Final Draft

Recommendations for A Recovery Plan for Rivers Inlet and Smith Inlet Sockeye Salmon

Prepared by:

Technical Coordinating Committee
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Contents

Executive summary

Sockeye from Rivers Inlet (Owikeno Lake) and Smith Inlet (Long Lake) once supported the largest fishery on British Columbia's Central Coast, and have served the food and cultural needs of local First Nations for hundreds of years. Since 1992, however, these two important sockeye stocks have declined dramatically and, despite fishery closures, are now at risk of local extinction. Recognizing the need for urgent action, Fisheries and Oceans Canada (DFO) formed an internal Technical Coordinating Committee (TCC) in late 1999 to develop a draft recovery plan for restoring Rivers and Smith Inlet stocks to acceptable levels. Recovery planning is one part of an overarching process for watershed-based fish sustainability planning in BC, and aims specifically to increase stocks to the point where their existence is no longer threatened.

This recovery plan was drafted by the TCC, with the help of three expert working groups on stock assessment and fisheries management, habitat protection and restoration, and salmon enhancement. Each of these groups prepared a detailed background paper summarizing knowledge and recommending actions (see the appendices to this report). The resulting draft recovery plan contains a technical review of stock status, an analysis of outlook, several options for recovery measures, and recommended action. It will now be circulated for comment to other agencies, First Nations, communities, and stakeholders groups.

In developing the plan, the TCC considered two possible goals of a recovery program: to reduce the risk of extirpation (the conservation objective), or to restore local fisheries through increased returns of adult salmon (the production objective). Given the immediate threat to the two stocks and the risks inherent in longer-term intervention, only those measures required for conservation are included in the plan. In addition, the plan is consistent with the principles of DFO's proposed *Wild Salmon Policy* that seeks to protect wild pacific salmon populations and their habitat.

To meet this conservation objective, the plan relies on continued precautionary management, increased stewardship, habitat protection and restoration, further research, and "conservation enhancement" – that is, artificial propagation (hatchery-produced salmon) to ensure the viability of the wild stocks. A decision model is specified for determining when stocks are low enough to warrant enhancement. The plan's key findings and recommendations are outlined below.

KEY FINDINGS – STOCK STATUS, RATIONALE, AND OUTLOOK

- Despite closure of the Rivers and Smith Inlet fisheries in 1996 and 1997, respectively, total returns have remained below target escapement levels (Table S.1). Escapement in both the Owikeno and Long Lake systems fell to record lows in 1999, under the minimum abundance levels or "Limit Reference Points" (LRPs) suggested for the two stocks.

- The drastic declines in abundance appear to be due to an extended period of poor marine survival that cannot be explained by any one event, such as sea-entry during an unusual El Niño year. At least two recent years (1996 and 1997) show signs of near-zero marine survival, but the reasons for those low survival rates are not known at this time.

- There is little evidence to suggest that logging or other human activity in either of the drainage basins has had more than small and localized impacts on sockeye spawning and rearing. The simultaneous declines in both basins – i.e., in Owikeno, where there has been extensive logging and in Long Lake, where there has been very little – is convincing evidence that the cause of the declines does not lie in freshwater habitat disturbance.

- The majority of sockeye in both stocks mature as 4- and 5-year-old fish. Fish that entered the ocean in 1996 and 1997 experienced near-zero survivals. If marine conditions were again unfavorable in 1998, then the returns in 2000 could also approach the records for low escapement. Without reliable forecasts of marine survival, the outlook for sockeye is highly uncertain. The Pacific Science Advice Review Committee (PSARC) has advised that another three years of extremely poor marine survival would greatly increase the extirpation risk for both stocks (Stocker and Macdonald 2000).

Table S.1. Recent catch and escapement data for Smith and Rivers Inlet sockeye.

	Smith Inlet – Long Lake			Rivers Inlet – Owikeno Lake		
year	commercial catch	First Nation catch	escapement	commercial catch	First Nation catch	escapement
1991	574,550		260,000	168,226	993	346,500
1992	722,816		220,000	508,068	1,089	343,005
1993	284,156		220,000	83,146	2,741	311,000
1994	57,169		100,000	40,320	1,382	91,500
1995	25,946		57,000	44,379	4,156	73,000
1996	8,513		54,000	0	2,697	65,000
1997	0		32,000	0	1,927	276,100
1998	0	170	76,000	0	2,161	52,000
1999	0	0	5,900	0	657	3,600
2000	0	0	1,430	0	0	21,100
2001	0	0	8,450	0	0	24,500

RECOMMENDED ACTIONS

Assessment and fisheries management

1. It is recommended that the commercial net fisheries remain closed in Areas 9 (Rivers Inlet) and 10 (Smith Inlet) and that there be non-retention of sockeye in all recreational fisheries in both areas. Furthermore, net fishing should be closed in portions of Area 8 (lower Fitzhugh Sound), where Owikeno and Long Lake sockeye have been intercepted in the past, and the minimum mesh sizes in remaining gillnet fisheries along probable migration routes should be increased to further minimize sockeye interception.

2. The Oweekeno and Gwa'Sala-Nakwaxaxda'xw First Nations have agreed to forgo their sockeye harvest for the 2000 season.

3. To better assess stock status and help design effective remedial actions, programs should be initiated to:

   - determine absolute escapement to Owikeno Lake instead of the current escapement index, to improve the credibility of stock assessment and help set conservation benchmarks;
   - improve the understanding of habitat use (pattern, habitat type, and seasonality) by sockeye juveniles in Owikeno Lake and smolts in the Wannock estuary; and
   - Investigate the status of ocean-type and lake-spawning sockeye, which are less familiar and, although not specifically covered in this plan, may require future intervention.

4. To allow early evaluation of the performance of conservation enhancement, enhanced fry should be marked for sampling during late winter (starting in 2001) or during a smolt program in 2002.

Habitat

5. Existing conceptual plans for habitat restoration developed by DFO, the provincial Watershed Restoration Program and other stakeholders should be evaluated for their potential long-term benefits to sockeye, and the feasibility of proposed restoration projects should be thoroughly assessed.

6. Habitat restoration projects could include the reconnection of spawning and early rearing habitats along the margins of floodplains and in side-channels that have been isolated by road construction or degraded by natural and logging-related activities.

7. Any habitat restoration projects that are undertaken should be monitored to determine their benefits for sockeye.

8. DFO and other agencies and stakeholders should continue to collaborate on developing habitat protection strategy during resource development planning processes (e.g., CCLCRMP, Forest Development Plans).

9. The site-specific and cumulative impacts of logging on habitats used by sockeye should be more comprehensively evaluated.

Enhancement

10. When deciding on the need for conservation enhancement or captive breeding, authorities should use Decision Model 2 (see Section 7.7 of the main report), which is based on marine survival and escapement relative to the stocks' provisional LRPs.

11. The selection of broodstock for conservation enhancement should attempt to capture as much of the spatial and phenotypic diversity of the sockeye stocks as possible.

12. All enhancement must follow strict protocols to protect genetic diversity and ensure the safe release of the maximum number of fry.

13. New fish culture capacity is required on the Central Coast to support the enhancement activities anticipated in this plan. For 2000, a portable hatchery being constructed at the Snootli Creek Hatchery will take sockeye eggs from the Owikeno (555,000) and Long Lake (200,000) systems for incubation at Snootli.

14. A mix of enhancement strategies is recommended for the 2000-2004 period:

    - Egg-to-fry cultivation at a hatchery (e.g., Snootli), with fry release after a short period of rearing to their natal stream;
    - Egg-to-eyed-egg cultivation at the hatchery, with transfer to an in-stream incubation system in a natal stream side-channel; and
    - Egg-to-eyed-egg cultivation at the hatchery, with transfer to floating cassette incubators in or at the mouth of the natal stream.

15. When the decision model determines that conservation enhancement is not needed, a minimum recommended egg-take target should be maintained to permit the refinement of

site-specific enhancement techniques. When the model determines that enhancement is warranted, the recommended egg target should be set to produce an equivalent number of fry to that which would have been produced by a naturally spawning population at LRP levels, subject to logistical constraints.

It is important to realize that conventional fry supplementation may not stop further declines in stock abundance, but would slow those declines and "buy time" for further action. If very poor marine survival persists, captive breeding may be the only way to keep the stocks from falling to levels where genetic diversity would be irreversibly lost.

1. Introduction

Rivers Inlet and Smith Inlet on British Columbia's Central Coast have witnessed dramatic declines in their sockeye salmon populations since 1992. Despite the closure of local fisheries in 1996 and 1997, respectively, poor adult returns continue to threaten sockeye survival in Owikeno Lake (Rivers Inlet) and Long Lake (Smith Inlet). Historically, these two stocks supported the largest commercial fishery on the Central Coast, and they have been an important food, social, and ceremonial resource for the Oweekeno and Gwa' Sala-Nakwaxaxda'xw First Nations. The federal and provincial governments, First Nations, and local communities and stakeholders are all concerned that the Owikeno and Long Lake sockeye may be at risk of local extinction.

Responding to these concerns, in late 1999 Fisheries and Oceans Canada (DFO) initiated a process of recovery planning with the goal to reverse Rivers and Smith Inlet stock declines. A Technical Coordination Committee (TCC) oversaw the efforts of three expert working groups in the areas of stock assessment and fisheries management, *habitat*, and *enhancement*.[1] Within their appropriate fields of expertise, each working group prepared a background paper[2] to summarize knowledge and make recommendations for the recovery plan. Based on the background papers, this draft plan was developed, and circulated for comment and input from other agencies and stakeholder groups.

The plan begins by introducing recovery planning and its role in the context of fisheries-related policy. In Section 2, the characteristics and status of the threatened sockeye stocks are outlined. Section 3 then considers and makes recommendations on the appropriate objective and approaches for the recovery plan. This is followed by a list of principles that the plan must observe (Section 4) and a description of the specific options for habitat protection and restoration (Section 5) and strategic enhancement (Section 6). Section 7 presents some decision rules for proceeding with an enhancement program. Finally, conclusions and recommendations of the recovery plan are provided in Section 8.

1.1 What is a recovery plan?

A recovery plan describes activities designed to assist a *stock*, sub-species, or *species* in increasing to a level of abundance where, at a minimum, its existence is not immediately threatened.[3] A rebuilding plan, on the other hand, aims to increase the abundance of a stock such that fisheries can be supported. The level of abundance sufficient for fisheries is usually in excess of that required to ensure the stock's survival. Consequently, a recovery plan is not a rebuilding plan; however, a recovery plan may well form part of a rebuilding plan.

Recovery plans can have several distinct components:

- Definition of the stock, sub-species, or species to establish the biological entity or entities to which the plan applies;
- Description of the stock status and immediate prognosis to demonstrate the extent of the threat, thus, the need for a recovery plan;

[1] See Appendix A for a listing of the TCC and working group members, as well as the tasks assigned to each working group.
[2] The background papers are attached in Appendix B (Assessment and Fisheries Management), Appendix C (Habitat), and Appendix D (Enhancement).
[3] See the Glossary in Section 9 for definitions of the terms stock, Conservation Unit, *population*, *sub-population*, and *Management* Unit. Throughout this plan, italicized terms are defined in the Glossary.

- Analysis of causal factors to determine why the stock is at risk, so that the most efficient and effective recovery solutions can be developed;
- Statement of plan objectives to help focus activities and strategies, and identify benchmarks for evaluating success or failure of the recovery plan;
- Description of the success of the recovery program in achieving stated objectives. Specifies the package of recovery activities and decision rules for starting, stopping, and sequencing them; and
- Identification of performance measures for evaluation to assess the recovery program's success or failure on an ongoing basis, so that activities that have achieved their objectives can be stopped, and unsuccessful activities can be improved or abandoned.

The draft recovery plan presented below contains most of these elements: definition of the Conservation Units (Section 2.2), current status and prognosis (Sections 2.3 and 2.4), statement of objectives (Section 3.4), and description of the recovery program (Sections 5, 6, and 7). Analysis of the causal factors that may have resulted in the current situation (Section 2.4) is unavoidably incomplete. In particular, the potential influences that freshwater habitat disturbance may have exerted on Rivers and Smith Inlet sockeye is uncertain at this time. Furthermore, the time frames required to evaluate and address such effects are not consistent with the immediate need to ensure the survival of the two Conservation Units. For these reasons, the activities related to habitat protection and restoration and associated performance measures are currently incomplete.

1.2 Recovery plans in the context of fisheries and habitat management

A recovery plan is one of several products in the cycles of fisheries and habitat assessment and management conducted by regulatory agencies. For fisheries managers, the process begins with the identification of conservation or management units, commonly referred to as "stocks." This is followed by the collection of existing and new information about the fish populations that make up the stock. The collected information is used to assess the status of the stock and, through production modeling, to determine whether there is a *harvestable surplus*.

If a harvestable surplus exists, then fisheries are designed, conducted, and monitored. If there is no harvestable surplus, then fisheries are prevented, curtailed, or stopped in order to allow the stock to rebuild. In the latter case, a "conservation concern" may be present such that the stock is: depressed to the point where rebuilding could take a long time; continuing to decline in the absence of fishing; and/or at rapidly increasingly risk of *extirpation*. Where there is a conservation concern, a recovery plan may be required if the stock's existence is threatened in the short term, that is, within the next couple of generations. To prepare such a plan, a recovery planning team has been formed (TCC) from DFO's various sectors (e.g., Stock Assessment Division, Habitat and Enhancement Branch).

Habitat managers carry out activities to protect, restore, and augment fish habitat, in decreasing order of priority. Habitat management becomes fully engaged in fisheries management when a conservation concern is raised for a depressed stock. The reasons for the stock's decline are investigated, including the status of supporting habitat and any habitat-related constraints on fish production and productivity. Habitat management is also intimately involved in both recovery and rebuilding planning, to ensure the removal or mitigation of habitat constraints.

While all species are considered in this annual cycle of assessment and management, each species' status determines where it is in the decision process. A great deal is known about Rivers and Smith Inlet sockeye and their habitats (see Appendix C), and the need for a recovery plan for them has been well established. Less is known about local Chinook stocks, although the intensity of data collection is being increased. For certain, Chinook stocks with similar life histories to sockeye, some fisheries management actions have been recommended to reduce harvest intensity while the status of these stocks is being more closely studied. Preliminary actions have also been taken for depressed pink and chum stocks within the inlets. The least amount of information is available for local Coho however; an *index program* established at Long Lake suggests that Coho stocks are currently not at risk.

1.3 Recovery plans in the context of watershed-based fisheries and habitat management and planning

Conservation, the maintenance of *biodiversity*, and fish habitat protection are the cornerstones of DFO's draft *Wild Salmon Policy (WSP)*, which has undergone public consultation and review (DFO 2000). The draft policy contains six principles (see Section 4.1) to ensure the conservation of wild Pacific salmon stocks, and recommends a number of activities to support those principles, including a review of enhancement and other operational guidelines, scientific research, and ongoing monitoring and reporting of stock status.

Conservation and the management of fisheries resources and habitats are key priorities not only for DFO, but also for the BC government, First Nations, and coastal communities in British Columbia. The future of the West Coast salmon resource depends largely on the successful integration of long-term fisheries management and long-term habitat management, since the two are inextricably linked.

The emphasis on conservation and coordinated fisheries and habitat management is reflected in a number of important initiatives, beginning with the 1997 *Canada – British Columbia Agreement on the Management of Pacific Salmon Fishery Issues*. This agreement created a new federal-provincial partnership for conserving and managing salmon and their habitat, including a commitment to "work jointly in watershed fish production planning processes, to be structured in consultation with stakeholders."[4] The commitment to watershed-based planning was then restated in several policy documents, including *A New Direction for Canada's Pacific Salmon Fisheries* (DFO 1998) and *A Federal-Provincial Framework for Habitat Restoration and Salmon Enhancement* (Federal-Provincial Habitat Restoration and Salmon Enhancement Working Group 1998).

The primary objectives of watershed-based fisheries and habitat planning are the maintenance of wild fish populations, the protection and restoration of fish habitat, and the management of fisheries such that salmon can make full use of their natural habitat. Recovery plans are prepared when managers must intervene to maintain wild fish populations. It is expected that cooperation at the watershed level involving all resource users in a collaborative and coordinated process – as illustrated by the proposed Central Coast Land and Coastal Resource Management Plan (CCLCRMP) and the proposed Watershed-based Fish Sustainability Process[5] – will reduce the need to develop recovery plans. When a recovery plan is needed, the effective coordination of watershed users is essential because of the interdependencies of fish, habitat, and *ecosystems*. Therefore, recovery planning will likely be one of the activities supported by watershed-based planning processes as these processes are implemented.

[4] See Section 4.1 of the agreement.

[5] DFO, the BC Ministry of the Environment, Lands and Parks (MELP), and the BC Ministry of Forests (MoF) have developed the framework for this process, which sets the priorities for fish management on a watershed basis and will coordinate the efforts of all agencies, industry, and interest groups engaged in restoring watersheds and protecting habitats.

1.3 Scope of this recovery plan

This recovery plan covers the sockeye salmon of the Owikeno Lake drainage in Rivers Inlet, including the Wannock River, and the sockeye of the Long Lake drainage in Smith Inlet.

For the purposes of designing a recovery program, recommended fisheries management actions are restricted to the year 2000, although similar measures may be recommended for subsequent years until the stocks recover. All other recommended actions (e.g., habitat restoration and sockeye enhancement) are multi-year and can be readily extended.

2. Rivers Inlet and Smith Inlet Sockeye

2.1 The nature of the life cycle

Sockeye are *anadromous* pacific salmon. They lay their eggs in fresh water, where *juveniles* rear until they go to sea as *smolts* and mature into adult fish. Eventually, the adults return to the system in which their parents *spawned* and repeat the cycle. The sockeye of Owikeno and Long Lake mature and return as 3-year-old, 4-year-old, and 5-year-old fish. Nearly all of their smolts enter the ocean after spending one summer and one winter as free-swimming fish, or two winters if the time that they spend as eggs and *alevins* in the gravel is included.

While this is not a complex life cycle, keeping track of fish of various ages can be a challenge. Figure 2.1 provides a diagrammatic representation of the life cycle of Owikeno and Long Lake sockeye, illustrating the *brood year*, *sea-entry year*, and *return years*. The return of 4-year-old fish in the fall of 2000 will be the first measurable return from smolts that entered the ocean in 1998.

2.2 Definition of the Conservation Units

Almost all sockeye returning to Rivers Inlet (Statistical Area 9) originate in spawning areas associated with Owikeno Lake (see Figure 2.2). Spawning occurs in ten tributaries feeding Owikeno Lake, along the lakeshore, and in the outlet river. Genetic survey data do not indicate any persistent population hierarchy in the lake, suggesting a high *straying* rate among spawning areas within the Owikeno Basin. High rates of straying between spawning locations and the successful reproduction of the "strays' acts to make the sockeye genetically homogeneous. Historically, Rivers Inlet sockeye have been managed as a single stock, which seems justified in light of the recent genetic survey data originating from Owikeno Lake.

All sockeye returning to Smith Inlet (Statistical Area 10) come from spawning areas associated with Long Lake, and are managed as a single stock. Spawning takes place in the Smokehouse River and Canoe Creek, which feed into Long Lake, and along the lakeshore. No genetic survey data are available regarding population structure within Long Lake.

Extensive data from surveys of parasite prevalence (Quinn et al. 1987), *allozymes* (Wood et al. 1994), and mitochondrial and microsatellite DNA (C. Wood and others, unpublished data) indicate that Owikeno sockeye are almost completely isolated reproductively from Long Lake sockeye, and can be easily recognized as genetically distinct linkages. For this reason, the two stocks should be considered as separate Conservation Units under the Wild Salmon Policy. As mentioned above, There may also be an ocean-type sockeye population in the Chuckwalla - Kilbella River system, and potentially other populations in both inlets, that would qualify as additional Conservation Units. It is advisable that these possibilities be investigated further prior to their inclusion in recovery planning.

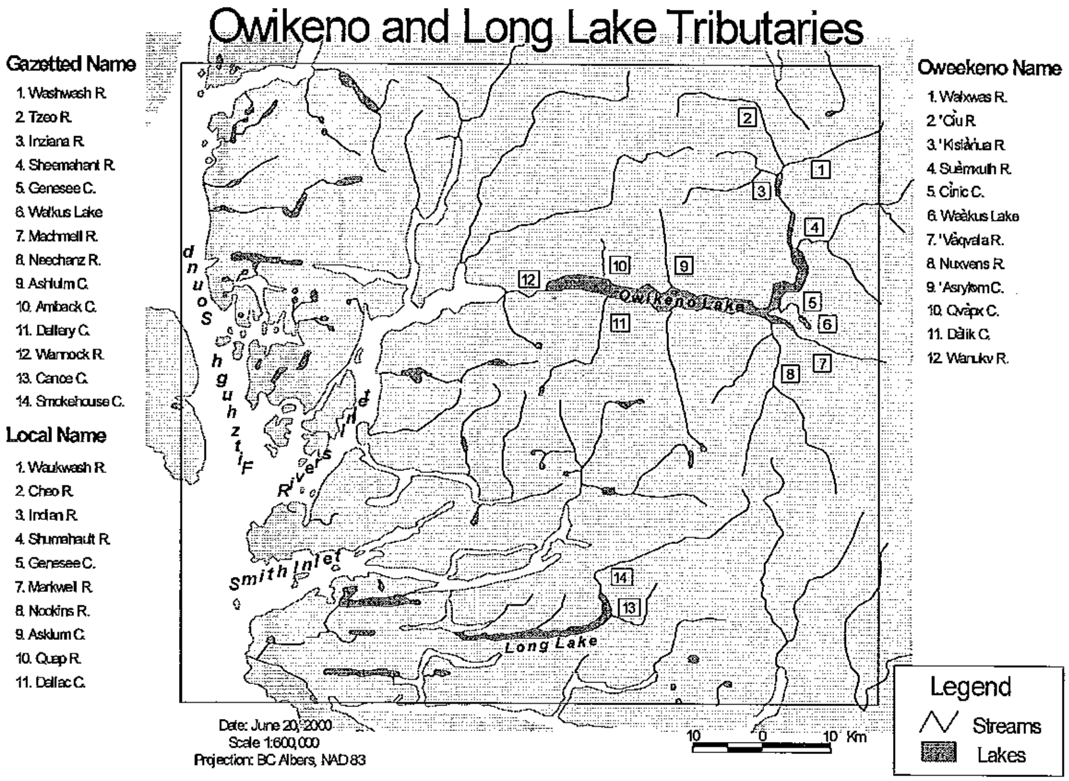

Figure 2.2. Map of Rivers Inlet and Smith Inlet. The tributaries to Owikeno Lake and Long Lake are shown. For some tributaries of Owikeno Lake, the gazetted name, the local name, and a transliteration of the name in the language of the Oweekeno First Nation are shown.

2.3 Provisional conservation benchmarks

The Wild Salmon Policy proposes the establishment of a minimum abundance level, or *Limit Reference Point* (*LRP*) that must be maintained to ensure conservation of a fish population. Consequently, provisional LRPs have been computed for the Owikeno and Long Lake sockeye Conservation Units using general procedures adopted for other sockeye systems in British Columbia. Participants at a DFO workshop in February 2000 recommended that the (provisional) LRP for *lake-type* sockeye be defined as the spawning *escapement* required to *seed* a nursery lake at 10 percent of its carrying capacity. It was also agreed that carrying capacity should be defined as the theoretical maximum smolt *biomass* predicted by the lake productivity model developed by Shortreed et al. (2000). The resulting LRPs for the Owikeno and Long Lake Conservation Units are 30,000 and 8,000 spawners, respectively (DFO memo from M. Stokner to L. Richards, Regional Director of Science, 16 February 2000).

2.4 Current status of the Conservation Units

Owikeno Lake in Rivers Inlet once supported the largest sockeye salmon fishery on the Central Coast. However, due to continued poor marine survival since sea-entry year 1992, sockeye returns have declined rapidly, as shown in Table 2.1.[6] Comparable declines over the same period have also occurred in Long Lake sockeye.

Table 2.1. Recent catch and escapement data for Smith and Rivers Inlet sockeye.

	Smith Inlet – Long Lake			Rivers Inlet – Owikeno Lake		
year	commercial catch	First Nation catch	escapement	commercial catch	First Nation catch	escapement
1991	574,550		260,000	168,226	993	346,500
1992	722,816		220,000	508,068	1,089	343,005
1993	284,156		220,000	83,146	2,741	311,000
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1997	0		32,000	0	1,927	276,100
1998	0	170	76,000	0	2,161	52,000
1999	0	0	5,900	0	657	3,600
2000	0	0	1,430	0	0	21,100
2001	0	0	8,450	0	0	24,500

Note: More complete information is presented in Appendix B.

Despite closure of the Rivers Inlet fishery since 1995, total returns to Rivers Inlet have been below the *target escapement level* and are considered inadequate to fully seed Owikeno Lake. A similar situation exists in Smith Inlet, where the fishery was closed in 1997. A more extensive discussion of the biology and population dynamics of the two sockeye stocks may be found in Appendix B.

Multiple consecutive years of low escapement will almost certainly lead to reduced smolt production, and reduced adult returns in 2000 through 2004, even if marine survival improves. If survival continues to be poor, sockeye populations in Areas 9 and 10 may be at serious risk of extirpation.

[6] See Appendix B, Rutherford et al. (1998), and Rutherford and Wood (2000).

In both locations, the working hypothesis for this plan is that there have been at least two successive sea-entry years, 1996 and 1997, of near-zero marine survival. Poor returns of 4-year-olds in 1998 and 5-year-olds in 1999 confirmed that smolts entering the ocean in 1996 did not survive well. Poor returns of 4-year-old fish in 1999 suggest that Rivers and Smith Inlet sockeye entering the ocean in 1997 fared no better that the smolts that entered the ocean in the previous year (see Figure B.2, Appendix B). This was confirmed by the 5-year return in 2000.

There are general indications that other salmon smolts entering the ocean in the vicinity of Rivers and Smith inlets and northern Vancouver Island experienced exceptionally poor conditions for survival in 1996 and/or 1997. The 1999 Chinook *carcass index of escapement* to the Wannock River was only 500 fish, the lowest on record since 1950. Although this figure is not considered a reliable estimate of total escapement because of the uncertainties in estimating escapement from a count of carcasses, McNicol (2000) concluded that the 1999 index reflected an exceptionally low number of spawners. Wannock River chum escapements in 1998 and 1999 were also very poor, and the contributing brood years of 1995 and 1996 would have gone to sea in 1996 and 1997, respectively (McNicol 2000).

Chuckwalla River (and likely Kilbella River) Chinook represent an exception to the pattern, since escapements did not decline in 1999 and there is no evidence of poor survival for Chuckwalla Chinook migrating to sea in 1996 and 1997 (McNicol 2000). This higher survival may be related to the fact that *stream-type* Chinook migrate to sea primarily as yearling smolts, whereas ocean-type Chinook, like Wannock River chum, migrate to sea as smaller, sub-yearling smolts. Although Owikeno sockeye migrate as yearling smolts, they are exceptionally small, averaging less than 2 grams, and are likely comparable in size to Wannock River Chinook (sub-yearling) smolts. However, size at sea-entry cannot fully explain the poor survival rates because Long Lake smolts are not unusually small and their survival was also extremely poor in both 1996 and 1997 sea-entry.

2.5 Prognosis

Prior to 1999, escapements to Owikeno Lake were considered adequate to meet DFO's conservation objectives, although prospects for a fishery in Rivers Inlet in the foreseeable future appeared bleak. Record low escapements to Owikeno and Long lakes in 1999 pose a much more serious conservation concern. These low returns cannot be attributed to a single unusual *El Niño* year of sea-entry, as most of these fish entered the ocean one year earlier in 1996; thus, at least two brood years appear to have suffered exceptionally poor marine survival. Most central coast sockeye mature at age 5, so that another three years of exceptionally poor marine survival will greatly increase the risk of extirpation of sockeye in all lakes in Areas 9 and 10.

Given the 5-year maturity age, poor returns in 2000 reflected poor survival of fish that entered the ocean in 1997. The populations can be considered to consist of five *broodlines*, of which two are now threatened. Another three years of exceptionally poor marine survival will greatly increase the risk of sockeye extirpation in both of the systems. Smolts from two of those three years have already entered the ocean.

3. Approaches to Recovery Planning

3.1 Clarifying the objective – conservation or production?

The serious and continuing decline in Owikeno and Long Lake sockeye makes a strong case for action of some kind to help reverse the trend. Importantly, however, the best strategy for *intervention* will depend on the objective of recovery activities. Two primary objectives might be considered:

- Conservation objective: To secure the viability of both Conservation Units. Recovery activities would be designed to reduce the risk that either Conservation Unit would become non-viable, i.e., would be extirpated.
- Production objective: To restore fishing opportunities to Rivers and Smith Inlets by increasing adult returns. This objective implies activities to increase adult numbers more quickly than would be observed without intervention.

The conservation objective could be achieved by conducting activities of small scale and short duration to stabilize the abundance of spawners in the face of poor marine survival. Both the draft Wild Salmon Policy and the proposed federal Species at Risk Act (SARA) provide for action to ensure the viability of a wild stock. The production objective, on the other hand, would require larger-scale, ongoing intervention where success would hinge on an improvement in marine survival. Both objectives can be accommodated within a recovery plan.

3.2 Uncertainties and risks of artificial propagation

Artificial propagation refers to hatcheries and other measures that involve human intervention in fish reproduction. For artificial propagation to succeed, eggs that are removed from the wild and incubated artificially must have, on average, a higher probability of surviving to maturity and spawning naturally than eggs that are left alone. When wild salmon abundance is very low, it is also imperative that the variability in egg-to-adult survival be lower under artificial propagation than in the wild. If the variability in survival under artificial propagation is comparable to that in the wild, then the benefits of propagation can be lost through chance events. This requirement may be difficult to ensure if there is a risk of mechanical failure, occasional human error, or disease epidemics in a *hatchery*. If the above conditions are not met, artificial propagation will reduce the reproductive potential of the stock by removing reproductive adults. However, if applied strategically hatchery technology can be useful in increasing the number of spawning adults.

The risks associated with artificial propagation can be minimized by using strict protocols for *broodstock* collection, spawning, and incubation in secure facilities, in order to ensure that the *genetic diversity* and viability of all reproductive units is protected. Large-scale intervention would have to be of short duration.

3.3 Risk assessment and the desirable extent of artificial propagation

The benefits and costs of intervention to support Rivers and Smith Inlet sockeye are highly dependent on what happens to marine survival over the next few years. The following four general courses of action have been considered under a scenario of continuing poor marine survival (Scenario A, Table 3.1) and one of average marine survival (Scenario B, Table 3.2):

Approach 1. No artificial propagation and continued *precautionary management*. This approach would be least costly and most effective from a long-term conservation perspective if marine survival were certain to return to normal within a year or two. However, if marine survival continues to deteriorate, the risk of extirpation may become unacceptable, and opportunities to stabilize abundance will be reduced the longer intervention is delayed.

Approach 2. No artificial propagation and increased stewardship, habitat restoration, and research. This approach is likely to have modest costs and increase the long-term viability of the wild stocks if marine survival improves. However, if marine survival does not improve, the risk of extirpation could increase beyond acceptable limits.

Approach 3. Short-term artificial propagation for conservation (conservation enhancement) plus the increased stewardship and habitat activities of Approach 2. This approach offers some insurance for the viability and genetic diversity of wild stocks in both the short term and long term. However, expenditures would be higher than for Approach 2, and could prove unnecessary if marine survival returns to normal in the near future. If marine survival continues its declining trend, then modest levels of propagation may be insufficient to reduce the extirpation risk to acceptable levels.

Approach 4. Long-term artificial propagation for production (production enhancement) is not consistent with the objective of conserving wild salmon populations as outlined in the proposed 'Wild Salmon Policy'. This approach would involve the higher costs of building new infrastructure, and could mean increased risk for the long-term viability of the wild stocks. It is only worth pursuing if the potential to restore fishing opportunities in the short term is considered an important objective that outweighs the additional cost and risk.

Because of the low population numbers and apparent marine survival bottleneck, any of the above approaches would likely take a number of generations (20 – 50 years) to achieve full recovery.

