.] Fence removed early.

[d.] Others refers to smolt mortalities recorded at fence site.

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1954	1956	1957	1958	1959	1960	1961	1962	1963	1967	1968
Pre-Mar	-	-	-	-	-	-	-	-	-	-	-
1-Mar	-	-	-	-	-	-	-	-	-	-	-
2-Mar	-	-	-	-	-	-	-	-	-	-	-
3-Mar	-	-	-	-	-	-	-	-	-	-	-
4-Mar	-	-	-	-	-	-	-	-	-	-	-
5-Mar	-	-	-	-	-	-	-	-	-	-	-
6-Mar	-	-	-	-	-	-	-	-	-	-	-
7-Mar	-	-	-	-	-	-	-	-	-	-	-
8-Mar	-	-	-	-	-	-	-	-	-	-	-
9-Mar	-	-	-	-	-	-	-	-	-	-	-
10-Mar	-	-	-	-	-	-	-	-	-	-	-
11-Mar	-	-	-	-	-	-	-	-	-	-	-
12-Mar	-	-	-	-	-	-	-	-	-	-	-
13-Mar	-	-	-	-	-	-	-	-	-	-	-
14-Mar	-	-	-	-	-	-	-	-	-	-	-
15-Mar	-	-	-	-	-	-	-	-	-	-	-
16-Mar	-	-	-	-	-	-	-	-	-	-	-
17-Mar	-	-	-	-	-	-	-	-	-	-	-
18-Mar	-	-	-	-	-	-	-	-	-	-	-
19-Mar	-	-	-	-	-	-	-	-	-	-	-
20-Mar	-	-	-	-	-	-	-	-	-	-	-
21-Mar	-	-	-	-	-	-	-	-	-	-	-
22-Mar	-	-	-	-	-	-	-	-	-	-	-
23-Mar	-	-	-	-	-	-	-	-	-	-	-
24-Mar	-	-	-	9	-	-	-	-	-	-	-
25-Mar	-	-	-	4,501	-	21	-	-	-	-	-
26-Mar	-	-	-	12,792	-	40	-	-	-	-	-
27-Mar	-	-	-	18,093	2	30	-	-	-	-	-
28-Mar	-	-	-	13,820	1	61	-	-	38	-	-
29-Mar	-	-	-	8,601	6	68	-	-	140	-	167
30-Mar	-	-	-	9,374	9	58	-	-	57	-	563
31-Mar	-	-	-	11,284	33	80	-	-	114	-	329
1-Apr	-	-	-	0	-	106	75	-	592	-	1,469
2-Apr	-	-	-	8,228	-	111	66	6	574	-	531
3-Apr	-	-	-	30,248	-	161	0	18	662	345	339
4-Apr	-	-	-	60,540	-	367	1,088	31	285	818	387
5-Apr	-	56	57	99,071	-	825	2,585	66	1,139	1,322	2,833
6-Apr	-	36	841	80,032	-	526	14,469	96	680	1,155	10,480
7-Apr	232	4	447	70,525	-	2,844	547	31	607	1,476	10,041
8-Apr	48	0	104	6,213	3	2,707	3,749	139	1,855	445	14,789
9-Apr	83	4	382	9,545	416	7,583	17,823	112	6,378	1,141	12,945
10-Apr	126	7	11,699	49,988	547	16,616	1,236	248	9,649	6,539	48,252
11-Apr	300	14	1,464	64,652	860	5,656	12,431	256	15,652	3,850	12,219
12-Apr	169	29	419	41,477	964	1,029	53,645	1,784	11,972	1,333	2,485
13-Apr	29	81	18,081	13,058	1,277	521	15,908	4,644	14,710	1,078	13,926
14-Apr	1,361	21	1,381	21,776	2,409	784	7,815	713	5,287	4,361	61,529
15-Apr	907	2,204	1,558	4,116	3,459	1,532	5,870	411	21,180	7,152	117,407
16-Apr	150	1,059	22,253	91,047	2,090	3,149	6,210	675	17,009	2,645	60,329
17-Apr	308	56,730	23,501	3,711	1,266	24,597	29,710	3,295	14,204	11,357	31,869
18-Apr	4,572	30,254	143,699	50,000	5,947	5,277	24,677	5,173	37,103	7,564	249,901
19-Apr	121	55,665	167,405	30,000	7,388	1,714	80,912	2,629	21,889	5,749	259,512
20-Apr	5,527	35,194	170,054	11,132	4,914	7,033	32,201	2,634	88,208	6,506	106,829
21-Apr	8,087	9,948	97,760	28,578	3,234	124,367	44,500	46,237	67,198	2,579	40,993
22-Apr	5,002	115,320	124,573	13,190	11,870	34,868	116,580	75,824	55,045	11,114	83,569
23-Apr	24,207	174,998	116,186	21,487	5,000	13,569	69,317	87,830	61,355	8,338	32,319
24-Apr	9,176	93,424	395,083	29,454	15,903	40,350	17,196	74,615	60,080	4,960	68,518
25-Apr	9,680	80,076	58,794	15,260	9,576	108,293	27,766	68,099	61,760	2,748	239,558
26-Apr	21,453	79,876	167,272	28,927	28,687	140,328	22,487	53,024	29,966	9,045	56,529
27-Apr	26,712	29,326	54,442	14,390	16,306	144,282	28,064	25,020	40,844	2,390	166,960

