Enhancement Guidelines

For Salmon Enhancement Programs

3/31/2008

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2 Introduction

Who is the audience for this document? What exactly is this to be used for once it's completed?

Salmon populations have been in the public focus for a significant period and assessments of British Columbia stocks show mixed results. Overall patterns of abundance of salmon in the Pacific Northwest has decreased sharply from the levels of the late 1800s and early 1900s, although there have been some upward trends (Northcote and Atagi 1996). Starting in the mid 1800s, the human population of the Pacific Northwest began growing and this coincided with the advent of more efficient fishing methods and the ability to efficiently preserve and distribute the catch in cans. Also, the timing and approximate size of the annual salmon was predictable, thus fishermen, canners, and distributors could plan accordingly. The effect on many salmon stocks was massive and rapid.

By the early 1900's many stocks were reduced below levels required to ensure reproductive success, let alone support fishing; some probably were extirpated. Competition for salmon harvest has been severe throughout the 20th century; recreational, commercial, and First Nations users demanded a portion of a dwindling catch and successfully pressured fisheries managers to maintain relatively high catch levels. The general pattern of rapidly increasing harvest and eventual over exploitation of Pacific Northwest salmon, far from being an aberration, is typical in renewable natural resource management (Hilborn et. al. 1995).

High harvest rates are not the only major cause of salmon decline. Dams have been built on many rivers and streams for purposes of navigation, irrigation, power generation, and flood control. Dams impede passage of returning spawners and migrating young fish and moving salmon past dams has been a challenge. Further, dams also alter the quantity and timing of water flow and sediment transport, causing a number of ecological changes potentially adverse to salmon. Water diversions (and dams) for irrigation, coupled with wide-scale use of chemical fertilizers and pesticides, have contributed to reductions in salmon runs. In the Columbia Basin, for example, approximately a third of the annual flow is used for irrigation (Mundy et. al 1996). Many agricultural practices, such as grazing of cattle and sheep, can reduce salmon runs by altering water quality and spawning and nursery habitat, especially if the run size is already small.

Timber in British Columbia is of high commercial quality and there has been considerable use of this natural resource. The harvest and transport (initially via water and later by an extensive system of forest roads) of timber has also had adverse consequences on salmon spawning and rearing. Logging and associated road construction (especially prior to widespread adoption of current best practices) may cause increased water temperature and sediment load, as well as many other changes, that can, at least temporarily, decrease the quality of salmon habitat (Meehan and Bjornn, 1991).

Pacific salmon can be spawned and raised under the artificial conditions provided by hatcheries and spawning channels and this grown extensively in practice since stock depletion was first noted. Hatcheries were often successful in maintaining salmon runs that would not have otherwise survived, but hatchery programs have been argued to have accelerated declines of wild salmon (NRC 1996). Opponents of hatcheries argue that hatchery-produced fish may introduce diseases, compete with naturally spawned fish, and alter genetic diversity through inter-breeding, which may have impacts on the fitness of subsequent generations (Hilborn 1992, Waples 1999) and feel that large-scale hatchery programs in the Pacific Northwest have largely failed to provide the anticipated benefits.

Since the late 1800's, when hatcheries were first used to help enhance salmon stocks, attitudes have evolved from near universal support to some skepticism as some became concerned with preserving wild salmon rather than simply maintaining runs (Bottom, 1996). Some individuals are openly hostile to the use of hatcheries, contending that the hatcheries releasing salmon into the river systems actually worsen conditions for wild salmon and it has been contended that "… hatchery production of salmon masks the decline of wild salmon, contributes to the genetic dilution and loss of wild salmon, and increases competition for limited freshwater and ocean resources on which wild salmon depend" McGinnis (1994). The counter argument is that hatcheries *can* maintain salmon runs, even in rivers where there is no other practical option.

Decline of the Pacific salmon stocks cannot be blamed on circumstances in the freshwater systems, we must also consider the marine component of their life-cycles since most salmon spend the majority of their life in the sea and oceanic factors play an important role their productivity. Similarly, El Niño and La Niña events may have effects on salmon. It is undisputed, however, that high quality freshwater habitat plays a critical role in the health of salmon stocks during periods of unfavorable ocean conditions (Bisson 1996). Climatic variations and change also affect the condition of salmon stocks (Pearcy 1996). As with oceanic variations, the type and extent of ecological effects caused by climate variations is rarely easily resolved. Recent environmental fluctuations have resulted in unusually warm and dry winters in the Pacific Northwest.

Predation, especially by marine mammals, birds, and northern squawfish, are often identified as causes of the decline of. For example, since the early 1970's populations of harbor seals and sea lions have increased dramatically and rebounded to near historical levels due to a ban on harvest (Fresh 1996). Because these animals congregate at river mouths, they are very effective in capturing returning salmon (NRC). Other marine mammals, birds, and other species of fish prey on salmon and can have significant local effects, but they are not believed to be one of the dominant causes of the general decline of wild salmon stocks (Fresh 1996).

There are also significant regional difference in salmon populations and these show a significant degree of variation. An inverse relationship exists between the size of salmon runs between northern and southern halves of their distributions. When populations in the southern half are low, runs in the northern half of the geographic distribution are often large (Hare 1996, Pearcy 1996). This reciprocal relationship is thought to be driven by oscillating climatic conditions, the resultant effect on ocean currents and upwelling that support salmon food supplies, and the subsequent consequences for salmon during the ocean phase of their life cycles. As ocean currents shift, often abruptly, marine habitat for salmon can rapidly degrade (Lackey 1999). This north-south dominance cycle appears to repeat every 20–30 years.

The bottom line is that , although no species of salmon is near extinction many wild stocks of salmon in the Pacific Northwest have been extirpated or are experiencing population decline. This highlights the need for a multipronged approach to salmon restoration. One prong of this approach is the restoration of habitat and ecosystem health through changes to resource usage and other means. A second component of salmon restoration involves a practical approach to salmon population enhancement using appropriate practices and management of risks. Historic and current habitat complexity and connectivity and intrapopulation life history diversity must be considered. The following describes the Salmon Enhancement Program, its objectives, and risks, outlines considerations in planning enhancement programs and identifies the policies that govern such programs. It also provides guidelines for specific enhancement practices. It is not designed to fully detail every operating procedure carried out at each facility, as these are detailed elsewhere (e.g. site specific Fish Health Management Plans).

3 The Salmon Enhancement Program (SEP)

The Pacific salmonids are an important resource from economic, social and aesthetic perspectives, and have come to symbolize the distinctive characteristic of West Coast fisheries and marine resources. There has been growing concern over salmon stocks for decades, and much of the public concern over salmon policy is driven by the documented decline of wild salmon (Smith and Steel, 1996). While the complete extent of the decline is not accurately known, the decline and public concern are genuine. Public concern is not limited to loss of a food or recreational resource because farm-raised and imported wild salmon are readily available for sale, and supplemental stocking could maintain at least some runs indefinitely. Many view salmon as a cultural symbol and deem further reduction of remnant wild runs as an indicator of a grave decline in the quality of life in the Pacific Northwest (Lang, 1996; National Research Council, 1996). Such passion for salmon does not necessarily mean that advocates are unwilling to trade salmon for competing priorities, but it does mean that maintenance of salmon is a pivotal policy for them; in fact, for some individuals, restoring wild salmon runs is a central public policy objective.

As anadromous fish, adult Pacific salmon spawn in rivers and lakes, and travel downstream as juveniles to the ocean where they may migrate thousands of kilometres in the North Pacific. Close to 10,000 (9,662) anadromous stocks of salmon have been identified in British Columbia (Slaney et.al. 1996). Populations range from several fish (e.g. Sakinaw) to runs numbering in the millions (e.g. Fraser River). Slaney et.al. (1996) identified 866 Chinook, 1,625 chum, 2,594 coho, 2,169 pink, 917 sockeye, 867 steelhead and 612 sea-run cutthroat trout stocks. Assessment of over 5,000 of the commercially important stocks indicated that 624 were considered to be at high risk, 78 moderately at risk, 230 of special concern and 142 stocks had been driven to extinction. Over 4000 stocks were not assessed due to small population size. Some stocks have had drastic reductions in very short time-spans. For example, abundance of Sakinaw sockeye was reportedly stable between 1955 and 1985. In just three generations, (1985-1997) their numbers declined by 98% to only 80 fish in 1996 (DFO 2002). Similarly, the Cultus Lake sockeye stocks decreased by 51% in three generations and escapements between 1998 and 2001 were the lowest ever recorded (DFO 2003). Many other stocks and species have also been deemed to be at risk.

The potential to enhance these resources has long been recognized and hatchery programs have been utilized intermittently in B.C. since the early 1880's. Initially, these hatchery programs were designed in an attempt to compensate for habitat destruction and over-exploitation but it wasn't until much later that an organized, wide-spread program to address declining stocks in British Columbia was brought into existence. The British Columbia Salmonid Enhancement Program was undertaken in 1977 to rebuild stocks and increase catch through the use of enhancement technology. The program was also designed to involve the public and raise awareness of the salmonid resource, generate employment and economic development in coastal and First Nations communities, and improve the understanding of salmonid populations. In 1995, SEP was combined with Habitat Management to form the Habitat and Enhancement Branch (HEB). All elements of SEP were managed centrally until 2001, at which time it moved to a delivery model with more local management of area programs and a small central coordinating body. In 2004, the Oceans program was merged with HEB to form the Oceans, Habitat and Enhancement Branch (OHEB) with the enhancement component still known as SEP. The SEP acronym will be used throughout this document to connote the OHEB enhancement program.

When the Salmonid Enhancement Program (SEP) began in 1977, it integrated three existing federally run spawning channels built in the 1960's and five production hatcheries built in the early 1970's. These hatcheries and spawning channels were supplemented with removal of obstructions, enrichment of lake systems, and other enhancement techniques (MacKinlay et.al. 2004). SEP is now managed as part of the DFO Pacific Region Oceans, Habitat and Enhancement Branch (OHEB) and consists of approximately 300 diverse projects throughout British Columbia that produce Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), chum (*O. keta*), pink (*O. gorbuscha*), and sockeye salmon (*O. nerka*), as well as small numbers of rainbow trout and steelhead salmon (*O. mykiss*) cutthroat trout (*O. clarki*). The latter two species are the responsibility of the province of British Columbia but are raised in partnership with a few DFO facilities.