3.4 Recommended approach for recovery planning

The Technical Coordination Committee has reviewed the potential objectives and approaches for recovery planning in the case of Owikeno and Long Lake sockeye, and makes two recommendations.

First, ***the TCC recommends that the recovery plan adopt a conservation objective.*** All proposed artificial propagation should be designed only to reduce the risk of extirpation. Dangerously low stock levels, combined with the cost of larger-scale, short-term or long-term propagation measures, preclude enhancement for fish production at this time.

Second, ***the TCC recommends that the recovery plan should pursue both Approach 2 and Approach 3, with a decision-rule process for determining whether to initiate conservation enhancement.*** Approach 1 (status quo) appears to carry too much risk, and may violate the principle of precautionary management, given that marine survival is inherently unpredictable and has been declining since sea-entry year 1992. Approach 4 (production enhancement) does not address the conservation objective and would require substantial expenditures since the necessary infrastructure is not currently in place.

Table 3.1. Decision matrix under Scenario A – poor marine survival continues, LRPs are not expected to be attained.

Approach	"Pro"	"Con"
1. Status Quo		Missed opportunity if decline continues and risk to stocks increases
2. More stewardship, habitat restoration, and research	Long-term habitat improvement, increased knowledge	Decline may continue and risk to stocks increases; modest cost
3. Strategic enhancement	Short-term viability secure	Modest cost; minor risk of long-term impacts on viability
4. Artificial propagation for production	Short-term viability secure	Costly; unnecessary for conservation; increased risk of long-term impacts on viability; risk of reliance on technology in the long-term

Table 3.2. Decision matrix under Scenario B – average marine survival returns, LRPs are expected to be exceeded.

Approach	"Pro"	"Con"
1. Status Quo	No additional costs; no risk of adverse impacts	
2. More stewardship, habitat restoration, and research	Low risk of adverse impacts; modest cost; long-term habitat improvement, increase in knowledge	Unnecessary for conservation
3. Strategic enhancement	Modest cost	Unnecessary for conservation; minor risk of long-term impacts on viability
4. Artificial propagation for production	May produce cost-effective benefits to fishery	Costly; unnecessary for conservation; increased risk of long-term impacts on viability; risk of reliance on technology over the long-term.

Note: Based on the projected returns reported in Table 5 of Appendix B.

4. Principles for Recovery Planning

4.1 Principles of the draft Wild Salmon Policy

Recovery planning for Rivers and Smith Inlet sockeye should fully consider the six principles of the draft Wild Salmon Policy, to ensure that all actions in the recovery program are consistent with the policy's requirements:

Principle One – Wild Pacific salmon will be conserved by maintaining diversity of local populations and their habitats. All spawning sites within the Owikeno and Long Lake basins should be protected. Persistent differences in *run* timing to spawning areas in inlet tributaries to the upper versus lower basins, and in the outlet tributary (Wannock River), suggest local adaptation to predictable differences in temperature regime. The Owikeno Basin is a mix of logged and unlogged watersheds, while Long Lake is a relatively pristine basin, with some A-frame logging. The sudden and dramatic decline in abundance in all spawning areas within the two basins has occurred without any obvious habitat change or reduction of diversity in freshwater habitat. However, a habitat working group has been assigned to provide an update on habitat status, identify data gaps, and provide information and advice to the steering committee as well as to the *land and resource planning* process (CCLCRMP) that is currently underway (see Section 5 and Appendix C). Regardless of the roles that habitat damage and loss may have played in the decline of sockeye, habitat protection in both basins is essential to preservation of the sockeye and other fish stocks.

Principle Two – Wild Pacific Salmon will be managed and conserved as aggregates of local populations called Conservation Units. The sockeye of Owikeno and Long Lake basins are considered two separate Conservation Units because genetic survey data indicate that these populations have evolved from independent lineage's and are reproductively isolated. However, the data do not reveal any persistent population structure in Owikeno Lake, which suggests straying among tributaries within the basin. Therefore, it is appropriate to manage Owikeno sockeye as a single population. From an enhancement perspective, individual tributaries should be treated as separate sub-populations, since there is some evidence of *phenotypic* differentiation that may reflect local adaptation.

Principle Three – Minimum (limit reference point or LRP) and target levels of abundance will be determined for each conservation unit. The LRP is established as an escapement benchmark, below which there is an unacceptable risk of extirpation or a loss of capacity to rebuild to the target zone within a reasonable period of time. Provisional LRPs for Owikeno and Long lakes are 30,000 and 8,000 spawners, respectively. In 1999, estimated escapement was 3,600 spawners or 12% of the LRP for Owikeno Basin, and 5,900 spawners or 74% of the LRP for Long Lake. The target reference point (TRP) defines the lower boundary of the abundance zone within which *sustainable* benefits can be achieved. It seems reasonable to use the current target escapements (200,000 spawners for each lake) as provisional TRPs, although both target escapements need to be thoroughly reviewed.

Principle Four – Fisheries will be managed to conserve wild salmon and optimize sustainable benefits. Past and proposed fisheries management actions for both Conservation Units are consistent with this principle. For example, fisheries were first curtailed in the 1980's and then halted in the mid-1990's when returns first began to decline (see Appendix B).

Principle Five – Salmon cultivation techniques may be used in strategic intervention to preserve populations at greatest risk of extirpation. Strategic intervention is proposed for both

Conservation Units. A major portion of this recovery plan is devoted to examining alternative interventions and defining how intervention will be carried out and under what circumstances.

Principle Six – For specified conservation units, when genetic diversity and long-term viability may be affected, conservation of wild salmon populations will take precedence over other production objectives involving cultivated salmon. Reducing the risk of extirpation of the Conservation Units (conservation) is the primary objective of this recovery plan.

4.2 Guiding principles for the recovery plan

Each of the three working groups was asked to develop a set of guiding principles to be used in developing recommendations for a recovery plan. The principles are meant to help ensure that recovery effort remains focused on conserving the two sockeye stocks and their habitats. The overarching guiding principle of the recovery planning process is to do no harm. Therefore, it is important to carefully consider all interventions with that primary principle in mind.

Principles for stock assessment and fisheries management

The following principles are to be applied when conducting stock assessments and making fisheries management decisions for the Conservation Units:

1. Rivers and Smith Inlet sockeye stocks should be managed in a risk-averse manner based, wherever possible, on peer-reviewed science methods, as well as other pertinent knowledge.

2. Wherever possible, point estimates of abundance, forecast returns, and other quantified variables are to be accompanied by measures of uncertainty.

3. Subject to conservation needs, First Nations are to be given first priority for any sockeye harvest opportunities, in order to provide fish for food, social, and ceremonial purposes.

4. Fisheries management plans should be feasible and enforceable. In addition to closures of the Rivers and Smith Inlet fisheries, fisheries outside these areas are to be managed to avoid interception of Rivers and Smith Inlet sockeye salmon.

5. Harvest of other salmon stocks will be permitted in Rivers and Smith inlets only if it does not pose significant risk to sockeye stocks in these areas, and provided that the preeminence of principle (3) above is recognized.

Principles for habitat protection and restoration

DFO's long-term policy objective is the achievement of an overall net gain in the productive capacity of fish habitats (DFO 1986). That objective is being pursued through the protection of existing undamaged habitat, the restoration of previously damaged habitat, and the development of additional productive habitat. Habitat protection is guided by the principle of "no net loss," whereby unavoidable losses of habitat are balanced by the substitution of equivalent habitats. The guiding principles below were developed in accordance with DFO's Habitat Management Policy. They should be used for Watershed Based Fish Sustainability Planning and broader planning exercises such as the CCLCRMP and Central Coast IMP and the evaluation of any development or restoration projects that may impact habitat.

1. Vulnerable habitats should be protected to maintain their current *natural productive capacity*. Escapement and resultant fry *recruitment* to both the Owikeno and Long Lake systems has

exceeded target levels as recently as the early 1990s, suggesting that current habitat productive capacity of the spawning and *rearing* habitat is still sufficient to support the recovery and rebuilding of both stocks. Nevertheless, protection of known spawning areas for sockeye should receive high priority.

2. Damaged habitats should be restored to regain their pre-impact natural productive capacity. Better information on habitat use at the different life stages of sockeye may be required to adequately identify critical habitats as candidates for habitat restoration or improvement projects. Restoration projects should be prioritized based on best estimates of expected biological success and logistical considerations. Restoration projects should not benefit one species at the expense of another.

3. Limiting habitat should be enhanced to increase natural productive capacity. Application of this principle requires determination of the habitat limitations to sockeye production and whether those limitations can be affected by production.

Principles for conservation enhancement

The objective of the sockeye conservation enhancement program for Owikeno and Long Lake basins is to maintain levels of abundance sufficient to ensure the viability of the wild populations (i.e., to prevent their extirpation). It is anticipated that stocks would subsequently rebuild to harvestable levels.

The following principles must be applied in rigorously examining all interventions involving transfers, transplants, and propagation of sockeye salmon before such interventions take place:

1. The focus of the enhancement program is on conservation. Enhancement for conservation must be coupled with continued harvest restrictions and habitat protection and restoration.

2. Artificial propagation will only be contemplated when stocks are in danger of extirpation.

3. The program will conform to existing DFO policies, procedures, and guidelines for the collection and use of fish, including, but not confined to, those relating to transplant, disease protocol, genetic practices, *captive brood programs*, and the draft Wild Salmon Policy. The potential long-term adult production will be limited such that the enhanced portion of the escapement is no more than 50 percent of the actual stock size. However, this limit may be exceeded during the short-term rapid rebuilding phase if spawning populations are well below the LRP.

All of these principles, together with the primary objective of conservation, have been considered in preparing the recovery program described below.

5. Habitat Protection and Restoration Options

There are numerous options for protecting and restoring habitats in the Owikeno Lake and Long Lake watersheds. The options are not mutually exclusive, and a strategy that incorporates a range of them would yield the best results. The general options available to DFO include:

- continue with the current habitat management process that focuses on responding to development proposals and participating in multi-stakeholder planning processes;
- propose and implement new habitat management strategies, in cooperation with other stakeholders;

- develop a number of different habitat restoration and improvement projects; and
- conduct assessment and monitoring programs to improve the understanding of habitat impacts and their importance.

The Habitat Working Group has recommended specific options for a recovery plan, including:

- investigate the seasonal timing and duration of habitat use through all sockeye freshwater and *estuarine* life stages, to help determine how much habitat is affecting stocks and to aid in developing a directed habitat restoration program;
- evaluate conceptual restoration plans developed by DFO, the provincial Watershed Restoration Program (WRP), and other stakeholders to assess the feasibility and effectiveness of proposed restoration projects[7] for improving long-term viability;
- implement and monitor pilot restoration projects in the short term, to examine their benefits for Owikeno and Long Lake sockeye;
- assess the site-specific and cumulative impacts of logging on sockeye habitats; and
- continue to work with other stakeholders in resource development planning (e.g., land use and forestry planning) to develop habitat protection strategies.

Background on sockeye habitat and protection and restoration options is provided in Appendix C.

5.1 Habitat protection options

DFO is currently involved in habitat protection in the Owikeno Basin through ongoing participation in the forest development planning process. Department staff provide comment and recommendations to the Ministry of Forests and forest companies with respect to the potential impacts of Forest Development Plans (FDPs) on fish and fish habitat. DFO is involved through all stages in forest planning and development, from reviewing general, landscape-level plans to assessing detailed block and stream-crossing plans to conducting pre- and post-logging field reviews. Generally, the Department's role has been to provide advice, thus ensuring that fish habitats are protected and that the habitat-related sections of the Fisheries Act are enforced.

In view of the current stock decline, one habitat protection option being considered is to the establishment of *habitat refugia* in the Owikeno Basin. The objective of defining and protecting riverine refugia habitats on a watershed scale is to protect remaining *salmonid* populations that are disproportionately dependent on these habitat pockets for short-term survival. Long-term recovery would be assisted by managing these areas for the primary purpose of salmonid conservation until recovery trends have been established and substantial habitat restoration in other areas has occurred.

The CCLCRMP and Watershed Based Fish Sustainability Planning process provides a useful forum in which to advocate for the protection of certain watersheds as refugia for recovering sockeye populations. There are three pristine watersheds adjacent to Owikeno Lake (the Ashlum, Dallery, and Amback tributaries) and the Long Lake Basin is largely undeveloped. Under an *adaptive management* approach, DFO could request that logging in these watersheds be deferred while population trends are monitored over two to three life cycles (8-15 years). These areas could also be established for baseline data collection to test the efficacy of the land use planning recommendations and sockeye recovery programs.

[7] Examples of such projects include the reconnection of habitats along the margins of floodplains, the reconnection of isolated estuary habitats, and pilot spawning channel development.

Another option is the protection of key sockeye habitats at the river-*reach* scale throughout the Owikeno Basin. This could be accomplished by identifying vulnerable areas and protecting them using higher-level direction from the CCLCRMP, which would then be implemented at the lower planning levels. An example would be the designation of habitats as Old Growth Management Areas through provincial Landscape Unit Planning. Landscape units that contain important sockeye habitats could be given high priority for planning, with a focus on fisheries issues. For example, the *floodplains* along sockeye spawning reaches of several Owikeno tributaries (Amback, Ashlum, Dallery, Genesee, Inziana, Tzeo, and Washwash) are currently unlogged. Through the CCLCRMP, WBFSP and landscape unit plans, DFO could request higher levels of protection in these areas. This approach would address the direct impacts of floodplain logging on sockeye habitat, but not the potential cumulative impacts from upstream logging activities.

Several areas containing key sockeye habitat in the Owikeno and Long Lake basins are being considered for either Goal 1 or Goal 2 protected areas status by the Central Coast Land and Coastal Resource Management Planning Table.[8] Goal 1 protected areas are designed to preserve representative examples of natural diversity, including marine, terrestrial, and freshwater ecosystems. Goal 2 protected areas target special natural features, including critical habitats. Throughout the consultation process, DFO can and should provide support to proposals that protect important habitats.

5.2 Habitat restoration options

Historically, DFO has been involved several minor habitat improvement projects in the Owikeno Basin. For example, Washwash Creek has been a concern since the 1920s, when it broke through its banks on the *alluvial fan* to flow directly into the glacial Tzeo River. In 1971, DFO installed a *riprap* dyke to maintain flow in the old channel; nonetheless, a new channel broke through to the Tzeo River in 1980, with resulting heavy loss of spawn. From a *geomorphologic* perspective, the reach of river from the breakthrough to the lake is a deposition area, where the river deposits large volumes of coarse bedload on the fan. It is, therefore, unclear whether further intervention would be effective.

The provincial Watershed Restoration Program has been active in the Owikeno Basin since 1996. Overview-level and detailed habitat assessments have been completed in the Sheemahant, Machmell, and Neechanz watersheds (Hillaby 1998a,b,c). In 1999, *culvert* replacement projects were implemented to address fish access to off-channel habitats in the Machmell and Sheemahant watersheds. Similar projects are planned for 2000, including reestablishing access to a 1-km-long spring-fed wetland in the Sheemahant floodplain (M. Parker, MELP, pers. comm.).

Habitat assessment reports of various Owikeno watersheds indicate a number of locations where *side-channels* have become isolated from the *mainstem* either by road development or by channel migration across the floodplain. Further investigation is needed to determine if any of these sites were previously used as spawning habitat by sockeye. There may be some potential to restore groundwater side-channel habitat on a pilot basis and to monitor the resulting benefits. Because there are so few examples of groundwater side-channel development for sockeye, this type of work must be considered experimental. Egg-fry survival rates would almost certainly benefit, particularly in those river systems with highly unstable channels. Numerous *riparian* and bank stability restoration projects were identified during the WRP habitat assessments. These projects are located mainly in smaller tributaries above sockeye access, and are designed to address sediment transport into spawning reaches.

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[8] See Appendix C, Table 4.

The severe decline in escapements has undoubtedly reduced the nutrient regime in the Owikeno Lake and Long Lake basins by interrupting the flow of nutrients from the North Pacific Ocean carried in the adult sockeye. Experimental fertilization[9] of Long Lake in the 1980's appeared successful (Stockner, J.G. and K.D. Hyatt, 1984) but was discontinued because of the associated costs. In 2001, the potential for nutrient enrichment in Owikeno Lake was evaluated (Shortreed, in preparation). Stream enrichment (Stockner, J.G. and K.R.S. Shortreed, 1978) may have some potential for use in the Long Lake and Owikeno watersheds, but would primarily benefit species other than sockeye. To assess the feasibility of fertilizing deeper marine habitats adjacent to the estuaries requires more information on the oceanography and circulation patterns (K. Shortreed, DFO Cultus Lake Lab, pers. comm.). To date in British Columbia, only the Yakoun River estuary has been fertilized, and study results were not encouraging as to its effectiveness (Stockner and Levings 1982). According to Frank Whitney at DFO's Institute of Ocean Sciences (IOS) in Sidney, IOS surveys in 1998 and 1999 suggested that the 1997-98 El Niño affected nutrient supply all along the BC coast and into Alaska. While both winter supply and summer *upwelling* were affected off of Barkley Sound and probably also in the Queen Charlotte Sound area, it remains uncertain as to how coastal supply might affect coastal inlets. Dr. Whitney has requested that researchers currently on board the Research Vessel Tully sample Rivers Inlet during their cruise. He and Dario Stucchi of the IOS would like to conduct limited sampling in the Rivers and Smith Inlet area three to four times over the next year (2000/2001), to assess what processes are controlling nutrient supply to surface waters.

In addition, DFO should assess the feasibility of other habitat restoration projects in the Wannock River estuary. In the 1970s, approximately one hectare of the estuary was dyked to accommodate construction of the currently operating log dump facility. The isolated portion of the estuary is not being used for industrial purposes and reconnecting this habitat could produce beneficial results. A cannery operated at the north end of the estuary in the first part of the century. Recently, a preliminary survey of the cannery area detected a layer of metal filings on the substrate, which could be inhibiting invertebrate and plant production. Further assessment is required, and if necessary, the feasibility of removing these metal filings should be investigated.

5.3 Information Gaps

Improving the understanding of habitat use through freshwater and estuarine life stages would help develop a directed habitat strategy for sockeye in the Owikeno and Long Lake basins. The typical sockeye life history pattern includes mainstem river or beach spawning, followed by one year of lake rearing and the seaward *migration* of yearling smolts (Burgner 1991). However, sockeye can exhibit considerable variation around this generalized pattern. The extensive use of habitats along floodplain areas (e.g., spring-fed ponds, sloughs, side-channels, tributary creeks) for spawning and early rearing has been reported in several systems, particularly glacial rivers (Burgner 1991; Lorenz and Eiler 1989; Murphy et al. 1989). Groundwater upwelling areas also seem to be important for sockeye spawning and successful incubation in these rivers (Burgner 1991; Lorenz and Eiler 1989; Lorenz 1994). Estuary and nearshore residence by sockeye smolts varies across sockeye populations and can range from brief transitory residence to periods of up to 5 months (Burgner 1991). Extended estuary use is often associated with small age-0 smolts.

Studies of habitat use will assist in accomplishing three goals critical to a successful recovery strategy:

1) determine the impacts of land use development on sockeye habitat – Much of the identified logging-related impacts have occurred in the lower floodplains of the

[9] Lake fertilization is considered as a conservation enhancement option in Section 6.1 below.

larger glacial rivers (i.e., Machmell and Sheemahant rivers). The impacts are primarily associated with isolating or destabilizing habitats along floodplain margins that may be key spawning and early rearing habitat for sockeye in these systems. Furthermore, understanding river delta and estuary use will determine whether logging impacts in those habitats are affecting sockeye production.

2) identify critical habitats that are priorities for protection – It is especially important to single out habitats that contribute disproportionately to sockeye production relative to their availability. The identification of critical habitats is also the fundamental step needed for recovery planning under the proposed endangered species legislation (SARA).

3) prioritize habitats for restoration – Restoration projects are usually quite expensive and resources to undertake them are limited. Better understanding of habitat use will help focus the restoration program on those habitats that are most likely to improve sockeye production.

6. Conservation Enhancement

The decision of when and to what extent to engage in conservation enhancement will be made according to a set of decision rules described in Section 7. This section deals with the recommended choices, siting, and magnitude of activities, once it has been decided to pursue enhancement. Much of the technical background on conservation enhancement is contained in Appendix D.

6.1 Enhancement options

Table 6.1 presents six conservation enhancement options for Owikeno and Long Lake sockeye and discusses each option. The list of options is certainly not an exhaustive one, but rather is intended to show those options considered most feasible, given the current status of the stocks. Snootli hatchery in Bella Coola, within 100km by air from Rivers and Smiths Inlets, is identified as the enhancement facility of choice at this time. There are serious concerns over staffing (experience and technical expertise), available infrastructure, risk management capabilities, and costs associated with creating or rebuilding a facility in Owikeno.

After careful consideration, the Enhancement Working Group recommends the following mix of enhancement activities:

- Egg-to-fry cultivation at Snoolti Hatchery, with fry being released after a short period of rearing to their natal stream (Option 1);
- Egg-to-eyed egg cultivation at the hatchery, with transfer to an in-stream incubation system in a natal stream side-channel. (Option 2); and
- Egg-to-eyed egg cultivation at the hatchery, with transfer to floating cassette incubators in or at the mouth of the natal stream (Option 3).

The effectiveness of captive breeding remains unproven, for this reason this enhancement option was not recommended at this time. However, the cryo-preservation of milt from key stocks was recommended, to conserve genetic diversity should the situation worsen. Lake fertilization is being investigated as a "soft" enhancement technique to increase smolt size and survival, which could be used in conjunction with options 1,2 or 3. Estuary and Marine enrichment was also not recommended for implementation at this time due to the experimental and unproven status of this potential tool.

Table 6.1. Evaluation of enhancement options.

Option	"Pros"	"Cons"
1. Primary and secondary incubation at Snootli hatchery, fry release to natal stream	• High survival to fry stage in controlled conditions • Disease management protocols more easily implemented at Snootli Hatchery • More control over *emergence* timing, with option of short-term feeding • Adult assessment possible through *otolith marking*	• Egg transport "out" and fry transport "back" required • Short period of fry *imprinting* on natal stream • Risk of *IHN* outbreak at Snootli increases during secondary incubation • Hatchery effluent management required • Benefits limited where there is a marine survival problem
2. Primary incubation at Snootli, secondary incubation using in-stream incubators in natal stream where no anadromous spawning occurs above egg location	• High survival to *eyed egg stage* in controlled conditions • Lowered risk of IHN outbreak at Snootli and in natal stream • Longer imprinting period in natal stream • Adult assessment possible through otolith marking	• Egg transport out and back required • In-stream incubators still considered experimental, uncertain survivals in incubators exposed to varying flow conditions • Hatchery effluent management needed • Possible disease exposure concerns during secondary incubation • Hatchery incubation temperatures must be carefully managed to ensure optimal emergence timing • Benefits limited where there is a marine survival problem
3. Primary incubation at Snootli, secondary incubation in floating cassettes in or at mouth of natal stream	• High survival to eyed egg stage in controlled conditions • Lowered risk of IHNV outbreak at Snootli • Longer imprinting period in natal stream • Adult assessment possible through otolith marking • Option of short-term pen-rearing if necessary to match emergence timing	• Egg transport out and back required • Cassette incubators still considered experimental, uncertain survivals in incubators exposed to varying flow conditions • Hatchery effluent management needed • Possible disease exposure concerns during secondary incubation • Benefits limited where there is a marine survival problem
4. Captive breeding	• Greatest buffering of survival problems at any life-stage • Potentially the greatest egg to adult survival possible • Provides living gene bank in the event of stock extinction • Adult assessment possible through otolith marking	• Highest risk of disease problems and systems failures • Potential erosion of genetic diversity due to greater amplification factor • Potential for domestication selection • Experimental, little empirical evidence to demonstrate viability of post-*supplementation* population • Possible homing concerns • Most expensive option
5. Lake fertilization	• Least intrusive and lowest risk intervention • Potentially increases marine survival through increases in smolt size • Benefits all populations at the same time in proportion to current status	• Not proven, low fry smolt recruitment situation therefore benefits uncertain • Assessment more difficult, but may be less important since enrichment is less intrusive and low risk • More expensive for large lake like Owikeno with weak, deep *thermocline*
6. Estuary & Marine Enrichment	• Low risk • May increase marine survival through increases in smolt size • May benefit all populations at the same time in proportion to current status	• Assessment difficult • Results of fertilization of Yakoun river estuary not encouraging in terms of effectiveness • Cost may be high

Note: Lake fertilization may also be considered as habitat enhancement, but is treated here as a short-term measure to increase smolt survival (i.e., conservation enhancement).

6.2 Selection of broodstock

As outlined in Section 2.2, the Owikeno Basin is home to at least twelve sub-populations distributed throughout three sub-basins. Since it is impractical for the recovery program to cover all sub-populations at this time, one sub-population from each basin and stream-temperature type, plus the Genesee and Wannock sub-populations – for a total of seven Owikeno sub-populations – are recommended as candidates for enhancement (see Table 6.2).

Long Lake Sockeye spawn in two tributaries (Smokehouse and Canoe) and on the lake's beaches. The proposed enhancement program includes the Smokehouse and Canoe sub-populations because they comprise a majority of the run. Some concerns have been raised that the beach spawners may be a less productive sub-population than the tributary spawners, and thus may be adversely affected if the tributary sub-populations are restored more quickly through intervention.

6.3 Duration of conservation enhancement

It is recommended that hatchery intervention be considered for at least a five-year term, from 2000 through 2004. The level of intervention would be reduced when stocks are at or above the LRPs during that period. This should allow for the refinement of enhancement techniques, as well as for the *marking* of sockeye for assessment purposes. Further curtailment of the intervention would be considered if escapement rebuilds rapidly in response to improved marine survival. If marine survival does not improve, or deteriorates further, then conservation enhancement would likely be insufficient to prevent further declines in the stocks and they would be at increased risk of extirpation. Further interventions, such as captive breeding, might then be considered.

6.4 Level of intervention and egg targets

To help determine the *egg-take* requirements for cultivation, egg targets have been calculated for individual sub-populations based on the proportion that each sub-population has historically comprised of the candidate stock. The first three columns of Table 6.3 list the candidate sub-populations from Owikeno and Long lakes, their respective historic target escapements, and their proportional contributions to the candidate stock. The remaining four columns of the table provide egg and adult production targets, assuming that a minimum level of intervention is maintained even if the LRP is met during the 2000-2004 period (Scenario 1).

Alternatively, a higher level of intervention could be pursued involving enhanced fry production to augment wild fry when escapements are below the LRP and there are fry recruitment shortfalls (Scenario 2). Table 6.4 outlines egg-take requirements at various levels of shortfall. Candidate sub-populations and the proportion of eggs taken from each sub-population are the same as those presented in Scenario 1. The figures in Table 6.3 and 6.4 are provided simply for illustrative purposes and to give perspective about the level of involvement required. Field operations in 2000 and 2001 proved that the egg targets shown are achievable, and that fewer adults are required as broodstock, due to higher than projected fecundities in all systems.

Table 6.2. Stock-specific enhancement techniques.

Stock	Cultivation Method	Incubation Primary – Egg to Eyed Egg Location/Technique	Incubation Secondary – Eyed Egg to Fry Location/Technique	Ponding & Rearing *Swim-up*+~1 month rearing Location/Technique
OWIKENO BASIN (RIVERS INLET)				
WashWash	Hatchery	Snootli hatchery – health tray	Snootli hatchery – health tray	Snootli hatchery – small circ. tub
Inziana	Hatchery	Snootli hatchery – health tray	Snootli hatchery – health tray	Snootli hatchery – small circ. tub
Sheemahant	Hatchery	Snootli hatchery – health tray	Eggs transported back to natal system and placed in bulk instream or Scotty Jordan boxes	Snootli hatchery – small circ. tub or cap trough, instream = volitional
Genesee	Captive brood	Snootli hatchery – health tray	Snootli hatchery – health tray	Snootli hatchery – small circ. tub, instream = volitional
Neechanz	Hatchery	Snootli hatchery – health tray	Snootli hatchery – health tray	Snootli hatchery – small circ. tub, instream = volitional
Ambach	Hatchery	Snootli hatchery – health tray	Snootli hatchery – health tray	Snootli hatchery – small circ. tub
Wannock	Hatchery	Snootli hatchery – health tray	Eggs transported back to floating cassette incubators in Wannock River	Snootli hatchery – small circ. tub or cap trough, Wannock River = *net pen*
LONG LAKE BASIN (SMITH INLET)				
Smokehouse	Hatchery	Snootli hatchery – health tray	Snootli hatchery – health tray/Kitoi box	Snootli hatchery – small circ. tub
Canoe	Hatchery	Snootli hatchery – health tray	Snootli hatchery – health tray/Kitoi box	Snootli hatchery – small circ. tub

Table 6.3. Conservation Enhancement Scenario 1 – minimal intervention to verify enhancement techniques.

Stock	Historic Target	% of GRP Total	Scenario 1 – Minimum targets Adult Prod.	# Eggs required	Adults
OWIKENO PROPOSED STOCKS LRP = 30,000					
WashWash	100,000	13%	293	65,000	44
Inziana	75,000	10%	225	50,000	34
Sheemahant	200,000	27%	608	135,000	90
Genesee	25,000	3%	225	50,000	34
Neechanz	50,000	7%	225	50,000	34
Ambach	100,000	13%	293	65,000	34
Wannock	200,000	27%	608	135,000	90
Total GRP	750,000		2,475	550,000	360
Whole basin	1,012,000				
GRP as % of whole		74%			

Stock	Historic Target	% of Total	Scenario 1 – Minimum targets Prod.	# Eggs	Adults
LONG LAKE BASIN STOCKS LRP = 8,000					
Smokehouse	150,000	75%	675	150,000	100
Canoe	50,000	25%	225	50,000	34
Total GRP	200,000		900	20,000	134

Assumptions:

1. 50% male and female in escapements.
2. 3,000 eggs/female.
3. 90% *egg-to-fry* survival and 0.5% fry-to-adult survival (half of bio-standards to be conservative).

Table 6.4. Conservation Enhancement Scenario 2 – magnitude of intervention to maintain stocks at LRPs.

Owikeno Lake Escapement	LRP Spawner Shortfall	Wild Fry Recruitment Shortfall	# Eggs Required to Compensate for Fry Shortfall	Maximum # of Broodstock Available	# of Broodstock Required	Enhanced Fry Production
27,000	3,000	675,000	900,000	8,100	600	810,000
24,000	6,000	1,350,000	1,800,000	7,200	1,200	1,620,000
21,000	9,000	2,025,000	2,700,000	6,300	1,800	2,430,000
18,000	12,000	2,700,000	3,600,000	5,400	2,400	3,240,000
15,000	15,000	3,375,000	4,500,000	4,500	3,000	4,050,000
12,000	18,000	4,050,000	5,400,000	3,600	3,600	4,860,000

Long Lake Escapement	LRP Spawner Shortfall	Wild Fry Recruitment Shortfall	# Eggs Required to Compensate for Fry Shortfall	Maximum # of Broodstock Available	# of Broodstock Required	Enhanced Fry Production
7,000	1,000	225,000	300,000	2,100	200	270,000
6,000	2,000	450,000	600,000	1,800	400	540,000
5,000	3,000	675,000	900,000	1,500	600	810,000
4,000	4,000	900,000	1,200,000	1,200	800	1,080,000
3,000	5,000	1,125,000	1,500,000	900	1,000	1,350,000

Assumptions:

1. Spawner sex ratio of 1:1.
2. *Fecundity* of 3,000 eggs.
3. Wild egg-fry survival of 15%.
4. Enhanced egg-fry survival of 90%.

Note: Wild fry recruitment lost as a result of broodstock removal from wild population is compensated for in egg targets.

7. Decision Points for Initiating Conservation Enhancement in 2000

This section presents two decision models that could be used in making the decision of whether to go ahead with intervention (artificial propagation). The second model includes a rule to decide if the intervention should take the form of conventional fry supplementation or captive breeding. Each model consists of a series of decision rules that compare observed abundance to conservation benchmarks.