Continued

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1954	1956	1957	1958	1959	1960	1961	1962	1963	1967	1968
28-Apr	11,770	101,869	250,799	22,806	9,625	117,999	32,664	52,645	41,373	1,104	88,250
29-Apr	23,798	155,181	119,333	7,246	1,509	205,422	17,378	61,939	31,701	781	43,932
30-Apr	13,707	234,414	21,503	6,863	8,768	60,878	14,688	14,047	35,839	1,146	26,197
1-May	32,360	55,026	43,500	5,171	11,965	27,147	16,802	24,078	40,400	3,851	28,392
2-May	14,174	43,129	74,585	3,224	19,555	3,650	29,981	63,660	23,570	758	37,943
3-May	83,897	14,451	88,128	4,039	21,582	671	22,945	27,429	28,676	6,849	13,876
4-May	34,930	56,116	155,608	3,850	13,822	5,329	35,234	140,579	27,215	3,928	9,496
5-May	48,587	24,157	71,588	3,568	7,590	98,355	41,174	17,516	86,585	2,721	13,145
6-May	22,004	73,121	39,869	1,615	25,237	1,170	131,626	42,179	39,767	3,310	41,966
7-May	6,319	82,832	52,520	915	22,103	61,057	126,942	32,814	56,496	692	31,043
8-May	2,621	82,078	51,717	855	12,498	63,762	23,049	11,429	36,742	0	17,461
9-May	7,168	28,559	22,536	803	7,618	42,221	31,660	6,411	30,031	-	17,821
10-May	4,784	5,258	26,043	325	6,914	4,492	17,834	13,475	23,970	-	1,781
11-May	8,377	14,631	11,388	302	3,890	351	7,003	6,624	25,311	-	0
12-May	25,079	25,405	18,446	1,607	2,202	3,019	17,088	25,652	11,777	-	1,500
13-May	17,338	39,572	25,134	1,050	1,042	12,516	5,739	13,526	4,920	-	10,186
14-May	16,326	14,992	20,878	740	569	6,909	23,288	8,782	12,192	-	38
15-May	13,744	16,742	6,699	534	1,704	5,632	12,607	6,421	6,485	-	-
16-May	19,430	22,790	7,127	-	1,488	984	10,343	7,026	11,637	-	-
17-May	20,656	11,323	11,133	-	1,946	5,052	18,578	-	2,612	-	-
18-May	28,250	14,394	2,409	-	3,166	312	5,759	-	680	-	-
19-May	9,329	3,989	3,523	-	929	24	5,163	-	900	-	-
20-May	18,193	1,076	5,506	-	994	224	6,615	-	246	-	-
21-May	7,359	2,828	2,225	-	1,895	682	2,344	-	-	-	-
22-May	4,133	1,968	2,000	-	2,370	2,346	6,395	-	-	-	-
23-May	4,850	5,815	-	-	613	2,430	2,236	-	-	-	-
24-May	126	5,063	-	-	1,389	121	4,195	-	-	-	-
25-May	4,607	2,296	-	-	113	6,400	5,150	-	-	-	-
26-May	4,312	2,126	-	-	898	0	800	-	-	-	-
27-May	-	1,778	-	-	956	0	1,000	-	-	-	-
28-May	-	750	-	-	656	-	1,000	-	-	-	-
29-May	-	-	-	-	692	-	1,200	-	-	-	-
30-May	-	-	-	-	433	-	2,300	-	-	-	-
31-May	-	-	-	-	62	-	1,150	-	-	-	-
1-Jun	-	-	-	-	41	-	9,200	-	-	-	-
2-Jun	-	-	-	-	56	-	2,000	-	-	-	-
3-Jun	-	-	-	-	422	-	-	-	-	-	-
4-Jun	-	-	-	-	100	-	-	-	-	-	-
5-Jun	-	-	-	-	100	-	-	-	-	-	-
6-Jun	-	-	-	-	-	-	-	-	-	-	-
7-Jun	-	-	-	-	-	-	-	-	-	-	-
8-Jun	-	-	-	-	-	-	-	-	-	-	-
9-Jun	-	-	-	-	-	-	-	-	-	-	-
10-Jun	-	-	-	-	-	-	-	-	-	-	-
11-Jun	-	-	-	-	-	-	-	-	-	-	-
12-Jun	-	-	-	-	-	-	-	-	-	-	-
13-Jun	-	-	-	-	-	-	-	-	-	-	-
14-Jun	-	-	-	-	-	-	-	-	-	-	-
15-Jun	-	-	-	-	-	-	-	-	-	-	-
16-Jun	-	-	-	-	-	-	-	-	-	-	-
17-Jun	-	-	-	-	-	-	-	-	-	-	-
18-Jun	-	-	-	-	-	-	-	-	-	-	-
19-Jun	-	-	-	-	-	-	-	-	-	-	-
20-Jun	-	-	-	-	-	-	-	-	-	-	-
21-Jun	-	-	-	-	-	-	-	-	-	-	-
22-Jun	-	-	-	-	-	-	-	-	-	-	-

Continued

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1954	1956	1957	1958	1959	1960	1961	1962	1963	1967	1968
23-Jun	-	-	-	-	-	-	-	-	-	-	-
24-Jun	-	-	-	-	-	-	-	-	-	-	-
25-Jun	-	-	-	-	-	-	-	-	-	-	-
26-Jun	-	-	-	-	-	-	-	-	-	-	-
27-Jun	-	-	-	-	-	-	-	-	-	-	-
28-Jun	-	-	-	-	-	-	-	-	-	-	-
29-Jun	-	-	-	-	-	-	-	-	-	-	-
30-Jun	-	-	-	-	-	-	-	-	-	-	-
Other [d]	-	-	-	-	-	3,300	-	-	-	4,638	11,724
Total	626,478	1,908,055	2,711,652	1,040,632	319,679	1,432,008	1,330,057	1,029,842	1,225,357	135,788	2,102,328

[d.] Others refers to smolt mortalities recorded at fence site.