Projects range in size from spawning channels that produce nearly 100 million juvenile salmon annually, to school classroom incubators that produce fewer than one hundred juveniles annually. The majority of hatchery and incubation projects are small, producing less than 1000 expected adults based on production targets and average survival rates. Projects are operated by OHEB staff, contracted to community and First Nations groups, or operated by volunteer groups with some OHEB support – up to 10,000 volunteers participate in the SEP program annually. There are also fish habitat restoration and improvement projects that OHEB has designed and implemented with First Nations, industry, community groups and other government agencies. Collectively, these projects fall into the three following categories:

Major production facilities: Currently 18 DFO-funded facilities are operated by staff who are federal government employees. Technical oversight is provided by support biologists. These facilities tend to be relatively large, compared to facilities in the other components of the hatchery program and include hatcheries designed to conserve stocks and support fisheries. Rigorous data reporting (including detailed brood stock and juvenile records) and production planning is undertaken for these facilities.

Community Economic Development Projects (CEDP): There are currently 22 of these facilities. They produce important but smaller numbers of salmon than the large production facilities and are usually operated, under contract, by First Nations or community groups. Technical oversight and support are provided by Community Advisors and sometimes by staff from Federal facilities, with additional technical advice provided by biologists. The CEDP facilities tend to be small to mid-size compared to major projects. Data reporting requirements focus on the numbers of adults utilized for brood stock, eggs taken and juveniles released. Data on marked releases and adult recoveries are also collected at those facilities where juvenile fish are marked.

Public Involvement Program (PIP) Projects: There are currently approximately 178 PIP projects , of which about 100 are hatcheries or incubation facilities. PIP projects are operated largely by volunteers and part time staff and receive little or no direct funding from DFO (although some seed funding may have been used for start-up). In some cases because of external fund-raising they are able to retain an individual as full time staff. Technical support is usually provided by a DFO Community Advisor who acts as a liaison with headquarters, with local biologists providing support and production planning. The PIP facilities tend to be relatively small, and have similar data collection requirements to the CEDP projects. Collectively, CEDP and PIP projects are generally referred to as Community Projects.

SEP hatcheries and incubation facilities are used to meet a number of objectives that involve restoring and rebuilding populations and supporting fisheries. However, the objectives of some projects are more broadly defined and include production to provide mark groups for the assessment of wild salmon or, in the case of school or other small programs, releases of small groups of hatchery salmon for education and public awareness.

Depending on species and enhancement strategy, juveniles are released from hatcheries at various stages. Chum and pink salmon are released either immediately after emergence (as unfed fry) or following approximately one month of feeding (as fed fry). Coho may be released as fry, usually after 1-3 months of rearing, or as smolts after one year of rearing. Coastal stocks of Chinook are released after 3-4 months of rearing, while interior Chinook stocks are frequently reared for one year. Most sockeye are produced in spawning channels, but a small number are hatchery-incubated and short-term reared.

Not taking into consideration the production from spawning channels, Chinook and chum salmon comprise the majority of releases from SEP facilities. Recent declines in releases of chum have been due to reduced production targets because of successful rebuilding or declining fisheries. Maximum release production of Chinook and coho smolts was achieved in the early to mid 1980's and has been relatively stable since. Unfed pink salmon fry releases fluctuate annually because of natural cycles in the Fraser River and the phasing in and out of pink projects since the 1988 brood year. Pink fed fry releases peaked in 1985 at more than 5 million but have since declined due to reduced emphasis on this strategy. Sockeye releases have declined in recent years because disease (e.g. *Loma*, *Ichthyophthirius*, *Parvicapsula*) mortality has affected spawning success in the Skeena River channel system. Additionally, production from Fraser River sockeye channels fluctuates due to natural cycles.

4 Policies or other DFO guidelines affecting enhancement operation and planning

How do the following affect SEP Practices?

The American Fisheries Society (AFS) recommended a number of considerations prior to implementing a stocking program (Anonymous 1995). Categorically, these are: biological feasibility, effects analysis, an economic evaluation, public involvement and administrative considerations. The SEP takes an approach that meets or exceeds the recommended guidelines for the use of cultured fish in resource management and MacKinlay et. al. (2004) consider each of these below:

1. Biological feasibility can be better thought of as an assessment of the carrying capacity of a target ecosystem and the SEP has covered this through extensive feasibility studies carried out prior to implementation of all major facilities.
2. Effects analysis in BC is mainly concerned with genetic effects and the main problem is generally agreed to be genetic effects from introduced fish on local populations. However, this is not thought to be a concern where cultured fish are from the local, wild population.
3. The SEP carried out thorough economic evaluation by examining benefit:cost analyses on all major projects.
4. Encouragement of public involvement has been an integral component of the SEP since its inception.
5. Interagency cooperation is another major part of the SEP original structure.
6. The SEP has clear management objectives, operational guidelines for each facility and strategic plans both for biological and agency processes have been part of SEP's continual redefinition of itself since its inception. This meets the AFS recommendations for administrative considerations

The HRSG recommended that hatchery programs be evaluated in the context of the regions and watersheds in which they operate and goals set for them by managers (HRSG 2004). The SEP uses a number of integrated regional processes in which enhancement goals can be incorporated.

4.1 Integrated Fisheries Management Planning

The Integrated Fisheries Management Planning (IFMP) process is a major planning process that the department uses to consult with stakeholders on annual resource management plans. Integrated Fisheries Management Plans (IFMPs) for salmon in the north and south coast of British Columbia are prepared annually to identify the anticipated fishing opportunities and constraints for the coming season. The IFMPs are developed based on a scientific analysis of environmental conditions, stock assessments and stakeholder input (DFO 2007). Pacific salmon species covered in the plan include sockeye, coho, pink, chum, and Chinook salmon. Due to their significance and the very high level of interest in ensuring the stocks can sustain themselves, prudent and careful management supported by the broad spectrum of interests is required.

In order to effectively manage stocks, a series of policies and regulations have been adopted to address biological uncertainty, legal requirements and sharing of resources. The IFMP's describe the management of Pacific salmon fisheries in B.C. and the factors which influence decision-making. They incorporate the results of consultations and input from the Integrated Harvest Planning Committee (IHPC), First Nations, and recreational and commercial advisors.

Departmental policy development related to the management of fisheries is guided by a range of considerations that include legislated mandates, judicial guidance and international and domestic commitments that promote biodiversity and a precautionary, ecosystem-based approach to the management of aquatic resources. While the policies themselves are not subject to annual changes, implementation details are continually refined where there is general support.

Salmon management programs are guided by a number of policy and operational initiatives. These include; Canada's Policy for Conservation of Wild Pacific Salmon (WSP), an Allocation Policy for Pacific Salmon, First Nations and Canadian Fisheries Framework,, Excess Salmon to Spawning Requirements, Pacific Fisheries Reform, a Policy for Selective Fishing, the Integrated Harvest Planning Committee, and Pacific Region Fishery Monitoring and Reporting Framework, the Species at Risk Act (SARA), and the Pacific Salmon Treaty. The Watershed-based Fisheries Management Planning (WFSP), Community Roundtables, Community Advisors and scientific support also guide many aspect of the enhancement process.

4.2 The Wild Salmon Policy (WSP)

Canada's Policy for Conservation of Wild Pacific Salmon (also called the Wild Salmon Policy) sets out the vision regarding the importance and role of Pacific Wild salmon as well as a strategy for their protection.

The *Wild Salmon Policy* was developed to promote a healthier resource to support sustainable fisheries and sets out a process for the protection, preservation and rebuilding of wild salmon and their marine and freshwater ecosystems (DFO 2005). The policy provides for the identification of irreplaceable groupings of stocks (called "Conservation Units") and the identification of upper and lower benchmarks that are a measure of the status of each CU. Other features of the WSP include the monitoring of habitat status and a process for public engagement in the establishment of long term strategic plans for Conservation Units.

Genetic diversity must be safeguarded by protecting groups of wild salmon that, if extirpated, would be unlikely to recolonize naturally in a human lifetime. The WSP sets clear objectives for salmon biodiversity, develops comprehensive strategies for achieving these objectives and describes actions to anticipate and address future pressures on wild salmon.

Habitat and ecosystem integrity is to be maintained by building in ecosystem considerations in planning and decision-making for habitat and fisheries management. Maintaining the well-being of the ecosystem is inseparable from maintaining the future of wild salmon and the WSP habitat program links watershed protection and stewardship initiatives with fish production objectives by integrating habitat monitoring and program planning.

Fisheries must be managed for sustainability and resource management decisions need to consider biological, social and economic consequences; must be guided by a precautionary approach; must reflect best science including Aboriginal Traditional Knowledge (ATK); and must maintain the potential for future generations to meet their needs and aspirations. The maintenance of biodiversity and healthy ecosystems must be considered in the context of human needs for use now and in the future.

Further information on the Wild Salmon Policy can be located at:

http://www-comm.pac.dfo-mpo.gc.ca/publications/wsp/wsp_e.pdf

4.3 An Allocation Policy of Pacific Salmon

In the coastal fishery, the Minister of Fisheries and Oceans awards access and divides harvest opportunities. The exercise of this discretion is subject to aboriginal and treaty rights, general administrative law principles and, where it can be demonstrated to exist, aboriginal title to resources. *An Allocation Policy for Pacific Salmon* (DFO 1999) contains principles to guide the management and allocation of the Pacific salmon resource between First Nations, commercial and recreational harvesters.

The Allocation Board helps to ensure that fisheries management is open and transparent, fair, involves public participation and provides an economical decision making process. Public participation in the key decisions on the management of a public resource provides benefits vital to the well-being of individuals and communities. The Board was designed to support the Crown in reaching conservation goals, meetings obligations to First Nations and supporting sustainable recreational and commercial fisheries. The Allocation Board is intended to provide advice regarding the implementation of established allocation principles and licensing rules and long-term change to those allocation principles and commercial licensing rules. It has a coast-wide mandate to advise on domestic allocation, covering both commercial and recreational fisheries. First Nations food, social and ceremonial harvesting and treaty obligations are excluded from the Board's mandate.