7.1 Decision rule based on the LRP

A straightforward rule for initiating a conservation enhancement program would be to make any intervention contingent on escapement falling below the provisional Limit Reference Point (LRP). Such a decision rule attaches considerable importance to the LRP and distorts somewhat what it actually indicates about the status of a Conservation Unit. The LRP is a conservation benchmark that shows a level of abundance where the risk of extirpation is still very low, but where the ability of the Conservation Unit to recover to target levels within a reasonable period is rapidly diminishing.

The LRP is a convenient decision point that could be used to flag whether intervention should be considered. When escapement exceeds the LRP, intervention is not necessary; however, the need to intervene should be carefully examined whenever escapement is less than the LRP. Such a decision process leaves open the possibility of initiating interventions whose magnitudes are contingent on how far below the LRP escapement falls. For example, in some of the decision rules presented below, captive breeding, a large intervention, can be triggered by a series of extremely poor escapements.

7.2 Problems with decision rules based on the LRP

The most significant problem in doing an assessment of Owikeno Lake sockeye is the uncertainty in escapement estimates. Most of this uncertainty reflects the extreme difficulty of counting adults in glacial streams, but a portion is also due to the lack of documentation on how escapement estimates were made in all streams prior to 1980. The current *expansion factor* is approximately three, which is simply the average ratio between the total estimated escapement and the estimated escapement to the *clear index streams* over the period 1980 through 1999. Any escapement estimate that uses the expansion factor should be recognized as an index (i.e., relative measure) of escapement, as opposed to an absolute estimate.

The LRP is calculated in absolute numbers that are not strictly comparable with escapement indices. Therefore the application of LRP – based decision rules is somewhat arbitrary for Owikeno sockeye. Escapement estimates at Long Lake and Owikeno Lake are derived from an absolute fence count (Docee River)[10] and clear stream/glacial stream index (Owikeno Lake). The result of any comparison would depend on the expansion factor used at Owikeno Lake. For example, if the actual expansion factor were less than the assumed value of three, the real escapement would be less than the index estimate. Consequently, decisions made using the index value would not be as conservative as they appear on face value.

Little can be done about this uncertainty in the short term. A mark-recapture program would provide information for calculating a better expansion factor estimate, but this could not be accomplished within the next few years. Likewise, while the establishment of an in-river monitoring program (e.g., *fish-wheel*, and electronic counts) might eventually allow in-season

[10] Since 1972, escapement to Long Lake has been measured at a counting fence on the Docee River at the lake's outlet. Therefore, all Long Lake escapement estimates are absolute ones.

projections of escapement, supporting data would take several years to collect. Long-term programs to obtain reliable estimates of escapement to Owikeno Lake are essential to properly assess stock status and monitor the progress of the Recovery Plan.

7.3 Alternative decision rule models

There are two basic decision rule models that could be applied to Rivers and Smith Inlet sockeye. The first model (DR Model 1) uses the provisional LRPs for both Conservation Units as the trigger points for intervention. Intervention is not required if escapement exceeds the LRP; otherwise, it is warranted. The uncertainty issue discussed above would be handled by assuming that the index and absolute escapements are comparable, i.e., that the expansion factor is approximately correct. The inherent risk of this assumption would be acknowledged by choosing a conservative probability level in the estimation process (see below).

The second model (DR Model 2) uses marine survival rates relative to those observed in 1996 and 1997 as the trigger points for intervention. In this case, intervention is not necessary if survival appears to have returned to normal in 1998 sea-entry, and is otherwise warranted.

Under both models, a limited egg-take leading to the release of fry into the lakes may occur even if the LRPs are reached (DR Model 1) or marine survivals are normal (DR Model 2), in order to allow for the refinement of enhancement techniques.

The sequence of decision rules involves determining the probable abundance of both stocks and comparing that abundance to the benchmarks. In 2000, stock abundance, total return, and escapement will be numerically equivalent because fisheries have been stopped. Determining abundance of the Long Lake stock is straightforward because of the Docee River fence, which enables an estimate of absolute escapement. Abundance of the Owikeno Lake stock can only be estimated through a variety of procedures that relate the stock size of escapement to an observed escapement. Hence, there is a sequence of decisions for the Owikeno stock that involves the accumulation of additional information as it becomes available.

7.4 Probability level for comparing estimated escapement to benchmarks

The consequences of failing to achieve escapements in excess of the LRP are deemed sufficiently serious to warrant intervention. Therefore, where uncertainty exists regarding escapement, a conservative probability level should be chosen when invoking the decision rules. The probability level represents the likelihood that the LRP will be met or exceeded. It must be specified in advance and the same level should be applied to all decisions. The recommended probability level is 19 times out of 20.

7.5 Decision Rule Model 1

Pre-season forecasts of total sockeye abundance for Rivers and Smith inlets indicate that there is a significant possibility that returns could be lower than the Limit Reference Points for the two stocks. Given that a return to either stock less than the LRP is sufficient cause to intervene, the decision steps that follow stipulate conditions under which intervention might not be necessary. This model does not deal with situations that might require strong intervention, such as captive breeding.

7.5.1 Determining abundance of Long Lake stock in 2000 and beyond

Sockeye counts through the Docee River fence at the outlet of Long Lake will provide the first quantitative indication of run strength. The total count through the fence is the escapement to Long Lake, and is the sole basis for determining whether there is a need for conservation enhancement of Long Lake sockeye. Total Long Lake escapement is also correlated with escapement to Owikeno Lake. In the absence of direct estimates of total Owikeno escapement, an estimate can be made using the historical relationship between the Docee fence count and Owikeno escapement estimates.

7.5.2 Decision rule for Long Lake sockeye

DECISION RULE 1.1: No intervention need be pursued in Long Lake if the final count of sockeye through the Docee River fence exceeds the Limit Reference Point of 8,000.

The Docee Fence will commence operation on July 1, 2000 and escapement counts will be provided to the TCC on a daily basis. The "normalized average run timing model" will be used during the run to provide an early indication of final sockeye escapement. Due to historical variation in run timing, model forecasts cannot be considered reliable until after July 12th, when on average 20% of the stock is expected to have passed through the fence. The "like-1996" sea-entry year pre-season forecast was for only 3,900 sockeye. In 2000, the Docee fence count was only 1430, a clear indication that marine survival did not moderate in 1998. In 2001, the Docee fence count increased to 8450.

7.6 Owikeno Lake sockeye

Owikeno escapement or total return can be estimated in one of three ways: from escapement to Long Lake (i.e., the Docee River fence count), from tributary escapement estimates, and directly through a fish-wheel mark-recapture program with tag application prior to lake-entry. Although a fish-wheel cannot be used to directly estimate escapement in 2000, it can by itself indicate that the LRP has been reached, if 30,000 sockeye are captured and released alive from the wheel. For this reason alone, a decision rule involving the fish-wheel is provided below.

7.6.1 Estimated from Long Lake escapement

A decision rule based on Owikeno escapement estimated from the observed Long Lake escapement should only be used if no other estimate of escapement to Owikeno Lake is available.

A statistically significant relationship exists between the total stock sizes of Rivers Inlet and Smith Inlet sockeye:

$$S_{Rivers} = 6.3527 S_{Smit}^{0.927}$$

where S_{Rivers} and S_{Smith} are the stock sizes in the two inlets. This model predicts that the LRP for Owikeno sockeye would be observed on average when the stock size of Long Lake sockeye was approximately 9,200. Although the model explains about 59% of the variance, predictions at low escapements have wide confidence limits. Depending on the risk that the real stock size in Rivers inlet is less than the forecast, the decision rule could use a "risk-prone" or "risk-averse" Docee fence count, as the following table indicates.

Observed escapement at the Docee fence	Probability that Rivers Inlet escapement exceeds the LRP
9.2×10^3	50%
16.5×10^3	75%
27.4×10^3	90%
37.1×10^3	95%
65.7×10^3	99%

<u>DECISION RULE 1.2</u>: No intervention need be pursued in Owikeno Lake if the total escapement to Owikeno that is estimated from escapement to Long Lake exceeds the LRP with a pre-specified probability. The TCC recommends that the pre-specified probability be 19 times out of 20, or 95%.

7.6.2 Wannock River fish-wheel

A pilot fish-wheel was operated in the Wannock River in 1999 to assess the feasibility of using this technology to quantify sockeye escapement. Because only a single year of data has been collected so far, no quantitative method of estimating escapement using the fish-wheel can be developed.

<u>DECISION RULE 1.3</u>: No intervention need be pursued in Owikeno Lake if the catch and live release in the Wannock fish-wheel exceeds the Limit Reference Point of 30,000. Note that this decision rule specifies <u>catch</u> and, thus, excludes from consideration extrapolations that are based on unverified run-timing models.

7.6.3 Visual Stream Surveys in Owikeno Lake

Spawning times vary somewhat among the tributaries to Owikeno Lake, so that it may be possible to estimate total escapement to the lake, and whether the LRP has been exceeded, with sufficient time to intervene if required. Three likely candidates for visual stream surveys are, in order of priority, the Inziana River (earliest and clear), Washwash River (early and clear), and Neechanz River (early, but partially glacial). In the Inziana, spawner surveys begin around the beginning of September. Estimated escapement to each of these systems is significantly correlated to total escapement. The table below summarizes the predictive relationship and the escapements that would be required to predict that the LRP had been reached at various levels of confidence.

Probability that Rivers Inlet escapement exceeds the LRP	Inziana River	Washwash River	Neechanz River
Model*	$E_o = 1692E_P^{0.523}$	$E_o = 712E_P^{0.5}$	$E_o = 295E_P^{0.713}$
50%	243	567	648
75%	640	1,115	1,184
90%	1,460	2,020	2,005
95%	2,425	2,890	2,755
99%	6,240	5,680	5,015

* Where E_O is Owikeno escapement and E_P is the escapement in the predictor system

DECISION RULE 1.4: Intervention need not be pursued in Owikeno Lake if the total escapement to Owikeno that is estimated from escapement to at least two of the three early run streams exceeds the LRP with a pre-specified probability. The TCC recommends that the pre-specified probability be 19 time out of 20 or 95%

7.6.4 Mark-recapture or other estimate of Owikeno escapement

Decision rules covering yet-to-be established estimation techniques would be formulated in the same manner as done for the tributary escapement estimators above.

7.7 Decision Rule Model 2

This set of decision rules is driven by inferences about marine survival and whether or not it has returned to normal. The decision rules include a tentative rule for initiating captive breeding. Although captive breeding is not feasible in 2000, it has been retained as an option if returns continue to decline and extirpation is deemed imminent.

7.7.1 Decision rules for Long Lake sockeye

DECISION RULE 2.1: Intervention need not be pursued for Long Lake sockeye if escapement exceeds the 10^{th} percentile of the "average-survival model" (19,000 in year 2000[9]) or the LRP (i.e., 8,000), whichever is greater.[10]

DECISION RULE 2.2: Captive breeding need not be pursued for Long Lake sockeye if escapement exceeds the 50^{th} percentile (i.e., the mean) of the "pessimistic-survival model" (8,600 in year 2000) or 25% of the LRP (i.e., 2,000), whichever is greater.

The percentile of the LRP at which captive breeding is advisable is currently an arbitrary figure, and may be revised at some point in the future.

7.7.2 Decision rules for Owikeno Lake sockeye

DECISION RULE 2.3: Intervention need not be pursued for Owikeno Lake sockeye if escapement exceeds the 10^{th} percentile of the "average-survival model" (33,000 in the year 2000) or the LRP (i.e., 30,000), whichever is greater.[11]

DECISION RULE 2.4: Captive breeding need not be considered for Owikeno Lake sockeye if escapement exceeds the 50^{th} percentile of the "pessimistic-survival model" (12,000 in the year 2000) or 25% of the LRP (i.e., 7,500), whichever is greater.

For Owikeno Lake sockeye, total escapement would be estimated from the Docee Fence count and from escapement to the early run, clear streams. In the case of decisions about low-intensity interventions, use of the 95% probability level of the point forecast might be excessively conservative in that it would lead to many unnecessary interventions. The recommended approach is not to use decision rules 2.3 and 2.4, but to intervene in Owikeno Lake in the same manner as the intervention undertaken for Long Lake sockeye. Consequently, **Decision Rules**

[9] The probability that the escapement will exceed the specified value.
[10] The reason for stating the decision rule in this manner (i.e., when both percentile of the forecast and the LRP are known) is that the forecast will differ in future years, but the decision rule would always use the same percentile of the forecast.
[11] See the previous footnote.

2.5 and 2.6 would be modified from Decision Rules 2.1 and 2.2, respectively, such that returns to Long Lake would trigger interventions to both Long Lake and Owikeno Lake.

7.8 Recommended Decision Model and Rules

At this time the TCC recommends intervention in the 2000, 2001, 2002, and 2003 brood years, no matter what the escapement, to develop Strategic Enhancement capacity. After the 2003 brood year, strategic intervention would be reviewed in view of Decision Rules 1.1 to 1.4 and 2.1 to 2.4.

8. Conclusions and Recommendations

This draft recovery plan has presented a range of activities to meet the conservation objective for Rivers Inlet and Smith Inlet sockeye. The plan relies on continued precautionary management, increased stewardship, habitat protection and restoration, further research, and conservation enhancement to help prevent the extirpation of Owikeno and Long Lake stocks.

Actions that may be taken in this recovery period are highly dependent on realised adult returns. These returns are, in turn, dependent on smolt outputs, which can be estimated, and on marine survivals, which cannot be predicted with any certainty. This lack of certainty has led to the creation of decision rules, which will guide implementation of specific activities over the recovery period.

The absence of specific recommendations for 2001 and beyond should not be interpreted to mean that there are no conservation concerns after 2000. Some habitat restoration programs are already underway, and the need for specific studies on habitat use by juvenile sockeye has been identified for the Owikeno Basin. Further habitat work may be required as a result of proposed studies. Hence, the protection and restoration of sockeye habitat in Rivers and Smith inlets remains a key priority for DFO management efforts.

In the area of artificial propagation, the plan's recommendations do not include intensive programs, such as captive brood programs, in 2000 but do include limited strategic intervention over the next cycle (brood years 2000, 2001, 2002 and 2003). However, continued poor marine survival would require that such programs be considered in future years, in order to minimise the risk of extirpation.

Key findings and recommendations of the recovery plan are provided below, grouped by study area.

8.1 Assessment

1. A period of poor to extremely poor marine survival is the principal cause of the decline in abundance of both Owikeno and Long Lake sockeye.

2. Continuation of the poor marine survival through 1998 and 1999 sea-entry years will considerably increase the risk of extirpation for both stocks.

3. The prognosis for both stocks is contingent on marine survival, which is highly uncertain in the absence of reliable forecasts.

4. Insufficient information is available on ocean-type sockeye populations in Rivers Inlet, as well as on ocean-type and lake-spawning populations in Smith Inlet, to specifically address them

in recovery planning at this time. Reductions in fisheries will certainly have benefited these populations, and efforts should be made to learn more about them and their status. There may be a need to intervene in these populations in the near future if poor marine conditions persist.

5. The determination of absolute escapement to Owikeno Lake is essential to better assess the stock's status and to determine conservation benchmarks. Programs to do so should be given high priority.

6. To enable early assessment of the performance of conservation enhancement, enhanced fry should be marked for sampling during late winter (beginning in 2001) or during a smolt program in 2002.

7. A better understanding of the habitat use (pattern, habitat type, and seasonality) of sockeye juveniles in Owikeno Lake, and of smolts in the Wannock estuary, is needed to help prioritize habitat restoration and protection programs.

8.2 Fisheries management

Several additional measures have been incorporated in the proposed fishing plans contained in the DFO document, *Pacific Region Integrated Fisheries Management Plan Salmon Coastal B.C. North 2000.*

1. Closure of the commercial net fisheries in Statistical Areas 9 and 10 should be continued.

2. Non-retention of sockeye in the recreational fisheries should remain in Areas 9 and 10.

3. For the commercial gillnet fishery starting July 3, 2000 and the seine fishery starting July 24, 2000 (both in lower Fitzhugh Sound), the southern boundary has been moved north of Hakai pass to reduce the possibility of interceptions for the stocks at risk migrating through Hakai Pass.

4. Incidental sockeye catch in the gillnet fishery will be further minimized by the use of a 149 mm mesh.

5. First Nations have been asked to forgo any harvest of Owikeno and Long Lake sockeye for food, social, and ceremonial purposes unless total returns at or near the Limit Reference Point are projected.

8.3 Habitat

Habitat restoration and protection programs are seldom directed specifically at sockeye, either because their use of streams and rivers is highly seasonal and largely restricted to spawning, or because the benefits of such activities to sockeye are difficult to measure.

1. There is little evidence to suggest that logging or other human activities in either the Owikeno or Long Lake drainage's have had other than small and localized impacts on sockeye spawning and rearing habitats. However, the ability to assess potential impacts is limited by an incomplete understanding of the timing and extent of habitat use by juveniles and smolts.

2. The feasibility of proposed restoration projects should be thoroughly assessed. DFO, the provincial Watershed Restoration Program, and other stakeholders have developed several

conceptual restoration plans that should be examined to evaluate the possible long-term benefits for sockeye. Examples of such projects include the reconnection of habitats along the margins of floodplains and in isolated estuaries.

3. Any habitat restoration projects that are undertaken should be carefully monitored to determine their benefits for sockeye.

4. The site-specific and cumulative impacts of logging on habitats used by sockeye should be more comprehensively evaluated.

5. Collaborative work with other stakeholders during resource development planning (e.g., land use and forest development plans), to develop habitat protection strategy, should continue.

8.4 Enhancement

It must be emphasized that fry supplementation is unlikely to prevent further declines in the abundance of either stock in the face of continued poor marine survivals. Fry supplementation could slow those declines and thus give more time to react and to intervene with more intensive artificial propagation. In the face of continuing, extremely poor survival, captive breeding might be considered to arrest declines in abundance so that genetic diversity would not be irreversibly lost. However, this technology is unproven for large-scale application.

1. In deciding on whether to intervene with conservation enhancement, or to use captive breeding, Decision Rule Model 2 (see Section 7.7.2) should be used. This decision model is based on relative changes in marine survival and on comparisons of escapement to conservation benchmarks.

2. Selection of the broodstock for conservation enhancement should seek to capture as much of the spatial and phenotypic diversity as possible.

3. All enhancement must follow strict protocols to protect genetic diversity and ensure the safe release of as many fry as possible.

4. A mix of enhancement strategies is recommended combining different techniques of incubation, ponding, and rearing of sockeye eggs and fry at the Snootli Hatchery and in the vicinity of natal streams.

5. Gene banking should be undertaken to further guard against the loss of genetic diversity.

6. Even where the decision rule model determines that conservation enhancement is not needed, a minimum recommended egg-take target should be maintained to allow for the refinement of site-specific enhancement techniques. If enhancement appears warranted, the recommended egg target should be set to produce an equivalent number of fry to that which would have been produced by a naturally spawning population at LRP levels, subject to logistical constraints.

9. Glossary of Terms and Acronyms

Absolute escapement. The true *escapement* as opposed to an index of escapement. (see *Index program*)

AFS. Aboriginal Fisheries Strategy (DFO).

Adaptive management.[1] The process of implementing policy decisions as scientifically-driven management experiments that test predictions and assumptions in management plans, and use the resulting information to improve the plans.

Alevin.[1] The developmental life stage of young salmonids and trout that are between the egg and *fry* stage. The alevin has not absorbed its yolk sac and has not emerged from the spawning gravels.

Allozymes.[1] Alternate forms of an enzyme produced by different alleles (alternate forms of genes) and often detected by protein electrophoresis.

Alluvial fan. A large, fan-shaped pile of sediment formed at the intersection of drainage basins or at the base of mountains or hills.

Anadromous.[2] The life history characteristic of returning from the sea to reproduce in freshwater.

Artificial propagation.[2] Human intervention made at some stage of the biological reproductive cycle. This term usually describes conventional hatchery practices, but may include any technique where there is human intervention in the biological aspects of reproduction, such as cloning. Techniques such as fish ladders or spawning channels that relate to habitat or access but do not involve human interventions in the act of reproduction would not be considered artificial propagation.

Biodiversity.[2] The variability among living organisms from all sources – including terrestrial, marine, and other aquatic ecosystems – and the ecological complexes of which they are a part. This includes diversity within species, between species, and of ecosystems.

Biomass.[3] The weight of living material usually expressed as a dry weight, in all or part of an organism, population, or community. Commonly expressed as a weight per unit area, a biomass density

Broodline. A loose description of relatedness associated with the tendency in many populations of Pacific salmon for the majority of fish to mature and spawn at a particular age. For Rivers and Smith Inlet sockeye, the majority of fish spawn when they are five years old, so that there are five broodlines. The description is exact only for pink salmon, where all fish mature as two—olds, giving rise to even-year and odd-year broodlines.

Broodstock.[1] Adult fish used to propagate the subsequent generation of hatchery fish.

Brood year.[1] The year in which the eggs were spawned.

Captive breeding/broodstock program.[1] A form of artificial propagation involving the collection of individuals (or gametes) from a natural population and the rearing of these individuals to maturity in captivity.

Carcass index of escapement. All Pacific salmon adults die after spawning. When compared across several years, a count of carcasses can provide a relative indication or index of yearly variations in escapement (see *Index Program*)

CCLCRMP. Central Coast Land and Coastal Resource Management Plan. See *Land and Resource Management Planning.*

Clear index streams. In the Owikeno Lake drainage, many of the streams are glacial, which prevents visual counts of spawners. Counts from non-glacial streams, which have clear water, are used as an index of total escapement to the drainage. (see *Expansion factor*)

Conservation.[1] The process or means of achieving recovery of viable populations.

Conservation Unit.[2] A group of one or more local populations that share a common genetic lineage and can be managed effectively as a unit by virtue of their common productivity and vulnerability to existing fisheries. For more practical purposes, Conservation Units are synonymous with populations in the sense defined by Wood and Holtby (1998). A Conservation unit is not necessarily a stock.

Cultivated.[2] Referring to a species or population that is artificially propagated in whole or in part by continuing human intervention to increase production to meet other human needs.

Culvert.[1] A buried pipe that allows streams, rivers, or drainage to pass under a road.

DFO. Department of Fisheries and Oceans (Fisheries and Oceans Canada).

Ecosystem.[2] A community of organisms and their physical environment interacting as an ecological unit.

Egg-take.[1] The number of eggs taken at hatcheries when adult salmon and steelhead are spawned.

Egg-to-fry survival.[1] The numerical difference between the number of fertilized eggs produced by a group of fish and the number of fry resulting from those eggs.

El Niño.[1] An intermittent warm water current that originates from the tropics and overrides the normal cold water currents that persist along the Pacific coast, resulting in warmer-than-normal ocean conditions.

Emergence.[1] The act of fish leaving their incubation environment in the gravel to forage for food.

Enhancement.[4] Artificial techniques to increase salmon populations; these include hatcheries, incubation boxes, and spawning channels.

Escapement.[4] The number of mature fish that pass through (or escape) the fisheries and return to their rivers of origin to spawn.

Estuarine/Estuary.[1] Pertaining to a coastal body of water that is semi-enclosed, openly connected with the ocean, and mixes with freshwater drainage from land.

Extirpation.[2] The extermination of a population of a species from a given area.

Expansion factor. The escapement counted in clear index streams of the Owikeno drainage is expanded to an estimate of total escapement to the drainage by multiplying by an expansion factor.

Eyed egg stage.[1] A fish egg containing an embryo that has developed enough so that the eyes are visible through the egg membrane.

Fecundity.[1] The total number of eggs produced by a female fish.

Fish-wheel. A device for catching fish alive in a river that is powered by river flow. It resembles a Ferris Wheel mounted on floats, where the seats are baskets that catch fish and dump them into a holding pen as the wheel spins with river flow.

Floodplain.[1] Land that is covered with water as a result of the flooding of a nearby stream. Or level lowland bordering a stream or river onto which the flow spreads at flood stage.

Fry.[1] A stage of development in young salmon or trout. During this stage, the fry is usually less than one year old, has absorbed its yolk sac, is rearing in the stream, and is between the *alevin* and *parr* stage of development.

Gene banking.[2] The cryo-preservation (freezing at extremely low temperatures) of salmon sperm to be used for artificial reproduction at some later date.

Genetic diversity.[1] The array of genetic traits that exists within a population which enables it to adapt to changing conditions.

Geomorphologic. Pertaining to the study of the earth's physical features, and of the relationship between these physical features and the geologic structures underneath.

Habitat.[2] The natural spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly in order to carry out their life processes.

Habitat refugia.[5] Habitats or environmental factors that convey spatial and temporal resistance and/or resilience to biotic communities impacted by biophysical disturbances.

Harvestable surplus. The number of fish that can be caught and removed from the population while leaving enough to sustain the population.

Hatchery.[1] Refers to facilities that incubate eggs and rear the young for release into streams and rivers.

HEB. Habitat and Enhancement Branch (DFO).

HRSEP. Habitat Restoration and Salmon Enhancement Program (DFO).

IHNV.[1] Infectious haematopoietic necrosis virus; a viral disease endemic to salmonid fishes of the Pacific Coast of North America that can cause high mortality in 3-week to 6-month-old fish.

Imprinting.[1] The physiological and behavioral process by which migratory fish assimilate environmental cues to aid their return to their stream of origin as adults.

Index program. In the context of programs designed to estimate *escapement*, an incomplete count that varies proportionately to total abundance and that serve as a measure or index of relative abundance.

Intervention.[2] The application of technology to the objective of artificially increasing salmon survival and abundance.

Juvenile.[1] Fish from one year of age until sexual maturity.

Lake enrichment/fertilization. The addition of nutrients, such as nitrogen and phosphorus, into a lake to stimulate the growth of algae and other aquatic plants, increasing food sources for fish.

Lake-type sockeye. The common life-history type of sockeye where the juveniles rear for a year or more in lakes before going to sea. (see *Ocean-type sockeye*)

Land and Resource Management Planning.[6] A sub-regional process for developing management plans that consider and address all resource values through active public participation, interagency coordination, and consensus-oriented decision-making.

Limit Reference Point (LRP). See *Reference Point.*

Local Population.[2] A group of one more sub-populations that are relatively isolated from other such groups and are likely adapted to the local habitat. For the purposes of this paper, population is equivalent to local population unless otherwise indicated.

Mainstem.[1] The principal channel of a drainage system into which other smaller streams or rivers flow.

Management Unit.[2] A grouping of one or more Conservation Units that have sufficiently similar behaviors and productivity's that they can be managed as a single entity.

Marking.[1] The marking (e.g., tagging, thermal marking) of individuals in a population of fish so that they can be identified in subsequent life history stages.

Maximum sustainable yield.[1] The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. (For species with fluctuating *recruitment*, the maximum might be obtained by taking fewer fish in some years than in others.)

Migration.[2] The movement of an organism or group from one habitat or location to another.

Natural productive capacity. A synonym of "carrying capacity," or the number of individuals that the resources of a habitat can support.

Net pen.[1] A fish rearing enclosure used in lakes and marine areas.

Ocean-type sockeye. A life history type of sockeye whose juveniles rear in rivers, not lakes, and which migrate to the ocean primarily as sub-yearlings. Ocean-type salmon tend to show genetic differences (e.g., fewer vertebrae) relative to more common *lake-type sockeye.*

Otolith marking. Thermal *marking* of the bone in a salmon's inner ear to distinguish hatchery-reared fish.

Parr.[1] The developmental life stage of salmon and trout between *alevin* and *smolt*, when the young have developed parr marks (vertical bars on their sides) and are actively feeding in freshwater.

PCAD. Program Coordination and Assessment Division (HEB, DFO).

Phenotypic. Relating to the characteristics of an organism produced by its genotype interacting with the environment.

Population. See *Local Population.*

Precautionary management.[2] Management based on the "precautionary principle," as embodied in Principle 15 of the Declaration of the UN Conference on Environment and Development: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Rearing.[1] Refers to the amount of time that juvenile fish spend feeding in nursery areas of rivers, lakes, streams, and estuaries before migration.

Recruitment.[1] The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area.

Reference Point.[2] An estimated value derived from an agreed-upon scientific procedure or model that corresponds to be state of the resource/fishery and that can be used as a guide for fisheries management. Some reference points are general and applicable to many fish stocks, while others are stock-specific. A distinction should be made between *target* reference points and *limit* reference points, or thresholds, the latter representing low states of the stock to be avoided.

Return year. The year in which adult salmon return from the ocean to spawn in the natal stream.

Riparian. The banks of streams, lakes, or rivers.

Riprap.[1] Usually refers to rocks or concrete structures used to stabilize stream or riverbanks from erosion.

River reach.[1] Any defined length of a river.

Run.[1] A group of fish of the same species that migrate together up a stream to spawn, usually associated with the seasons, e.g., fall, spring, summer, and winter runs. Members of a run interbreed, and may be genetically distinguishable from other individuals of the same species.

Salmonid.[1] Fish of the family Salmonidae that includes salmon and steelhead.

SARA. Species at Risk Act.

Sea-entry year. The year in which a juvenile salmon migrates to the ocean.

Seed. A lake is fully seeded when escapement was sufficient to produce enough juveniles to completely utilize the lake's productive capacity. To fully seed a lake is to allow the necessary escapement.

SEP. Salmonid Enhancement Program (DFO).

Side-channel: Small and often ephemeral channels or pools connected to rivers and streams that commonly are relic (old) stream channels. In many situations, side-channels are heavily used by juvenile salmon.

Smolt.[1] Refers to the salmonid or trout developmental life stage between parr and adult, when the juvenile is at least one year old and has adapted to the marine environment.

Spawning.[2] The release of gametes or eggs into the water.

Species.[1] A group of organisms of common ancestry that closely resemble each other structurally and physiologically and that can interbreed, producing fertile offspring.

StAD. Stock Assessment Division (Science Branch, DFO).

Stock.[2] A grouping of one or more Conservation Units whose components behave similarly enough that they can be managed as a single unit, i.e., a Management unit. An alternative definition is that a stock is part of fish population that is under consideration from the point of view of actual or potential utilization.

Straying.[1] A natural phenomena of adult spawners not returning to their natal stream, but entering and spawning in some other stream.

Stream-type salmon. Salmon populations that spend time feeding in streams and rivers before migrating to the ocean, usually after reaching one year of age.

Sub-population.[2] A group of interbreeding organisms that is partially isolated and genetically differentiated from other such groups, and that may be adapted to the local habitat.

Substrate.[1] The composition of a streambed, including either mineral or organic materials.

Supplementation.[1] The release and management of artificially propagated fish in streams with the intent to increase or establish wild fish populations while minimizing associated genetic and ecological risks.

Sustainable use.[2] The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations. Sustainable is not meant to imply that abundance is constant.

Swim-up fry.[1] A salmonid fry that is swimming in the water column in search for food.

Target escapement level.[4] The spawning *escapement* objective set by the fishery management authority for individual stocks of salmon; ideally, target escapement levels are set to ensure *maximum sustainable yield* of the stock.

TCC. Technical Coordination Committee for this recovery plan.

Thermocline. The layer of water in a lake that separates an upper warmer zone ("epilimnion") from a lower colder zone ("hypolimnion").

Upwelling.[1] The movement of nutrient rich waters from the bottom of the ocean to the surface.

Watershed.[1] The area that drains into a stream or river.

Watershed restoration.[1] Improving current conditions of watersheds to restore degraded fish habitat and provide long-term protection to aquatic and riparian resources.

WRP. Watershed Restoration Program (Forest Renewal BC).

Wild population.[2] A local population comprising naturally spawning and rearing wild salmon.

Wild salmon.[2] A salmon produced by natural spawning from parents that were spawned and reared in fish habitat. This definition recognises that wild salmon may continue to exist even after intensive cultivation of a previously wild population. Wild salmon in cultivated populations warrant protection under the Wild Salmon Policy to ensure the long-term viability of populations in natural surroundings. However, the WSP may not afford similar protection to transplanted salmon that now spawn in habitat where the species did not occur naturally.

WSP. Wild Salmon Policy (DFO).

Sources

1. STREAMNET, Northwest Aquatic Information Network, *Glossary of Terms, http://www.streamnet.org/ff/Glossary.*
2. DFO, *Wild Salmon Policy Discussion Paper*, March 2000.
3. Ricklefs, *Ecology*, 1973.
4. DFO, *Pacific Salmon Treaty*, May 1996.
5. Sedell et al., "Role of Refugia in Recovery from Disturbances: Modern Fragmented and Disconnected River Systems," 1990.
6. British Columbia Environmental Assessment Office, *The Salmon Aquaculture Review Final Report*, Volume 1, August 1997.