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1969	1970	1971	1972	1973	1974	1976	1977	1978	1984
Pre-Mar	-	-	-	-	-	-	-	-	-	-
1-Mar	-	-	-	-	-	-	-	-	-	-
2-Mar	-	-	-	-	-	-	-	-	-	-
3-Mar	-	-	-	-	-	-	-	-	-	-
4-Mar	-	-	-	-	-	-	-	-	-	-
5-Mar	-	-	-	-	-	-	-	-	-	-
6-Mar	-	-	-	-	-	-	-	-	-	-
7-Mar	-	-	-	-	-	-	-	-	-	-
8-Mar	-	-	-	-	-	-	-	-	-	-
9-Mar	-	-	-	-	-	-	-	-	-	-
10-Mar	-	-	-	-	-	-	-	-	-	-
11-Mar	-	-	-	-	-	-	-	-	-	-
12-Mar	-	-	-	-	-	-	-	-	-	-
13-Mar	-	-	-	-	-	-	-	-	-	-
14-Mar	-	-	-	-	-	-	-	-	-	-
15-Mar	-	-	-	-	-	-	-	-	-	-
16-Mar	-	-	-	-	-	-	-	-	-	-
17-Mar	-	-	-	-	-	-	-	-	-	-
18-Mar	-	-	-	-	-	-	-	-	-	-
19-Mar	-	-	-	-	-	-	-	-	-	-
20-Mar	-	-	-	-	-	-	-	-	-	-
21-Mar	-	-	-	-	-	-	-	-	-	-
22-Mar	-	-	-	-	-	-	-	-	4	-
23-Mar	-	-	-	-	-	-	200	-	7	-
24-Mar	-	-	-	-	-	-	200	-	0	-
25-Mar	-	-	-	-	-	-	300	-	0	-
26-Mar	-	-	-	-	-	-	400	-	0	-
27-Mar	-	-	-	-	-	-	325	-	0	-
28-Mar	-	-	-	-	-	-	200	-	0	-
29-Mar	-	-	-	-	-	-	168	-	18	-
30-Mar	-	-	-	-	-	-	125	-	18	-
31-Mar	-	-	-	-	-	-	326	-	102	-
1-Apr	-	-	0	-	-	-	59	-	78	-
2-Apr	-	2,821	45	-	-	-	182	-	0	-
3-Apr	-	136	203	-	-	-	70	-	65	-
4-Apr	-	2,505	271	-	-	-	1,480	-	419	-
5-Apr	-	3,250	248	-	-	-	1,506	-	513	-
6-Apr	-	4,130	135	-	-	-	2,719	-	999	-
7-Apr	-	7,200	406	2	339	500	356	1,996	1,468	-
8-Apr	-	12,301	542	200	361	1,000	2,996	10,119	591	-
9-Apr	-	8,125	497	3,000	90	2,000	6,243	3,272	766	-
10-Apr	-	9,502	745	4,253	271	4,000	333	3,575	1,220	-
11-Apr	-	29,160	497	1,804	68	6,000	995	7,520	674	-
12-Apr	-	33,494	474	3,167	429	8,547	43,616	6,778	715	-
13-Apr	-	28,913	925	13,710	204	7,536	17,953	6,708	906	-
14-Apr	-	18,823	1,241	19,608	677	2,759	92,151	11,164	1,741	-
15-Apr	-	48,006	2,122	20,566	587	1,243	73,896	10,166	685	-
16-Apr	-	34,171	2,392	8,218	68	628	14,568	71,556	1,291	-
17-Apr	78	24,376	3,859	29,721	2,415	2,396	14,993	86,782	1,259	-
18-Apr	16	6,139	4,875	50,778	5,777	3,894	75,069	73,715	3,028	-
19-Apr	12	10,879	3,927	22,338	11,264	1,841	97,717	191,413	1,510	-
20-Apr	45	64,640	4,333	2,752	18,420	5,220	79,752	72,276	9,842	-
21-Apr	266	29,251	3,408	24,178	20,293	3,742	100,588	18,963	9,730	-
22-Apr	278	10,788	5,304	51,294	24,718	5,825	9,135	61,391	4,883	-
23-Apr	682	31,441	2,708	8,743	55,982	21,647	2,458	115,609	35,346	-
24-Apr	547	12,616	5,191	7,686	55,950	10,128	29,064	78,543	15,520	-
25-Apr	923	36,721	9,276	29,398	112,145	2,494	177,861	48,207	7,067	-
26-Apr	553	41,778	11,849	111,914	68,658	2,764	59,004	87,989	2,890	-
27-Apr	469	51,075	5,710	32,953	76,016	2,065	22,055	57,238	1,074	-