Management is guided by:

1. **Conservation:** Conservation of Pacific salmon stocks is the primary objective and takes precedence in managing the resource – the Board states that conservation will not be compromised to achieve salmon allocation targets. The Wild Salmon Policy (see below) is aimed at defining conservation as it applies to wild salmon and identifying how conservation goals and objectives can be achieved in practice.
2. **First Nations:** After conservation needs are met, First Nations' food, social and ceremonial requirements and treaty obligations to First Nations have first priority in salmon allocation. Each year, Fisheries and Oceans Canada staff consult with First Nations on their needs for food, social and ceremonial fish and matters that may affect fishing and preferred fishing methods. Fisheries and Oceans Canada respects that fishing has a cultural component for First Nations.
3. **Common Property Resource:** Salmon is a common property resource that is managed by the federal government on behalf of all Canadians, both present and future. Common property does not imply open access. Although Pacific salmon are common property of all Canadians, the federal government has a constitutional responsibility to decide who has access to salmon resources and under what conditions. The Fisheries Act provides the Minister of Fisheries and Oceans Canada with legislative authority for management and regulation of the fishery. It grants the Minister discretion and powers necessary to regulate access to the resource, to impose conditions of harvesting and to develop and enforce regulations.
4. **Recreational Allocation:** After conservation needs are met, and priority access for First Nations as set out in Principle 2 is addressed, recreational anglers are provided priority to directed fisheries on chinook and coho salmon and predictable and stable fishing opportunities for sockeye, pink and chum salmon. The opportunity to harvest chinook and coho salmon is the mainstay of the recreational fishery.
5. **Commercial Allocation:** After conservation needs are met, and priority access for First Nations as set out in Principle 2 is addressed, the commercial sector is allocated at least 95 per cent of combined commercial and recreational harvest of sockeye, pink and chum salmon and the commercial harvest of chinook and coho will occur when abundance permits. The harvest of sockeye, pink and chum salmon is the mainstay of the commercial fishery. The commercial industry harvests the vast majority of these species. Special consideration for the commercial sector with respect to these species is appropriate in support of a viable commercial industry.
6. **Selective Fishing:** To encourage selective fishing, a portion of the total available commercial catch is set aside for existing commercial licence holders to test (is this still true?) alternative, more selective harvesting gear and technology and, over time, commercial allocations will favour those that can demonstrate their ability to fish selectively. Given the mixed stock nature of the Pacific salmon fishery, more selective fishing practices are required in order to maximize the harvest of target species, in particular sockeye, pink and chum, and minimize the by-catch of other species.

7. **Gear Allocations:** Target allocations for the commercial sector are established on a coast-wide basis by gear, with the catch of all species expressed on a sockeye equivalent basis, and subject to adjustments over time, to account for conservation needs, including selective fishing, and possible changes resulting from the Voluntary Salmon Licence Retirement Program.

4.4 First Nations and Canada's Fisheries Framework

The Government of Canada's legal and policy frameworks identify a special obligation to provide First Nations the opportunity to harvest fish for food, social and ceremonial purposes. The Aboriginal Fisheries Strategy (AFS) was implemented in 1992 to address several objectives related to First Nations and their access to the resource. These included:

- improving relations with First Nations,
- providing a framework for the management of the First Nations fishery in a manner that was consistent with the 1990 Supreme Court of Canada Sparrow decision,
- greater involvement of First Nations in the management of fisheries, and
- increased participation in commercial fisheries (Allocation Transfer Program or ATP).

The AFS continues to be the principle mechanism that supports the development of relationships with First Nations including the consultation, planning and implementation of fisheries, and the development of capacity to undertake fisheries management, stock assessment, enhancement and habitat protection programs.

The Aboriginal Aquatic Resources and Oceans Management (AAROM) program has been implemented to fund aggregations of First Nation groups to build the capacity required to coordinate fishery planning and program initiatives. AAROM is focused on developing affiliations between First Nations to work together at a broad watershed or ecosystem level – a level at which there is a certain number of common interests and where decisions and solutions can be based on integrated knowledge of several Aboriginal communities. In the conduct of their activities, AAROM bodies are working to be accountable to the communities they serve, while working to advance collaborative relationships between member communities, DFO and other interests in aquatic resource and oceans management.

4.5 Excess Salmon to Spawning Requirements (ESSR)

Under circumstances where the salmon returning to a system after passing through the various fisheries are at a level that exceeds the habitat or hatchery spawning capacity, an Excess Salmon to Spawning Requirements (ESSR) fisheries may occur and excess fish may be provided to First Nations groups.

The existing ESSR policy indicates salmon fisheries are managed to minimize surpluses to both naturally spawning stocks and returns to federal enhancement facilities. The first opportunity to access any surpluses identified after outstanding First Nations' need for food, social and ceremonial fish requirements have been addressed, is provided to First Nations who live in the area. These fish may be sold subject to certain harvest, stock assessment and reporting requirements.

4.6 Pacific Fisheries Reform

The Pacific Fisheries Reform, announced by the Department in April of 2005, provides a vision of a sustainable fishery where the full potential of the resource is realized, Aboriginal rights and title are respected, there is certainty and stability for all, and fishery participants share in the responsibility of management. Future treaties with First Nations are contemplated, as is the need to be adaptive and responsive to change. This policy direction provides a framework for improving the economic viability of commercial fisheries, and to addressing First Nations aspirations with respect FSC and commercial access and involvement in management. Work has also been initiated with the recreational sector to better understand their place in the future fishery. Pacific Fisheries Reform is entirely consistent with the existing fisheries management policies of the Department and is central to ensuring well integrated, sustainable fisheries for all species.

4.7 Policy for Selective Fishing in Canada's Pacific Fisheries

In January 2001, the Department released A Policy for Selective Fishing in Canada's Pacific Fisheries. Under the Department's selective fishing initiative, harvester groups have experimented with a variety of methods to reduce the impact of fisheries on non-target species, with a number of measures reaching implementation in fisheries. Consultative elements of an Improved Decision Making discussion paper have been implemented through establishment of the ???

4.8 Integrated Harvest Planning Committee

The Integrated Harvest Planning Committee (IHPC) for salmon is comprised of First Nations, recreational and commercial interests (as represented by the Sport Fishing Advisory Board and the Commercial Salmon Advisory Board) and the Marine Conservation Caucus (representing a coalition of "environmental" organizations. This committee is recognized to be the primary source of stakeholder input into Integrated Fisheries Management Plans.

4.9 Species at Risk Act

The Species at Risk Act (SARA) came into force in 2003. The purposes of the Act are "to prevent wildlife species from being extirpated or becoming extinct, and to provide for the recovery of a wildlife species that are extirpated, endangered or threatened as a result of human activity and to manage species of special concern to prevent them from becoming endangered or threatened". In addition to the existing prohibitions under the Fisheries Act, it is illegal to kill, harm, harass, capture, take, possess, collect, buy, sell or trade any of the animals listed under the SARA or any part or derivative of an individual. It is also illegal to damage or destroy a listed species residence. These prohibitions apply unless a person is authorized, by a permit, licence or other similar document issued in accordance with SARA, to engage in an activity affecting the listed species or the residences of its individuals.

Further information on the SARA can be found at:

http://www.dfo-mpo.gc.ca/species-especes/home_e.asp

http://www.sararegistry.gc.ca/

http://www.cosewic.gc.ca/rpts/Detailed_Species_Assessments_e.html

http://www.cosewic.gc.ca/

Three populations of salmon (Cultus Lake sockeye, Sakinaw Lake sockeye, and Interior Fraser coho) have been designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Following extensive public and stakeholder consultation processes for each population, the Minister of Environment, in consultation with the Minister of Fisheries and Oceans, did not include these population on Schedule I of SARA. However, recovery efforts are continuing for each population. DFO, in cooperation with the Interior Fraser Coho Recovery Team, have developed the Conservation Strategy for Coho Salmon, Interior Fraser River Populations. This strategy is an integral tool in effecting recovery of these unique coho populations. It is a science-based document that describes the species' biology, habitats and threats. The strategy also identifies a recovery goal, with accompanying principles and objectives designed to guide activities to achieve recovery.

The conservation strategy can be found at:

http://www.pac.dfompo.gc.ca/species/salmon/InteriorFraserCohoCS/default_e.htm

4.10 *Fishery Monitoring and Catch Reporting*

A complete, accurate and verifiable fishery monitoring and catch reporting program is required to successfully balance conservation with the objectives of optimal harvest levels. Across all fisheries, strategies are being developed to improve catch monitoring programs by identifying standards that must be achieved as well as clarifying roles and responsibilities of the Department and harvesters. As well, new technologies (e.g., E logs) are being used to facilitate the timely submission of data directly into centralized DFO databases. These and other changes will ensure that the fishery information required to make critical management decisions is available to all those who need it, when it is required. Furthermore, catch data required to manage shares will be available to and have the confidence of all harvesters.

4.11 *The Pacific Salmon Treaty*

In March 1985, the United States and Canada agreed to co-operate in the management, research and enhancement of Pacific salmon stocks of mutual concern by ratifying the Pacific Salmon Treaty (PST). The Pacific Salmon Commission (PSC), established under the PST, provides regulatory and policy advice as well as recommendations to Canada and the United States with respect to interception salmon fisheries. Under the terms of the Treaty, the responsibility for in-season management of all species rests with the Parties to the agreement, except for the in-season management of Fraser River sockeye and pink salmon, where the Fraser River Panel (FRP) is specifically delegated the responsibility for in-season management, with assistance from PSC staff.

In order to properly account for the full impact of fishing on Chinook and coho stocks, the PST specifies that all parties develop programs to monitor all sources of fishing related mortality on Chinook and coho. Catch monitoring programs are being modified to include estimates of encounters of all legal and sub-legal Chinook and coho, as well as other salmon species, in all fisheries. Coded-wire tag (CWT) data are essential to the management of Chinook and coho salmon stocks under the PST. In 1985, the United States and Canada entered into a Memorandum of Understanding in which "the Parties agree to maintain a coded-wire tagging and recapture program designed to provide statistically reliable data for stock assessments and fishery evaluations". Both countries recognized the importance of the CWT program to provide the data required to evaluate the effectiveness of bilateral conservation and fishing agreements. This approach has been confirmed with the recent release of an expert panel review that concluded the CWT system was the only technology that is currently capable of providing the data required for PST management regimes for Chinook and coho salmon.

4.12 *Watershed-based Fisheries Management Planning (WFSP)*

The WFSP is a set of formal processes based on a guidebook developed by DFO and the Province of BC in 2001 (BC Ministry of Fisheries et al. 2001) "to ensure effective long-term conservation of fish and fish habitat." The Guidebook outlines a practical steps to enhancement, management and guide fisheries habitat improvements, as well as management and enhancement efforts, using methods and processes that seek to "maintain and restore natural ecosystem processes" on a regional or watershed scale.

4.13 *Round Tables*

The Streamkeepers Program trains and supports citizens in the monitoring, protection and improvement of aquatic habitat thereby increasing public awareness and involvement at the local level

The Salmon Enhancement and Habitat Advisory Board, a public consultation group assists Fisheries and Oceans Canada in developing policy

4.14 Community Advisors

British Columbia has an extensive history of stewardship and community involvement through initiatives such as the SEP. The concept of stewardship goes beyond legal obligations to encompass moral obligations and a sense of responsible care. It refers to a wide range of actions and activities of individuals, communities, groups and organizations acting alone or in partnership, to promote, monitor and conserve and restore freshwater and oceans ecosystems.