10. References

Anderson, David (Hon.). 1998. *A New Direction for Canada's Pacific Salmon Fisheries*. Vancouver: DFO, October.

British Columbia. Environmental Assessment Office. 1997. *The Salmon Aquaculture Review Final Report*. Volume 1. Victoria: EAO, August.

Burgner, R.L. 1991. "Life History of Sockeye Salmon (*Oncorhynchus nerka*)." In C. Groot and L. Margolis (ed.), *Pacific Salmon Life Histories*. Vancouver: UBC Press.

Canada. Department of Fisheries and Oceans. 2000. *Wild Salmon Policy Discussion Paper*. Vancouver: DFO, March.

__________. 2000. *1999 Pacific Region State of the Ocean*. DFO Science Ocean Status Report 2000/01. Vancouver: DFO.

__________. 1996. *Pacific Salmon Treaty*. Vancouver: Policy and Communications Branch, May.

__________. 1986. *Policy for the Management of Fish Habitat*. Ottawa: Fish Management Habitat Branch.

Federal-Provincial Habitat Restoration and Salmon Enhancement Working Group. 1998. *Federal-Provincial Framework for Habitat Restoration and Salmon Enhancement in British Columbia*. Vancouver: DFO, September.

Hillaby, J.E. 1998a. *Machmell Watershed Level I Fish Habitat Assessment*. BC Watershed Restoration Report Prepared for Western Forest Products, Campbell River: WFP. July.

__________. 1998b. *Neechanz Watershed Level I Fish Habitat Assessment*. BC Watershed Restoration Report Prepared for Western Forest Products, Campbell River: WFP, July.

__________. 1998c. *Sheemahant Watershed Level I Fish Habitat Assessment*. BC Watershed Restoration Report Prepared for Western Forest Products. Campbell River: WFP, July.

Lorenz, J.M. 1994. *Distribution and Habitat of Adult Salmon in the Situk River Alaska: Potential Impacts of Flooding from Russell Fjord*. US Department of Commerce NOAA Technical Memo. NMFS-AFSC-30. Washington, DC: National Oceanic and Atmospheric Administration.

Lorenz, J.M., and J.H Eiler. 1989. "Spawning Habitat and Redd Characteristics of Sockeye Salmon in the Glacial Taku River, British Columbia and Alaska." *Transactions of the American Fisheries Society*, Vol. 118, pp. 495-502.

Murphy, M.L., J. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989. "Habitat Utilization by Juvenile Pacific Salmon (*Oncorhynchus*) in the Glacial Taku River, Southeast Alaska." *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 46, pp. 1677-1685.

McNicol, R. 2000. *An assessment of Rivers Inlet chinook stocks*. Pacific Scientific Advice Review Committee Working Paper S00-10. Vancouver: PSARC.

Quinn, T.P., C.C. Wood, L. Margolis, B.E. Riddell, and K.D. Hyatt. 1987. "Homing in wild sockeye salmon (*Oncorhynchus nerka*) populations as inferred from differences in parasite prevalence and allozyme allele frequencies." *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 44, pp. 1963-1971.

Rutherford, D.T., and C.C. Wood. 2000. "Trends in abundance and pre-season 2000 stock size forecasts for major sockeye, pink, and chum salmon stocks in the central coast and selected salmon stocks in northern British Columbia." Pacific Science Advice Review Committee Working Paper, S00-01. Nanaimo: PSARC.

Rutherford, D.T., C.C. Wood, and S. McKinnell. 1998. *Rivers Inlet sockeye salmon: stock status update*. Canadian Stock Assessment Secretariat Research Document 98/91. Ottawa: CSAS.

Sedell, J.S., G.H. Reeves, F.R. Hauer, J.A Stanford, and C.P. Hawkins. 1990. "Role of Refugia in Recovery from Disturbances: Modern Fragmented and Disconnected River Systems." *Environmental Management*, Vol. 14, No 5, pp. 711-724.

Shortreed, K.S., J.M.B. Hume, J.G. Stockner. 2000. "Using photosynthetic rates to estimate the juvenile sockeye salmon rearing capacity of British Columbia lakes." In E.E. Knudsen, C.R. Steward, D.D. MacDonald, J.E. Williams, and D.W. Reiser (ed.), *Sustainable Fisheries Management: Pacific Salmon*. Boca Raton: CRC Press.

Stocker, M., and A. MacDonald. 2000. *Report of the PSARC Salmon Subcommittee Meeting, March 7-9, 2000*. CSAS Proceedings Series 2000/03. Nanaimo: PSARC, March.

Stockner, J.G. and C.D. Levings. 1982. "Biological reconnaissance of the Yakoun River estuary, Queen Charlotte Islands, and results of a trial fertilization with urea." *Canadian Technical Report Fisheries and Aquatic Sciences*, No. 1132, 119 p.

Stockner, J.G. and K.D. Hyatt. 1984. Lake fertilization: State of the art after 7 years application. Can. Tech. Rep. Fish. Aquat. Sci. 1329: 33 p.

Stockner, J.G. and K.R.S. Shortreed. 1978. Enhancement of autotrophic production by nutrient additon in a coastal rainforest stream on Vancouver Island. J. Fish. Res. Bd. Can. 35: 28-34.

Wood, C.C., and L.B. Holtby. 1998. "Defining conservation units for Pacific salon using genetic survey data." In B. Harvey, C. Ross, D. Greer, and J. Carolfeld (ed.), *Action before Extinction: Proceedings of an International Conference on Conservation of Fish Genetic Diversity*. World Fisheries Trust conference, February 16-18, 1998, Vancouver. Victoria: WFT.

Wood, C.C., B.E. Riddell, D.T. Rutherford, and R.E. Withler. 1994. "Biochemical genetic survey of sockeye salmon (*Oncorhynchus nerka*) in Canada." *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 51 (Suppl. 1), pp. 114-131.

Appendix A The Recovery Planning Team

The development of this recovery plan was coordinated by a Technical Coordinating Committee drawn from different sectors of DFO's Pacific Region. The background papers (Appendices B, C, and D) were prepared by three working groups of technical experts in the areas of stock assessment and fisheries management, habitat restoration, and enhancement. The composition of these groups and their respective tasks are outlined below.

A.1 Technical Coordination Committee

Members

Blair Holtby (Chair)	Stock Assessment Division (StAD), Science Branch, Nanaimo
Carol Cross	Habitat and Enhancement Branch (HEB), Vancouver
Ron Goruk	Fisheries Management, Prince Rupert
Sandie MacLaurin	HEB, Bella Coola
Rick McNicol	StAD, Vancouver
Brian Pearce	HEB, Vancouver
Chris Picard	HEB, Prince Rupert
Dennis Rutherford	StAD, Nanaimo
Kristen Smith	AFS, Port Hardy
Garry Taccogna	HEB, Vancouver
Chris Wood	StAD, Nanaimo

Specific tasks

1. Coordinate and review the work of the three working groups.
2. Prepare the recovery plan with input from the working groups.

A.2 Stock Assessment and Fisheries Management Working Group

Members

Dennis Rutherford	StAD, Nanaimo.
Rick McNicol	StAD, Vancouver
Chris Wood	StAD, Nanaimo
Ron Goruk	Fisheries Management, Prince Rupert
Dan Ware	StAD, Nanaimo
Ron Tanasichuk	StAD, Nanaimo

Specific tasks

1. Provide a description of stock status.
2. Provide a forecast for returns in 2000 through 2003.
3. Summarize the current understanding of reasons for the survival trends.
4. Develop decision rules for intervention.
5. Prepare a discussion paper presenting the above.

A.3 Habitat Working Group

Members

Russ Hilland	HEB, Snootli Hatchery, Bella Coola
Brad Koroluk	HEB, Bella Coola
Wayne Krause	HEB, Vancouver
Herb Langin	Ministry of Environment Lands and Parks, Williams Lake
Sandie MacLaurin	HEB, Bella Coola
Wayne Peterson	HEB, Vancouver
Chris Picard	HEB, Prince Rupert
Chuck Rown	Ministry of Forests, Nanaimo
Gary Taccongna	HEB, Vancouver
Nick Winfield	HEB, Vancouver

Specific Tasks

1. Describe habitat status in the Owikeno Lake and Long Lake watersheds
2. Describe habitat impacts in the watersheds
3. Describe proposed land use developments that may impact habitat in the watersheds.
4. Propose potential habitat restoration and protection options.
5. Identify information gaps.
6. Prepare a discussion paper presenting the above.

A.4 Enhancement Working Group

Members

Don Bailey	Program Coordination and Assessment Division (PCAD)
Russ Hilland	HEB, Salmonid Enhancement Program (SEP) Operations
Dorothy Kieser	Fish Health
Don MacKinlay	HEB, Lake Enrichment
Sandie MacLaurin	HEB, Community Involvement
Ken Shortreed	Science Branch, Cultus Lake Laboratory
Gary Taccogna	Group Leader, HEB, RRD
Chris Wood	StAD

Additional resource people:

Brian Anderson	HEB, SEP Operations
Greg Bonnell	PCAD
Doug Lofthouse	HEB, SEP Operations

Specific tasks

1. Review available biophysical information to assist the selection of candidate stocks for strategic enhancement.
2. Summarize enhancement objectives and guidelines.
3. Summarize enhancement strategies that could be employed in a sockeye recovery plan.
4. Recommend enhancement options for consideration.
5. Prepare a background paper presenting the above.

Appendix B Assessment and Fisheries Management Background Paper

This document has been prepared by the Stock Assessment and Fisheries Management Working Group, in response to a request from the Rivers and Smith Inlet Technical Coordinating Committee (TCC) for a background document dealing with the assessment and management of Statistical Areas 9 and 10 sockeye salmon. It is required to aid and guide the TCC in developing recovery options.

The paper is organized into three sections. Section B.1 is a summary of assessment data, stock status, and the future outlook for Rivers and Smith Inlet sockeye. Section B.2 outlines proposed fisheries management actions for 2000 and beyond. Some supporting information is attached in Section B.3.

B.1 Summary of assessment data, stock status, and outlook for Rivers and Smith Inlet sockeye salmon

The Rivers and Smith Inlet sockeye salmon stocks have received a great deal of attention recently due to a dramatic decline in total abundance. The decline of sockeye in Rivers Inlet led to total closure of the commercial fishery in 1996 and culminated in a record low escapement estimate of only 3,600 sockeye salmon in 1999. Similarly, in neighboring Smith Inlet, the commercial fishery has been closed since 1997 and a record low escapement of only 5,900 sockeye was recorded in 1999. Escapements rebounded slightly in 2000 and 2001 in Rivers Inlet (21,100; 24,500) and in 2001 in Smith Inlet (8,450), however remain well below historical norms.

Comprehensive assessments of Rivers and Smith Inlet sockeye were last reviewed by the Pacific Scientific Advice Review Committee (PSARC) in 1998 (Rutherford et al. 1998) and 1995 (Rutherford and Wood 1995), respectively. This summary document incorporates information from the PSARC working papers, as well as updated information collected from ongoing assessment programs.

Almost all sockeye production from Rivers Inlet (Area 9) originates from spawning areas associated with Owikeno Lake. Spawning occurs in 10 tributaries feeding Owikeno Lake, along the lakeshore, and in the outlet river. Some sockeye have also been observed in the Chuckwalla/Kilbella River system, suggesting that there may also be some ocean-type sockeye stocks in Rivers Inlet tributaries. All sockeye production from Smith Inlet (Area 10) originates from spawning areas associated with Long Lake. Spawning occurs in the Smokehouse River and Canoe Creek that feed into Long Lake.

B.1.1 Data sources

<u>Adult escapement</u>

The glacial turbidity of Owikeno Lake and its major spawning streams precludes the reliable estimation of spawning escapement by visual survey (Walters et al. 1993, Rutherford et al. 1998). Nevertheless, estimates of sockeye salmon spawning escapements to Area 9 are recorded for the years 1948-1999. DFO's Stock Assessment Division (StAD) currently uses "area under the curve" (AUC) procedures to estimate escapement to the clear water streams that are foot or jet boat accessible. These clear streams include the Ashlum, Dallery, Genesee, Inziana, and Washwash rivers. An overall sockeye escapement index for Owikeno Lake in 1999 was calculated and expressed in units comparable to the total escapements reported in previous years. Previous estimates of total escapement (for the period 1948-1996) were regressed on the total of the clear stream escapement estimates. The resulting equation y=2.998x, was then used to generate a comparable total escapement index for Owikeno Lake in 1999. Fisheries management partitions the total escapement index, less the clear stream index, among the remaining non-surveyed streams in Owikeno Lake and reports these estimates in the BC16 database. However, such partitioning is considered too unreliable for assessment purposes.

In contrast to Owikeno Lake, reliable estimates of total sockeye escapement have been obtained for Smith Inlet (Long Lake) since 1972. Commencing in 1972, sockeye escapements to Long Lake have been enumerated through the Docee River counting fence located at the outlet of Long Lake. Prior to 1972, sockeye escapements to Long Lake were estimated from visual surveys of the two major spawning tributaries, the Smokehouse River and Canoe Creek, except for the years 1963, 1968, 1970, and 1972, where a count of sockeye entering Long Lake was conducted from a tower located on the Docee River. To conform to the BC16 database, the Docee River sockeye fence count for a given year is arbitrarily partitioned as follows: 75% of the total sockeye count is reported as Smokehouse escapement, and the remaining 25% is reported as Canoe Creek escapement. However, visual surveys of Smokehouse River and Canoe Creek have not been carried out since the establishment of the Docee Fence.

Catch

The commercial catch estimates used in the assessment of Rivers Inlet (Area 9) and Smith Inlet (Area 10) are from the Regional Catch Database. Catch data are considered reliable because of the early timing of these stocks into the terminal areas and because fisheries tend to occur in the terminal areas. First Nation catch is from records maintained by the Bella Coola fisheries office.

Age composition

Age composition data are collected from the escapement assessment programs in Owikeno Lake and Docee River. All data collected from the various spawning sites in Owikeno Lake within a given year are pooled to estimate overall age composition of the escapement. Age data collected at the Docee Fence are weighted by run size through the Docee Fence to estimate overall age composition of the escapement. Age composition data from the commercial fishery are collected through the Charter Patrol Program.

Total returns

Estimates of total stock size and total returns by brood year for Owikeno Lake are unreliable. Although catch is known reliably, total escapement to Owikeno Lake is measured as an approximate (and probably unreliable) index of escapement. In contrast, total stock size for Long Lake since 1972 is considered reliable because both catch and escapement are measured in comparable absolute units.

Juvenile abundance

Within Owikeno Lake, juvenile abundance is measured by night-time surface trawling using the standardized methods described by Wood and Schutz (1970) to index abundance. For years in which surface trawling was not carried out, juvenile abundance indices have been inferred from either pre-smolt weight or freshwater scale growth (McKinnell et al., 2001). Indices of juvenile abundance were converted to absolute pre-smolt abundance using swept area calculations, in order to evaluate trends in pre-smolt biomass and freshwater survival rates.

Within Long Lake, juvenile abundance is measured using hydroacoustic and trawl techniques. These estimates are available from StAD for most in-lake years from 1976 to 1998 (K. Hyatt, Pacific Biological Station, pers. comm.).

Marine survival indices for both Owikeno and Long lakes were estimated using juvenile and brood year return data as follows:

marine survival index = brood year returns/juvenile index

B.1.2 Status of stocks

Escapement trends

An overall increasing trend in the total sockeye escapement index for Area 9 occurred from 1948 through 1993 (Table 1, Figure B.1). However, a dramatic drop in escapement was observed in 1994 and the decline has continued with the exception of 1997, when the escapement was estimated to be slightly above the 200,000 target (275,000). In 1999, sockeye escapement fell to a record low of only 3,600 sockeye.

Similarly, total sockeye escapement to Area 10 increased from 1972 to 1993, then dropped dramatically in 1994, and the decline has continued (Table 2, Figure B.1). Sockeye escapement fell to record lows of only 5,900 fish in 1999 and 1430 in 2000. Sockeye escapements in 1994–1998 were low, but always above the 1979 count of 20,257 sockeye.

Total returns by brood year for both Rivers and Smith Inlet sockeye have shown the same dramatic decline since brood years 1989-1990 (Tables 3 and 4).

Catch trends

Area 9 sockeye catch was variable and without trend for most of the first half of the twentieth century, although some outstandingly high catches were recorded in 1968 and 1973 (2,727,552 and 1,760,156 respectively). Beginning in the early to mid-1970s, the average catch declined significantly. An adaptive management plan implemented in 1979 restricted commercial catch from 1979 through 1988 (Walters et al. 1993). Commercial catch continued to decline and the fishery has been closed since 1996. Area 10 commercial sockeye catch has been variable, but has shown a general increasing trend from 1972 to 1993. Catches in 1994-1996 were poor and the fishery has been closed since 1997.

Survival and juvenile abundance trends

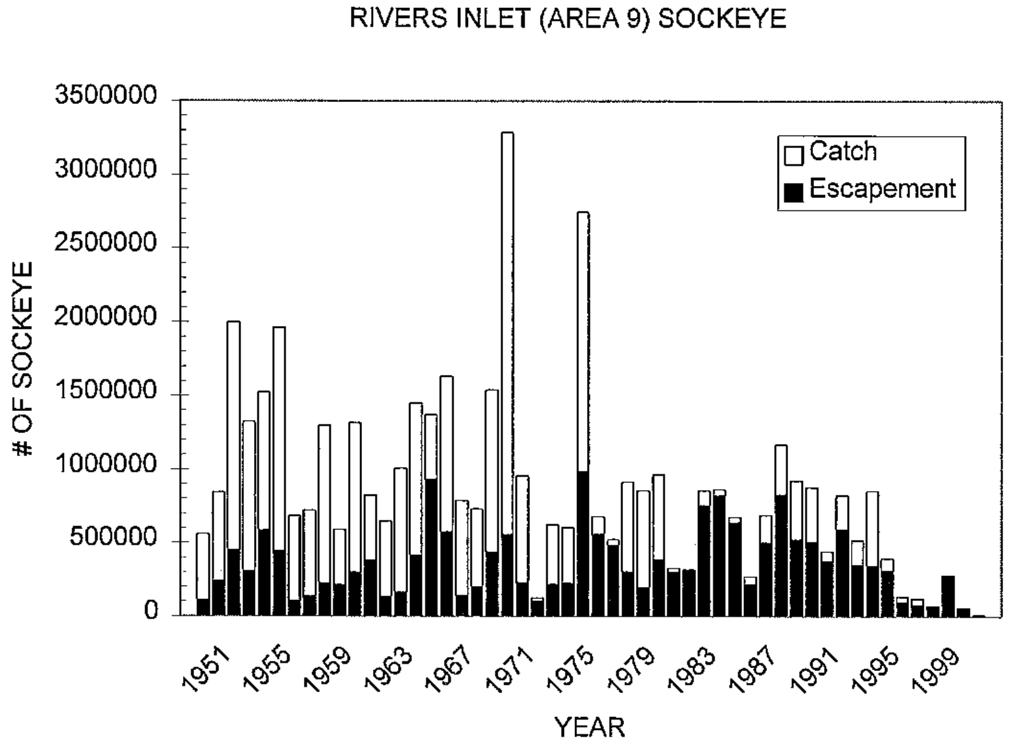
The freshwater and marine survival indices for Owikeno Lake must be considered as crude indications of relative survival. Both indices are the ratio of measurements that may be biased or imprecise. For example, the total escapement estimate for Owikeno Lake is calculated as approximately three times the clear stream estimate. Because the historical estimates of escapement to the glacial systems are highly uncertain, the expansion factor and the estimate of total escapement are both highly uncertain. The estimate of total escapement may be reasonable for low escapements, but may underestimate true abundance at high density (i.e., historically). Similarly, juvenile abundance is determined by trawling in the surface (top 1m) layer. Although this provides a reasonably consistent index for monitoring trends in abundance, absolute abundance and hence freshwater survival will be underestimated to the extent that some juveniles occur deeper in the water column and either are not vulnerable to capture or simply evade the net.

These measurement problems are reduced for Long Lake where the escapement is counted through a fence, and juvenile abundance is determined hydroacoustically. In general, hydroacoustic surveys tend to underestimate juvenile fish abundance, and in Long Lake, there are additional problems obtaining separate estimates for sockeye and sticklebacks that occur

Table 1. Catch, escapement, and total stock for Area 9 sockeye salmon, 1948-1999.

Year	Catch	Esc	Total Stock
1948	451727	105273	557000
1949	603120	236880	840000
1950	1549338	444662	1994000
1951	1016495	304500	1320995
1952	938722	582500	1521222
1953	1522285	440000	1962285
1954	575664	103800	679464
1955	584245	132900	717145
1956	1072332	223500	1295832
1957	373976	212900	586876
1958	1017545	296750	1314295
1959	439419	380500	819919
1960	516503	128800	645303
1961	842953	161850	1004803
1962	1035917	413500	1449417
1963	437459	932500	1369959
1964	1053591	573900	1627491
1965	644974	140150	785124
1966	528212	200000	728212
1967	1102838	435250	1538088
1968	2727552	555000	3282552
1969	727330	226000	953330
1970	19019	102250	121269
1971	402538	215900	618438
1972	379006	224000	603006
1973	1760156	985000	2745156
1974	118574	557025	675599
1975	40631	480002	520633
1976	613067	300000	913067
1977	659819	192600	852419
1978	577908	383000	960908
1979	28328	297525	325853
1980	528	313000	313528
1981	98706	753075	851781
1982	39180	823000	862180
1983	35161	636502	671663
1984	53879	214301	268180
1985	184543	500430	684973
1986	337443	825626	1163069
1987	398854	521700	920554
1988	372018	503000	875018
1989	63746	375175	438921
1990	234281	586500	820781
1991	168226	346500	514726
1992	508068	343005	851073
1993	82529	311000	393529
1994	40139	91500	131639
1995	45426	73000	118426
1996	2697[a]	65000	67697
1997	1894[a]	275000	276894
1998	2161[a]	52000	54161
1999	657[a]	3600	4257

[a] First Nation catch only



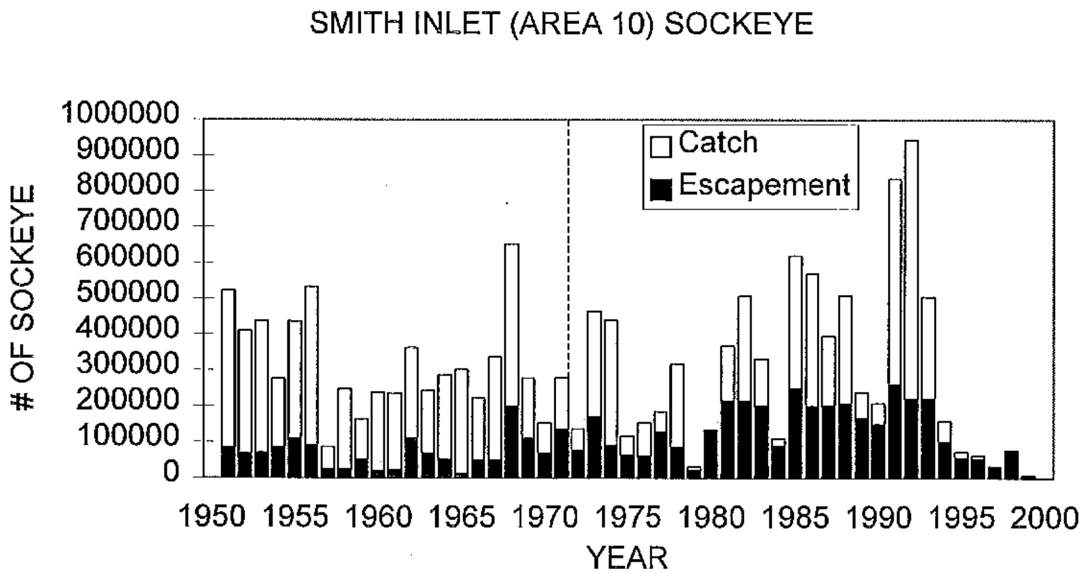


Figure B.1. Catch, escapement, and total stock size for Rivers Inlet and Smith inlet sockeye by calendar year. Dotted vertical line on Smith Inlet frame indicate start of the Docee Fence operation.

Table 2. Catch, escapement, and total stock for Area 10 sockeye salmon, 1951-1999.

Year	Catch	Escapement	Total Stock
1950			
1951	439095	82500	521595
1952	342243	67500	409743
1953	367070	70000	437070
1954	190760	85000	275760
1955	325478	110000	435478
1956	442256	90000	532256
1957	63647	22575	86222
1958	223702	22575	246277
1959	113329	50000	163329
1960	219341	18525	237866
1961	213277	22525	235802
1962	252058	110075	362133
1963	174996	68686	243682
1964	236432	50200	286632
1965	289821	11000	300821
1966	172091	50000	222091
1967	286000	50000	336000
1968	454106	197930	652036
1969	166998	110200	277198
1970	82677	70065	152742
1971	142955	135068	278023
1972	59397	76248	135645
1973	294619	169753	464372
1974	347705	91013	438718
1975	52673	62967	115640
1976	92201	60919	153120
1977	54855	128601	183456
1978	233381	84105	317486
1979	11022	20257	31279
1980	2349	129435	131784
1981	154355	214345	368700
1982	292958	213674	506632
1983	131212	199653	330865
1984	21160	89012	110172
1985	369178	250000	619178
1986	369854	199000	568854
1987	194926	200000	394926
1988	301731	207000	508731
1989	71821	166810	238631
1990	58579	149000	207579
1991	574550	260000	834550
1992	722816	220000	942816
1993	284156	220000	504156
1994	57830	100000	157830
1995	15944	56244	72188
1996	7918	54000	61918
1997	0	32000	32000
1998	170[a]	76000	76000
1999	0	5900	5900

[a] First Nation catch only

Table 3. Escapement, total returns and age composition, by brood year for Area 9 sockeye salmon.

Brood Year	Escapement	Total Return	Proportion returning at Age 4	Proportion returning at Age 5
1948	105273	1153518	0.54	0.46
1949	236880	1704254	0.84	0.16
1950	444662	809280	0.50	0.50
1951	304500	1514881	0.21	0.79
1952	582500	334990	0.39	0.61
1953	440000	1314619	0.29	0.71
1954	103800	1015739	0.36	0.64
1955	132900	523607	0.30	0.70
1956	223500	776379	0.32	0.68
1957	212900	750798	0.62	0.38
1958	296750	1898856	0.61	0.39
1959	380500	1926026	0.31	0.69
1960	128800	469674	0.44	0.56
1961	161850	954824	0.52	0.48
1962	413500	745310	0.35	0.65
1963	932500	3988610	0.26	0.74
1964	573900	811310	0.28	0.72
1965	140150	394110	0.85	0.15
1966	200000	188589	0.26	0.74
1967	435250	667900	0.70	0.30
1968	555000	2943810	0.12	0.88
1969	226000	691677	0.24	0.76
1970	102250	399093	0.32	0.68
1971	215900	710362	0.34	0.66
1972	224000	889448	0.48	0.52
1973	985000	1282148	0.29	0.71
1974	557025	168206	0.21	0.79
1975	480002	445964	0.42	0.58
1976	300000	606957	0.09	0.91
1977	192600	1022459	0.28	0.72
1978	383000	640792	0.16	0.84
1979	297525	223059	0.57	0.43
1980	313000	682493	0.25	0.75
1981	753075	1083199	0.16	0.84
1982	823000	940301	0.27	0.73
1983	636502	1002406	0.21	0.79
1984	214301	291045	0.30	0.70
1985	500430	952561	0.25	0.75
1986	825626	426956	0.23	0.77
1987	521700	896819	0.20	0.80
1988	503000	411050	0.25	0.75
1989	375175	186187	0.45	0.55
1990	586500	124604	0.21	0.79
1991	346500	56159	0.36	0.64
1992	343005	259006	0.11	0.89
1993	311000	90772	0.43	0.57
1994	91500	4380	0.49	0.51
1995	73000	2043[a]		
1996	65000			
1997	275000			
1998	52000			
1999	3600			

[a] partial return, only includes those fish from the 1995 brood that matured at 4 years.

Table 4. Escapement, total returns and age composition, by brood year for Area 10 sockeye salmon.

Year	Escapement	Total Return	Proportion returning at Age 4	Age 5
1950				
1951	82500			
1952	67500			
1953	70000			
1954	85000			
1955	110000			
1956	90000			
1957	22575			
1958	22575			
1959	50000			
1960	18525			
1961	22525			
1962	110075			
1963	68686			
1964	50200			
1965	11000			
1966	50000			
1967	50000			
1968	197930			
1969	110200			
1970	70065			
1971	135068			
1972	76248			
1973	169753	442532	0.31	0.69
1974	91013			
1975	62967			
1976	60919	167604	0.18	0.82
1977	128601	666512	0.34	0.66
1978	84105			
1979	20257			
1980	129435	193274		
1981	214345	876389	0.56	0.44
1982	213674	471087	0.38	0.62
1983	199653	427436	0.21	0.79
1984	89012	290781	0.59	0.41
1985	250000	231186	0.51	0.49
1986	199000	587994	0.16	0.84
1987	200000	1173692	0.29	0.71
1988	207000	456103	0.22	0.78
1989	166810	256400	0.55	0.45
1990	149000	101784	0.40	0.60
1991	260000	41095	0.26	0.74
1992	220000	56675	0.55	0.45
1993	220000	78000	0.08	0.92
1994	100000	6941	0.44	0.56
1995	56244	1652[a]		
1996	54000			
1997	32000			
1998	76000			
1999	5900			

[a] Partial return, only includes those fish from the 1995 brood that matured at age 4.

together in the limnetic zone. Nevertheless, marine survival indices for Owikeno and Long Lake sockeye indicate that marine survival has been extremely poor for all brood years entering the ocean since 1991 (Figure B.2).

For the period up to and including 1994, there are no indications that sockeye pre-smolt biomass declined in either Owikeno or Long Lake (Figure B.3). This suggests that low pre-smolt biomass was not the cause of the recent low escapements. Since 1994, however, low escapement has led to below- average pre-smolt biomass. Biomass estimates are below the maximum carrying capacity suggested by the PR model in Shortreed et al. (2000), which is based on photosynthetic rate (Figure B.3). However, juvenile census techniques likely underestimate the true abundance of pre-smolts in Owikeno and Long lakes.

Historically, estimates of egg to pre-smolt survival ranged from <1% to 12% for Owikeno Lake, and no obvious change in egg to pre-smolt survival rates were evident prior to 1980 (mean 0.27) and post-1980 (mean 0.28) (Figure B.4). Given the uncertainty in measuring absolute abundance, it is somewhat surprising that calculated egg deposition to pre-smolt survival rates are in the same order of magnitude as those expected for typical coastal sockeye lakes (Foerster 1968). Egg to pre-smolt survival rates for Long Lake are also within the same range.

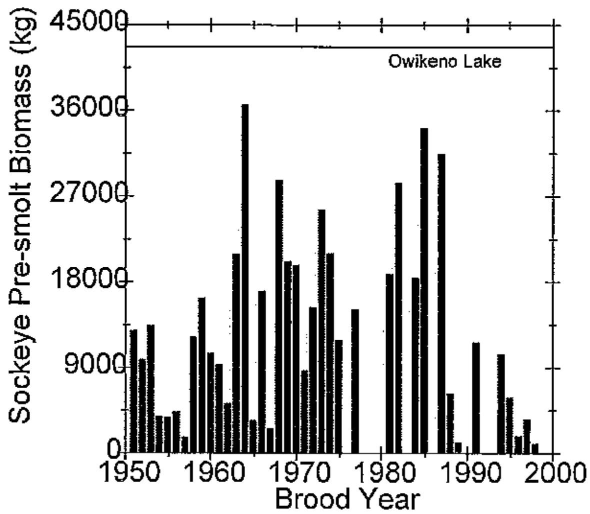
B.1.3 Outlook

Projected returns in 2000 were calculated assuming two different scenarios; (1) a pessimistic scenario which assumes that the poor survival rate measured for 1996 sea-entry (1994 brood) will continue for sea-entry years 1997 and 1998; and (2) a more optimistic scenario that took into account the observed poor survival for sea-entry year 1997, but assumed average age at maturation and average smolt survival for sea-entry year 1998 (Rutherford and Wood 2000) Under the optimistic scenario, returns to both Owikeno and Long Lake in 2000 were expected to be above levels that raise conservation concerns. Conversely, under the pessimistic scenario, returns in 2000 were forecast to be well below conservation limits, actual returns were below the Limit Reference Point for both Owikeno and Long Lake. Projected returns in 2001 through 2004 were also calculated using the two different scenarios. Again, the pessimistic scenario was calculated assuming that the poor survival measures for the 1996 sea-entry year would continue. The optimistic scenario assumed average survivals; actual returns reflected the pessimistic scenario. The adverse effects of recent low escapements are expected to build up by 2004, resulting in very few returns (Table 5).