Continued

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1969	1970	1971	1972	1973	1974	1976	1977	1978	1984
28-Apr	5,161	80,485	2,641	94,478	122,670	3,276	18,259	35,140	8,414	-
29-Apr	12,910	27,220	6,568	32,086	56,493	6,271	33,007	42,753	7,597	-
30-Apr	11,742	24,556	9,728	38,834	45,479	5,788	6,524	20,471	10,379	-
1-May	16,082	34,622	2,731	15,229	51,121	1,719	3,038	19,821	9,252	-
2-May	49,340	34,465	16,521	22,457	31,215	11,960	356	6,406	14,345	-
3-May	168,853	25,188	31,169	31,281	47,171	25,374	2,719	15,574	5,154	-
4-May	179,875	30,311	3,995	24,511	73,601	11,070	1,506	20,681	2,119	-
5-May	251,818	27,535	8,351	16,995	84,231	4,100	1,480	15,110	1,393	-
6-May	275,905	26,271	4,943	4,107	46,087	1,698	70	13,114	2,527	-
7-May	191,154	22,639	15,438	6,500	7,537	899	182	4,851	1,454	-
8-May	83,684	7,132	8,825	8,104	10,720	2,338	59	3,876	1,242	-
9-May	61,560	9,367	2,821	3,928	16,251	2,329	-	3,783	486	-
10-May	175,440	11,488	2,799	7,162	18,576	565	-	1,578	592	-
11-May	138,180	6,003	2,460	8,623	21,938	-	-	2,019	296	-
12-May	105,600	8,870	993	8,937	7,336	-	-	998	-	-
13-May	119,300	12,008	1,241	22,569	7,020	-	-	371	-	-
14-May	117,442	5,349	790	11,752	1,173	-	-	-	-	-
15-May	120,970	12,571	384	2,642	-	-	-	-	-	-
16-May	74,244	11,444	858	633	-	-	-	-	-	-
17-May	20,624	7,177	-	813	-	-	-	-	-	-
18-May	39,710	-	-	90	-	-	-	-	-	-
19-May	33,800	-	-	-	-	-	-	-	-	-
20-May	64,700	-	-	-	-	-	-	-	-	-
21-May	28,116	-	-	-	-	-	-	-	-	-
22-May	28,695	-	-	-	-	-	-	-	-	-
23-May	22,651	-	-	-	-	-	-	-	-	-
24-May	7,925	-	-	-	-	-	-	-	-	-
25-May	7,120	-	-	-	-	-	-	-	-	-
26-May	10,970	-	-	-	-	-	-	-	-	-
27-May	0	-	-	-	-	-	-	-	-	-
28-May	25,000	-	-	-	-	-	-	-	-	-
29-May	-	-	-	-	-	-	-	-	-	-
30-May	-	-	-	-	-	-	-	-	-	-
31-May	-	-	-	-	-	-	-	-	-	-
1-Jun	-	-	-	-	-	-	-	-	-	-
2-Jun	-	-	-	-	-	-	-	-	-	-
3-Jun	-	-	-	-	-	-	-	-	-	-
4-Jun	-	-	-	-	-	-	-	-	-	-
5-Jun	-	-	-	-	-	-	-	-	-	-
6-Jun	-	-	-	-	-	-	-	-	-	-
7-Jun	-	-	-	-	-	-	-	-	-	-
8-Jun	-	-	-	-	-	-	-	-	-	-
9-Jun	-	-	-	-	-	-	-	-	-	-
10-Jun	-	-	-	-	-	-	-	-	-	-
11-Jun	-	-	-	-	-	-	-	-	-	-
12-Jun	-	-	-	-	-	-	-	-	-	-
13-Jun	-	-	-	-	-	-	-	-	-	-
14-Jun	-	-	-	-	-	-	-	-	-	-
15-Jun	-	-	-	-	-	-	-	-	-	-
16-Jun	-	-	-	-	-	-	-	-	-	-
17-Jun	-	-	-	-	-	-	-	-	-	-
18-Jun	-	-	-	-	-	-	-	-	-	-
19-Jun	-	-	-	-	-	-	-	-	-	-
20-Jun	-	-	-	-	-	-	-	-	-	-
21-Jun	-	-	-	-	-	-	-	-	-	-
22-Jun	-	-	-	-	-	-	-	-	-	-

Continued

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1969	1970	1971	1972	1973	1974	1976	1977	1978	1984
23-Jun	-	-	-	-	-	-	-	-	-	-
24-Jun	-	-	-	-	-	-	-	-	-	-
25-Jun	-	-	-	-	-	-	-	-	-	-
26-Jun	-	-	-	-	-	-	-	-	-	-
27-Jun	-	-	-	-	-	-	-	-	-	-
28-Jun	-	-	-	-	-	-	-	-	-	-
29-Jun	-	-	-	-	-	-	-	-	-	-
30-Jun	-	-	-	-	-	-	-	-	-	-
Other [d]	6,700	35,931	-	-	-	2,172	-	-	-	-
Total	2,459,140	1,022,873	194,439	808,014	1,103,351	175,788	996,263	1,231,526	169,679	0

[d.] Others refers to smolt mortalities recorded at fence site.

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1990	1991	1992	2001	2002
Pre-Mar	-	-	-	-	-
1-Mar	-	-	-	-	-
2-Mar	-	-	-	-	-
3-Mar	-	-	-	-	-
4-Mar	-	-	-	-	-
5-Mar	-	-	-	-	-
6-Mar	-	-	-	-	-
7-Mar	-	-	-	-	-
8-Mar	-	-	-	-	-
9-Mar	-	-	-	-	-
10-Mar	-	-	-	-	-
11-Mar	-	-	-	-	-
12-Mar	-	-	-	-	-
13-Mar	-	-	-	-	-
14-Mar	-	-	-	-	-
15-Mar	-	-	-	-	-
16-Mar	-	-	-	-	-
17-Mar	-	-	-	-	-
18-Mar	-	-	-	-	-
19-Mar	-	-	-	-	-
20-Mar	-	-	-	-	-
21-Mar	-	-	-	-	-
22-Mar	-	-	-	-	-
23-Mar	-	-	-	-	-
24-Mar	-	-	-	-	-
25-Mar	-	-	-	-	-
26-Mar	-	-	-	-	-
27-Mar	-	-	-	-	-
28-Mar	-	-	-	-	-
29-Mar	-	-	-	-	-
30-Mar	-	-	-	-	-
31-Mar	-	-	-	0	-
1-Apr	-	-	-	0	-
2-Apr	-	-	-	0	-
3-Apr	-	-	-	0	-
4-Apr	-	-	-	1	-
5-Apr	-	-	-	3	0
6-Apr	-	-	-	0	0
7-Apr	-	-	-	20	0
8-Apr	-	-	14	28	0
9-Apr	-	-	110	10	0
10-Apr	-	-	114	15	0
11-Apr	-	-	162	9	0
12-Apr	25	1	117	8	0
13-Apr	125	1	214	11	0
14-Apr	75	0	690	78	0
15-Apr	180	1	2,286	79	0
16-Apr	275	0	2,136	33	1
17-Apr	210	2	6,009	116	0
18-Apr	350	3	7,556	402	0
19-Apr	300	2	4,513	511	8
20-Apr	175	9	7,736	340	4
21-Apr	150	27	997	763	3
22-Apr	280	15	5,679	687	0
23-Apr	250	63	3,760	4,749	4
24-Apr	1,150	50	695	496	8
25-Apr	625	17	822	1,905	0
26-Apr	1,850	133	501	771	3