The regional guiding principles are consistent with those of the Canada Stewardship Agenda and the national Oceans Sector Stewardship Framework which recognizes and confirms that Stewardship is implemented at the local level, recognizing the diverse social and economic conditions and introduces integrated planning as a concept.

The Community Involvement Program brings people from communities throughout the province together to participate in locally-based enhancement efforts. This Program involves:

Eighteen Community Advisors provide technical advice and support to approximately 300 volunteer salmon enhancement and watershed stewardship projects and approximately 21 CEDP projects which are working to re-establish salmonid populations in rivers and streams in their communities and neighbourhoods.

A range of educational material to teach schoolchildren about the value of the salmon resource. Salmonids in the Classroom, endorsed by the B.C. Ministry of Education, has been studied by more than one million schoolchildren throughout B.C. and the Yukon.

4.15 Scientific Support

The research activities of the Department's science branch are summarized in scientific papers that are peer reviewed through the Pacific Scientific Advice Review Committee (PSARC). The advice is then forwarded to the appropriate sectors for review and adoption as required.

5 Objectives of enhancement

Loss of biological diversity (biodiversity) has been listed by the USEPA as one of the four greatest risks to natural ecology and human well-being (USEPA 1990). Geological fossil records have indicated that throughout history, sporadic periods of massive loss of biodiversity has occurred. Current rates of global species loss have been likened to those we see in those records. Biodiversity, can be defined as "the variety of life and its processes" (USDOI and USDA 1992) and is generally recognized at four levels in a biological hierarchy (Norse et al. 1986; OTA 1987; Cairns and Lackey 1992):

1. genetic diversity is the amount of genetic information among and within individuals of a population, species, assemblage, or community;
2. species diversity is the number and frequency of species in a biological assemblage or community;
3. ecosystem diversity is the collection of assemblages, communities, and habitats within an area; and
4. landscape diversity is the spatial variation of the various ecosystems within a larger area ranging in size from 100 km^2 to 10,000 km^2.

Recovering and rebuilding populations includes re-establishing extirpated populations and rebuilding populations through a range of stock status levels (i.e. from high risk of extirpation to anywhere in the conservation assessment unit rebuilding zone), and mitigation for habitat loss. Technical operational guidelines are particularly important during the rebuilding phase for stocks of conservation concern when population size is small and the potential for negative genetic selection and drift high. Prior to the outset of any enhancement program, clearly defined, specific, measurable, attainable and realistic objectives must be identified. These will determine the relevant technical guidelines.

The two primary overriding reasons for embarking on an enhancement program are recovering and rebuilding stocks, and sustaining fisheries. In both cases, the goal is not to outcompete natural populations, certainly this must be avoided, but to support the natural populations and reach a sustainable level of production where human use of resources may occur without depleting stocks to a point from which they cannot recover.

Populations targeted for enhancement should be those stocks that are believed likely to become extinct in a few generations without intervention, or are currently at a level that is substantially below the carrying capacity of a given system. Enhancement for sustaining fisheries aims to increase a population above a natural productivity level (or return it to a former productivity level) and may be used to establish, stabilize or maintain harvest opportunities for First Nations, recreational, community or commercial fisheries. These are fisheries that would not occur, or would be significantly constrained without the contribution of enhanced salmon.

The current goals of SEP can be outlined as below:

1. **Restoration of depleted stocks.** Stock depletion occurs for any number of reasons in both the freshwater and/or marine environment. While SEP does not have the ability to directly affect marine survival, there are a number of measures that can be taken to improve the freshwater survival of salmonids. Use of hatcheries and spawning channels can directly improve freshwater survival whereas the enhancement or restoration of aquatic and streamside habitat can indirectly increase survival.
2. **Alleviation of major habitat loss**. Over the past several decades, human impacts have eroded habitat, polluted waterways, dammed river systems and deforested riparian systems. Dams and

urbanization projects have resulted in loss of spawning environment as well as reduced or altered water flow and supply due to agriculture and industry. Through habitat enhancement projects and open communication with other users, alleviation of some of the impacts are possible, thereby improving or reopening habitat that has become unproductive.

3. **Provision of fisheries harvest opportunities**. First Nations, commercial fisheries and sport fisheries benefit from enhancement projects that provide increased harvest opportunities. In regions where salmon populations have been extirpated due to dams or other habitat loss, new stocks may be/have been introduced through hatchery projects creating valuable opportunities that also restore biodiversity to systems.
4. **Re-establishment of extirpated stocks.** In some systems, salmon populations have failed to survive changes to their environment. Through careful evaluations, the introduction of fish from similar stocks into abandoned, and presumably underutilized, habitat has restored salmon runs to many systems.

6 Risks Associated with Enhancement

Pacific salmon are vitally important in Canada at both cultural and socio-economic levels. For this fundamental reason, conservation of salmon stocks is imperative. To conserve the Pacific salmon, specific actions are taken to not only ensure protection of fish stocks, but also freshwater and marine habitats. Protecting the larger ecosystem is the most prudent way of maintaining biodiversity and genetic integrity. Management of this natural resource comes with a series of inherent risks. Tentative forecasting, variability in biological systems and in the environment, changes in fisheries practices; all add risks that can threaten conservation. Thus, management practices need to be precautionary and risk assessment needs to be considerable.

Enhancement projects enjoy overall strong public support. However, the use of hatcheries has been the subject of considerable debate (e.g. Hilborn 1992, Meffe 1992, Lackey 1999, Lichatowich et al 1999 Waples 1999, Brannon et. al. 2004). There have been arguments that salmon hatcheries provide no net gain to harvesters, that hatchery fish displace the productivity of wild fish, or that, at best, they can only mitigate losses due to habitat degradation (ISG 1996). Waples (1999) and Lichatowitch (1999) summarize the major issues as ecological, genetic, and demographic (fisheries management concerns). Brannon et al (2004) provide a somewhat different perspective and attribute some of the concern to "confusion of the effects of harvest management with the effects of artificial propagation." The debate has prompted a number of reviews of hatchery programs (ISAB 2004, HSRG 2004) including the Hatchery Reform Project undertaken in Washington State, which originated with a report by a group of leading scientists in 1999 to the U.S. Congress indicating that hatcheries have the potential to benefit the recovery of naturally spawning salmon populations (HSRG 2004). The Congress responded in 2000 by creating and funding the Puget Sound and Coastal Washington Hatchery Reform Project – a systematic, science-driven evaluation of hatcheries in Puget Sound and coastal Washington. A key component of the project was the development of recommendations to help redesign hatchery operations under two main objectives (HRP, 2004):

1. recovery of salmonid populations
2. support of sustainable fisheries

Over 200 hatchery programs at over 100 facilities in Puget Sound and coastal Washington were reviewed, and 18 system-wide recommendations were ultimately developed along with 1,000 program-specific recommendations for hatchery reform. Many aspects of the system-wide recommendations have already been considered and operationalized in SEP as there are common elements between SEP facilities and those in the US Pacific Northwest.

6.1 Ecological risks

Salmon hatcheries in the Pacific Northwest result in the release of hundreds of millions of fish are released annually from hundreds of enhancement facilities. One of the key concerns with enhanced populations of salmonids (or any fish) is that enhancement may upset a balance in the ecological structure of a system and appears to many to have become a surrogate for responding to the origins of ecosystem decline (Waples 1999). By enhancing stocks, there is a perception that increased hatchery production could compensate for continued habitat destruction (Lichatowich et al. 1996) and it is well recognized that hatchery production alone will not restores stocks of salmon in most systems. A multi-pronged approach is required to address not only the declining numbers of fish, but also the restoration of sensitive habitat and ecosystem viability (Nehlsen et. al. 1991) . It is not entirely difficult to identify the risks that hatcheries might represent to wild populations. What is considerably more complicated however, is determining the impacts, and the magnitude of those impacts, in a specific system. It is well known that there is a great deal of variation in return rates of salmon (both hatchery and wild) over time and space (Bradford 1999, Levin et al. 2001). To provide a meaningful assessment, comparisons of hatchery versus wild fish must be paired evaluations of the same species of salmon, hatchery and wild, at the same time and in the same location (Goodman 2004) and there has been some indications that the return rates of wild fish may, in fact, be greater than the corresponding hatchery reared fish.

In an attempt to identify risks and evaluate mitigation of those risks, scientific evaluations should be conducted. These will assist in the determination of the effects enhanced/stocked fish may have on the environment as well as on native and naturalized organisms in that environment. A number of points have been suggested for consideration when determining potential for impacts of stocking propagated fish that should be examined under a broad management plan to assess management strategies and weighs associated risks, benefits and costs (Mudrak and Carmichael, 2005). Most of these considerations apply equally well to enhancement programs.

1. Any probable beneficial or harmful effects on diversity of native fishes and their aquatic habitat, with particular emphasis on threatened and endangered species, must be examined.
2. The potential beneficial or harmful genetic effects on native fish if there is a possibility of interbreeding between cultured and native fish should be investigated and evaluated.
3. Potential beneficial or harmful effects (physiological, behavioral, health, genetic) of cultured fishes on population abundance and population variables, such as size structure, growth rate, recruitment rate, and mortality rate, of native and naturalized fishes, should be examined.
4. The history of the target stocked species and other fish transplants into the fishery must be evaluated to determine the history and genetic composition of existing fish populations.
5. The potential for 'propagated fishes to introduce virulent disease agents to native fishes and naturalized fishes should be considered.
6. Disease susceptibility of wild fish populations (host, pathogen, environment) need to be evaluated and the potential for pathogenic agents to establish a disease epizootic in the wild should be determined.
7. Relative occurrences of fish disease agents in the wild, and their potential interactions and impacts on propagated fishes, should be evaluated.
8. Potential interspecific and intraspecific behavioral interactions, such as competition, predation, changes in reproductive behavior, that would have significant adverse effects on native and naturalized fishes should be considered.
9. The potential for stocked fish to invade non-target areas or expand their range to non-target habitats should be determined.
10. Any potential beneficial or harmful environmental effects of fish propagation, such as water discharge, broodfish collection, and fish escapement, on the local aquatic community must be identified.
11. Potential beneficial or harmful effects of increased and directed public use of aquatic environments on biotic communities and human communities.
12. Public health issues that may be of importance to hatchery operations and enhanced fishes, as might be related to external factors, such as bioaccumulation of chemical contaminants, should be evaluated.