Based on the "average" sibling/smolt model, PSARC forecasted stock size for Owikeno and Long Lake sockeye in 2000 at 66,000 and 41,000, respectively, with a 25% chance that the return will be less. However, the pessimistic forecasts of 2,200 and 3,900 sockeye for Owikeno and Long Lake, respectively, are recommended for management decisions under the precautionary approach (Rutherford and Wood 2000; Stocker and MacDonald 2000).[12]

We have no information on early marine survival for these sockeye stocks in sea-entry year 1998, and therefore have no basis for choosing between optimistic or pessimistic survival. Environmental indicators have suggested that the marine survival of smolts entering the ocean in 1998 was below average, but we are unsure how much weight to put on this indicator since it predicted above-average survival for sea-entry year 1997 (see Section B.3.2). Very few 4-year-old sockeye from sea-entry year 1997 returned in 1999, suggesting that marine survival for this brood was poor (assuming average age at maturation). The reasons for the variability in the marine survival of these sockeye stocks are unknown at this time.

[12] See also Section B.3.2.



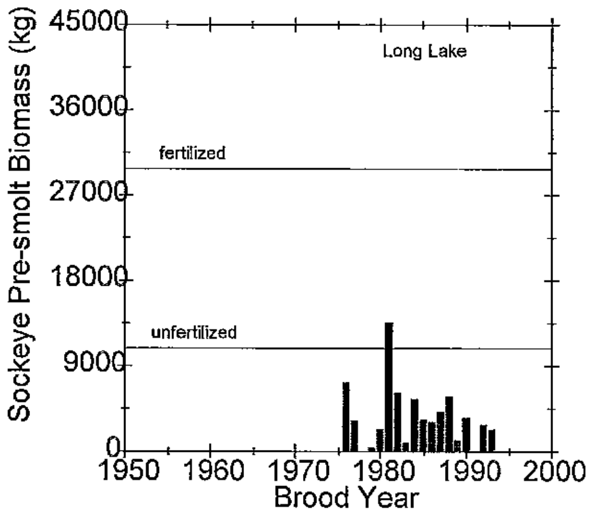


Figure B.3. Biomass of Owikeno and Long Lake sockeye pre-smolts. Horizontal lines indicate estimated maximum biomass using the PR model (Shortreed et al. 2000).

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[12] See also Section B.3.2.

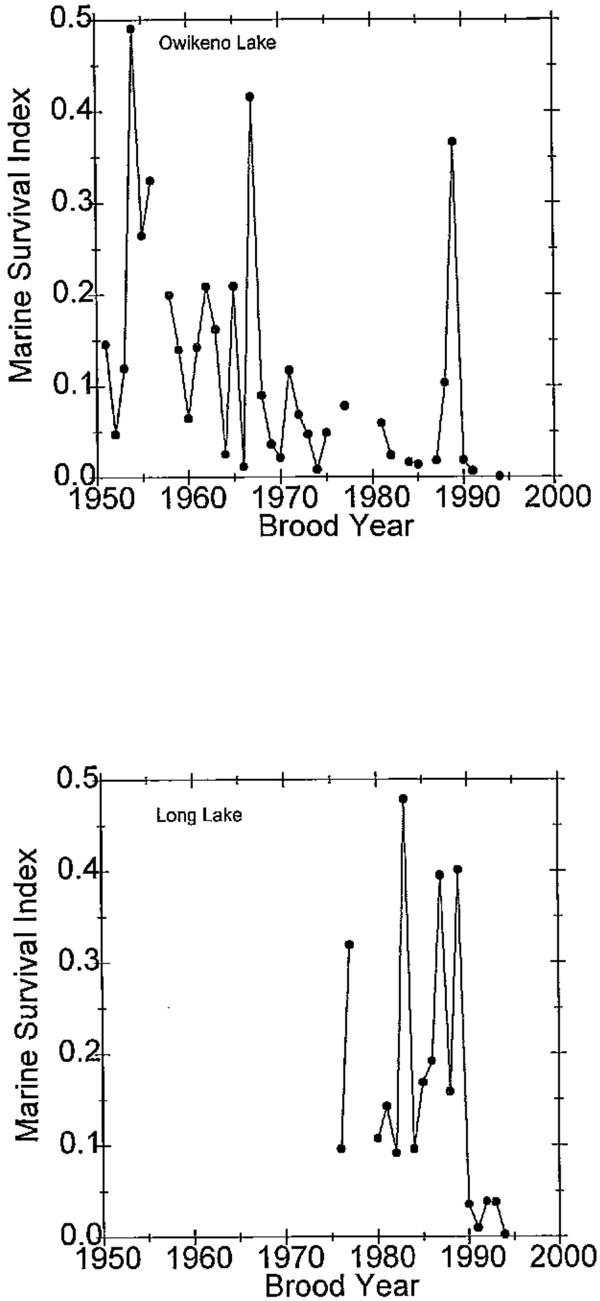
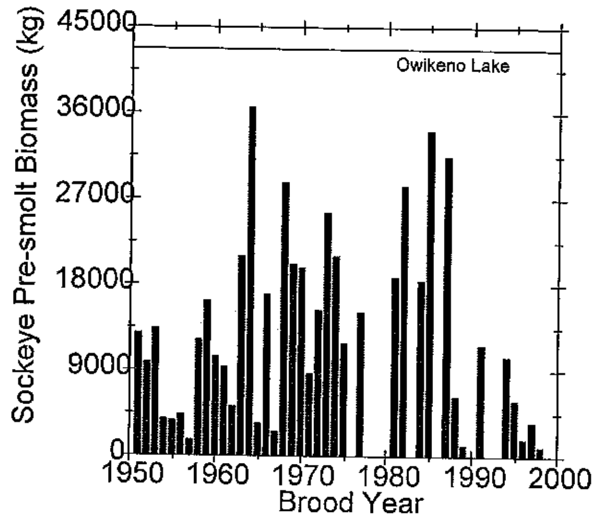


Figure B.2. Marine survival trends for Owikeno and Long Lake sockeye.



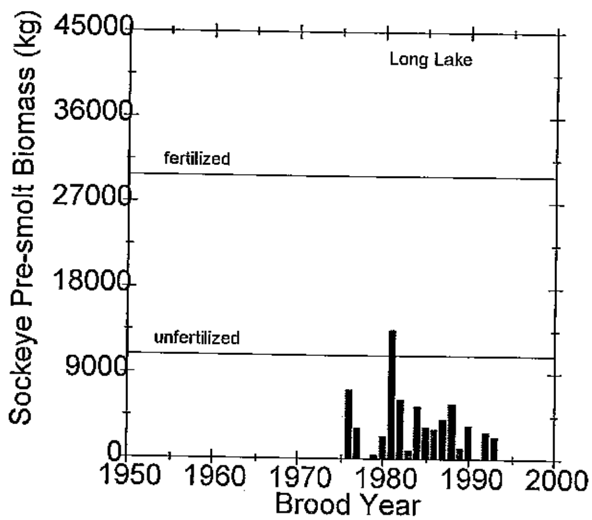


Figure B.3. Biomass of Owikeno and Long Lake sockeye pre-smolts. Horizontal lines indicate estimated maximum biomass using the PR model (Shortreed et al. 2000).

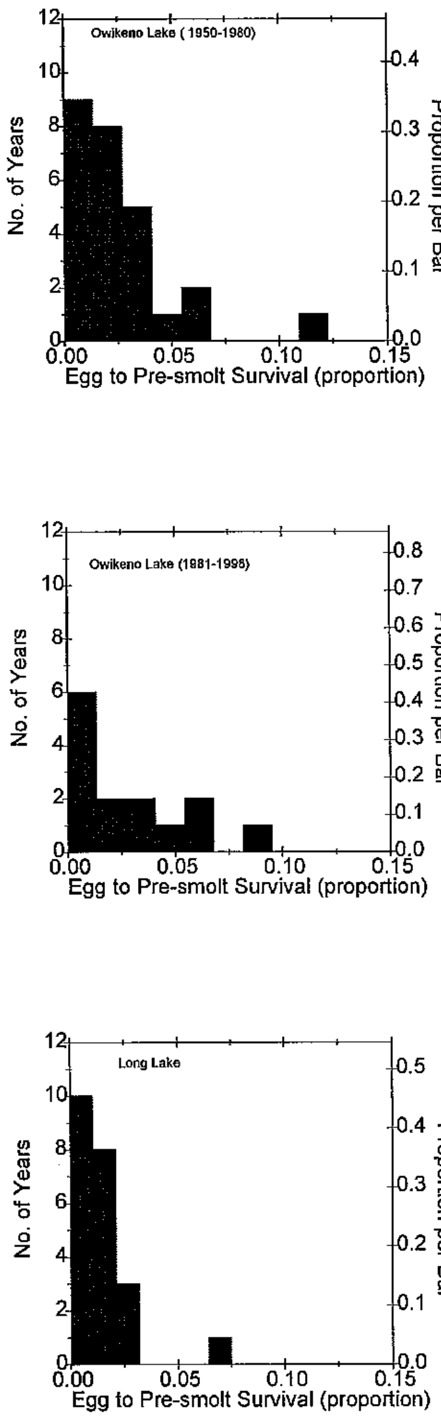


Figure B.4. Egg to pre-smolt survivals for Owikeno and Long Lake sockeye.

Table 5. Projected returns to Owikeno and Long Lake based on pessimistic and optimistic survival rates.

OWIKENO LAKE

Scenerio	Brood Year	Escapement	Sockeye Returns in Calendar Year 2000	2001	2002	2003	2004
Pessimistic	1995	73000	2084				
	1996	65000	143	2009			
	1997	275000		4667	8498		
	1998	52000			882	1607	
	1999	3600				61	111
	2000						37
	Combined		**2,227**	**6,676**	**9,380**	**1,668**	**148**
Optimistic	1995	73000	11592				
	1996	65000	112322	204971			
	1997	275000		297072	540950		
	1998	52000			56174	102289	
	1999	3600				3889	7082
	2000						150690
	Combined		**141,893**	**502,043**	**597,124**	**106,178**	**157,772**

LONG LAKE

Scenerio	Brood Year	Escapement	Sockeye Returns in Calendar Year 2000	2001	2002	2003	2004
Pessimistic	1995	56244	2111				
	1996	54000	1811	2353			
	1997	32000		824	1394		
	1998	76000			1964	3311	
	1999	5900				152	257
	2000						101
	Combined		**3,922**	**3,177**	**3,358**	**3,463**	**358**
Optimistic	1995	56244	6750				
	1996	54000	72940	123029			
	1997	32000		34107	57521		
	1998	76000			81003	136612	
	1999	5900				6288	10605
	2000						97617
	Combined		**91,596**	**157,136**	**138,524**	**142,900**	**108,222**

B.1.4 Conclusions

All available data indicate that the recent declines, including the 1999 poor sockeye returns to both Owikeno and Long lakes resulted from poor marine survival, not a failure in freshwater production. However, the declining escapements have now resulted in reduced fry recruitment in recent years. The conservation measures (commercial fishery closure) implemented for Rivers Inlet and Smith Inlet since 1996 and 1997, respectively, will probably not be sufficient to maintain these stocks, if marine survival continues to be poor through 2006. Further conservation measures may be needed to ensure the continued viability of the two Conservation Units during the current adverse ocean conditions.

Our assessment and understanding of Owikeno Lake sockeye production is still limited primarily by the unknown precision and reliability of the adult escapement estimates. The reinstatement of the juvenile trawl program has addressed some of the uncertainties of using escapement and total stock data to monitor long term trends in sockeye production for Owikeno Lake. The juvenile abundance index for brood year 1994 was above the long-term mean, suggesting that freshwater production potential has not declined from historic levels.

The sockeye stock of Long Lake has also declined to a record low level. Our assessment of Long Lake sockeye is more definitive than that for Owikeno Lake sockeye because of the reliability of the escapement estimates. We can be more certain that the decline in escapement has been due to very poor marine survival.

B.2 Proposed fisheries management actions for 2000

The sockeye counts at the Docee Fence will continue to be used as an indicator of abundance for both the Owikeno and Long Lake sockeye stocks, as outlined in the proposed fishing plans contained in *Pacific Region Integrated Fisheries Management Plan Salmon Coastal B.C. North 2000.*[13] Should the fence count indicate that there is a harvestable surplus of Long Lake sockeye, outer Smith Inlet (sub-area 10-3) will remain closed to conserve Owikeno Lake sockeye.

The gillnet commercial fishery starting July 3, 2000 in Lower Fitzhugh Sound has been modified from the original plan presented at the Central Coast Advisory Board in December 1999. These changes are in place to reduce the possibility of intercepting Owikeno and Long Lake sockeye migrating through Hakai Pass. Currently, the southern boundary has been moved north of Hakai Pass for the duration of this fishery. In addition, a minimum mesh restriction of 149mm (approx. 5- 7/8") will be enforced for the duration of this fishery to further reduce any incidental sockeye catch. The seine commercial fishery is scheduled to start July 24, 2000, and will adopt the same boundaries as the gillnet fishery, reducing the potential for intercepting Owikeno and Long Lake sockeye migrating through Hakai Pass.

First Nations in the area have been asked to forego any harvest of Owikeno and Long Lake sockeye for food, social, and ceremonial purposes. Alternate arrangements for sockeye are being negotiated.

[13] Available from DFO's Communications Branch in Vancouver.

B.3 Attachments

B.3.1 Marine survival of Long Lake sockeye salmon (Area 10)

Daniel Ware
DFO, Pacific Biological Station
3 March 2000

DATA. A marine survival index is available for 17 Long Lake sockeye brood years (1976 to 1994). It is important to note that all of these brood years went to sea during the current ocean climate regime, which has persisted since 1977. For reasons that are not understood at this time, four of the 17 brood years (23.5%) had anomalously high survival indices (> 0.3). If history repeats itself, there is a 23.5% chance that the Long lake sockeye marine survival index will be greater than 0.3 in 2000 (Figure B.5).

For the remaining 76.5% of the brood years, there was a highly significant decline in marine survival, with increasing sea surface salinity in the month of June around McInnes Island (Fig. B.6):

$$\text{Marine survival index} = 1.854 - 0.0572 * \text{JuneSSS}$$
$$r = 0.75,\ n=13,\ p=0.003$$

Where JuneSSS is the average sea surface salinity in June at McInnes Island (Figure B.7). This correlation is suggestive from a biological perspective because Long Lake sockeye smolts enter the ocean in May (out-migration peaks about May 24), and are believed to migrate northward along the coast. Consequently, ocean conditions around McInnes Island should reflect the environment that Long Lake sockeye smolts experience during their first month or two of sea life. Marine survival in this stock is also negatively correlated with sea surface temperatures in May and June around Egg Island (the point of sea-entry) and McInnes Island. However, the correlation with salinity is the strongest. There was no obvious correlation between marine survival and pre-smolt body weight in the data set.

IMPLICATIONS. The relationship shown in Figure B.7 can be used to estimate a marine survival index. The observed sea surface salinity's in June 1997, 1998, and 1999 suggest that the brood years that went to sea in 1997 and 1999 could have average survival rates, while survival for the 1996 brood year could be well below average.

Brood Year	Sea Entry	Return Year	June SSS at McInnes Island in the year of sea-entry	Estimated Survival Index
1994	1996	1998 & 1999	31.20	0.070
1995	1997	1999 & 2000	29.75	0.153
1996	1998	2000 & 2001	31.01	0.081
1997	1999	2001 & 2002	29.92	0.143

RISKS. The forecasting potential of the relationship shown in Figure B.7 is unproven. Therefore, there is a risk that the forecasts will not be accurate. On the other hand, the forecasts derived from Figure B.7 recognize that sockeye marine survival rates vary across years in response to changes in the state of the ocean. *It is important to note that upwelling-favorable winds were at a record high level in June 1998.* This was such an anomalous year that it is unclear what effect, if any, these extreme wind conditions may have on the marine survival of the 1996 brood year.

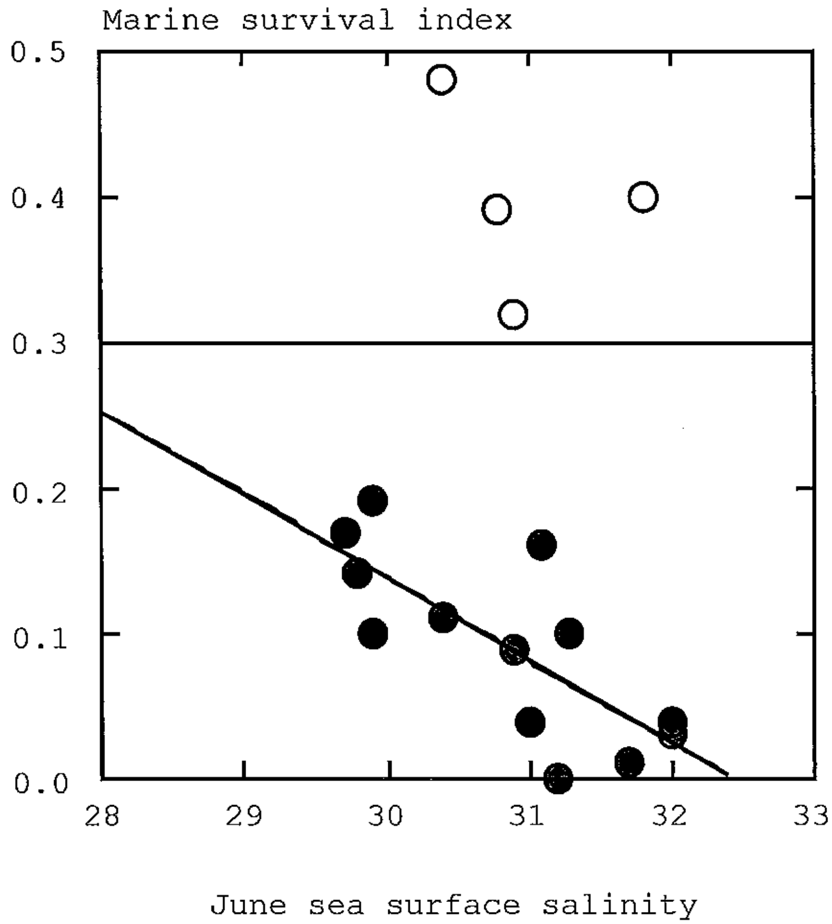


Figure B.5. Area 10 (Long Lake) sockeye marine survival index (by brood year) with respect to the average June sea-surface salinity at McInnes Island. The four brood years with the highest survival are considered anomalous.

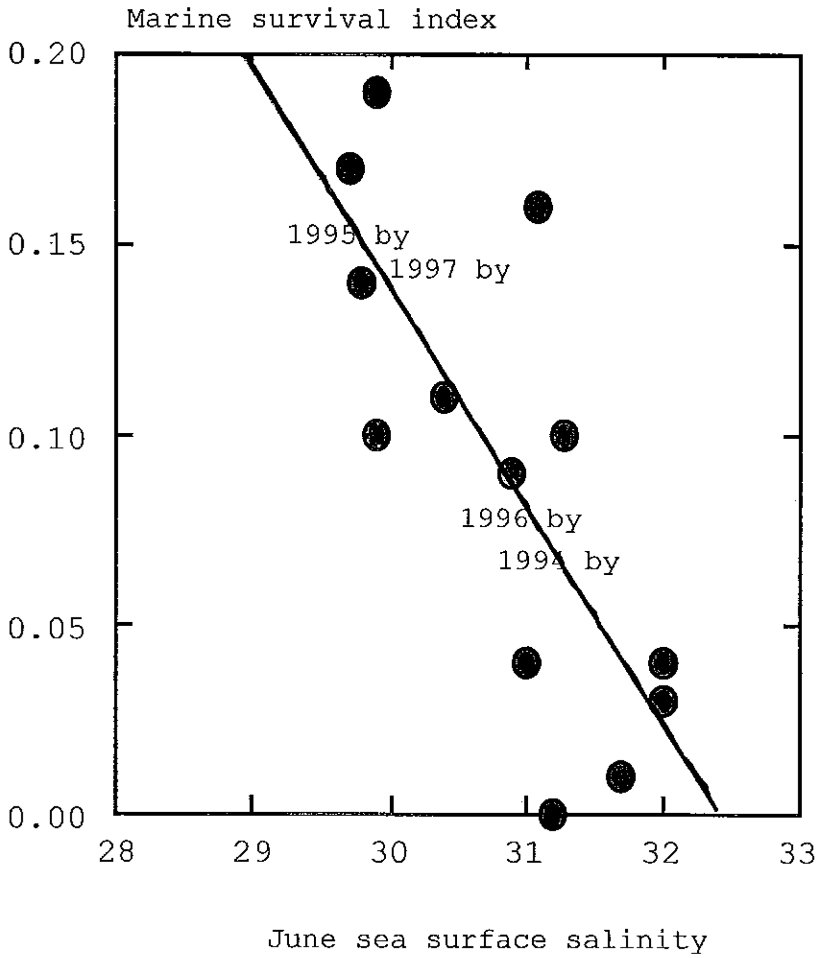


Figure B.6. Relationship between Long Lake sockeye marine survival index and June sea surface salinity at McInnes Island for the subset of brood years indicated by the solid circles in Figure B.5. The expected marine survival indices for brood years 1994 to 1997 are indicated.

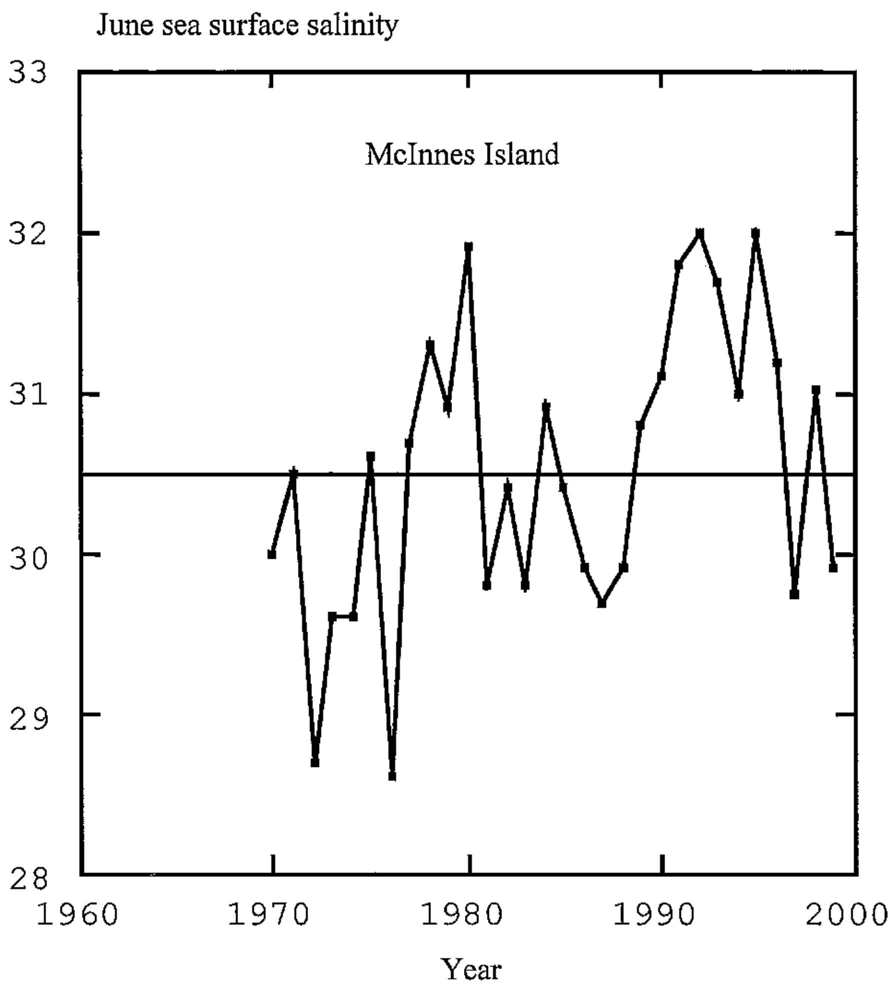


Figure B.7. June sea surface salinity at McInnes Island (1970-99.)

B.3.2 PSARC Working Paper S00-01 summary

Rutherford, D.T., and C.C. Wood. 2000. "Trends in abundance and pre-season 2000 stock size forecasts for major sockeye, pink, and chum salmon stocks in the central coast and selected salmon stocks in northern British Columbia."

This working paper includes pre-season 2000 stock size forecasts for nine sockeye, five pink, and five chum salmon stocks or stock groupings in central and northern British Columbia (Statistical Areas 1-100). The recommended forecasts (see Table 3 below) are based on simple models that have been previously evaluated (Wood et al. 1997).

The recent 5-year mean model is a simple time-series approach that effectively accommodates gradual changes (auto-correlated anomalies) in productivity. For northern populations of sockeye salmon, this model has performed as well or better than, other models because variations in the independent variables used by other models have been small, and their effects have been obscured by other factors. However, for Skeena River sockeye, the 5-year mean model should again be rejected in favor of the "sibling age-class" model that includes the effect of measured record low smolt production from the 1995 brood year. For Rivers and Smith Inlet sockeye, the 5-yr mean model should also be rejected because it performed very poorly in 1999. Alternative models were evaluated that incorporate the measured effects of the extremely poor 1994 and 1995 brood year (1996 and 1997 sea-entry years) marine survival, and the possibility of continued poor survival in 1998 sea-entry year. Although the average sibling/smolt forecast is statistically the best model, we recommend that the "like sea-entry 1996" sibling/smolt forecast be used to guide management decisions in 2000, in keeping with the precautionary approach.

Table 3. Summary of recommended pre-season stock size forecasts for 2000. Bold print is used to flag stock size forecasts that are well below escapement targets in stocks whose status has been reviewed previously by PSARC.

Species	Statistical Area	River or Lake	Escapement Target	Forecasts for reference probabilities[a] 25%	50%	75%	90%	Forecasting Model
Sockeye	1	Yakoun	under review	10,600	8,200	6,300	4,800	5-yr average
	2	Skidegate	9,525	15,900	13,200	11,100	9,100	5-yr average
	3	Nass	200,000	961,400	810,400	682,800	568,500	5-yr average
	4	Skeena	900,000	2,686,633	1,912,000	1,359,000	995,000	sibling
	6	Kitlope	20,000	48,700	35,100	25,300	17,900	5-yr average
	8	Atnarko	75,000	80,200	54,500	37,100	24,500	5-yr average
	8	Kimsquit	30,000	36,100	12,600	4,400	1,400	5-yr average
	9	Owikeno	200,000	302,700	141,900	66,300	33,100	Sibling/Smolt
	9	**Owikeno[c]**	200,000		**2,200**			Like 1996 sea-entry
	10	Long	200,000	205,600	91,600	40,700	19,000	Sibling/Smolt
	10	**Long[c]**	200,000		**3,900**			Like 1996 sea-entry
Pink	2E	all	731,225	1,464,800	910,900	566,200	364,500	Ricker[b]
	6	all	1,447,200	2,310,400	929,800	577,800	371,800	Ricker[b]
	8	all	1,475,400	3,720,800	2,308,600	1,432,300	920,400	Ricker[b]
	9	all	342,450	710,100	441,500	274,500	176,700	Ricker[b]
	10	all	65,600	6,000	3,700	2,300	1,500	Ricker[b]
Chum	2E	all	453,025	495,800	319,200	205,700	137,200	average
	6	all	518,350	421,800	266,600	168,700	110,600	average
	8	all	267,450	660,400	442,600	297,000	205,600	average
	9	all	150,700	75,300	42,100	23,500	13,800	average
	10	all	98,500	62,500	35,300	19,900	11,700	average

[a] probability that the actual stock size will exceed the specified forecast
[b] NLSRESC model of Wood et. al. (1995)
[c] recommended forecast for management decisions under precautionary approach

B.4 References

Foerster, R.E. 1968. *The Sockeye salmon, Oncorhynchus nerka.* Fisheries Research Board of Canada Bulletin 162.

McKinnell, S.M., C.C. Wood, D.T. Rutherford, K.D. Hyatt, and D.W. Welch. (2001) "The Demise of Owikeno Lake sockeye Salmon." *N. Am. J. Fish. Man. 21:774-791*

Rutherford, D.T., and C.C. Wood. 2000. *Trends in abundance and pre-season 2000 stock size forecasts for sockeye, pink, and chum salmon stocks in the central coast and selected salmon stocks in northern British Columbia.* Canadian Stock Assessment Secretariat Research Document 2000/01. Ottawa: CSAS.

Rutherford, D.T., C.C. Wood, and S. McKinnell. 1998. *Rivers Inlet sockeye salmon: stock status update.* Canadian Stock Assessment Secretariat Research Document 1998/91. Ottawa: Ottawa: CSAS.

Rutherford, D.T., and C.C. Wood. 1995. *Stock status and 1996 forecast of Smith Inlet sockeye salmon.* Pacific Scientific Advice Review Committee Working Paper S95-08. Nanaimo: PSARC.

Shortreed, K.S., J.M.B. Hume, and J. Stockner. 2000. "Using photosynthetic rates to estimate juvenile sockeye salmon rearing capacity of British Columbia lakes. In E.E. Knudsen, C.R. Steward, D.D. MacDonald, J.E. Williams, and D.W. Reiser (ed.), *Sustainable Fisheries Management: Pacific Salmon.* Boca Raton; CRC Press.

Stocker, M., and A. MacDonald. 2000. *Report of the PSARC Salmon Subcommittee Meeting, March 7-9, 2000.* Canadian Stock Assessment Secretariat Proceedings Series 2000/03: 36 p. Nanaimo: PSARC, March.

Walters, C. J., R.D. Goruk, and D. Radford. 1993. "Rivers Inlet sockeye salmon: An Experiment in adaptive management." *North American Journal of Fisheries Management* 13:352-262.

Wood, C.C., D.T. Rutherford, D. Peacock, S. Cox-Rogers, and L. Jantz. 1997. 'Assessment of recruitment forecasting methods for major sockeye and pink salmon stocks in northern British Columbia." *Canadian Technical Report Fisheries and Aquatic Sciences* 2187:85 p.

Wood, F.E., and D.C. Schutz. 1970. "Tow-net catches of juvenile sockeye salmon in Owikeno Lake 1960-1968." *Canadian Department of Fisheries and Forestry, Fisheries Service Manuscript Report* 1970-2, 124p.

Appendix C Habitat Background Paper

Sockeye salmon stocks in Rivers Inlet and Smith Inlet have declined drastically in recent years. Owikeno Lake and numerous spawning tributaries support Rivers Inlet sockeye production, and Smith Inlet sockeye production is primarily supported by Long Lake and two spawning tributaries. Between 1960 and 1993, average sockeye escapement and the total stock in Rivers Inlet (i.e., escapement plus harvest) were 426,282 and 918,216, respectively. However, between 1994 and 1999, average sockeye escapement and total stock were 93,537 and 107,844, respectively. In response to these reductions, the Owikeno stock has not been commercially fished in Rivers Inlet since 1996. Similar stock trends are evident in Smith Inlet, where fishing has been closed since 1997. Escapements in 1999 were the lowest recorded to date with Rivers and Smith Inlet escapements estimated at 3,600 and 5,900, respectively.