Continued

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1990	1991	1992	2001	2002
27-Apr	1,670	293	5,464	220	6
28-Apr	1,200	410	1,591	1,176	31
29-Apr	680	679	2,531	1,280	69
30-Apr	2,425	1,410	59,327	4,468	48
1-May	600	1,288	13,236	4,530	80
2-May	1,250	2,162	11,250	970	384
3-May	1,680	2,115	10,210	225	63
4-May	1,120	1,325	4,998	297	35
5-May	980	310	3,770	1,222	11
6-May	3,200	344	2,147	783	19
7-May	4,725	237	454	2,365	4
8-May	2,425	336	1,225	1,714	46
9-May	610	1,126	3,710	2,896	54
10-May	1,625	1,395	1,326	1,659	15
11-May	2,000	1,125	4,920	3,269	19
12-May	1,675	1,142	2,694	1,173	21
13-May	475	3,593	1,677	1,675	68
14-May	1,800	5,156	3,130	3,412	893
15-May	1,300	5,964	531	3,333	886
16-May	820	1,065	423	7,033	910
17-May	730	1,033	779	3,579	921
18-May	1,900	46	457	976	557
19-May	2,400	1,225	98	604	139
20-May	4,450	1,337	225	182	90
21-May	2,500	1,004	472	94	28
22-May	2,700	3,237	152	374	14
23-May	2,500	2,810	18	1,443	91
24-May	1,200	2,103	23	174	40
25-May	400	836	1	221	7
26-May	725	239	14	87	28
27-May	250	426	36	148	30
28-May	150	641	7	17	9
29-May	200	1,030	8	-	2
30-May	175	218	30	-	10
31-May	175	310	4	-	6
1-Jun	-	295	2	-	4
2-Jun	-	740	0	-	10
3-Jun	-	802	20	-	2
4-Jun	-	502	1	-	1
5-Jun	-	86	1	-	1
6-Jun	-	183	-	-	0
7-Jun	-	29	-	-	-
8-Jun	-	47	-	-	-
9-Jun	-	217	-	-	-
10-Jun	-	133	-	-	-
11-Jun	-	28	-	-	-
12-Jun	-	149	-	-	-
13-Jun	-	25	-	-	-
14-Jun	-	10	-	-	-
15-Jun	-	-	-	-	-
16-Jun	-	-	-	-	-
17-Jun	-	-	-	-	-
18-Jun	-	-	-	-	-
19-Jun	-	-	-	-	-
20-Jun	-	-	-	-	-
21-Jun	-	-	-	-	-
22-Jun	-	-	-	-	-
23-Jun	-	-	-	-	-

Continued

Appendix 7. Daily total smolt migration through the Sweltzer Creek enumeration fence, 1928 to 2002 continued.

Date	1990	1991	1992	2001	2002[e]
24-Jun	-	-	-	-	-
25-Jun	-	-	-	-	-
26-Jun	-	-	-	-	-
27-Jun	-	-	-	-	-
28-Jun	-	-	-	-	-
29-Jun	-	-	-	-	-
30-Jun	-	-	-	-	-
Other [d]	6,908	1,697	5,205	216	38
Total	65,643	53,237	186,278	62,850	5,721

d. Others refers to smolt mortalities recorded at fence site.

e. Includes 1,500 (+ last release on May 19) released from 2000 brood. Does not include 2,017 smolts retained for captive broodstock.

Appendix 8. Annual Cultus sockeye smolt production by age class and annual smolt migration timing at the Sweltzer Creek enumeration fence, 1926 to 2002. ("-" indicates no project that year; "na" indicates data are unavailable)