13. Potential for enhanced fish to persist and flourish without continued enhancement must be evaluated.
14. Monitoring activities should continue to evaluate effects after enhancement commences.
15. An adaptive management process should be implemented to acquire data to answer a set of questions that will determine if enhancement goals are being accomplished responsibly and in the most cost efficient manner.
16. Species stocked into altered habitats must be compatible with the physical, chemical, and biotic conditions of the altered habitat. In determining the species to be enhanced,
    - primary consideration should be given to native species
    - if no native species can meet management "goals", the nonnative species best suited to use the productivity of the altered habitat should be chosen
    - if nonnative species are used in the altered habits, impacts to existing native species and desired naturalized species must be considered

Risks associated with enhancement vary with the system in question. Each enhancement program carries with it some degree of risk from unintended consequences such as spread beyond the intended range, genetic effects on native stocks or a detriment from predation, competition of disease introduction. Three factors have been identified (Mudrak and Carmichael, 2005) as important.

1. The condition of the habitat
2. The composition of the current fish community
3. The goal of fisheries management for the system

Management decisions should be more risk averse in pristine habitats dominated by native species where the primary management goal is conservation. In those areas where habitat has been highly altered and/or where the primary goal is exploitation of a particular harvest fishery, decisions may be more risk tolerant.

6.2 Genetic Risks

Genetic risks fall into three major categories: domestication selection, inbreeding depression, and outbreeding depression. These risks are viewed as representing the most serious risks associated with salmonid enhancement programs. Extreme views, such as that taken by Bakke (1995) who refers to hatchery fish as being "a form of biological pollution that must be controlled to maintain not only native salmon, but ultimately the consumptive fisheries", do exist. There have been studies that have argued that hatcheries may result in a lower fitness level when compared with naturally reproducing populations and that this is a major factor in reduced returns in recent years. Miller et. al. (2004) reported lower fitness of hatchery and hybrid rainbow trout compared to naturalized populations in Lake Superior tributaries. Historically there have been large fluctuations of salmon in our coastal waters and these may also be a result of natural regime shifts (Beamish 1999) that lead to oscillations in overall ocean productivity (Gargett 1997) as well as at regional levels (Adkinson et. al. 1996) and this may be, to a large extent, a more important factor in decreasing salmon returns (Beamish et. al. 1995, Pearcy 1997, Beamish et. al. 1999).

While it is important to recognize that there may be impacts of hatcheries on natural populations, an understanding of the selective pressures that hatchery practices can exert is valuable to ensure that best practices are followed to reduce those risks.

6.2.1 Domestication Selection

It cannot be argued against that hatchery rearing does exert selective pressures, although the magnitude of these is debatable. Regardless of how hatchery fish are treated, ultimately there will be differences between hatchery and wild reared fish for the fundamental reason that their early experiences are different. The HSRG (2004) recommends that the mating of hatchery fish should be designed to achieve two principal objectives:

2. Maximize the genetic effective number of breeders
3. Ensure that each adult selected has an equal opportunity to produce progeny

Ultimately, the goal is to avoid selective breeding and artificial selection in the hatchery environment (HSRG 2004). Many enhancement practices are not random, and are therefore selective. An unintentional imposition of selective pressure for run timing and migration behaviour results from arbitrary timing and choice of location for broodstock collection. Because of rearing conditions, temps etc, juveniles are not necessarily released at the same size relative to those in the natural system. Use of artificial feeds and resulting increased fry survival is thought to reduce the advantage of large egg size. Improved juvenile condition in the hatchery, compared to wild, may affect predator selection resulting in selection for traits leading to larger size and faster growth (Goodman 2004).

It has been argued that these differences could result in magnified differences later on in life. Differences could include different migration schedules, different maturation schedules, different growth schedules and different run timing. Although a segregated program can lead to rapid domestication, an integrated program, where some wild fish are incorporated into the hatchery program at each generation, results in disruptive selection and may result in some compromises may be reached between the two levels of adaptation. It cannot be known which adaptations will be favoured though.

Based on modeling studies, Goodman (2004) indicates that restricting broodstock collection to only natural spawning fish would halve the risks associated with natural spawning fitness. However, it is also noted that the ability to satisfy the restrictions in a sustainable manner depends on the productivity of the stock, both in the hatchery and in the wild, as well as on the harvest rate. The less productive the spawning stock is, the less flexibility there is for maintaining it within a limited amount of supplementation. Also, the harvest, even if it is selective for hatchery fish, reduces the scope for maintaining the stock with a limited amount of supplementation.

Goodman (2004) reached a number of conclusions regarding the performance of a supplemented system relative to an unsupplemented population. Primarily, if continued indefinitely, it was suggested that it will be almost certain that integrated enhancement will increase the effective overall productivity, the potential for sustainable harvest, and the number of fish participating in natural spawning, but that these will likely plateau, and may decline, following termination of the enhancement program.

Goodman (2004) indicates that enhancement will not increase the natural spawning fitness of the stock and suggests that enhancement may depress the natural spawning fitness of the stock for as long as enhancement continues and for several generations after it ceases. It is suggested that, where strict protocols are in place for the use of only natural spawned fish for broodstock, there could be between zero and 50% reduction in spawning fitness, and that there could be a greater risk of domestication where a hatchery draws more heavily on returning hatchery progeny. The probability and magnitude of any depression in natural spawning fitness will obviously change with the scale of sustainable harvest extracted and with the extent of broodstock removal. How easily an enhancement program can adhere to protocols where broodstock is drawn strictly from natural origin fish or where the broodstock removal rate is capped will depend on natural and hatchery spawning productivities, and on harvest levels and limitations.

6.2.2 Inbreeding Depression

Inbreeding depression is reduced fitness through the introduction of deleterious recessive genes in a given population as a result of breeding closely related individuals an can lead to a population bottleneck (Lynch 1997). Breeding between closely related individuals results in more recessive deleterious traits manifesting themselves. The more closely related a breeding pair is, the more homozygous deleterious genes the offspring may have, resulting in unfit progeny. In general, populations with a greater degree of genetic variation are less at risk of inbreeding depression.

Over-dominance of heterozygous alleles is another mechanism that can lead to a reduction in the fitness of a population with many homozygous genotypes, even if they are not deleterious. Currently it is not known which of the two mechanisms is more important.

Introducing new genes from a different population can potentially reverse inbreeding depression. However, different populations generally have different deleterious traits, and should not result in homozygosity in most loci in the offspring. This introduction of new genetic material is known as outbreeding enhancement and is practiced by conservation managers to prevent homozygosity (Lynch 1997).

In generally, alleles at different loci interact so that groups of genes co-evolve in a population. These work together to the benefit of the animal, thereby producing a high level of fitness. Different isolated populations exist in slightly different habitat and are exposed to variations in environmental conditions. Over time, these conditions result in genetic changes that provide benefits to those animals living in that particular ecosystem (Lynch 1997). These assist the population into which they have evolved, but may not benefit another, unrelated, population in the same manner and cross-population matings may lead to a reduction in fitness in the offspring known as outbreeding depression.

6.2.3 Outbreeding Depression

Outbreeding depression has been a controversial topic in recent years (references) and has been cited by several authors as a genetic risk to wild populations, particularly in enhancement programs, in some cases considered to be a greater threat that inbreeding depression in the genetic makeup of wild populations. There is a lack of extensive literature to uphold this concept, but there are concerns. Outbreeding depression is defined at a reduction in fitness, either through reduced survival or lowered reproductive success, of progeny from distant parents (Templeton 1987, Lynch 1991). Two mechanisms can lead to outbreeding depression, both of which can occur simultaneously.

1. The first is through a breaking down of the genetic adaptations of a stock by “swamping” any locally adapted genes through displacement by immigration of genes adapted to a different environment of population. For example, large body size may be selected for in a population in one system while small body size is advantageous in another. Gene flow between the two populations could produce an intermediate body size which could be a disadvantage in both systems.
2. A second means by which outbreeding depression may occur is through a breakdown of physiological or biochemical compatibilities between genes themselves in different populations.

It has been suggested that both outbreeding depression and outbreeding enhancement may occur simultaneously in a population receiving immigrants (Lynch 1997). As individuals in a local population are crossed with individuals that are genetically more and more different, outbreeding depression builds. But outbreeding enhancement, because of the masking of deleterious recessive alleles, may also be occurring at the same time that outbreeding depression is occurring. If these divergent effects are averaged, small amounts of outbreeding may lead to an increase in fitness in a local, randomly mating population. However, this author also suggests that, at higher levels of outbreeding, outbreeding depression may exceed the beneficial effects of outbreeding enhancement. Lynch (1997) suggests that if populations have not been diverged for a long enough time to acquire separate, co-evolved gene complexes, then it is unlikely that outbreeding depression will occur. This author also suggests that it is also possible for a population to suffer from both outbreeding depression and inbreeding depression at the same time.

While there is extensive literature supporting outbreeding depression in plants, there is considerably less literature available for vertebrates. Arguments range from a belief that fish held in freshwater for a year or more genetically adapt to hatchery conditions and reduce overall population fitness (Reisenbichler and Rubin 1999) to a conclusion that there is a possibility of genetic depression from outbreeding (Gharrett et al. 1999). Although Goodman (2004) argues that, unless a population is so small as to be subject to inbreeding depression and genetic drift, there will not be a spontaneous decline in fitness it is still advisable that the concept must be considered when making management decisions involving enhancement efforts. Gharrett et. al. (1999) note that although hybrid crosses investigated would rarely occur naturally or in practice, results demonstrate that outbreeding depression can occur in salmonids. It has been contended that such outbreeding depression could occur and that hatchery fish may not perform as well as wild fish being genetically inferior (Reisenbichler and Rubin 1999). Goodman suggests that a key concern is whether cessation of a supplementation program after an extensive enhancement could result in a population with a lower genetically determined fitness, which would be extremely serious from a conservation perspective (Goodman 2004).

Information regarding the consequences of inbreeding and outbreeding depression in salmon is difficult to acquire (Lynch 1997). While it would be valuable to have concrete evidence of either process to prove that these may or may not be real issues in salmon, the only mechanism to gain this information, however is through the experimental process with salmon. Inbreeding depression is relatively uncomplicated to produce by monitoring the performance of offspring from full-sib matings, because these matings are genetically the closest possible in a sexually reproducing species. However, this may take over a decade to produce a full data set. Since the decline in fitness is shares a linear relationship with the degree of inbreeding, extrapolations to small populations could be made from the results of such experiments.