Logging is the primary land use in the watersheds and a primary objective of this background document is to examine the effects that logging and associated activities may have had on the productive capacity of the two systems. However, there is no evidence suggesting that the recent declines in sockeye are the result of changes in the productivity of any freshwater habitat. The most compelling evidence supporting a mechanism other than freshwater habitat are simultaneous declines in sockeye for Long Lake, where logging and other disturbances have been minimal, and in the Owikeno watershed, where logging has been extensive. Reduced abundance has also been observed throughout the Owikeno Lake system, including the three unlogged systems. Data from the Stock Assessment Division indicate that the primary cause of the decline is a period of poor marine survival (see Appendix B).

The objective of the habitat strategy for Rivers Inlet and Smith Inlet is to "manage habitat to ensure optimal natural productive capacity at all life stages" (DFO 1986). The objective of this recovery plan is conservation of the Rivers Inlet and Smith Inlet sockeye stocks or "Conservation Units." Limit Reference Points (LRPs) have been established for each Conservation Unit: 30,000 spawners for Owikeno Lake and 8,000 for spawners for Long Lake. The LRP is an escapement threshold below which there is a significant risk of extirpation. However, target escapements of 200,000 have also been established for each system and historical stock size in Rivers Inlet was well over 1,000,000. Clearly, to ensure long-tern productivity, habitat must be managed to accommodate historic stock levels, rather than either the LRP or the target levels.

This background paper is organized into five sections. Section C.1 outlines general geophysical characteristics of the Owikeno Lake and Long Lake watersheds. Section C.2 provides information on habitat status and outlines habitat impacts in the two watersheds, including a summary of past and proposed logging developments. Section C.3 provides habitat protection options that are being considered, including options proposed for the CCLRMP. Section C.4 describes habitat restoration options identified to date. Section C.5 outlines data and information gaps that should be addressed to improve future habitat management.

C.1 General geophysical characteristics

C.1.1 Rock and landform Information

Bedrock geology is similar in the Owikeno and Long Lake watersheds. The dominant rock types are granitoid plutons, consisting primarily of tonalite, quartz diorite, and granodiorite. Some meta-sedimentary rocks – quartzite, marble, argillite, and schist – are present in both watersheds. Young volcanic rock types are present in the upper Machmell watershed. At the upper end of the Sheemahant River is a large thrust fault, with a shear zone over 2 km wide.

C.1.2 Hydrology and geomorphology Information

The hydrology of both systems is likely dominated by high rainfall and rain-on-snow events at low elevations in the fall, and by snow melt from the extensive alpine areas in the early summer. Typically, this means that there will be a series of peak flows due to storm activity in October-November, and a large snowmelt-induced peak flow, with the peak occurring probably some time in early June.

Snow avalanche activity in the Owikeno Lake drainage's is very high. This can be seen by the broken forest cover pattern adjacent to the alpine terrain. The avalanches are a source of sediment and debris input to the creeks. The extent of alpine terrain and associated avalanche activity suggests a high but controlled level of sediment input. This tends to result in anastamosing (overlapping) channels, which are very sensitive to disturbance from changes in the sediment regime. The morphology of the Sheemahant and Machmell rivers confirms such a pattern. The sediment load in the mainstem channels is very high. Channel morphology has some characteristics of anastamosed and some of braided systems. Channel reaches can shift from anastamosed to braided morphology in response to sudden increases in sediment load. One example of this is Clowhom River on the Sunshine Coast, a similar avalanche dominated system. At Clowhom River, a debris flow that resulted from four road washouts on the same channel triggered the shift in channel pattern.

In contrast, Smokehouse Creek, the major tributary to Long Lake, is a lower elevation system with much less alpine terrain and relatively little in the way of avalanche activity. It is also rain-on-snow dominated for peak flow generation.

C.2 Habitat status and land use

C.2.1 Habitat characteristics

Sockeye spawning distribution is largely confined to the lower reaches of tributaries to each lake, along beach areas of each lake, and in the Wannock River, the outlet of Owikeno Lake (Table C.1). Much more spawning habitat is available in the Owikeno Lake system relative to the Long Lake system. Approximately 87 km of spawning habitat is accessible in 10 Owikeno tributaries and the Wannock River. Furthermore, up to seven beach spawning areas have been identified in Owikeno Lake. In contrast, only approximately 6 km of spawning habitat in two tributaries and two beach spawning areas have been identified in the Long Lake system.

Sockeye spawner density and thus habitat quality of the Owikeno tributaries seems to be inversely related to the amount of available habitat (Figure C.1, Table C.1). Spawner density is much higher in the clear water systems than in the glacial systems. Using aerial photograph interpretation and escapement data from 1970-1986, Pendray (1988) calculated habitat quantity and sockeye spawner density of the 10 Owikeno Lake tributaries. The Sheemahant and Machmell rivers provide the most extensive anadromous habitat, with sockeye observed up to 20 km from each river's mouth. However, spawner densities in these watersheds are the lowest in the Owikeno Basin. In contrast, Genesee, Amback, and Washwash creeks have the least available habitat, but the highest spawner densities.

Escapement estimates suggest that spawning and rearing habitat quantity and quality in the Long Lake and Owikeno Lake watersheds was still sufficient to support target sockeye escapements of 200,000 or more as recently as the mid-1990s. In addition, no obvious, catastrophic habitat impacts in either system have been observed in the last decade. Although logging-related impacts, primarily in the Owikeno Lake Basin, may have reduced habitat productive capacity, there are no indications that the large and precipitous declines in sockeye abundance could have been caused by changes to freshwater habitats.

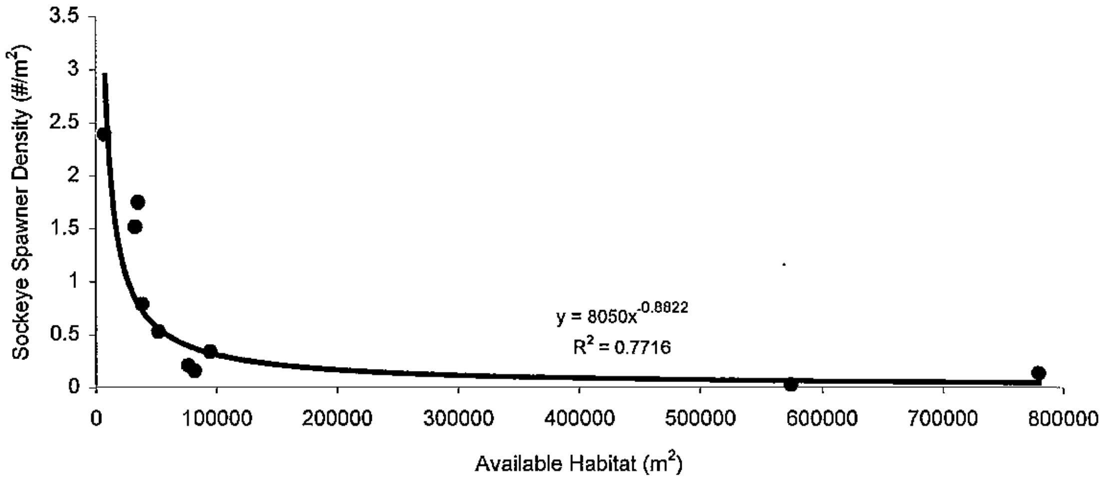


Figure C.1. Sockeye spawner density calculated using escapement data from 1970-1986 relative to amount of available habitat in 10 Owikeeno Lake tributaries. Source (Pendray 1988).

C.2.2 Logging developments

Very little logging has occurred in the Long Lake system. Small-scale A-frame and hand logging removed minor volumes of wood from Long Lake in the 1960s and 1970s. More recently, logging along the shores of Wyclees Lagoon has occurred since 1997. Neither the Smokehouse River nor the Canoe Creek watershed has been logged.

In contrast, logging in the Owikeno Basin has been extensive and continues currently. Prior to 1960, very little logging had occurred in the basin. In 1960, small patches were logged primarily near the mouth of Doos Creek and the first narrows. Approximately 10,000 m^3 of wood was harvested annually in the 1960s. Logs were flat boomed in the lake and then towed down the Wannock River when the river level was 13 feet on the staff gauge at the outflow of the lake on the south side. In 1965, construction commenced to establish the Owikeno Forest Service Road from the Rivers Inlet Cannery site to Owikeno Lake. Truck logging on the north side of the lower end of the lake started in 1968. The change from towing flat log booms down the Wannock River to dewatering bundled logs and trucking to the Rivers Inlet Cannery log dump occurred in 1970. A log dump and camp were developed at the Sheemahant River in 1971. Approximately 100,000 m^3 were harvested annually until 1979. Logging in the Machmell and Neechanz drainage's started in 1978 and 1985, respectively. The highest annual volume harvested from the Owikeno Lake area was approximately 240,000 m^3. At the present time, the annual allowable harvest is 195,793 m^3 and is primarily taken from the Neechanz, Machmell, and Sheemahant drainage's. The forest license (FL A16847) is held by Doman Western Lumber Ltd. and operated by Western Forests Products Ltd.

C.2.3 Summary of past logging in the Owikeno Basin by Landscape Unit

The Ministry of Forests (MoF) manages forests at the landscape scale through the use of Landscape Units (LUs). Consequently, variables quantifying previous logging activity, such as

Table C.1. Description of sockeye spawning tributaries and habitats in the Owikeno Lake and Long Lake basins.

Stream Name	Watershed Characteristics	Sockeye Spawning Habitat	Accessible Habitat (m^2)	% Gravel	Average Spawner Density 1970-1986
		Owikeno Basin			
Genesee	Clear, Logged	0.3-1.3 km	7800	N/A	2.39
Washwash	Clear, Logged	mainly lower 1.2 km, obstruction at 1.8km	33000	41	1.52
Inziana	Clear, Logged	lower 1.1km	38500	70	0.79
Neechanz	Clear, Logged	Mainstem: mainly lower 3.5 km, observed to 9km. Marble Creek: mainly lower 0.5 km, obstruction at 1.6 km	95000	60	0.34
Amback	Clear, Unlogged	mainly lower 1.1 km, observed to 4.4 km	35200	50	1.75
Dallery	Clear, Unlogged	mainly 1.8-2.7 km, observed to 9.0km	52000	50	0.53
Ashlum	Clear, Unlogged	mainly lower 1.2 km, observed to 6.4km.	76800	50	0.21
Tzeo	Glacial, Logged	mainly lower 4.0 km, observed to 9.0km	82000	40	0.16
Sheemahant	Glacial, Logged	up to cascades at 20.2 km, observed further upstream	780000	50	0.14
Machmell	Glacial, Logged	Mainstem: mainly lower 12 km, observed to 20 km. Clear Creek: mainly lower 0.4 km, obstruction at 0.6km	575000	40	0.03
Wannock	Glacial, Logged	mainly between 3.3 and 6.5 km			
Lake		Identified beach spawning sites: (1) near lake outlet on NW shore, (2) near mouth of Amback Creek, (3) mouth of Doos Creek, (4) 2nd narrows near Sheemahant River mouth, (5) and (6) mouths of two small creeks between 2nd and 3rd narrows, and (7) 3rd narrows.			
		Long Lake Basin			
Smokehouse		mainly lower 2km, observed to 5.3 km			
Canoe		mainly lower 1km, cascades from 1-2.5km			
Lake		Identified beach spawning sites: (1) Between Canoe and Smokehouse Creeks, (2) Beach south of Long Lake outlet into Docee River			

forest ages (from which previous logging activity can be inferred) and road networks, are tracked by LUs. Landscape units often approximate watershed boundaries; however, they may also cross some watershed boundaries or include only portions of larger watersheds.

In the Owikeno Lake basin, logging has occurred or is being planned in five LUs (Table C.2). A brief description of the landscape units and levels of current development is given below. All early seral stages include stands between the ages of 0 and 40 years. The area of early seral stage includes logged areas and some small fire-impacted areas, particularly in the Machmell, Sheemahant, Neechanz, and Washwash rivers.

MACHMELL

Total LU area = 57285.4 ha

Area of LU forest in early (0-40 years) seral stage = 3092.6 ha

The Machmell LU is described as the height of land encompassing watersheds flowing into the lower portions of the Machmell River. The eastern boundary follows the height of land between Pashleth Creek and Kilippi creeks. Watersheds included in this LU are the Pashleth Creek, Lower Machmell River, Selman Creek, Selman Lake, Walkus Lake, Genesee Creek, and Ankitree Creek.

Several cut-blocks have been harvested along the lower portions of the Machmell River, with other cut-blocks being concentrated along the lower and eastern sections of Pashleth Creek. Access along the Machmell River is provided by a mainline road that extends from the First Narrows area of Owikeno Lake to the area between Pashleth and Kilippi Creeks. Eight km of road accesses the east side of Pashleth Creek, and an additional five-km goes up the west side. Harvesting in Pashleth Creek is concentrated mostly along the east side of the drainage, and at the lower end, near the confluence with Machmell River. Two km of roads were built in the Walkus Lake area, accessing a few harvested areas. There are 5 km of road along the north side of Genesee Creek, with a few harvested cut-blocks present. To date, there has been no development in the Ankitree and Selman watersheds.

NEECHANZ

Total LU area = 47995.5 ha

Area of LU forest in early seral stage = 823.2 ha

The Neechanz LU is described as the height of land encompassing the Neechanz River watershed and other small drainage's flowing into the south side of Owikeno Lake. The western boundary follows the height of land between Cheetwoot Creek and the Machmell River. Its watersheds include Marble Creek, Kulee Creek, Cheetwoot Creek, Catheralle Creek, and the Neechanz River. A few cut-blocks have been harvested along the lower end of Marble Creek, between the confluences of Marble Creek and the Neechanz River and the Neechanz and the Machmell River. Branch roads off the Neechanz mainline road accessed these cut-blocks. The Kulee Creek main-line road runs along the Neechanz River, and approximately 3km along Kulee Creek. The Neechanz mainline road consists of about ten km along the Neechanz River. Forest harvesting in the area has been concentrated along the lower portions of the Neechanz River.

Table C.2. Summary of forest characteristics and logging development in the five developed Landscape Units in the Owikeno Basin.

Landscape Unit	Total Area (ha)	Total Forested Area (ha)[1]	Forested Area in Early Seral Stage (ha)[2]	Road Length (km)
Machmell[3]	57285	18556	3093	60.3
Neechanz[4]	47995	22710	823	1.8
Owikeno Lake[5]	38328	19621	391	15.9
Sheemahant[6]	50366	23296	3407	96.2
Washwash[7]	47449	15906	1594	1.3

Notes:

1. Includes logged areas, and all other forest types.
2. Includes forested areas with trees aged 1-40 years, primarily logged areas, but also some fire impacted areas.
3. Includes Pashleth River, Lower Machmell River, Selman Creek, Selman Lake, Walkus Lake, Genesee Creek, and Ankitree Creek.
4. Includes Marble Creek, Kulee Creek, Cheetwoot Creek, Catheralle Creek, and the Neechanz River.
5. Includes Ashlum Creek, Sowick Creek, Amback Creek, Phinney Creek, Reeve Creek, and several unnamed streams and waterbodies.
6. Includes Lemolo Creek, Lower Sheemahant River, and Kull Creek.
7. Includes Tzeo River, Keet Creek, Inziana River, Washwash River, and Frazee Creek.

OWIKENO

Total LU area = 38327.8 ha

Area of LU forest in early seral stage = 390.5

The Owikeno LU is described as the height of land encompassing watersheds flowing into the north side of Owikeno Lake. The watersheds include Ashlum Creek, Sowick Creek, Amback Creek, Phinney Creek, Reeve Creek, and several unnamed streams and water bodies. No recent harvesting has taken place in this landscape unit, but logging has been proposed.

SHEEMAHANT

Total LU area = 50365.5 ha

Area of LU forest in early seral stage = 3406.5 ha

The Sheemahant LU is described as the height of land encompassing watersheds that flow into the lower Sheemahant River. The eastern boundary follows the height of land north of the confluence of Sumquolt Creek and the Sheemahant River. Its watersheds include Lemolo Creek, Lower Sheemahant River, and Kull Creek.

Along the lower Sheemahant River, main access for harvesting is provided by 25 km of the East and North Sheemahant mainline roads, 7 km of West Sheemahant mainline, and 6 km of North Sheemahant mainline. Most of the harvested cut-blocks are spread out along the Sheemahant, with some concentration along the north side, across from Lemolo Creek. Approximately 7 km of road accesses cut-blocks along the west side of Lemolo Creek. Previously harvested cut-blocks are also located along the east side of Kull Creek, accessed by 6 km of road.

WASHWASH

Total LU area = 47448.8 ha

Area of LU in early seral stage = 1593.7 ha

The Washwash LU is described as the height of land encompassing the Tzeo River, Inziana River, and Washwash River watersheds that flow into the head of Owikeno Lake. The watersheds included are Tzeo River, Keet Creek, Inziana River, Washwash River, and Frazee Creek.

C.2.4 Future logging

Western Forests Products Ltd. has recently submitted a Forest Development Plan covering the five-year period from 1999 through 2003 (Table C.3). The plan outlines proposed logging and road construction in forest license A16847, and is now under review by MoF. Current operations within the forest license are proceeding under a previously approved forest development plan.

Most of the proposed logging in the license is planned for the Neechanz, Machmell, and Sheemahant watersheds. Approximately 1,000 ha and 500,000 m^3 is proposed for logging in the Neechanz watershed. Between 600 and 750 ha and 300,000 to 350,000 m^3 are proposed for the Machmell and Sheemahant watersheds. Approximately 350 ha and 230,000 m^3 are proposed for

Table C.3. Summary of proposed logging in various sub-basins of Owikeno Lake.

Year	Proposed Logging Area (ha)	Proposed Logging Volume (m^3)
Machmell Watershed		
1999	70.5	37632
2000	115.3	72311
2001	301.9	129389
2002	0	0
2003	139.3	83580
Total	**627.0**	**322912**
Neechanz Watershed		
1999	156.4	92256
2000	78.4	52826
2001	152.3	76420
2002	225.9	114000
2003	355.7	170300
Total	**968.7**	**505802**
Sheemahant Watershed		
1999	114.1	62000
2000	305.3	152721
2001	73.2	37000
2002	273.0	100120
2003	0	0
Total	**765.6**	**351841**
Genesee Watershed		
1999	8.6	5160
2000	0	0
2001	36	28800
2002	0	0
2003	0	0
Total	**44.6**	**33960**
Non-Salmon Tributaries to Owikeno Lake		
1999	113.7	92300
2000	25.3	18503
2001	114.8	68916
2002	9.6	6000
2003	80	42600
Total	**343.4**	**228319**
2000	0	0
2001	36	28800
2002	0	0
2003	0	0
Total	**722.8**	**485438**
Non-Salmon Tributaries to Owikeno Lake		
1999	113.7	92300
2000	25.3	18503
2001	114.8	68916
2002	9.6	6000
2003	80	42600
Total	**343.4**	**228319**

Source: West Forest Products Ltd., *1999-2003 Forest Development Plan.*

non-salmon bearing tributaries to Owikeno Lake, and 45 ha and 34,000 m^3 are proposed for the upper Genesee watershed.

Beyond the watersheds currently being logged, there are 4.5 million cubic metres of mature forests volume available in the unharvested and unassigned operating areas of the Owikeno Lake systems. This is broken down as follows:

Doos:	1.8 million m^3	Dallery:	1.6 million m^3
Medoweese:	0.3 million m^3	North Side:	0.8 million m^3

The estimated volume to be harvested from the Owikeno Basin on an annual basis would be approximated by the present allowable annual cut of 195,525 m^3 per year in Forest License A16847, which is currently operated by Doman Western Lumber Ltd. Forest License A16845, held by Doman Industries Ltd., has an operating area assigned in the Dallery Creek and Doos Creek watersheds. At present, there is no development in these two drainage's and a Forest Development Plan has not been submitted to the Ministry of Forests for review in those watersheds. It is possible that other harvesting opportunities could be assigned to the lake area as they arise.

C.2.5 Logging-related habitat impacts – General

Logging can alter hydrologic and sediment transport systems in watersheds. Such alterations can reduce fish habitat productivity by affecting the amount and quality of flowing water, gravel substrates, cover, and food required by fish for survival (Chamberlain et al. 1991). Scrivener et al. (1998) classified forest harvest impacts on fish habitat into three general categories based on temporal scale. The first group of impacts is directly related to vegetation removal and is evident immediately after logging. Examples of such impacts include increased stream temperature, and changes to nutrient and sediment delivery. The second group of impacts is only apparent after flood events with return periods of 5-10 years. Examples include increased sediment delivery and transport from mass wasting events, and bank erosion and changes to channel morphology. The third type of impact appears 10-20 years following logging, but persists through a forest rotation. An example is structural and habitat changes to river channels due to the loss of large wood debris.

These groups of impacts may be manifested in two spatial scales: (1) the site-specific scale, and (2) the watershed scales, also known as cumulative impacts. Site-specific impacts occur in a discrete location with readily measurable but localized impacts on fish habitat. An example may be a landslide that initiated at a mid-slope road and deposited sediment and debris on a spawning area.

Cumulative impacts are those that occur as a result of an accumulation of site-specific events and progressive logging and road-building activities that alter hydrologic and sediment regimes in a watershed. Cumulative impacts are much more difficult to define because of the technical complexity involved, and because they are often difficult to distinguish from the natural variability of watershed disturbances. The latter is especially true for coastal watersheds. Chamberlin et al. (1991) suggested five general categories of cumulative impacts that affect fish habitat:

- changes in timing and magnitude of runoff events;
- changes in streambank stability;
- changes in sediment supply;
- changes in sediment storage and structure in channels; and
- changes in energy relationships involving water temperature, snowmelt, and freezing.

C.2.6 Logging-related habitat impacts – Site-specific impacts

Several logging development-related impacts on habitat have been identified in the logged Owikeno sub-basins, including possible impacts on Owikeno Lake itself and the Wannock River estuary. Some habitat impacts may also be associated with logging and log handling in Long Lake and Wyclees Lagoon. These impacts are summarized on a sub-basin specific basis, along with a general description of each watershed discussed.

SHEEMAHANT

The Sheemahant has the largest sockeye escapements in the Owikeno Basin and provides the most habitat accessible to sockeye. Sediment sources to the Sheemahant River are likely to be dominated by alpine and glacial sources; however, it appears that the Sheemahant River does not have as large a sediment load as the Machmell River. As with the Machmell, there are a number of bedrock landslides, as well as logging-related slides. Flood protection works, logging and associated road network are extensive in the lower part of watershed, including the valley bottom.

A habitat assessment of this watershed was completed for the Watershed Restoration Program in 1998 (Hillaby 1998c). The assessment identified several logging-related impacts on the lower floodplain. Some side-channels and the floodplain portions of tributaries have been isolated and destabilized by road building and logging. Valley bottom impacts in the Sheemahant are more extensive than in the Machmell, and are associated with both the East and West mainline logging roads.

MACHMELL

The Machmell is a large glacially fed river that is subject to heavy flood flows. It has a naturally occurring large sediment load from numerous sources. Alpine areas, the Silverthrone Icefield, and bedrock landslides likely contribute large amounts of sediment to the river. The river cuts through glaciofluvial terraces that also appear to be contributing large amounts of fine and coarse sediment. Logging-related sources are also evident in aerial photographs from the early 1990s. Although the sediment contribution of logging-related sources relative to natural sources has not been evaluated, it is likely to be small. The channel morphology confirms that the sediment supply to the river is very large. The lower, salmon-accessible reaches of the river are large deposition zones resulting in channel braiding typical of glacial rivers. Before logging took place, Wood et. al. (1970) described the lower 10 miles as being "unstable and the river wanders considerably".

Numerous logging-related impacts were identified during a WRP habitat assessment of the watershed (Hillaby 1998a). Road construction and flood protection works on the lower floodplain have had similar impacts as in the Sheemahant floodplain. Some side-channels have been isolated and streamside logging has resulted in the erosion of hillside tributaries, leading to sediment transport to floodplain reaches and thus potentially impacting spawning and incubation habitat. This is particularly evident in Clear Creek and some left bank tributaries within the canyon reach.

NEECHANZ

The Neechanz River is a large, clear-water tributary to the Machmell River. The confluence is approximately 1.5 km upstream of the Machmell mouth. Logging development began in the Neechanz in the mid-1980s.

The main logging-related problem identified by Hillaby (1998c) was a logging road constructed adjacent to sockeye spawning habitat along the lower Neechanz and its tributary Marble Creek. The road is contributing sediment to the streams, which may be degrading spawning habitat.

GENESEE

Genesee Creek is a clear, lake-fed, stable river, and the lower salmon-accessible floodplain remains unlogged. In fact, it was intentionally kept this way to be used as a datum to monitor the effects of logging in the other rivers in Owikeno Basin. The upper watershed was logged numerous years ago and the current plan proposed additional logging. In the past, a Machmell River flood channel often broke through into the creek, depositing glacial silt in the lower 300 m of the creek. Flood protection dyking at the logging camp on the Machmell/Genesee alluvial fan has prevented reactivation of the flood channel.

Hillaby (1998a) suggested that there is evidence of reduced flows in Genesee Creek. According to her assessment, a large logjam at the base of the falls may be diverting a portion of the flow out of the main channel and onto the floodplain, where it is not accessible to spawning salmon. Hillaby intimated that the wood in the jam might have accumulated as a result of previous logging above the falls.

OWIKENO LAKE

Logging-related impacts on habitat identified in Owikeno Lake primarily relate to wood debris accumulation from log handling. Sloan (1972) studied turbidity, suspended wood fibre concentrations, and benthic wood debris accumulation caused by log dumping near the mouth of the Sheemahant River. He found that all three parameters increased near the dump when log handling was active. Adverse impacts on primary productivity are possible, but were not conclusively demonstrated in this study. Log dumping and related suspended and benthic wood debris accumulations occur annually at the Machmell and Sheemahant facilities, as well as the log load-out near the Wannock River.

The log load-out facility at the west end of Owikeno Lake may be impacting spawning habitat. The area near the facility is used by staging adult sockeye, and beach spawning is suspected. Debris accumulation associated with the facility could potentially smother the habitat; however, this possibility has not been investigated directly.

Wood debris accumulations at the deltas of the Machmell and Sheemahant rivers have increased dramatically since logging started in the two watersheds. The utilization of habitat by sockeye is not known in Owikeno Lake; however, fry in some systems feed in the littoral zone and nearshore areas for up to a month prior to moving offshore (Burgner 1991). Wood accumulations along the deltas could decrease productivity by physically smothering substrates and vegetation, or by shading vegetation.

WANNOCK ESTUARY

A portion of the Wannock River estuary was dyked and filled in 1973 to accommodate construction of a log dump facility. The lost habitat was described as tidal grasslands and was used by rearing chum, chinook, and coho salmon. Today, the habitat continues to be isolated from the estuary, although the area is no longer used as a log dump. While sockeye use of the Wannock estuary has not been documented, sockeye smolts in some systems are known to use estuaries as feeding areas prior to moving offshore (Burgner 1991).

Two log dump and storage facilities have operated adjacent to the Wannock River estuary. The first facility is located on the north side of the estuary and is currently active. All of the wood volume harvested in the Owikeno Lake watershed has been handled at this facility since it was first constructed in 1970. Wood volume handled approximates 5 million cubic meters. The second facility is located on the south side of the estuary near the mouth of the Nicknaqueet River, where wood harvested from the Nicknaqueet watershed has been handled.

DFO conducted a preliminary habitat impact assessment of the Wannock estuary in early May 2000. Extensive wood debris accumulations were observed near the northern log handling facility. Colonies of the bacterium *Begiotoa spp.* were growing on the wood debris, indicative of anoxic and sulfur dioxide-rich conditions. Scattered wood debris was also noted in the intertidal zone in the northern portion of the estuary. In addition, extensive areas of corroded metal filings were observed beneath the pilings that supported the Rivers Inlet Cannery. The filings appeared to smother the substrate and reduce primary productivity.

LONG LAKE

Debris accumulation associated with previous logging along the shore of Long Lake may have impacted beach-spawning habitat to the south of the head of the Docee River. Chinook beach spawning has been confirmed. In this area wood waste was introduced during A-frame logging in the 1960s and 1970s. Sockeye spawning in the area has not yet been confirmed.

Wyclees Lagoon

The Docee River flows into Wyclees Lagoon, a narrow T-shaped inlet off Smith Inlet. Due to a constricted connection with Smith Inlet, Wyclees Lagoon has a large freshwater influence and low salinity. Water level fluctuations are rarely more than 0.2 m, compared to 4-5 m fluctuations in nearby Rivers Inlet. While the lagoon has recently been used for log handling, debris impacts and sockeye residence in it had not been assessed prior to 2000.

C.2.7 Logging-related habitat impacts – Preliminary analysis of cumulative impacts

It is difficult at this stage to conclusively evaluate the cumulative impacts of logging developments in the Owikeno Basin. Detailed procedures such as the Watershed Assessment Procedure and Channel Assessment Procedure have been developed under the *Forest Practices Code* to consider cumulative impacts. However, these assessments have not been conducted to date. A preliminary analysis of Wannock River flow records and aerial photographs in the Owikeno Basin was conducted to determine whether obvious, large-scale cumulative impacts have occurred that could be attributed to logging.

The flow regime in the Owikeno watershed was evaluated using data from Water Survey of Canada gauging station 08FA002 on the Wannock River. This station constructed in 1927 records the total flow for the entire Owikeno Basin. The data were reviewed to examine total discharge during the expected high-flow periods – specifically, meltwater floods in spring and summer and rain-on-snow floods in autumn. Accordingly, a graph was produced summarizing monthly total discharges for the spring/summer meltwater run-off period of May, June, July, and August for the 1960-95 period (Figure C.2). A second graph was produced for the autumn period from October to December (Figure C.3).

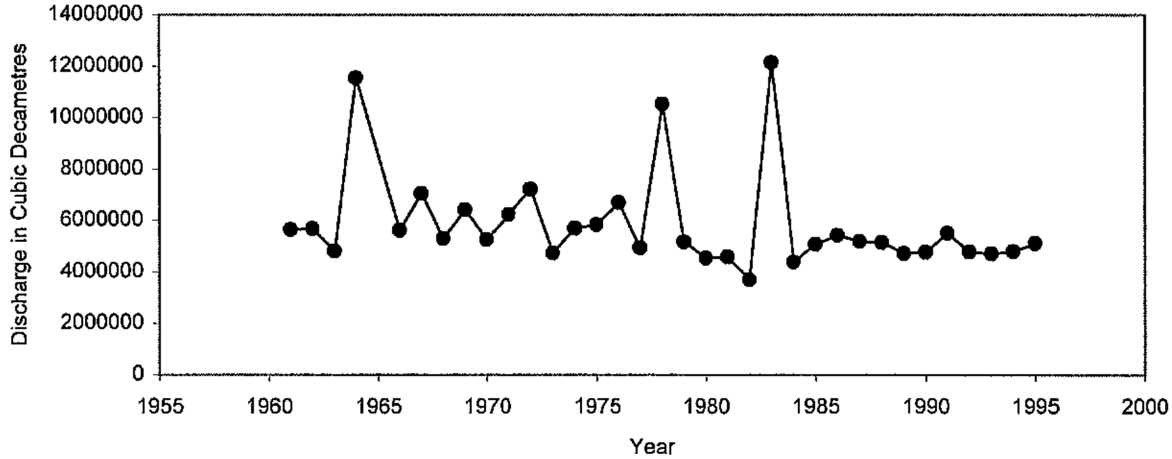


Figure C.2. Total discharge from May to August of the Whannock River between 1960 and 1995.

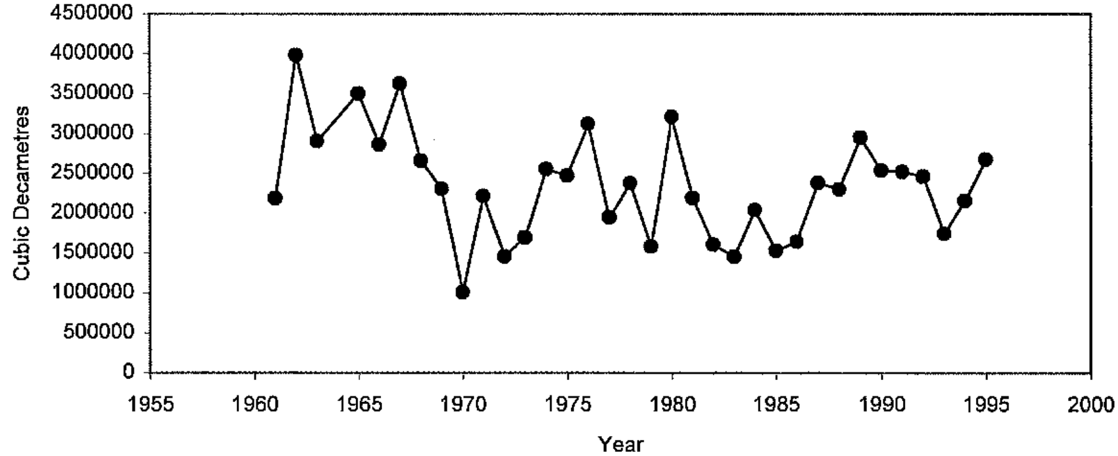


Figure C.3. Total October to December discharge of the Wannock River between 1960 and 1995.