	Estimated smolts at age			Sweltzer Creek fence dates			Fork length(mm) sample				
Year	Age-1	Age-2	Total	Fence installed[a]	50% adult migration	Fence removed[b]	N	mean	max	min	CI 95%
1926	1,398,000	na	1,398,000	-	-	-	-	-	-	-	-
1927	183,400	66,500	249,900	-	-	-	-	92 [c]	-	-	-
1928	336,200	1,700	337,900	19-Mar	26-Apr	11-Jun	-	81 [c]	-	-	-
1929	2,426,200	8,300	2,434,500	-	-	-	-	-	-	-	-
1930	38,600	66,600	105,200	-	-	-	-	-	-	-	-
1931	349,000	5,200	354,200	-	-	-	-	-	-	-	-
1932	788,400	200	788,600	-	-	-	-	-	-	-	-
1933	1,571,000	0	1,571,000	-	-	-	-	-	-	-	-
1934	121,200	63,300	184,500	-	-	-	-	-	-	-	-
1935	242,500	14,200	256,700	-	-	-	-	-	-	-	-
1936	501,600	1,400	503,000	-	-	-	-	-	-	-	-
1937	3,101,000	23,000	3,124,000	27-Mar	25-Apr	18-Jun	-	-	-	-	-
1938	1,627,000	20,000	1,647,000	16-Mar	25-Apr	26-Jun	-	-	-	-	-
1939	196,255	20,415	216,803	14-Mar	24-Apr	25-Jun	-	-	-	-	-
1940	1,374,800	138	1,376,736	28-Feb	10-Apr	10-Jun	-	-	-	-	-
1941	3,955,502	953	3,965,434	3-Jan	20-Apr	30-Jun	-	-	-	-	-
1942	1,752,551	20,705	1,777,964	25-Mar	27-Apr	21-Jun	-	-	-	-	-
1943	702,980	12,879	715,859	25-Mar	22-Apr	2-Jun	-	-	-	-	-
1944	2,009,186	2,730	2,015,179	16-Mar	22-Apr	16-Jun	-	-	-	-	-
1945	390,064	9,698	400,421	3-Mar	17-Apr	23-Apr	-	-	-	-	-
1946	-	-	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-	-	-
1948	-	-	-	-	-	-	-	-	-	-	-
1949	-	-	-	-	-	-	-	-	-	-	-
1950	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-	-	-	-
1953	392,801	<1%	392,801	6-Apr	19-Apr	14-May	-	-	-	-	-
1954	626,478	<1%	626,478	7-Apr	4-May	26-May	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-	-
1956	1,903,296	4,759	1,908,055	5-Apr	29-Apr	28-May	-	-	-	-	-
1957	2,688,063	23,589	2,711,652	5-Apr	26-Apr	22-May	-	-	-	-	-
1958	976,120	64,512	1,040,632	24-Mar	11-Apr	15-May	-	-	-	-	-
1959	319,495	184	319,679	27-Mar	2-May	5-Jun	-	-	-	-	-
1960	1,427,228	1,480	1,432,008	25-Mar	28-Apr	27-May	-	-	-	-	-
1961	1,327,842	2,215	1,330,057	1-Apr	28-Apr	2-Jun	-	-	-	-	-
1962	1,025,404	4,438	1,029,842	2-Apr	29-Apr	16-May	-	-	-	-	-
1963	1,200,498	24,859	1,225,357	28-Mar	27-Apr	20-May	-	-	-	-	-
1964	-	-	-	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-	-	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-	-
1967	131,106	4,682	135,788	3-Apr	21-Apr	8-May	-	-	-	-	-
1968	2,101,506	822	2,102,328	29-Mar	21-Apr	14-May	-	-	-	-	-
1969	2,441,694	17,446	2,459,140	17-Apr	8-May	28-May	-	-	-	-	-
1970	1,005,291	17,582	1,022,873	2-Apr	26-Apr	17-May	-	-	-	-	-
1971	186,787	7,652	194,439	2-Apr	2-May	16-May	-	-	-	-	-
1972	na	na	808,014	7-Apr	26-Apr	18-May	-	-	-	-	-
1973	1,086,016	17,335	1,103,351	7-Apr	28-Apr	14-May	-	-	-	-	-
1974	167,111	6,505	175,788	7-Apr	24-Apr	10-May	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-
1976	na	na	996,263	23-Mar	20-Apr	8-May	-	-	-	-	-
1977	na	na	1,231,526	7-Apr	22-Apr	13-May	-	-	-	-	-

Continued

Appendix 8. Annual Cultus sockeye smolt production by age class and annual smolt migration timing at the Sweltzer Creek enumeration fence, 1926 to 2002. ("-" indicates no project that year; "na" indicates data are unavailable)

	Estimated smolts at age			Sweltzer Creek fence dates			Fork length(mm) sample				
Year	Age-1	Age-2	Total	Fence installed[a]	50% adult migration	Fence removed[b]	N	mean	max	min	CI 95%
1978	na	na	169,679	22-Mar	24-Apr	11-May	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-	-	-	-
1987	-	-	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-	-	-	-
1990	65,184	459	65,643	12-Apr	10-May	31-May	196	85 [d]	102	70	1.0
1991	52,865	372	53,237	12-Apr	15-May	14-Jun	1,421	99 [d]	129	51	0.5
1992	178,357	2,716	181,073	8-Apr	30-Apr	5-Jun	402	106 [d]	152	78	1.1
1993	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-
1997	-	-	-	-	-	-	-	-	-	-	-
1998	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-
2000	-	-	-	-	-	-	-	-	-	-	-
2001	62,564	70	62,634	4-Apr	9-May	28-May	894	109 [d]	126	88	0.4
2002[e]	na	na	5,681	5-Apr	15-May	5-Jun	na	na	na	na	na
Averages											
1998 Cycle	1,180,064	1,772	1,131,741	25-Mar	23-Apr	29-May	na	na	na	na	na
1999 Cycle	1,767,522	10,261	1,732,210	23-Mar	26-Apr	25-May	na	na	na	na	na
2000 Cycle	800,267	29,345	711,483	30-Mar	28-Apr	27-May	na	na	na	na	na
2001 Cycle	356,489	15,694	372,196	29-Mar	29-Apr	30-May	na	na	na	na	na
All years	1,034,906	14,200	1,004,498	27-Mar	26-Apr	27-May	na	na	na	na	na

a. Fence installation date is based on historical timing information and the first observation of migrating sockeye smolts.

b. Fence removal date is based on historical timing information and the last observations of migrating sockeye smolts.

c. Length data sample for one-year-old migrants only.

d. Length data sample includes one and two-year-old migrants.

e. Aging data not available as of July 15.

Appendix 9. Annual catch of Cultus sockeye adults by fishery, 1974-2001.