The demonstration of outbreeding depression also requires a significant investment in time and effort. Hatchery and wild fish must be crossed to make first generation hybrids, which would then be released for normal ocean migration. Second generation offspring would be made from returning hybrid individuals, which may represent only a small fraction of those released (Lynch 1997). The effects of outbreeding depression, however, may not be apparent in these early generations, so the crosses of further generations are required. A hybridization between odd- and even-year pink salmon made with cryopreserved sperm yielded only a small amount of evidence about outbreeding depression after several years of work (Gharrett and Smoker 1991). As for inbreeding depression studies, quantitative results would take years to generate.

While there is currently limited knowledge available to support or refute the concept, the potential is a valid consideration, particularly where conservation efforts are concerned. However, the extent of the effects are difficult to predict and the risks are dependent on the program goals. Ultimately the goal is to reach a point where the population again becomes self sustaining and supplementation may be terminated. If hatchery-reared fish are only one or two generations removed from wild populations, outbreeding depression is unlikely to be a problem. If the hatchery is being used to ensure the survival of large numbers of fry, and if the brood stock is continually taken from wild populations, outbreeding depression is unlikely to occur.

6.3 Demographic Risks

Demographic risks are those related to fisheries management issues. Large-scale releases of hatchery reared fish are argued to have exacerbated problems surrounding mixed-population fisheries. Selective fisheries are difficult as mixed stocks often migrate together and the probability of unintentionally taking fish from a threatened stock becomes problematic. Overfishing of an unintended target stock can occur, especially when overly ambitious exploitation rates are set based on the relatively large contribution represented by hatchery fish. Because of this demographic problem, wild populations in the mixed stock may be driven below levels at which escapements can sustain replacement (NRC 1996), the natural component cannot withstand the exploitation rate set for the hatchery component. Similarly, unenhanced populations may not be able to withstand aggregate fishing pressures. However, these risks may not be so much about hatcheries adulterating natural populations as it is about how fisheries managers utilize hatcheries as a tool (Brannon et.al. 2004).

7 Benefits of Enhancement

Historically, the SEP had broad socioeconomic objectives that went beyond attempting to reverse the downward trend of an important food item, it was predicted to be the catalyst in transforming small fishing and First Nations communities that were struggling with unemployment and lack of economic opportunities by allowing a significant increase in salmon catches. There are compelling arguments regarding the social benefits of the SEP in BC, regardless of conflicting verdicts about the ultimate success or failure of related efforts; salmonid enhancement has become integral to human life and the future of the salmon in British Columbia. Artificial production has never managed to completely alleviate the demand for more fish (Taylor 1998) but in the current global environment, the long term survival of the Pacific salmonids may well rest in the realm of artificial propagation (Lee and Roth 2005).

While the risks or enhancement are varied, extensive, and difficult to actualize, the benefits are much more easily and clearly identified.

7.1 Restoration/preservation of stocks

It is difficult to know exactly what state salmon populations in British Columbia would be in without enhancement facilities, certainly without the enhancement program some stocks are likely to have disappeared altogether and salmon would have been extirpated from many more systems than is currently the case.

Loss of stocks leads to loss of genetic diversity. Enhancement endeavours to utilize best genetic practices to maintain or increase genetic diversity and reduce the impacts of genetic bottlenecks that may have occurred in some systems.

Urbanization destroyed many stocks and these are being restored through many community projects operated by volunteers

7.2 Habitat restoration

Urbanization has historically resulted in devastation to and loss of much salmon bearing habitat. At one point in time there were at least 50 salmon and trout streams in Vancouver. Today, only two remain: Musqueam Creek and Cutthroat Creek, both running through Pacific Spirit Regional Park. Once, there were an estimated 100,000 sea-run trout and salmon spawning in the streams that transected the city of Vancouver, now the fish returning to these systems number in the dozens. In less than the lifetime of some local residents, the 14 streams flowing into False Creek have been exterminated, and False Creek itself has been reduced to one-third its original size. Approximately 700 kilometres of once open waterways now run under the streets of Vancouver.

The Salmon Enhancement Program and volunteer community groups are working towards reversing this through restoration of stream systems and, ultimately, salmon stocks. Culverts have been removed or overhauled in some neighbourhoods, making the passage more conducive to fish passage. With support from the SEP , groups such as the Streamkeepers have launched programs for local stream systems that involve removing litter from stream banks, restoring habitat, planting stream banks, conducting spawner and fry surveys, stream surveying, and water quality testing. Through community efforts, salmon have begun to repopulate systems that have lain empty for decades.

Similarly, agricultural and industrial practices such as mining and forestry have introduced sediments, pesticides and pollutants to fish bearing waterways and erosion has resulted in damaged important spawning habitat. In recent decades, it became apparent that production of salmon alone would not return stocks and focus was brought to protecting and restoring habitat subject to the effects of these practices. Production of animals cannot counterbalance destruction of habitat.

7.3 Harvest opportunities

Salmon are an important component of the social fabric of British Columbians. First Nations have relied on salmonids as a food source for thousands of years. Many people rely on the fishery for their livelihood and sport fishing is an important economic factor in the tourist industry of the province. Salmon enhancement benefits all of these by working towards improving survival of BC's salmon stocks and endeavouring to improve sustainability of fisheries opportunities for all interested parties and communities.

7.4 Public involvement and education

The public has a strong interest in Pacific salmon and, therefore, it is vital to encourage and support public involvement in salmon enhancement programs. The public should be kept informed of potential enhancement plans and any changes in existing ones. It is important to ensure that the public has been adequately informed on issues surrounding the biological and social benefits of enhancement programs. It is also of value to determine the public uses of the enhanced system and how enhancement may benefit or interfere with those uses. Outreach programs encourage public participation in enhancement programs and provide opportunities to educate the general public on fisheries management and the role of enhancement.

8 The Planning Process

Depending on the facility, species produced may include Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), chum (*O. keta*), pink (*O. gorbuscha*), and sockeye salmon (*O. nerka*), as well as small numbers of steelhead salmon (and rainbow trout) (*O. mykiss*) and cutthroat trout (*O. clarki*). The latter two species are the responsibility of the province of British Columbia but are raised at a few DFO facilities as part of a partnership arrangement. Each species presents its own set of challenges as does each stock. Planning for any enhancement program is a time consuming project that requires diligent planning. There are many factors to consider, some of the major considerations are as follow:

8.1 Identification of stock of concern

Identification of a stock status of concern may come from any sector including, but not limited to, First Nations, fishing industry, interest groups, the general public or the Community Adviser. Concerns should be passed along to various departmental staff.

8.2 Information gathering

The first step is to gather all the existing information for the population including its stock status, life history, patterns, habitat status, and overall productivity. In addition to the Community Adviser, other staff to be involved should include representatives from StAD (South Coast and Conservation Biology), Habitat Management, OCS (Watershed planning, assessment and support biologist(s)), Resource Management, AFS, and RHQ Habitat and Enhancement.

8.3 Supplemental assessment to fill information gaps

Inevitably there will be gaps in information which must be addressed before a rebuilding plan can be finalized. It would seem to be premature to take eggs and release fry if fry recruitment is not known to be the limiting factor. Supplemental studies may be necessary. Data gaps should be identified and a plan developed to address them.

8.4 Formal stock status report

A formal stock status report should be prepared and forwarded to PSARC.

8.5 Public consultation

This has been an important component in the development of rebuilding plans particularly in the context of watershed planning. Once initial information has been gathered, one option would be to have a local open house to allow the public to see it and express their concerns and ideas. Likewise, the appropriate First Nation should be consulted. There may also be an omnibus watershed stewardship group through which these consultations might be effected.

8.6 Ad hoc rebuilding committee

To facilitate communication and planning, if the stock status information and concerns indicate a conservation concern and that actions should be taken, a committee should be struck for the stock in question. This need not be formal, but minutes of discussions and decisions should be written up and distributed. Depending on the size and complexity of the program, members should include those mentioned above under information gathering and possibly from the First Nation and the public.

8.7 Recovery plan

The goals and objectives for the stock in question should be clear - particularly if it is a conservation concern. The status, options and plans for harvest and habitat management and improvements should be determined together with a plan for assessment of the results. A target reference point should be determined. A detailed rebuilding plan should be written which describes actions to be taken, those responsible, time lines, budgets, assessment plans and reporting requirements. Note that (although this seems unlikely) enhancement may not necessarily be a component of the plan. If it is, the level and strategy must be carefully planned.

8.8 Funding

The source(s) of funding should be clear and adequate to carry out the plan over the period required. Priorities should be determined ahead of time and fall back plans made should there be a shortfall in funding.

8.9 Enhancement component

If enhancement is to be a part of the rebuilding plan, a small enhancement sub-committee should be organized to include the Community Adviser (in this case), assessment and support biologists, the hatchery manager, support engineer (as appropriate), possibly the OCS chief and experts from RHQ HEB. Discussion areas to address should include: potential ecological interactions; potential genetic interactions (inbreeding and out breeding); how to assess returns per spawner for hatchery releases (relatively easy); how to assess returns per spawner for natural production (difficult); the proportion of returns from enhanced production; and the efficacy of artificial propagation in rebuilding the population. Items to be determined include:

8.10 Feasibility

This includes various biological, engineering and technical aspects that range from limiting factors, population levels and trends, manageability, and resource commitment to selection and collection of broodstock. For culture of stocks of conservation concern, only highly reliable federally operated or larger contract hatcheries well staffed with experienced fish culturists have been considered. For sockeye, because of the disease risks associated with IHNV and BKD, requirements become even more stringent including isolation and containment. Other aspects include brood capture, transport of gametes, size and number of containers, water supply, backups, labour requirements and assistance by staff experienced with protocols.

Reaching a decision to enhance a system should not occur until a series of feasibility studies have been carried out and established based on science-based evaluations that determine whether the system can support the enhancement effort and if stocking will achieve positive management objectives (Madruck and Carmichael 2005). These authors identify the following as key considerations in determining if management objectives will be met through enhancement.