The total discharge data analyzed do not suggest any obvious changes to hydrology that could be attributed to cumulative logging impacts. Total spring discharges show a very consistent range of flows from 450,000 to 700,000 cubic decameters (dams: 1 dam = 1000 cubic meters) with three years of anomalously large total discharge. There is no pattern of increasing flows over time (i.e., the graph does not slope upwards). Nor have there been more frequent or larger flows in recent years compared to the past. In fact, the most apparent trend is more consistent flows between 1985 and 1995 than at any previous time. The fall discharges show a range of flows within a consistent bandwidth. There is no pattern of change from 1960 to 1995.

Whitfield (unpubl. data) found significant changes in the mean daily flows, and in the seasonal distribution of coastal river flows between the periods 1976-1985 and 1986-1995. Flows were decreased throughout the summer and into the early fall (statistically significant decreases during July) and increased throughout the rest of the year, except for a decrease in December (statistically significant decreases occurred between November and April). These findings seem to contradict the conclusions summarized above; however, the apparent difference may be an artifact of parameters tested and the extent of variability incorporated. Whitfield's analysis examined mean daily flows, rather than total flows, as analyzed for this report. In addition, Whitfield did not review as long a record as was considered here (i.e., records older than 1976), and thus his results do not incorporate the same range of variability.

The preliminary analysis of flow in the Owikeno watershed was not designed to detect all hydrologic changes. Hydrologic changes within the logged sub-basins could not be analyzed since flow record data are only available for the Wannock River and not for any of the Owikeno sub-basins. The large volume and storage capacity of Owikeno Lake likely moderates flow in the Wannock River, so that modest flow changes would not be detected. In addition, analysis of total flow may mask changes to peak flow magnitude that have been attributed to logging and road construction (Jones and Grant 1996). More detailed flow analysis is not possible at this time.

Although peak flow changes were not directly examined in the preliminary analysis, their impacts are often manifested in changes to channel morphology. The preliminary assessment of aerial photographs did not reveal obvious channel changes. Much of the logging and other developments are concentrated in valley bottoms, which can result in decreased channel stability, particularly in alluvial channels. However, there is no clear evidence in the macro-channel stability to indicate obvious channel changes beyond the natural variation. These systems, especially the glacially influenced sub-basins, are characterized by very high natural sediment production rates, which results in naturally dynamic channel morphology. Separating logging-related changes to channel morphology from the natural variability in such systems is very difficult.

C.3 Habitat protection options

DFO is currently involved in habitat protection in the Owikeno Basin through ongoing participation in the forest development planning process. The Department provides comments and recommendations to both MoF and forest companies regarding the potential impacts of proposed developments on fish and fish habitat. DFO is involved through all stages in forest planning and development, from reviewing general, landscape-level plans to detailed block and stream-crossing specific plans and conducting pre- and post-logging field reviews. In general, DFO's role in forest development planning has been to provide advice to ensure that fish habitats are protected and that sections of the Fisheries Act are enforced.

As a result of the current sockeye stock decline, one habitat protection option being considered is the establishment of habitat refugia in the Owikeno Basin. Refugia are defined as habitats or environmental factors that convey spatial and temporal resistance and/or resilience to biotic communities impacted by biophysical disturbances (Sedell et al. 1990). The objective of defining and protecting riverine refugia habitats in the Owikeno Basin (i.e., on the watershed scale) is to protect remaining salmonid populations disproportionately dependent on these habitat pockets for short-term survival. Long-term recovery would be accomplished by managing these areas for the primary purpose of salmonid conservation until salmonid recovery trends are established and substantial habitat restoration in other areas has occurred. The Central Coast Land and Coastal Resource Management Planning process provides a good forum to advance the refugia concept with other stakeholders.

Many types of refugia habitats exist within a river system. These include localized habitats, unique reaches, riparian vegetation, floodplains, and groundwater. These function as source areas for natural re-colonization of habitat after some disturbance regime. Re-colonization can refer to more than simply the target species that has been impacted by disturbance. All components of the food chain that have been impacted must be considered in addressing the needs of species at the community level. In this example, we are referring to refugia at the watershed scale and have used the term "riverine refugia". Rivers are open, directional systems, so that protection of any one segment requires control over the entire upstream network and surrounding landscape. As such, within a larger drainage basin (Owikeno Lake) certain sub-basins should be left undisturbed to provide refugia for fish populations.

The concept of refugia habitats has been applied to recovery planning in the US Pacific Northwest. A key driver for recovery planning there is the federal *Endangered Species Act*. The term "key watersheds" is used by the Forest Ecosystem Management Assessment Team (FEMAT 1993). They state:

"A system of Key Watersheds that serve as refugia is critical for maintaining and recovering habitat for at-risk stocks of anadromous salmonids and resident fish species. These refugia include areas of good habitat as well as areas of degraded habitat. Areas in good condition would serve as anchors for the potential recovery of depressed stocks. Those of lower quality habitat have a high potential for restoration and will become future sources of good habitat with the implementation of a comprehensive restoration program."

C.3.1 Linking sockeye recovery to the CCLCRMP

The Central Coast Land and Coastal Resource Management Plan (CCLCRMP) is an opportunity for agencies and stakeholders to have input into land management activities and, in particular, for DFO to advance the protection of freshwater and nearshore fish habitats. DFO's approach on the terrestrial side has been to identify "Sensitive Watersheds", based on historical disturbance from forest development activities or by geophysical sensitivities and by fish populations at risk. DFO will be advocating that these sensitive watersheds receive special management beyond the minimum requirements of the *Forest Practices Code*. Almost all watersheds around Owikeno Lake have been classified as sensitive by DFO.

The CCLCRMP is a forum to introduce the principles of recovery planning as required under the future federal *Species At Rick Act* (SARA) and to advocate for the protection of certain watersheds as refugia for the recovering sockeye populations. There are three pristine watersheds adjacent to Owikeno Lake (i.e., Ashlum, Dallery, and Amback) and the Long Lake Basin is largely undeveloped. While DFO cannot at this stage request permanent protected areas status for these or other systems, we can suggest that these areas serve as temporary protected areas (i.e., refugia watersheds for the recovery of the Rivers Inlet and Smith Inlet sockeye stocks). Under an adaptive management approach, DFO could request that logging in these systems be deferred while the trends in the population are monitored over 2-3 life cycles (8-15 years). These areas can also be established for baseline data collection to test the efficacy of the land use planning recommendations and sockeye recovery programs. The principles behind the habitat refugia concept are described in the above paragraphs.

Another option is to protect key sockeye habitats at the river-reach scale throughout the Owikeno Basin. This could be accomplished by identifying areas that require protection and protecting them through higher-level direction from the CCLCRMP, which would then be implemented at the lower levels of planning. One option is the designation of habitat as Old Growth Management Areas through provincial Landscape Unit Planning. LUs containing important sockeye habitats could be given high priority for planning. For example, the floodplains along sockeye spawning reaches of several Owikeno tributaries (i.e., Amback, Ashlum, Dallery, Genesee, Inziana, Tzeo, and Washwash) are currently unlogged. Through the CCLCRMP and landscape unit planning, DFO could request higher levels of protection in these areas. This approach would address direct impacts from floodplain logging on sockeye habitat, but not the potential cumulative impacts from upstream logging activities.

Several areas incorporating key sockeye habitat in the Owikeno Lake and Long Lake basins are being considered for either Goal 1 or Goal 2 protected areas status by the CCLCRMP Planning Table (Table C.4). Goal 1 protected areas are designed to protect representative examples of natural diversity including marine, terrestrial, and freshwater ecosystems. Goal 2 protected areas protect special natural features, including critical habitats. Although DFO cannot propose the establishment of permanent protected areas at the CCLCRMP, we can provide support to proposals that protect important habitats.

C.4 Sockeye habitat restoration options

DFO has been involved in habitat improvement projects in the Owikeno Basin. For example Washwash Creek broke through its banks on the alluvial fan to flow directly into the glacial Tzeo River in the 1920s, thus reducing the quantity of high-quality spawning habitat available in the Creek. DFO installed a riprap dyke in 1973 to maintain flow in the old channel and extend the spawning habitat. Despite this work, a new channel broke through to the Tzeo River in 1980, with resulting heavy loss of spawn. The feasibility of repairing the previous works should be evaluated. From a geomorphologic perspective, the reach of river from the "breakthrough" to the lake is a typical alluvial fan. Basically, the river deposits large volumes of coarse bedload on the fan, and therefore, the river aggrades and often avulses around these deposits. High egg mortality can result when avulsions occur after spawning.

The provincial WRP has been involved in restoration in the Owikeno Basin since 1996. Overview-level and detailed habitat assessments have been completed in the Machmell, Neechanz, and Sheemahant watersheds (Hillaby 1998a,b,c). In 1999, culvert replacement projects were implemented to address fish access to off-channel habitats in the Machmell and Sheemahant watersheds. Similar projects are planned for 2000, including reestablishing access to a 1km long spring-fed wetland in the Sheemahant floodplain (M. Parker, MELP, pers. comm.). These projects are expected to primarily benefit coho salmon, rather than sockeye. However, sockeye in some systems do rear in such habitats prior to migrating downstream (Burgner 1991).

WRP habitat assessment reports of various watersheds in the Owikeno Basin indicate a number of locations where side-channels have become isolated from the mainstem either by road development or channel migration across the floodplain. Further investigation is required to determine whether any of these sites were formerly utilized as spawning habitat by sockeye. There may be some potential to restore groundwater side-channel habitat on a pilot basis and monitor its benefits to sockeye. Because there are so few examples of groundwater side-channel development for sockeye, this type of work must be considered experimental. Egg-fry survival rates would almost certainly benefit, particularly in those river systems with highly unstable channels. Numerous riparian and bank stability restoration projects were identified during the WRP habitat assessments. These projects are largely located in smaller tributaries above sockeye access, to address sediment transport into spawning reaches.

DFO's history of habitat restoration for sockeye is very limited. Most sockeye habitat manipulations have actually been enhancement efforts either to improve lake productivity through fertilization or to increase fry recruitment to the rearing area with spawning channels. Both strategies have enjoyed some success in addressing limiting factors to production in various locations. At this point, there are no known projects where sockeye habitat restoration has been undertaken within a lake environment.

DFO habitat restoration staff can only cite one example of a sockeye habitat restoration project with a long record of assessment. That project is a groundwater channel located along the shores of Kalum Lake, adjacent to sockeye beach-spawning habitat. As a result of logging developments,

Table C.4. Proposed Goal 1 and Goal 2 protected areas in the Owikeno and Long Lake Basins.

Area Proposed for Protection	Size (ha)	Importance for Sockeye
GOAL 1		
Ashlum-Reeve Upper Inziana	16993	The entire Ashlum watershed, the upper south fork of Inziana Creek and approximately 12.25 km of Owikeno Lake shoreline would be protected. Ashlum Creek and Inziana Creek are both sockeye spawning tributaries.
Smokehouse	38609	The entire Long Lake watershed, including Smokehouse and Canoe creeks, would be protected. This would protect the entire area that produces Smith Inlet sockeye.
GOAL 2		
Genesee Wetland	120	The lower portion of Genesee Creek and surrounding floodplain would be protected. Genesee Creek is an important sockeye spawning tributary.
Walkus Lake	895	Walkus Lake is in the upper watershed of Genesee Creek, above sockeye accessible habitat.
Neechanz/Machmell Wetland	282	The lower portion of Neechanz Creek, Machmell River and surrounding floodplain would be protected. The area proposed for protection is important sockeye spawning habitat
Sheemahant Wetland	484	The second narrows of Owikeno Lake would be protected. The area provides extensive beach spawning and rearing for sockeye.

A nearby stream deposited large volumes of silt on the lakeshore spawning beds. A 180-metre long and 6-metre wide groundwater spawning channel was constructed in 1984 along the lakeshore adjacent to the spawning beds to provide stable incubation habitat for this lake-spawning population. Through the 1980s, the spawner population ranged from 100 to 500 fish. In contrast, the population after channel construction through the 1990s ranged between 1,500 and 5,000 spawners.

In Washington State, a number of groundwater spawning channels and ponds have been constructed in the Skagit basin to replace natural off-channel habitats that had been lost to various developments. The primary species targeted were coho and chum. An unexpected benefit has been the colonization of some of these groundwater habitats by a small population of river-rearing sockeye. A channel and pond complex located near the natural spawning area for these sockeye was constructed in 1994. In addition to coho and chum, 100-200 sockeye spawners now utilize the groundwater channel. While it is known that sockeye fry are rearing to smolt in the adjacent groundwater pond, an assessment quantifying sockeye smolt production has not been undertaken at this project.

Similar groundwater channel and pond development has occurred in the Cedar River watershed in King County, Washington. Most of the work was done during the 1990s to mitigate the effects of increased peak flows resulting from urbanization. In this case, the restoration work was intended to improve egg-fry survival rates for sockeye. While King County biologists report extensive sockeye spawner utilization of the new groundwater side-channel habitats, assessment data are not yet available.

DFO's largest sockeye habitat enhancement projects have been spawning channels. Large-scale projects have been developed in the Babine system, Horsefly River, and Weaver Creek, a tributary to Harrison River. One of the longest time series of assessment data for sockeye enhancement channels in BC comes from the Babine project. While these are highly engineered production channels that are river-fed rather than groundwater-fed, the data provide an indication of the benefits realized by ensuring stable spawning habitat. During the 1964-1985 period, sockeye egg-to-fry survival in the controlled channels averaged 46% compared to an average egg-to-fry survival of 21% in Pinkut Creek and Fulton River (West and Mason 1987). Similarly, mean egg-fry survival in the Weaver Creek spawning channel is 68% (V. Ewert, pers. comm.).

Before deciding to proceed with large-scale spawning channel projects, several issues need to be considered. A secure water supply and stability of the adjacent river are critical to the long-term physical success of the project. Proximity to current spawning adults is important to ensure that the new habitat is utilized. Site accessibility for construction, operation, and maintenance has proven critical to the success of other spawning channels. River stability and accessibility are likely the two factors that make the Owikeno Basin unfavorable for spawning channel development.

The severe reductions in escapements may have reduced the nutrient regime in the Owikeno Lake and Long Lake watersheds. Lake enrichment may be considered to address the issue; however, this has been evaluated by the Enhancement Working Group (see Appendix D). Slow-release fertilizer pellets have been developed to augment stream nutrient concentrations and productivity in oligotrophic rivers (Ashley and Slaney 1997). Case studies have shown increased periphyton and benthic invertebrate biomass. Increased growth and smolt output of anadromous fishes with long stream residence times, such as coho, sea-run cutthroat trout, and steelhead, have been documented. While these species in Owikeno and Long lakes may benefit from stream fertilization, more information on post-emergent river residence and growth and feeding would be required before determining whether sockeye would benefit.

The option of fertilizing estuarine habitat may be considered to improve early marine survival. To date in BC, only the Yakoun River estuary has been fertilized. Study results (Stockner and Levings, 1982) were not encouraging. To quote from the abstract:

"The structure of plankton, benthic algae and invertebrate, vascular plant and fish populations in the Yakoun River estuary were examined over a 4 month period, in the spring and summer of 1980. An attempt was made to increase populations of salmonid food items by artificially fertilizing the estuary and stimulating production at the primary tropic level, based on the assumption that food availability was a significant limiting factor in the survival of juvenile pink salmon within this system. However, neither primary production nor nitrogen regeneration were appreciably accelerated following this fertilization...."

One problem with the study was that nutrient dynamics apparently were not well documented (C Levings, DFO West Vancouver, pers comm.). If it was decided to proceed with estuarine fertilization, solid "bricks" of slow-release fertilizer, used successfully by the Province in stream fertilization projects, might be a potentially useful new technology worth considering for intertidal and shallow subtidal habitats (K Shortreed, DFO Cultus Lake, pers comm.).

Before attempting to fertilize deeper marine habitats adjacent to the estuaries, more information on the oceanography and circulation patterns would be needed to properly assess the feasibility of such a strategy (K Shortreed, pers. comm.). F. Whitney (DFO Sidney, pers. comm.) advised that IOS nutrient surveys in 1998 and 1999 suggested that the 1997-98 El Niño affected nutrient supply all along the BC coast and into Alaska. While both winter supply and summer upwelling were affected off Barkley Sound and probably also in the Queen Charlotte Sound area, it remains uncertain as to how coastal supply might affect nutrient regimes in coastal inlets.

Dr. Whitney has requested that the researchers presently on board the Research Vessel Tully sample Rivers Inlet during their cruise. He and his colleague Dr. Stucchi want to conduct limited sampling in the Rivers/Smith Inlet area 3-4 times over the next year, in order to assess what processes are controlling nutrient supply to surface waters. They are intrigued by the problem facing salmon stocks in this area, would like to learn more about the proposed program, and feel that they may be able to contribute from an oceanographic perspective.

DFO should also assess the feasibility of other habitat restoration projects in the Wannock River estuary. In the 1970s, approximately one hectare of the estuary was dyked to accommodate construction of the currently operating log dump facility. The isolated portion of the estuary is not being used for industrial purposes and reconnecting this habitat may produce beneficial results. A cannery operated at the north end of the estuary in the first part of the century. A layer of metal filings was observed on the substrate during a preliminary survey of the cannery area. The metal filings may be inhibiting invertebrate and plant production, and the feasibility of removal should be investigated.

C.5 Data gaps

Improving our understanding of habitat use through all freshwater and estuarine life stages would be beneficial to developing a directed habitat strategy for sockeye in the Owikeno Lake and Long Lake basins. The typical sockeye life history pattern consists of mainstem river or beach spawning followed by one year of lake rearing and seaward migration of yearling smolts (Burgner 1991). However, sockeye can exhibit considerable variation around the generalized life-history pattern. Extensive use of habitats along floodplain margins for spawning (e.g., spring-fed ponds, side-channels, tributary creeks) has been reported in several systems, particularly glacial rivers (Burgner 1991; Lorenz and Eiler 1989). Groundwater upwelling areas also seem to be important for sockeye spawning and successful incubation in glacial rivers (Burgner 1991; Lorenz and Eiler 1989; Lorenz 1994). Extended use of habitats along floodplain margins (i.e., sloughs, side-channels, tributary mouths) by age-0 fry has been reported in several systems (Burgner 1991; Murphy et al. 1989). While this behavior is often associated with systems lacking lake-rearing habitats, such as the Taku River (Murphy et al. 1989), it has also been reported in systems with lakes (Burgner 1991). Estuary and nearshore residence by sockeye smolts also varies among sockeye populations, and can range from brief transitory residence to periods of up to 5 months (Burgner 1991). Extended estuary use is often associated with small age-0 smolts.

Habitat use studies would require field sampling to evaluate critical spawning areas (particularly in the glacial systems), post-emergent river residence, river deltas, lake nearshore residence, and estuary residence. This work could dovetail onto other proposed projects, such as downstream fry and smolt trapping and lake productivity studies proposed by the Enhancement Working Group.

Research on habitat use will assist in accomplishing three goals critical to a successful recovery strategy:

4) Improve our understanding of land use development impacts on habitat utilized by sockeye. Much of the identified logging-related impacts have occurred in the lower floodplains of the larger glacial rivers (i.e., Machmell and Sheemahant). The impacts are primarily associated with isolating or destabilizing habitats along floodplain margins that may be important spawning and early rearing habitat for

sockeye in these systems. Furthermore, understanding river delta and estuary use will determine whether impacts in those habitats are affecting sockeye production.

5) Identify critical habitats that are priorities for protection. Habitats that disproportionately contribute to sockeye production relative to their availability are especially important to identify. The identification of critical habitats is also the fundamental step needed for recovery planning under SARA.

6) Prioritizing habitats for restoration. Restoration projects are usually quite expensive and resources are limited. If restoration is to be pursued, better understanding of habitat use will help focus restoration program on those habitats that are most likely to improve sockeye production.

Improving our knowledge of logging impacts would promote improved land use decisions in the watersheds and may identify habitat restoration projects that benefit sockeye. Both site-specific and cumulative impacts should be addressed. Site-specific impacts that should be evaluated further include wood waste accumulation on beach spawning areas in Owikeno Lake and Long Lake, primary productivity reduction associated with suspended and benthic wood waste accumulations near log handling facilities, and the extent and importance of isolated habitats associated with floodplain developments. An improved evaluation of cumulative impacts should also be pursued. Such evaluation should incorporate currently known site-specific impacts, an improved evaluation of hydrological and sediment regime impacts of previous logging and predicted impacts of subsequent logging developments. To address cumulative impacts, two specific tasks should be pursued: (1) a more detailed evaluation of flow records to identify seasonal changes in flow that may indicate potential habitat impacts; and (2) DFO cooperation with other agencies (e.g., MoF, MELP) to initiate Watershed Assessments.

C.6 References

Ashley, K.I., and P.A. Slaney. 1997. "Accelerating Recovery of Stream, River, and Pond Productivity by Low-Level Nutrient Replacement." In. P.A. Slaney and D. Zaldokas (ed.), *Watershed Restoration Technical Circular* No. 9.

Burgner, R.L. 1991. "Life History of Sockeye Salmon (*Oncorhynchus nerka*)." In C. Groot and L. Margolis (ed.). *Pacific Salmon Life Histories*. Vancouver: UBC Press.

Chamberlin, T.W., R.D. Harr, and F.H. Everest. 1991. "Timber Harvest, Silviculture, and Watersheds Processes." *American Fisheries Society Special Publication* 19: 181-205.

DFO. 1986. *Policy for the Management of Fish Habitat*. Ottawa: Fish Management Habitat Branch.

FEMAT. 1993. *Report of the Forest Ecosystem Management Assessment Team: An Ecological, Economic and Social Assessment*. Washington, D.C.: FEMAT.

Hillaby, J.E. 1998b. *Machmell Watershed Level I Fish Habitat Assessment*. BC Watershed Restoration Report Prepared for Western Forest Products, Campbell River: WFP. July

Hillaby, J.E. 1998c. *Neechanz Watershed Level I Fish Habitat Assessment*. BC Watershed Restoration Report Prepared for Western Forest Products, Campbell River: WFP, July.

Hillaby, J.E. 1998a. *Sheemahant Watershed Level I Fish Habitat Assessment*. BC Watershed Restoration Report Prepared for Western Forest Products. Campbell River: WFP, July.

Jones, J.A., and G.E. Grant. 1996. "Peak Flow Responses to Clear-Cutting and Roads in Small and Large Basins, Western Cascades, Oregon." *Water Resources Research* 32: 959-974.

Lorenz, J.M. 1994. *Distribution and Habitat of Adult Salmon in the Situk River Alaska: Potential Impacts of Flooding from Russell Fjord.* US Department of Commerce NOAA Technical Memo. NMFS-AFSC-30. Washington, DC: National Oceanic and Atmospheric Administration.

Lorenz, J.M., and J.H Eiler. 1989. "Spawning Habitat and Redd Characteristics of Sockeye Salmon in the Glacial Taku River, British Columbia and Alaska." *Transactions of the American Fisheries Society* 118:495-502.

Murphy, M.L., J. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989. "Habitat Utilization by Juvenile Pacific Salmon (*Oncorhynchus*) in the Glacial Taku River, Southeast Alaska." *Canadian Journal of Fisheries and Aquatic Sciences* 46: 1677-1685.

Pendray, T. 1988. *Biophysical Inventory of Tributaries to Owikeno Lake – 1984-85.* Prince Rupert: North Coast Division, Habitat Management Unit, DFO.

Scrivener, J.C., P. Tschaplinski, and J. Stevenson MacDonald. 1998. "An Introduction to the Ecological Complexity of Salmonid Life History Strategies and of Forest Harvesting Impacts in Coastal British Columbia." In D.L. Hogan, P.J. Tschaplinski, and S. Chatwin (ed.), *Carnation Creek and Queen Charlotte Islands Fish/Foresty Workshop: Applying 20 Years of Coastal Research to Management Solutions.* Land Management Handbook No. 41:23-32. Victoria: Ministry of Forests.

Sedell, J.S., G.H. Reeves, F.R. Hauer, J.A Stanford, and C.P. Hawkins. 1990. "Role of Refugia in Recovery from Disturbances: Modern Fragmented and Disconnected River Systems." *Environmental Management*, Vol. 14, No. 5, pp. 711-724.

Sloan, J.P. 1972. *Statistical Analysis of some Preliminary Data on Effects of Logging on the Sheemahant Basin of Owikeno Lake.* Department of Environment, Fisheries Service, Manuscript Report 1972-2.

Stockner, J.G. and C.D. Levings. 1982. "Biological reconnaissance of the Yakoun River estuary, Queen Charlotte Islands, and results of a trial fertilization with urea." *Canadian Technical Report Fisheries and Aquatic Sciences*, No. 1132, 119 p.

West, C.J., and J.C Mason. 1987. "Evaluation of Sockeye Salmon (*Oncorhynchus nerka*) Production from the Babine Lake Development Project. In H.D. Smith, L. Margolis, and C.C. Wood (eds.) *Canadian Special Publication Fisheries and Aquatic Sciences* 96.

Wood, F.E.A., D.C. Schutz, and J.D.C. Holland. 1970. *Physical and Biological Data to 1968 from the Rivers Inlet Sockeye Spawning Areas.* Department of Environment, Fisheries Service, Manuscript Report 1970-1.

Appendix D Enhancement Background Paper

Sockeye from the Owikeno Lake and Long Lake basins once supported the largest sockeye salmon fishery on the Central Coast. However, both stocks have declined substantially through the 1990s. In 1999, escapement dropped below each stock's Limit Reference Point (LRP). The decline has been attributed to a period of poor marine survival. Because it is unknown whether marine conditions will improve in the foreseeable future, a range of intervention strategies and techniques are now being considered to conserve these stocks.

First Nations and other groups from the area have asked that intervention include artificial propagation and one group was given permission to work with DFO representatives on a small pilot project in 1999. In response to the requests for enhancement, the Science Branch and Habitat and Enhancement Branch prepared a series of briefing notes for the Regional Director General in the fall of 1999. These notes recommended that any intervention in the area should be consistent with current DFO policies (e.g., the proposed Wild Salmon Policy) and should focus on meeting conservation objectives rather than production to create harvest opportunities. Two options were recommended under the conservation objective:

1) Increased stewardship, habitat restoration, and research; and
2) Artificial propagation for conservation.

This document is organized into four sections. Section D.1 provides pertinent background biophysical information. Section D.2 lists DFO enhancement objectives and guidelines, with a focus on how these apply to the Central Coast sockeye situation. Section D.3 provides a brief summary of enhancement techniques currently employed in Alaska and the Pacific Northwest. Section D.4 presents a list of feasible enhancement options for Owikeno and Long lakes, as well as a proposed list of candidate sub-populations and enhancement strategies for the respective stocks.

D.1 Biophysical background information

D.1.1 Sockeye production in Owikeno and Long lakes

Tables D.1 and D.2 present average escapement data for the 1980s, 1990s, and 1999 for the major sockeye spawning streams in Owikeno Lake and Long Lake. Fry recruitment to the lakes from each spawning stream is estimated based on the following assumptions:

- 50% of the spawners are female;
- average fecundity is 3000 eggs; and
- average egg-fry survival is 15% (SEP bio-standards for sockeye natural spawn).

Given the above assumptions, estimated fry recruitment from the 1999 brood is less than 1% of the 1980s average in Owikeno Lake and 3% of the 1980s average in Long Lake.

Low levels of fry and smolt abundance may be an important factor in the accelerated decline of sockeye production in Owikeno and Long lakes. Studies in Alaska indicate that predator consumption rates of sockeye smolts are proportionately higher during years of low smolt abundance (Burgner 1991). BC studies have observed the same predator-prey relationship for sockeye fry (Burgner 1991). The Alaska studies of migrating smolts indicate that consumption rates of sockeye smolts increase with greater numbers of smolts up to a threshold density, above which mortality decreases. This suggests that an important survival strategy for sockeye may be

Table D.1. Owikeno Lake Basin Sockeye Production Estimates.

Watershed	Estimated Ave. 1980-89 Escapement	Estimated Ave. 1980-89 Fry Recruitment	Estimated Ave. 1990-99 Escapement	Estimated Ave. 1990-99 Fry Recruitment	Estimated 1999 Adult Escapement	Estimated Ave. 1999 Fry Recruitment	Spawner Distribution
UPPER BASIN							
Wash Wash	46,620	10,489,500	16,590	3,732,750	420	94500	mainly lower 1.2 km, obstruction at 1.8 km
Tzeo	11,350	2,553,750	3,250	731,250	50	11250	mainly lower 4 km, observed to 9 km
Inziana	27,893	6,275,925	18,253	4,106,925	595	133875	lower 1.1 km, obstruction at 1.1 km
Subtotal	**85,863**	**19,319,175**	**38,093**	**8,570,925**	**1,065**	**239,625**	
MIDDLE BASIN							
Sheemahant	144,600	32,535,000	67,397	15,164,325	970	218250	spawning to cascades at 20.2 km, some above
Genesee	13,760	3,096,000	1,997	449,325	10	2250	0.3 - 1.3 km, obstruction at 1.3 km
Subtotal	**158,360**	**35,631,000**	**69,394**	**15,613,650**	**980**	**220500**	
LOWER BASIN							
Machmell	21,100	4,747,500	5,786	1,301,850	unk	unk	mainly lower 12 km, observed to 20 km
Neechanz	38,030	8,556,750	15,385	3,461,625	200	45,000	mainly lower 3.5 km, observed to 9 km
Ashlum	23,220	5,224,500	8,333	1,874,925	25	5,625	mainly lower 1.2 km, observed to 6.4 km
Amback	62,450	14,051,250	17,595	3,958,875	100	22,500	mainly lower 1.1 km, observed to 4.4 km
Dallery	28,050	6,311,250	5,123	1,152,675	130	29,250	mainly 1.8 - 2.7 km, observed to 9 km
Wannock	119,750	26,943,750	55,400	12,465,000	1,000	225,000	mainly 3.3 to 6.5 km
Lake	9,718	2,186,550	1,972	443,700	100	22,500	various locations, see Habitat Assessment Table
Subtotal	**302,318**	**68,021,550**	**109,594**	**24,658,650**	**1,555**	**349,875**	
TOTAL	**546,541**	**122,971,725**	**217,081**	**48,843,225**	**3,600**	**810,000**	
1999 escapement and fry recruitment estimate as % of 1980's average						.66%	
1999 escapement and fry recruitment estimate as % of 1990's average						1.66%	
NOTE: fry recruitment estimated using 3,000 eggs/female and 15% egg-fry survival							

Table D.2 Long Lake Basin Sockeye Production Estimates.

Watershed	Estimated Average 1980-89 Escapement	Estimated Average 1980-89 Fry Recruitment	Estimated Average 1990-99 Escapement	Estimated Average 1990-99 Fry Recruitment	Estimated 1999 Adult Escapement	Estimated Average 1999 Fry Recruitment	Spawner Distribution
Smokehouse	130,822	29,434,950	82,173	18,488,925	4,130	929,250	mainly lower 2 km, observed to 5.3 km
Canoe	56,067	12,615,075	35,217	7,923,825	1,770	398,250	mainly lower 1 km, cascades from 1 - 2.5 km
Lake							lakeshore between Canoe and Smokehouse Cks
Total	**186,889**	**42,050,025**	**117,390**	**26,412,750**	**5,900**	**1,327,500**	
1999 escapement and fry recruitment estimate as % of 1980's average					3%	3%	
1999 escapement and fry recruitment estimate as % of 1990's average					5%	5%	

Table D.3: Long Lake Basin Sockeye River Entry and Spawn Timing

	JULY		AUG		SEPT		OCT		NOV		DEC	
Sub-population	1-14	15-31	1-14	15-31	1-14	15-31	1-14	15-31	1-14	15-31	1-14	15-31
RIVER ENTRY TIMING												
CANOE				X	X							
SMOKEHOUSE		X	X	X								
LAKE												
SPAWN TIMING												
CANOE					X	X	P	X	X	X		
SMOKEHOUSE				X	X	X	P	X				
LAKE												

to "swamp" predators with large numbers during critical migration periods. This may be even more important for Owikeno sockeye, given the small smolt size. Ecologists hypothesize that at a threshold level of abundance, predators either become satiated during a feeding period or are limited in the number of prey items they can capture.