	Panel Waters		Non-Panel Waters			
Year	United States	Canada	United States	Canada	Fraser River First Nations and Sport	Total Catch
1974	12,758	12,508	0	9,782	765	35,813
1975	21,735	9,873	0	4,470	657	36,735
1976	5,358	13,318	0	7,609	125	26,410
1977	77	144	0	164	16	401
1978	1,508	12,737	0	7,797	322	22,364
1979	33,576	15,212	0	25,174	3,658	77,620
1980	1,000	1,140	0	2,473	106	4,719
1981	139	131	0	931	0	1,201
1982	13,158	17,695	0	21,125	408	52,386
1983	8,817	4,900	1,951	71,897	387	87,952
1984	1,068	1,808	0	2,914	92	5,882
1985	232	135	9	165	0	541
1986	1,749	3,794	19	3,472	129	9,163
1987	25,841	13,028	0	29,544	124	68,537
1988	1,502	6,501	0	888	33	8,924
1989	208	448	111	876	36	1,679
1990	1,460	3,645	198	3,204	33	8,540
1991	7,808	11,694	317	23,584	1,359	44,762
1992	617	1,586	248	3,733	114	6,298
1993	1,283	833	352	7,334	6	9,808
1994	2,541	1,324	313	14,577	89	18,844
1995	2,657	1,079	91	3,919	1,280	9,026
1996	187	447	0	170	81	885
1997	147	236	23	1,097	9	1,512
1998	72	33	39	173	21	338
1999	85	380	158	813	0	1,436
2000	144	181	7	390	75	797
2001	15	25	0	44	18	102
Average	5,205	4,816	137	8,869	355	19,381
%	27%	25%	1%	46%	2%	100%

Appendix 10. Annual total return, catch, escapement and exploitation rate for Cultus sockeye adults 1952 to 2001.

Year	Total adult escapement	Total catch	Total adult return	Exploitation rate
1952[a]	17,833	19,987	37,820	52.8%
1953	11,543	29,029	40,572	71.5%
1954	22,036	79,628	101,664	78.3%
1955	25,922	143,195	169,117	84.7%
1956	13,718	23,808	37,526	63.4%
1957	20,375	53,208	73,583	72.3%
1958	13,324	49,162	62,486	78.7%
1959	47,779	234,701	282,480	83.1%
1960	17,640	22,304	39,944	55.8%
1961	13,396	14,395	27,791	51.8%
1962	26,997	20,536	47,533	43.2%
1963	20,303	31,541	51,844	60.8%
1964	11,067	13,722	24,789	55.4%
1965	2,455	4,349	6,804	63.9%
1966	16,919	18,564	35,483	52.3%
1967	33,198	98,802	132,000	74.9%
1968	25,314	45,539	70,853	64.3%
1969	5,942	16,011	21,953	72.9%
1970	13,941	26,138	40,079	65.2%
1971	9,128	87,978	97,106	90.6%
1972	10,366	38,639	49,005	78.8%
1973	641	4,390	5,031	87.3%
1974	8,984	35,813	44,797	79.9%
1975	11,349	36,735	48,084	76.4%
1976	4,435	26,410	30,845	85.6%
1977	82	401	483	83.0%
1978	5,076	22,364	27,440	81.5%
1979	32,031	77,620	109,651	70.8%
1980	1,657	4,719	6,376	74.0%
1981	256	1,201	1,457	82.4%
1982	16,725	52,386	69,111	75.8%
1983	19,944	87,952	107,896	81.5%
1984	994	5,882	6,876	85.5%
1985	424	541	965	56.1%
1986	3,256	9,163	12,419	73.8%
1987	32,184	68,537	100,721	68.0%
1988	861	8,924	9,785	91.2%
1989	418	1,679	2,097	80.1%
1990	1,860	8,540	10,400	82.1%
1991	20,157	44,762	64,919	69.0%
1992	1,203	6,298	7,501	84.0%
1993	1,063	9,808	10,871	90.2%
1994	4,399	18,844	23,243	81.1%
1995	10,316	9,026	19,342	46.7%
1996	2,022	885	2,907	30.4%
1997	88	1,512	1,600	94.5%
1998	1,959	338	2,297	14.7%
1999	12,392	1,436	13,828	10.4%
2000	1,227	797	2,024	39.4%
2001	515	102	617	16.5%

[a.] Incomplete data, no estimates for 5_2 and 5_3 adult returns are available.

Appendix 11. Age-1 smolt production, subsequent catch and escapement at ages 4_2 and 5_2, and marine survival of Cultus sockeye for the 1951 to 2000 brood years.