1. A thorough assessment of the watershed and fish population is necessary to determine the status of fish populations and the carrying capacity of the system
2. Determine what the driving force to stock propagated fish into the existing biological system is, and if the decision to stock propagated fishes in a particular habitat is warranted
3. The condition and trends of existing fish populations must be examined to determine whether there is a need for stocking

4. The current native species in the system must be evaluated to determine the most appropriate fish species to stock. This must be compatible with existing species and be one that will achieve desired management benefits. At the same time it must possess the least risk of negative genetic impact and ecological interactions
5. Pilot studies or a review of data from similar stocking programs in similar habitats should be conducted to evaluate survival, growth, and reproduction of stocked fish, to presumptively identify positive or negative impacts of stocking, and to develop stocking protocols
6. Selected species for enhancement must be appropriate for conservation programs dealing with species recovery, population rehabilitation, or fishery restoration propagated fish
7. The harvest and biological productivity of aquatic ecosystems should be monitored to predict carrying capacity and stocking rate
8. Opportunities for habitat restoration should be assessed to ensure that native and naturalized fish populations can be sustained
9. Where habitat restoration and native species management are unlikely due to highly altered environments, native species should be considered first, prior to the introduction of compatible non-indigenous species
10. Environmental requirements of species considered to be appropriate as candidates for enhancement should be compared with habitat conditions (including fish populations) to predict the suitability of the habitat for the candidate species
11. Hatchery production capability should be assessed for the ability to meet fishery management objectives

8.11 Protocols

Genetics protocols for all SEP facilities have been in place since 1986 and are periodically updated. All hatcheries are expected to follow them. These include a specific direction not to pool milt. The enhancement plan should include a detailed description of how these will be interpreted for the project with agreement by the enhancement sub-committee and StAD Conservation staff. For sockeye salmon culture, in addition to the genetics guidelines, standard procedure is to follow the guidelines published by the Alaska Department of Fish and Game in 1994. Note however, each case is different and the guidelines must be interpreted and agreed to with Science Fish Health staff.

8.12 Production planning

All SEP facilities have goals and objectives that are set individually for each species and stock. A given hatchery may encompass a number of species and stocks, each with different objectives and goals. Objectives include supporting targeted fisheries, rebuilding or re-establishing stocks, providing assessment data and providing educational opportunities through small classroom or community facilities. Goals are set as juvenile production targets that are designed to produce sufficient adults to address rebuilding or harvest objectives.

A production planning exercise will establish brood, egg and release targets and expected adult production. If the stock is extremely low in number, the first concern may simply be preservation. Beyond this, targets for expected adult production from enhancement must be set (e.g. 50% of the target escapement) and an egg target worked out using expected survival rates. Details of the protocols to be used should be made clear and understood by all.

Annual egg production targets and juvenile releases are determined pre-season for each species and stock, in consultation with project managers and local biologists who manage fisheries and assess stocks. Factors considered when developing production targets include potential adult production (based on previous average survival rates), likely exploitation rates, harvest concerns, the status and presence of natural fish populations in the stream, species interactions and effects on natural stocks, habitat capacity and project capacity. The size of each program is highly dependent on the specific objectives. For example, enhancement programs geared to assist in the recovery of threatened populations have been designed as part of an integrated recovery plan to achieve the desired adult returns in the shortest time-period possible. In some instances, SEP hatcheries are utilized to maintain a fish population where the habitat is greatly reduced, either permanently (e.g. due to construction of a dam) or temporarily (degraded and unusable in the short-term, although there may be long-term potential for habitat recovery) Where habitat is permanently lost production targets are not necessarily designed to meet current habitat availability but may be set to maintain a core population or even provide a fishery opportunity. In instances of temporary loss, targets may be set to address future habitat availability.

Goals are linked to the watersheds and fisheries objectives through the use of production planning processes. Depending on the size of the facility and its objective, these processes range from largely internal to DFO and facility focused to processes that are integrated with harvest and habitat considerations and include external participants. A few projects are involved in Formal - Watershed-based Fish Sustainability Planning (WFSP) processes – based on a guidebook developed by DFO and the province of BC in 2001 (BC Ministry of Fisheries et al. 2001) is “to ensure effective long-term conservation of fish and fish habitat.” The Guidebook outlines a practical steps to enhancement, management and guide fisheries habitat improvements, as well as management and enhancement efforts, using methods and processes that seek to “maintain and restore natural ecosystem processes” on a regional or watershed scale.

The Integrated Fisheries Management Planning IFMP process is a major planning process that the department uses to consult with stakeholders on annual resource management plans. Production targets for DFO hatcheries were included for the first time in the IFMP process in 2005 and can be found in the IFMP document. Production targets for community projects were added in 2006 and public involvement project targets will be added to the IFMP process in future years.

There is some form of annual planning for every facility, including detailed operational planning and goal setting meetings but not all planning is integrated into more regional goals. Although there a number of regional planning processes which include enhancement, there is a tendency to focus on larger facilities, (DFO and larger community sites) particularly where they support a fishery, with less specific planning for smaller facilities. In these instances, there tends to be more Informal production planning groups which aggregate around community facilities.

Due to significant changes in B.C. fisheries in recent years (e.g. reduced harvest rates, hatchery mark selective fisheries and more fisheries in terminal areas) some regional and area-specific objectives, and in particular enhancement targets, are being reviewed and in some case re-developed to suit new harvest regimes. Production targets are open to annual review by local and headquarters staff and for DFO facilities through the IFMP process. Significant changes to production targets take time to implement because broad departmental and stakeholder involvement is undertaken when revising targets. Because enhancement targets influence fisheries and recovery efforts 3 – 4 years from egg take, responses can lag behind current harvest objectives.

The production planning process can be complex. Public expectations can make it difficult to reduce production targets, due to a perceived “loss” of fish available for harvest. Also, a given program may have strong competing objectives (e.g., harvest opportunities versus stock rebuilding), or it may be difficult to decide if the rebuilding of a stock is "complete". As well, objectives for each population may be perceived differently by the department and client groups, e.g. client groups may consider that a population needs rebuilding while the DFO considers the population health to be satisfactory. This has a bearing on developing and sizing targets. Integrated watershed processes can be protracted and regional and watershed priorities may be de-linked from influencing driving forces (e.g. large marine or lower river fisheries) that reside beyond the watershed with no effective planning process to provide a linkage. Full incorporations of production targets within the IFMP approach will provide a venue for stakeholder involvement in setting objectives and sizing programs which should lead to more effective planning of production targets

8.12.1 Where the enhancement objective is rebuilding, recovering, or habitat mitigation

When developing a recovery plan in which enhancement plays a role, release targets and the component deriving from enhancement should be explicitly identified in the plan. The duration of enhancement should to be established and benchmarks should be identified, including a decision process for discontinuing enhancement.

Under ideal conditions, the release targets would result in hatchery-origin adults comprising no more than 50% of the naturally spawning escapement target. During the rebuilding stages however, returns of hatchery-origin adults may be greater than 50%. By targeting a proportion of less than 50% This strategy should moderate possible hatchery selective pressures on the natural population by subjecting at least half of the return to natural selective and adaptive pressures.

Unfortunately, constraining hatchery-origin adults to 50% of the actual return is, in most cases, impractical due to the inherent difficulties in assessment. To achieve this goal, a commitment is needed to accurately assessing the total return & enhancement component annually, and adjusting egg target accordingly to result in adults several years later. It can be difficult to set a target if a given stock size is fluctuating or is there are periodic natural catastrophes.

Targets should be based on some sense of the natural capacity of a given system and should consider survival & harvest rates. As a stock increases, the enhancement target would increase and could result in return greater than the natural capacity of the system at which point it would meet the a sustaining fishery objective.

Where the conservation unit is comprised of more than one population, no more than 50% of the populations may be considered for enhancement. I don't get this Where the enhancement objective is sustaining a population as mitigation for habitat loss and there is little natural habitat to support natural production (for example, where a dam has cut off access to most productive habitat area, (e.g. Capilano river), the proportion of hatchery origin adults may exceed 50% of the naturally spawning population.

8.12.2 Where the enhancement objective is fisheries sustainment

Where the enhancement objective is sustaining a fishery, release targets may result in hatchery-origin adults comprising more than 50% of the total return to the hatchery and the naturally spawning escapement. Targets should consider fishery requirements and escapement goals, taking into account exploitation rates, expected survival rates, hatchery brood stock requirements, and natural spawning requirements, if applicable.

8.13 Approvals and licenses

Prior to any field work being done, a number of approvals are required. The most important of these is a transplant approval. This is a requirement since eggs and fish are to be removed from the stream of origin - even if they are to be returned. A brood stock collection permit should be obtained and the need for a release approval should be considered. This may be necessary in the future under the Act (which act?).

Non-native species or non-native run timings have been introduced to streams, often to provide harvest opportunities, but sometimes to re-establish populations. These introduced fish are intended to spawn naturally. Where the intent is to establish a harvest opportunity, there is to be no native population of that species with co-incident spawn timing. Where there is an existing population of that species, the introduced population is to be one with a different run timing (e.g. spring spawners vs. fall from the native species to segregate them temporally from native populations by timing. For re-establishment, populations selected for compatibility with the receiving system may be introduced if populations have been extirpated or have become logistically too small to restore.

While under ideal circumstances, hatchery programs are developed around natural populations in the system of interest, this may not always be feasible. A transplant may be acceptable under the following circumstances:

- Where a native stock is a remnant and near extirpation, at high risk, or the population is extremely depressed
- Where the native stock has been extirpated and an approved recovery/re-establishment plan has been developed
- Where there is an approved plan for development of a non-native hatchery population for maintaining a specific fishing opportunity
- See transplant brood stock selection guidelines for information on selecting an appropriate donor stock.

Where salmon are transferred or introduced to areas outside of their normal range, all movements and transfers must be reviewed by the Introductions and Transfers Committee (ITC) to ensure the transfer request is in keeping with the proper management and control of fisheries.

http://www-heb.pac.dfo-mpo.gc.ca/intro_trans/transfers_e.htm

In this regard, each application must undergo some level of assessment which considers three main categories:

Ecological	Effects on the distribution or abundance of local species resulting from alterations in relationships such as predation, prey availability and habitat availability
Disease	Effects on the prevalence, distribution and/or impact of disease on local species
Genetic	Effects on the capacity of local species to maintain and transfer to successive generations its current genetic identity and diversity

Based on the review outcome, the Committee will make its recommendations and, if approved, issue a license. Conditions of the license may identify potential mitigation requirements such as egg disinfection, treatment of effluent and quarantine holding.

8.13.1 Transplant Stock Selection

The primary goal when transplanting a new stock into a depleted habitat is to match the genetic and life history characteristics of the donor stocks as closely as possible to the receiving stream, as transplant success increases for best matched donor stocks.

Note that broodstock selection may depend on the purpose of the transplant. For example, some variation in selection criteria may be appropriate if the objective is to “engineer” a totally new run for harvest purposes only.

Before considering a transplant determine that the native stock is totally or virtually extinct.