D.1.2 Migration and spawn timing For Owikeno and Long Lake sockeye

Tables D.3 and D.4 present sockeye spawner migration and spawn timing for the major sockeye spawning streams in Long and Owikeno lakes (P denotes peak spawning activity).

Temperature data collected from data-loggers for the period October through December 1998 are as follows:

System	Characteristics	Average Water Temperature (degrees C)			
		Oct.	Nov.	Dec.	Oct. – Dec.
Washwash	Upper basin, clear	7	4	2	4.5
Inziana	Upper basin, glacial influence	7	4	2	4.5
Neechanz	Lower basin, glacial influence	7	4	2	4.5
Ashlum	Lower basin, clear	7	5	3	5
Dallery	Lower basin, tea color	7	5	3	5
Genesee	Middle basin, clear, lake-fed	10	6	3	6.5
Wannock	Lower basin outlet, lake-fed	11.5	9.5	7.5	9.5

In general, peak spawn timing is earlier in the colder upper basin and glacier-influenced systems, and later in the warmer lower basin and lake-influenced systems. Water temperatures likely influence various sub-population characteristics, such as spawn timing and egg-to-fry development period. These timing characteristics may reflect local adaptations to nursery environments. Consequently, enhancement efforts should endeavor to select representative sub-populations from across the range of physical environments found in the basin. For example, candidate sub-populations in the Owikeno Basin might include the Wannock River, as well as a clear system and a glacial system from each of the lower, middle, and upper basins.

D.2 Departmental policies, regulations, and guidelines pertaining to conservation

The guiding principles for enhancement intervention ensure that all propagation and other manipulations of fish sub-populations will strictly adhere to existing policy, regulations, and guidelines. Those policies, etc. are briefly summarized in the following sections.

D.2.1 Transplants[14]

At this point, transplants from other systems to rebuild Owikeno and Long Lake sockeye stocks are not being considered. However, the development of sockeye enhancement options for these Conservation Units will likely involve the movement of eggs from natal watersheds to satellite incubation and rearing facilities in another watershed. Fry will be released back to natal watersheds.

[14] This discussion is taken from Federal-Provincial Fish Transplant Committee Guidelines (Kieser 1999) and a review of salmon transplant procedures (Fedorenko and Shepherd 1986).

Table C.4. Owikeno Basin Sockeye River Entry and Spawn Timing

	JULY		AUGUST		SEPT		OCT		NOV		DEC	
Sub-population	1-14	15-31	1-14	15-31	1-14	15-31	1-14	15-31	1-14	15-31	1-14	15-31
RIVER ENTRY TIMING												
TZEO				X								
WASH		X	X									
INZIANA		X	X	X								
SHEEMAHANT				X								
GENESEE				X								
NEECHANZ		X	X									
MACHMELL		X	X									
ASHLUM		X	X	X								
DALLARY				X								
AMBACH				X	X							
LAKE					X	X						
WANNOCK		X	X	X								
SPAWN TIMING												
TZEO				X	P	X	X	X				
WASH			X	X	X	P	X	X				
INZIANA				X	P	X	X	X				
SHEEMAHANT					X	P	X	X				
GENESEE				X	X	P	X	X	X	X		
NEECHANZ				X	P	X	X	X				
MACHMELL				X	P	X	X	X				
ASHLUM				X	X	P	X	X				
DALLARY					X	X	P	X				
AMBACH					X	X	X	P	X			
LAKE						X	P	X				
WANNOCK				X	X	X	X	X	P	X	X	X

The Federal-Provincial Fish Transplant Committee considers three key questions when assessing the risk of a proposed transplant:

1. Ecological – Are there probable effects on the distribution or abundance of local species resulting from alterations in relationships such as predation, prey availability, and habitat availability? Because transplants would only involve a temporary relocation of eggs for incubation purposes, rather than release into a new watershed, the ecological risks are minimal. Risk could arise if the enhancement techniques resulted in the released fish straying from their natural distribution patterns.

2. Disease – Are there probable effects on the prevalence, distribution, and/or impact of disease on local species? This is the area of greatest concern when considering the propagation of sockeye. Because of the prevalence of IHN virus in sockeye, and the transmissibility of this disease agent between individuals and to other species, IHNV prevention protocols, such as egg disinfection, IHNV-free water supply, and effluent treatment, must be strictly adhered to at the satellite facility.

3. Genetic – Are there effects on the capacity of a local species to maintain and transfer its current genetic identity and diversity to successive generations? Risk is minimal for the same reasons outlined above under "Ecological".

D.2.2 Alaska Sockeye Protocol

Propagation of sockeye salmon must strictly adhere to the Alaska Sockeye Protocol (McDaniel et al. 1994). This protocol was developed to reduce transmission and fish mortality as a result of the IHN virus that is prevalent in most sockeye sub-populations. The main keys to success in dealing with the virus are:

- handle each adult in isolation of others (treat each fish as if it were infected);
- keep each lot of eggs isolated and disinfect eggs prior to plant;
- incubate in IHNV-free water; and
- maintain isolation during incubation – ideally, the size of each isolation unit is dictated by the largest number of eggs that can be destroyed without jeopardizing the conservation effort should a disease outbreak occur in any one unit.

D.2.3 Genetic practices for hatcheries[15]

While there is a hierarchy of options available for maximizing genetic integrity of individual stocks, the preferred options for Owikeno and Long Lake sockeye are:

1. Broodstock selection. Native sub-populations should be used and fish from individual rivers should be kept separate. This will be done even though sub-populations from the Owikeno and Long Lake basins are each managed as aggregates.
2. Broodstock numbers. If the number of adults in the river is more than 50, no more than 30% of the available broodstock should be taken and gametes from as many individuals as possible should be taken, up to the 30% guideline or the egg-take target/limit, whichever is less. In systems where there are between 30 and 50 individuals, no more than 30% should be taken for broodstock, irrespective of the egg target. In systems with less than 30 individual adults, no broodstock will be taken. This is only the case in

[15] This discussion is based on Bonnell (1999).

one or two of the Owikeno Basin sub-populations. The rationale here is that there are too few fish to risk. In such cases, a captive brood program may be considered using a portion of out-migrant fry.

3. Mating Practices. If more than 50 pairs are used, then mating will be one to one. If there are less than 50 pairs, it is recommended that the eggs from each female be divided into 2-4 lots, each to be fertilized by a different male.
4. Rearing and Release Practices. A stratified random sub-population should be maintained during any rearing program. All juveniles should be released to the natal system and spread out in the system as much as possible. The number of fish released should be in keeping with Guiding Principle #1 to minimize the potential for negative impact on wild stocks. The release strategy should be selected to match wild timing and fish size as much as possible.

D.2.4 Captive breeding program[16]

In theory captive breeding programs offer the greatest security against extirpation when natural survival is near zero and sub-populations in the wild are not able to sustain themselves. Captive breeding programs are unproven and expensive and for that, reason should only be considered a last resort to prevent extirpation. The risk of extirpation has increased considerably if marine survival did not improve for smolts entering the ocean in 1998 and 1999. If marine survival did not improve, then captive breeding might be carefully considered in 2001 and beyond. Further discussion of sockeye captive brood experiences is presented in Section D.3.3 on Idaho. A cryo-preservation program (gene banking) would be recommended in the years leading up to potential egg-takes from captive brood adults to provide out-mixing and maximize diversity of the captive brood population.

D.2.5 Gene Banking

Cryo-preservation of sperm is a reasonable precautionary activity that could provide out-mixing opportunity in future artificial propagation programs, including captive breeding. At a minimum, it should be pursued in all systems where egg-takes are planned and conform to existing draft DFO guidelines (Cross 1999).

D.3 Summary of sockeye enhancement techniques and experiences

D.3.1 Hatchery experience with sockeye in British Columbia

Currently, there are only two full-time sockeye hatchery programs in operation here in BC: one at Henderson Lake and the other on the Upper Pitt River. A third program, hatchery enhancement of the Upper Adams sockeye stock, occurs every fourth year.

The incubation techniques are similar at all sites in that eggs are incubated using IHNV-free water in bulk-type incubators, such as Kitoi or Atkins models (over screen to eyed then in substrate). In all cases, egg/alevin development is timed to match the wild sub-population as much as possible. At swim-up, fry are either transported and released to the natal system shortly after swim-up or reared for various periods prior to release. Recent studies from other areas postulate that unfed enhanced fry can experience a high mortality rate during the early post-release period (D. Lofthouse, pers. comm.). Short-term rearing (2-3 weeks) may give enhanced fish the slight advantage required to get past this critical stage.

[16] This section is based on *Methods to Assist in the Rebuilding of Wild Pacific Salmon Populations,* (Anon. 1996).

Assessment of different strategies has or is being conducted using finclip, CWT, and otolith marking of a portion of the population prior to release.

D.3.2 Hatchery experience with sockeye in Alaska

In terms of volume and success in sockeye hatchery production, Alaska leads the way. This has been accomplished through the institution of strict disease avoidance protocols that have allowed hatchery producers to work around the presence of IHN virus in most sockeye populations.

The main purpose of sockeye enhancement in Alaska is to support commercial fisheries. To that end, a number of hatchery strategies are employed. In coastal settings, smolt releases are conducted from both hatcheries and saltwater net pens. In other situations, fry are out-planted into underutilized lake-rearing habitat. In these cases, outplants may be as unfed or short-term fed fry, often using pens located at the release location. Incubation techniques are similar to what is done in BC.

D.3.3 Idaho

There have been preliminary discussions with staff[17] of the National Marine Fisheries Service (NMFS) about the status and success of the Redfish Lake sockeye captive breeding program. Both experts consider that the program has been successful from a culture perspective, and that sockeye are easier to raise as captive breeding populations than chinook. However, it is too soon to judge the success of the overall restoration effort, since the first major return is expected in 2000. In addition, Redfish Lake sockeye face a very different journey (9 dams) than Rivers Inlet sockeye. The eventual success or failure of that restoration problem may not mean much for the Central Coast situation.

NFMS has undertaken a captive broodstock program for Redfish Lake sockeye (Snake River stock) since that stock was listed as endangered in 1991. From 1991 to 1997, a total of only 15 adult sockeye returned to Redfish Lake. The first significant returns from captive brood releases into the wild are expected in the fall of 2000. The following observations summarize their sockeye captive broodstock experiences to date (Flagg et al. 1998):

1. Generally, captive broods have matured at an earlier age and smaller size than wild fish. Redfish Lake sockeye raised in captivity matured at 3 years of age and 1.2 kg compared to 4 years and 2.0 to 3.0 kg for wild fish.
2. Eyed-egg viability of spawners has averaged about 60%, although egg viability's averaging less than 60% are common.
3. Fry-to-adult survival has ranged from 13% to 81%, with an average of 50%+.
4. Husbandry methods producing the highest survival to maturity are ranked as follows: (1) circular tanks supplied with pathogen-free water; (2) circular tanks supplied with pumped, filtered, and UV-sterilized seawater; and (3) seawater net pens. In recent years, methods 1 and 2 have been employed for Redfish Lake sockeye, as they appear to ensure much higher survival than method 3.
5. Redfish Lake sockeye captive broodstock egg production translates to a yearly amplification of 55-240 times the number of eggs taken into protective culture.

There have also been discussions with Ward Griffion in the aquaculture industry, who, in his DFO tenure, did some work on sockeye with Roly Brett at the Pacific Biological Station. They successfully reared Babine sockeye to pan-size (300 g) in freshwater. There were problems with

[17] T. Flagg in Manchester and P. Kline in Idaho.

IHNV through the early rearing period, which later disappeared. Rearing in seawater was also attempted, but Griffion advises against doing so, given his experiences and those of some Alaska contacts.

Don MacQuarrie, another former DFO employee, operates the only certified sockeye aquaculture facility in BC. It is a freshwater facility located in Darcy, producing sockeye to 5 kg. In his experience, female sockeye fecundities at this facility have ranged from 2000 to 4000 eggs. Egg viability has been a problem and BKD occurrences have resulted in some production losses. He also has found that culturing sockeye to maturity in freshwater yields better results than in seawater.

In summary, we should not rule out a captive breeding program because of concerns about the feasibility of sockeye culture.

D.3.4 Fish culture considerations

The following considerations should apply in matters of fish husbandry:

1. Wherever possible, IHNV avoidance protocols should be followed. This includes the use of an IHNV-free water supply, thorough disinfection, and complete isolation during incubation. Such a requirement has been well proven by recent Alaskan sockeye enhancement experiences.
2. DFO Fish Health strongly recommends viral and BKD screening of adults to give prior warning of potential problems.
3. When eyed eggs or fry are returned from a satellite facility to their natal stream, development timing should closely match that of wild sub-populations. This strategy appears to lead to increased survivals. The same may also apply to smolt releases.
4. Fry releases should also consider the migration pattern of wild fish (direction fry swim to enter nursery lake).
5. If possible, juvenile marking should be performed to allow for assessment of the enhanced contribution to future adult escapement, and possibly contribution to catch. Without some kind of marking, evaluation of the performance of any enhancement program, let alone one that is conservation-based, is impossible.

D.3.5 Lake Fertilization

Owikeno Lake produces among the smallest smolts of any BC sockeye nursery lake. Smolt weight is <2 g in high-density brood years and <3 g in low-density years. Despite this small range, growth of Owikeno sockeye fry is highly density-dependent. These data indicate that Owikeno sockeye smolts grow bigger when more food is available. With regard to ocean survival, published data show that the relationship between smolt size and smolt-to-adult survival is curvilinear. In other words, a 30% increase in size of a 2-3 g smolt produces a greater incremental increase in survival than a 30% increase in size of a 6 g smolt. If lake fertilization produces more zooplankton, Owikeno sockeye should get bigger and, regardless of oceanic conditions, should survive better than they would have at a smaller size.

In 1978, DFO did an intensive limnological study of Owikeno Lake, sampling it monthly from April to November (Stockner and Shortreed 1979). Photosynthetic rate data from that study indicate that the lake is quite productive (at least in the surface layer). Owikeno is turbid, but not excessively so, since mean euphotic zone depths in 1978 were 5.3 m in the main basin. This is similar to euphotic zone depths found in many organically stained coastal lakes, several of which have been successfully fertilized in the past. What made Owikeno a less than attractive candidate for fertilization in the 1970s was that, besides being relatively turbid, it had a very weak and deep (>30 m) thermocline. Despite the weak thermocline, however, substantial epilimnetic nutrient declines occurred during the growing season.

The conclusion was that, in order to get the desired response in Owikeno, fertilizer loading rates would have to be higher than in a comparable lake with a well-defined epilimnion. In the late 1970s, benefit/cost was one of the most important non-biological factors governing a lake's suitability for fertilization. Owikeno was ruled out as a candidate, not because fertilization would be ineffective, but because at the time there were a number of other coastal lakes where enrichment demonstrated a higher potential benefit/cost ratio. More recently, criteria other than the benefit/cost ratio are being considered, and the restoration of sockeye stocks has become a valid reason for fertilization (e.g., Adams Lake). With migration and management problems in the Fraser and Skeena Rivers intensifying, a large central coast stock that has fewer management or migration problems is becoming more valuable. Given climate change, a cold lake like Owikeno may have a brighter fisheries future than warmer lakes, such as Great Central, Sproat, and Shuswap.

Until 2001 (other than a single survey in June 1996), available limnological data on Owikeno Lake were 23 years old. To determine if conditions today are similar and if fertilization is a viable option, in 2001 limnological sampling comparable to what was done in 1978 was carried out (Shortreed). It should be kept in mind that Owikeno's large size and unstable physical environment mean that fertilization would be costly. A rough preliminary estimate is that the annual cost of fertilizing Owikeno Lake would be $175,000 to $200,000. This assumes that a suitable boat and crew to carry out the fertilizer applications could be found locally, and the cost does not include a sampling program to assess the effects of fertilization.

When considering fertilization for Owikeno and Long lakes, the following considerations are worth noting:

1. Given low fry recruitment, large smolt size is expected for the next several years. Is this the time when fertilization should be considered? Fry densities are going to be 0.66-1.66% of the 1980 and 1990 ten-year averages for Owikeno Lake and 3-5% of the averages for Long Lake. Have nutrient levels suffered because of substantially reduced numbers of spawners in the system? The lake fertilization specialists indicate that enrichment will produce larger smolts at any level of fry recruitment.
2. Can we determine whether Long Lake stocks benefited from fertilization during the brood years where a drastic decline has occurred in spite of it? Would the decline have been worse without fertilization?
3. To date, there is no compelling evidence that freshwater habitat and/or productivity is the causal factor in stock declines. However, fertilization would improve lake productivity, which, in turn, would improve smolt size and early marine survival.
4. If both the number and size of smolts are important factors in the stock's ability to "survive" (in sufficient numbers to avoid extirpation), then under the current scenario fertilization alone will not address conservation goals. Fertilization in combination with techniques to increase fry recruitment is likely the most effective means of stock restoration, provided that marine survival returns to normal.

D.4 Enhancement options and recommendations for the recovery plan

D.4.1 Enhancement options

Table D.5 presents a list of enhancement options for Owikeno and Long Lake sockeye, together with the "pros and cons" of each option. This is certainly not an exhaustive list of possible enhancement measures, but rather shows the options considered most feasible for the Central Coast sockeye situation. The options listed identify Snootli Hatchery as the facility of choice at this time. There are concerns over staffing (experience and technical expertise), available infrastructure, risk management capabilities, and costs associated with creating or rebuilding a facility in Owikeno.

It is recommended that a hatchery intervention project be considered for at least a five-year term from 2000 through 2004, regardless of whether escapement levels are above LRPs during that period. This would allow for faster rebuilding to target reference levels and would help increase our technical capacity to enhance these sockeye stocks in case returns beyond 2004 necessitate a longer-term or more dramatic intervention strategy. Should escapements reach or exceed targets for five years in succession (a full cycle), intervention would no longer be required.

Table D.6 proposes a list of sub-populations that should be considered for enhancement and the specific enhancement strategy recommended for each. A mix of enhancement strategies is proposed:

- Egg to fry at Snoolti Hatchery with fry being released after a short period of rearing to natal stream;
- Egg to eyed egg at Snootli Hatchery with transfer to an in-stream incubation system in a natal stream side-channel; and
- Egg to eyed egg at Snootli Hatchery with transfer to floating cassette incubators in or at the mouth of the natal stream.

D.4.2 Selection of broodstock

For the purpose of this document, sub-populations from both Owikeno and Long lakes are included as candidates for enhancement. Using LRP figures, the Owikeno Basin stock is in the most "need," with 1999 escapement at only 12% (3,600) of the LRP of 30,000. The escapement to Long Lake was 75% (5,900) of the LRP of 8,000 in 1999.

The Owikeno Basin is home to at least twelve sub-populations of sockeye entering three sub-basins. Since it is very unlikely that a recovery project could include all sub-populations at this time, one representative sub-population from each basin and stream type, as well as the Genesee and Wannock sub-populations, are chosen as candidates for enhancement. Using this strategy, a total of seven Owikeno sub-populations would be included in the project to start (see Table D.7).

There are three sub-populations that comprise the Long Lake Basin run: the Smokehouse, Canoe, and Long Lake beach spawners. The enhancement proposal includes the Smokehouse and Canoe sub-populations, which comprise a majority of the run, because of the logistical problems associated with obtaining beach-spawners (Table D.7).

Table D.5. Enhancement options.

Option	"Pros"	"Cons"
1. Primary and secondary incubation at Snootli hatchery, fry release to natal stream	• High survival to fry stage in controlled conditions • Disease management protocols more easily implemented at Snootli Hatchery • More control over emergence timing, with option of short-term feeding • Adult assessment possible through otolith marking	• Egg transport "out" and fry transport "back" required • Short period of fry imprinting on natal stream • Risk of IHN outbreak at Snootli increases during secondary incubation • Hatchery effluent disinfection required • Benefits limited where there is a marine survival problem
2. Primary incubation at Snootli, secondary incubation using in-stream incubators in natal stream where no anadromous spawning occurs above egg location	• High survival to eyed egg stage in controlled conditions • Lowered risk of IHN outbreak at Snootli and in natal stream • Longer imprinting period in natal stream • Adult assessment possible through otolith marking	• Egg transport out and back required • In-stream incubators still considered experimental, uncertain survivals in incubators exposed to varying flow conditions • Hatchery effluent management needed • Possible disease exposure concerns during secondary incubation • Hatchery incubation temperatures must be carefully managed to ensure optimal emergence timing • Benefits limited where there is a marine survival problem
3. Primary incubation at Snootli, secondary incubation in floating cassettes in or at mouth of natal stream	• High survival to eyed egg stage in controlled conditions • Lowered risk of IHNV outbreak at Snootli • Longer imprinting period in natal stream • Adult assessment possible through otolith marking • Option of short-term pen-rearing if necessary to match emergence timing	• Egg transport out and back required • Cassette incubators still considered experimental, uncertain survivals in incubators exposed to varying flow conditions • Hatchery effluent management needed • Possible disease exposure concerns during secondary incubation • Benefits limited where there is a marine survival problem
4. Captive breeding	• Greatest buffering of survival problems at any life-stage • Potentially the greatest egg to adult survival possible • Provides living gene bank in the event of stock extinction • Adult assessment possible through otolith marking	• Highest risk of disease problems and systems failures • Potential erosion of genetic diversity due to greater amplification factor • Potential for domestication selection • Experimental, little empirical evidence to demonstrate viability of post-supplementation population • Possible homing concerns • Most expensive option
5. Lake fertilization	• Least intrusive and lowest risk intervention • May increase marine survival through increases in smolt size • Benefits all sub-populations at the same time in proportion to current status	• Not proven, low fry smolt recruitment situation therefore benefits uncertain • Assessment more difficult, but may be less important since enrichment is less intrusive and low risk • More expensive for large lake like Owikeno with weak, deep thermocline
6. Estuary & Marine Enrichment	• Low risk • May increase marine survival through increases in smolt size • May benefit all populations at the same time in proportion to current status	• Assessment difficult • Results of fertilization of Yakoun River estuary not encouraging in terms of effectiveness • Cost may be high

Note: Lake fertilization may also be considered as habitat enhancement, but is treated here as a short-term measure to increase smolt survival (i.e., conservation enhancement).

Table D.6. Owikeno and Long Lake sockeye – sub-population-specific enhancement techniques.

		INCUBATION	INCUBATION	PONDING & REARING
SUB-POPULATION	CULTIVATION	PRIMARY - EGG TO EYED	SECONDARY - EYED EGG TO FRY	SWIM UP+~1MO. REARING
	METHOD	LOCATION/TECHNIQUE	LOCATION/TECHNIQUE	LOCATION/TECHNIQUE
OWIKENO BASIN SUB-POPULATIONS (RIVERS INLET)				
WASHWASH	HATCHERY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY - SMALL CIRC. TUB
INZIANA	HATCHERY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY - SMALL CIRC. TUB
SHEEMAHANT	HATCHERY	SNOOTLI HATCHERY- HEATH TRAY	EGGS TRANSPORTED BACK TO NATAL SYSTEM AND PLACED IN BULK INSTREAM OR SCOTTY JORDAN BOXES	SNOOTLI HATCHERY - SMALL CIRC. TUB OR CAP TROUGH, INSTREAM = VOLITIONAL
*GENESEE	CAPTIVE BROOD	SNOOTLI HATCHERY- HEATH TRAY *IF EGGS TAKEN*	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY - SMALL CIRC. TUB, INSTREAM = VOLITIONAL
NEECHANZ	HATCHERY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY - SMALL CIRC. TUB, INSTREAM = VOLITIONAL
AMBACH	HATCHERY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY - SMALL CIRC. TUB
WANNOCK	HATCHERY	SNOOTLI HATCHERY- HEATH TRAY	EGGS TRANSPORTED BACK TO FLOATING CASSETTE INCUBATORS IN WANNOCK RIVER	SNOOTLI HATCHERY - SMALL CIRC. TUBS OR CAP TROUGH, WANNOCK RIVER = NETPEN
LONG LAKE BASIN SUB-POPULATIONS (SMITHS INLET)				
SMOKEHOUSE	HATCHERY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY- HEATH TRAY/KITOI BOX	SNOOTLI HATCHERY - SMALL CIRC. TUB
CANOE	HATCHERY	SNOOTLI HATCHERY- HEATH TRAY	SNOOTLI HATCHERY- HEATH TRAY/KITOI BOX	SNOOTLI HATCHERY - SMALL CIRC. TUB

*NOTE: in 1999 the escapement estimate was 10 fish so this could be a prime candidate for captive brood (collecting fry from 99 brood out-migrants).

Table D.7. Scenario 1 egg targets.

OWIKENO BASIN PROPOSED SUB-POPULATIONS

		% OF	SCENARIO 1 – MINIMUM EGG TARGET			
SUB-POPULATION	HISTORIC	GROUP	ADULT	EGG	BROODSTOCK	
	TARGET	TOT.	PROD.	TARGET	FEM.	ADULTS
WASHWASH	100,000	13%	293	65,000	22	44
INZIANA	75,000	10%	225	50,000	17	34
SHEEMAHANT	200,000	27%	608	135,000	45	90
GENESEE	25,000	3%	225	50,000	17	34
NEECHANZ	50,000	7%	225	50,000	17	34
AMBACH	100,000	13%	293	65,000	22	44
WANNOCK	200,000	27%	608	135,000	45	90
TOTAL GRP.	750,000		2275	550,000	185	370
WHOLE BASIN	1,012,000	(Group tot. as % of Basin = 74%)				

LONG LAKE BASIN PROPOSED SUB-POPULATIONS

			SCENARIO 1- MINIMUM EGG TARGET			
SUB-POPULATION	HISTORIC	%OF	ADULT	EGG	BROODSTOCK	
	TARGET	TOT.	PROD.	TARGET	FEM.	ADULTS
SMOKEHOUSE	150000	75%	675	150,000	50	100
CANOE	50000	25%	225	50,000	17	34
TOTAL GRP.	200000		900	200,000	67	134

Assumes:

1. 50% male and female in escapement.
2. 3,000 eggs/female.
3. 90% egg-fry and .5% fry-adult (half of bio-standards to be conservative).

D.4.3 Level of intervention – Egg target considerations

To assist with setting egg targets for individual sub-populations, we examined the proportion that each sub-population comprised of the candidate stock aggregate and used these proportions to develop egg-take targets for each of the candidate sub-populations. The first three columns of Table D.7 list the candidate sub-populations from Owikeno and Long lakes, their respective historic target escapements, and the proportional contribution of each to the candidate stock aggregate. The remaining columns of the table provide egg and adult production targets based on the following scenario:

Scenario 1 recommends a minimum level of enhancement intervention even if the LRP is met during the project period. This will allow for the refinement of enhancement techniques and will provide the required number of returning spawners for enhancement assessment purposes. Note that the egg targets in this scenario are higher for Genesee and Neechanz sub-populations than the proportional formula would recommend. This is due to the logistical difficulties of compartmentalizing egg lots of less than 50,000. Compartmentalization is a sockeye fish culture strategy employed to minimize the risk of total loss in the event of an IHNV outbreak. Should 50,000 eggs represent removing more than 30% of available spawners from a system, the utility of taking any eggs at all will have to be reviewed.

Scenario 2 entails enhanced fry production to augment wild fry recruitment shortfalls when escapements are below the LRP. Table D.8 outlines egg-take requirements at various LRP escapement shortfalls. Candidate sub-populations and the proportion of eggs taken from each are the same as those presented in Scenario 1. These figures are provided simply for planning purposes and to give perspective about the level of involvement required. It may not be possible to achieve these egg targets due to logistical difficulties.

The actual level of intervention will depend largely on several factors, notably:

- strict adherence to existing guidelines limiting such interventions in wild systems;
- capacity of secure facilities for incubating sockeye and the availability of operating resources, and
- availability of broodstock in 2000 and various operational considerations in obtaining broodstock.

Table D.8. Scenario 2 egg targets.

Oweekeno Lake Escapement	LRP Spawner Shortfall	Wild Fry Recruitment Shortfall	# Eggs Required to Compensate for Fry Shortfall	Maximum # of Broodstock Available	# of Broodstock Required	Enhanced Fry Production
27,000	3,000	675,000	900,000	8,100	600	810,000
24,000	6,000	1,350,000	1,800,000	7,200	1,200	1,620,000
21,000	9,000	2,025,000	2,700,000	6,300	1,800	2,430,000
18,000	12,000	2,700,000	3,600,000	5,400	2,400	3,240,000
15,000	15,000	3,375,000	4,500,000	4,500	3,000	4,050,000
12,000	18,000	4,050,000	5,400,000	3,600	3,600	4,860,000

Long Lake Escapement	LRP Spawner Shortfall	Wild Fry Recruitment Shortfall	# Eggs Required to Compensate for Fry Shortfall	Maximum # of Broodstock Available	# of Broodstock Required	Enhanced Fry Production
7000	1,000	225,000	300,000	2,100	200	270,000
6000	2,000	450,000	600,000	1,800	400	540,000
5000	3,000	675,000	900,000	1,500	600	810,000
4000	4,000	900,000	1,200,000	1,200	800	1,080,000
3000	5,000	1,125,000	1,500,000	900	1,000	1,350,000

Assumptions:
1. Spawner sex ratio of 1:1
2. Fecundity of 3000 eggs
3. Wild egg-fry survival of 15%
4. Enhanced egg-fry survival of 90%

Note: Wild fry recruitment lost as a result of broodstock removal from wild sub-population is compensated for in egg targets

D.5 References

Anon. 1996. *Methods to Assist in the Rebuilding of Wild Pacific Salmon Populations: Conceptual Framework and Review of Methods with Special Emphasis on the Quickstart Initiative.* Vancouver: DFO, 34 p. (Unpubl.)

Bonnell, G. 1999. "Genetic Practices for Hatcheries." Vancouver: DFO, 4 p. (Unpubl.).

Burgner, R.L. 1991. "Life History of Sockeye Salmon," In C. Groot and L. Margolis (ed.), *Pacific Salmon Life Histories.* Vancouver: UBC Press.

Cross, C. 1998. "The DFO Gene Banking Program: Context, Rationale and Guidelines." Vancouver: DFO, 3 p. (Unpubl. Draft)

Fedorenko, A.Y., and B.G. Shepherd. 1986. "Review of Salmon Transplant Procedures and Suggested Transplant Guidelines." *Canadian Technical Report Fisheries Aquatic Science* 1479: 144 p.

Flagg, T.A., W.C. McAuley, M.R. Wastel, D.A. Frost, and C.V.W. Mahnken. 1998. "Redfish Lake Sockeye Salmon Captive Broodstock Program, NMFS." In R.Z. Smith (ed.). *Proceedings of the 48th Annual Pacific Northwest Fish Culture Conference*, pp. 127-135. Gleneden Beach, OR.

Kieser, D. 1999. "Federal-Provincial Fish Transplant Committee." Nanaimo: DFO. (Unpubl.).

Lofthouse, D. Enhancement Operations Division, DFO, Vancouver. Pers. comm.

McDaniel, T.R., K.M. Pratt, T.R. Meyers, T.D. Ellison, J.E. Follett, and J.A. Burke. 1994. *Alaska Sockeye Salmon Culture Manual.* Alaska Department of Fish and Game, Special Publication #6: 41 p.

Stockner, J.G., and J.S. Shortreed. 1979. *Limnological Studies of 13 Sockeye Salmon Nursery Lakes in British Columbia, Canada.* Canadian Fisheries and Marine Services Technical Report 865: 125 p.