Brood year	Smolt migration year	Age-1 smolts	Catch plus escapement at age 4_2	5_2	Total	Marine survival
1951	1953	388,873	166,043	4,527	170,569	43.9%
1952	1954	620,213	32,999	11,266	44,265	7.1%
1953	1955	-	62,317	855	63,172	-
1954	1956	1,903,296	61,631	1,933	63,565	3.3%
1955	1957	2,688,063	274,490	1,184	275,674	10.3%
1956	1958	976,120	35,165	1,067	36,232	3.7%
1957	1959	319,495	26,724	1,264	27,988	8.8%
1958	1960	1,427,228	46,269	1,097	47,365	3.3%
1959	1961	1,327,842	50,631	1,449	52,079	3.9%
1960	1962	1,025,404	22,606	414	23,020	2.2%
1961	1963	1,200,498	5,954	0	5,954	0.5%
1962	1964	-	35,483	0	35,483	-
1963	1965	-	131,466	3,157	134,623	-
1964	1966	-	67,696	1,550	69,246	-
1965	1967	131,106	19,606	0	19,606	15.0%
1966	1968	2,101,506	40,079	435	40,514	1.9%
1967	1969	2,441,694	96,671	6,114	102,785	4.2%
1968	1970	1,005,291	42,418	0	42,418	4.2%
1969	1971	186,787	5,031	0	5,031	2.7%
1970	1972	799,934	44,797	150	44,947	5.6%
1971	1973	1,086,016	47,715	313	48,027	4.4%
1972	1974	167,111	30,020	3	30,023	18.0%
1973	1975	-	480	189	669	-
1974	1976	986,300	27,251	1,831	29,082	2.9%
1975	1977	1,219,211	107,820	267	108,087	8.9%
1976	1978	167,982	6,109	0	6,109	3.6%
1977	1979	-	1,457	0	1,457	-
1978	1980	-	69,111	0	69,111	-
1979	1981	-	106,617	1,627	108,244	-
1980	1982	-	4,639	0	4,639	-
1981	1983	-	965	0	965	-
1982	1984	-	12,419	5,529	17,948	-
1983	1985	-	95,192	711	95,903	-
1984	1986	-	9,074	32	9,106	-
1985	1987	-	1,980	122	2,102	-
1986	1988	-	10,278	0	10,278	-
1987	1989	-	64,919	917	65,836	-
1988	1990	65,184	6,584	1,142	7,726	11.9%
1989	1991	52,865	9,729	1,012	10,741	20.3%
1990	1992	178,357	22,231	2,300	24,531	13.8%
1991	1993	-	16,722	733	17,455	-
1992	1994	-	2,150	0	2,150	-
1993	1995	-	1,600	0	1,600	-
1994	1996	-	2,297	138	2,435	-
1995	1997	-	13,690	510	14,200	-
1996	1998	-	1,497	0	1,497	-
1997	1999	-	617	na	617	-
1998	2000	-	na	na	na	-
1999	2001	62,564	na	na	na	-
2000	2002	5,681	na	na	na	-

Appendix 12. Brood year escapement, subsequent return by age in the catch and escapement, and returns per spawner for Cultus sockeye adults, 1948-2001 brood years.

Brood year	Adult escapement	Return 3_2	4_3	4_2	5_2	5_3	Total	Return per spawner
1948	12,746	-	0	37,820	1,256	1,827	40,903	3.2
1949	9,055	1,662	16	37,489	0	0	37,489	4.1
1950	29,928	3,623	0	101,664	0	3,074	104,738	3.5
1951	12,677	3,498	0	166,043	4,527	0	170,569	13.5
1952	17,833	159	0	32,999	11,266	0	44,265	2.5
1953	11,543	497	0	62,317	855	0	63,172	5.5
1954	22,036	1,631	44	61,631	1,933	6,056	69,621	3.2
1955	25,922	1,610	204	274,490	1,184	3,596	279,270	10.8
1956	13,718	1,273	0	35,165	1,067	0	36,232	2.6
1957	20,375	95	0	26,724	1,264	0	27,988	1.4
1958	13,324	3,547	0	46,269	1,097	117	47,482	3.6
1959	47,779	114	94	50,631	1,449	735	52,814	1.1
1960	17,640	483	0	22,606	414	436	23,456	1.3
1961	13,396	194	0	5,954	0	0	5,954	0.4
1962	26,997	524	201	35,483	0	534	36,017	1.3
1963	20,303	3,825	0	131,466	3,157	0	134,623	6.6
1964	11,067	1,357	0	67,696	1,550	797	70,043	6.3
1965	2,455	1,380	34	19,606	0	0	19,606	8.0
1966	16,919	4,551	0	40,079	435	0	40,514	2.4
1967	33,198	7,716	0	96,671	6,114	473	103,258	3.1
1968	25,314	36	0	42,418	0	0	42,418	1.7
1969	5,942	1,446	0	5,031	0	0	5,031	0.8
1970	13,941	910	56	44,797	150	219	45,166	3.2
1971	9,128	2,673	58	47,715	313	512	48,540	5.3
1972	10,366	337	3	30,020	3	0	30,023	2.9
1973	641	44	0	480	189	0	669	1.0
1974	8,984	636	0	27,251	1,831	0	29,082	3.2
1975	11,349	7,700	0	107,820	267	0	108,087	9.5
1976	4,435	20	0	6,109	0	0	6,109	1.4
1977	82	114	0	1,457	0	0	1,457	17.8
1978	5,076	4,837	18	69,111	0	1,279	70,390	13.9
1979	32,031	1,662	0	106,617	1,627	610	108,854	3.4
1980	1,657	186	0	4,639	0	0	4,639	2.8
1981	256	579	0	965	0	0	965	3.8
1982	16,725	883	8	12,419	5,529	0	17,948	1.1
1983	19,944	423	0	95,192	711	0	95,903	4.8
1984	994	215	0	9,074	32	85	9,191	9.2
1985	424	329	0	1,980	122	0	2,102	5.0
1986	3,256	210	0	10,278	0	0	10,278	3.2
1987	32,184	19	0	64,919	917	0	65,836	2.0
1988	861	99	0	6,584	1,142	0	7,726	9.0
1989	418	4	0	9,729	1,012	0	10,741	25.7
1990	1,860	236	0	22,231	2,300	320	24,851	13.4
1991	20,157	23	0	16,722	733	24	17,479	0.9
1992	1,203	67	0	2,150	0	0	2,150	1.8
1993	1,063	11	0	1,600	0	0	1,600	1.5
1994	4,399	7	0	2,297	138	0	2,435	0.6
1995	10,316	240	0	13,690	510	17	14,217	1.4
1996	2,022	12	0	1,497	0	0	1,497	0.7
1997	88	0	0	617	na	na	617	na