Where the remnant stock is nearly extinct, it is important to locate, identify and characterize the available fish stocks and carefully consider the cross-breeding of any available native spawners with the best-matched donor stock (e.g., a few local males are capable of fertilizing many donor females). Attempting to match the genetic makeup of the stock as best possible will help preserve a portion of the previously successful genotypes (Krueger et al. 1981). Transplant the best-matched donor stock, matching life histories, and biological and morphological characteristics of the donor and native stocks. The greater the similarity between the stocks, the greater their genetic compatibility and the greater the chance for transplant success. In consultation with geneticists and area biologists, select the best matched donor broodstock considering the following:

A small wild donor stock may be more suitable than a large hatchery supplemented stock

Consider the abundance of donor stock. Do not use a depressed population for donor stock

Disease profiles of donor and native stocks and sites should match or at least not place either system at risk. Where possible, use a pathogen-free donor stock. Do not transplant fish from a watershed which carries a given disease into an area where that disease has never been detected

Consider the timing of spawning and the incubation period and fry emergence.

Life history type of juveniles (e.g., stream-rearing vs. lake-rearing forms of sockeye and coho, immediate versus delayed migration to sea of Chinook juveniles)

Consider the freshwater migration route of juveniles (length, complexity and orientation, where orientation refers to stream and lake orientation based on compass direction of water flow). For sockeye and cutthroat trout, match migratory direction of newly emergent fry from the inlet and outlet spawning streams to rearing areas.

Consider the adult migration route (length, complexity and orientation). When selecting within the same system, the donor stock should come from an upriver rather than a downriver site in order to reduce straying. If a donor stock has to make an extensive journey upstream to the new site, select also for that characteristic.

If the biological and morphological characteristics of the native stock are not known (totally or virtually extinct) or if historically there had been no native stocks, use fish from a nearby river that has similar stream habitat characteristics as the receiving stream (see below). In particular, match water temperature regimes in the donor and receiving streams since temperature greatly affects migration and spawning timing. Such matching should ensure successful fertilization and incubation, as well as favorable emergence timing for the fry.

Match habitat characteristics (freshwater and early marine) for native and potential donor stocks (from spawning and incubation to rearing). Include the following considerations:

Water temperature and flow regimes,

Water depth and stream gradient,

Spawning habitat and gravel size (e.g., sockeye donor stock that will be spawning primarily on lake beaches (compared to tributaries) should be selected for that trait),

Presence of stream cover and channel stability,

Presence or absence of a lake,

pH and water quality,

Available food resources for rearing fish. For example, for a successful sockeye transplant, the receiving nursery lake should have an adequate seasonal timing of preferred forage items, and sufficient density and body size of forage species to allow for efficient fry growth rates (Fedorenko and Shepherd 1986).

It is also important to consider the estuarial and near-shore marine habitat at both the native and donor sites. Provide an assessment of factors such as the available rearing area, temperature and salinity profiles, abundance of food resources.

Because salmonid life histories are partially genetically controlled, and are likely adapted to specific types of rivers, when matching habitat types, do not mix stocks from:

large stable and small unstable rivers,

fast-flowing and slow-flowing streams,

glacial and non-glacial systems,

systems with different water temperature regimes, water quality parameters, stream gradients or substrate types.

Where two potential donor stocks have equal ratings on the life history and habitat profiles, select the stock that is geographically closest to the receiving stream. Avoid introduction of distant stocks because of high and unpredictable risks posed to native stocks, increased straying and reduced survival of transplanted fish (Reisenbichler and McIntyre 1986, Campton 1995).

The use of the nearest neighbour population should generally result in greater genetic and environmental compatibility, lower risk of disease transfer (since similar disease profiles and disease resistance can be expected for geographically close stocks), and better adaptation and homing to the new site. Even with subsequent straying, the use of nearby donor stocks should reduce the genetic impact on adjacent fish populations.

8.14 Field Work

A field schedule should be worked out and organized, local contacts arranged and notifications made (e.g. local C&P staff).

8.15 Technical support

Depending on the nature of the operation, some technical support may be available from the professional fish culturists and biologists experienced with the protocols necessary for the stock to be enhanced. These staff are able to work with those with local knowledge of timing, spawning locations, etc..

8.16 *Assessment / Experimental design*

From the outset of the Salmon Enhancement Program, the evaluation of performance relative to objectives has been based on estimating total adult returns to specific fisheries. Escapement data and an intensive assessment component has been used to support these estimates. The contribution of hatchery-produced chinook, coho, sockeye and chum salmon, and their survival rate from release to recovery is estimated by applying marking strategies. Fin clipping and/or Coded Wire Tag (CWT) are the predominant marking strategies used at enhancement facilities, but other marks such as chemical dyes and otolith marks have been used at some facilities prior to release. Adults are recovered through coast-wide sampling programs in sport and commercial fisheries, and through recovery programs on spawning grounds or at project sites. For stocks with no juveniles marking, adult production and contribution are estimated using standard survival rates (bio-standards); these are based on results from marking programs at comparable facilities or historical data.

The number of population marking studies that are undertaken to assess specific hatchery strategies at individual facilities has been reduced in recent years and is now done less frequently. Current SEP assessment programs consist primarily of marking of index stocks and, as a result, assessments are becoming progressively more reliant on indicator sites. It is not always practical to conduct tagging studies where production numbers are small. Again, assessments of small projects rely heavily on indicator-type projects. This results in data sets that may be complete for these index sites, but that may not adequately represent other projects hereby providing incomplete data for biostandards. As index marking does not encompass the full range of enhancement strategies, there are potential effects on the overall assessment program.

SEP assessment and stock assessment programs that focus on wild salmon have become increasingly aligned because of the capacity of hatchery marking programs to provide data important for assessment and management of wild salmon. Data from hatchery chinook marking forms the basis for much of the Canadian assessment work associated with the Pacific Salmon Treaty and hatchery coho marking provides data for domestic management purposes.

In addition to contribution to the catch and escapement, other measures of performance have also been used for hatchery evaluation. Currently these include a broad range of non-financial indicators, such as First Nations benefits and assessment benefits. Although these indicators are more difficult to quantify satisfactorily, they provide a means evaluating objectives other than harvest contribution, such as assessment or education. While non-quantitative performance indicators are useful ways to assess projects with broader goals, they can be difficult to develop and because the imputed social values to fish may vary from individual to individual. This leaves them open to criticism due to their subjective nature.

Data requirements for CEDP and PIP projects, and for outside-funded programs are more limited that those required for major projects, often because marking has been infrequent or rotated from site to site.

Each facility has standard juvenile and adult data collection requirements. The data are stored in a common centralized data system that shares information with departmental and international databases. Data recording requirements include numbers of adults removed for broodstock, numbers of eggs taken, numbers and data juveniles released (both marked and unmarked); and for marked populations, adult mark-sampling and enumeration of returns to the hatchery and sometimes to adjacent streams. Additional data may be collected to address area-specific analytical needs. For marked populations, data are analyzed to determine the post-release survival rates and distribution of hatchery fish.

Release information and adult recovery data for projects funded by or receiving technical support from DFO's OHEB are reported and stored in a centralized database maintained by OHEB. Copies of these data are also provided to the Regional Mark Recovery Program database (Kuhn 1988, Kuhn et al. 1988) and to the coast-wide database maintained by the Pacific States Marine Fisheries Commission (ref). Assessment data collection, storage, and management are coordinated by a centralized group. (WHO?)

There are stock assessment programs at all Chinook index sites and two coho index sites that address the co-mingling of hatchery and natural fish through escapement estimation and sampling programs.(still true? Which ones?) The proportion of hatchery fish in the catch is determined through annual monitoring and mark-sampling in fisheries. However, evaluation of the effects of hatchery fish on natural fish populations (beyond inferential information on proportions of hatchery fish), is limited because of the difficulty structuring such studies and their durations, and the reduced number of fish marked and in the potential changes in the freshwater and/or marine environments over the duration of the studies.

Assessment has been undertaken on many other aspects of project and system specific assessment (diets, release strategies, rearing densities citations of experimental database.) Database holdings of assessment data are extensive and hatchery practices have been modified as a result of experimental outcomes, however, although results are distributed internally, they are frequently not published externally.

A strategy for assessment must be in place before any program begins. Parameters and techniques to be used to measure the results (e.g. fry or smolt recruitment, adult returns, proportion of returns from enhanced production, etc.) must be agreed upon. If marking is to be employed, a decision on which methods to use for marking and recovery and how recoveries will be sampled at given levels of confidence and error must be reached.

Assessment falls into different categories:

Basic Assessment involves biophysical assessments that determine life stage and habitat factors limiting production and measure length and area of the pertinent habitat (e.g. summer low flow, winter refuge during high flows (south) winter low flow and freezing (north), early summer floods, fall droughts) and lake overall and littoral area.

8.16.1 Basic/Indicator Assessments

Juvenile assessments involve downstream trapping and seasonal density estimates, which should be planned with support and assessment staff and co-ordinated with Science, Stock Assessment Division activities and use acceptable techniques

Adults Returns involve fishery recoveries if fish groups have been coded-wire tagged, and escapement estimates by mark recapture, fence counts, and aerial and ground surveys

8.16.2 Indicator Assessments

Indicator assessments involve simple comparisons and allow escapement monitoring of stocks at indicator locations

8.16.3 Experimental Assessments

Return Rate Comparisons (Efficacy of Enhancement)

Return rate comparisons are based on the hypothesis that return rates per spawner for hatchery production and natural production are the same. Such comparisons require marking of hatchery and/or natural releases to provide fishery and escapement data. Coded-wire tagging, finclips or thermal marking can provide escapement comparisons and provide and estimation of wild and enhanced under yearling juvenile and smolt emigration

Paired Watershed Comparisons

Paired watershed comparisons are based on the hypothesis that supplemented systems will rebuild at a higher rate. Such studies require a comparison of changes in escapement numbers of enhanced and unenhanced streams. This does not require marking but coded-wire tagging or thermal marking of hatchery groups an advantage. Systems of similar size, geomorphology, life history and population size should be chosen and more than one pair should be used to increase statistical power by supplementing one system in each pair, but not the other. Juveniles may be estimated through downstream trapping or seasonal density estimates. Adults may be estimated through the use of fences and / or AUC estimates, CWT or otolith recovery

8.17 Reporting

There are a number of basic reporting requirements for any enhancement program. Information on status, release and escapement sampling results must be supplied to the Enhancement Support and Assessment Unit in Vancouver. If a major facility is involved, the information will be supplied as part of its standard requirements. Additional anecdotal reporting to the recovery team may be useful - possibly on a monthly basis.

9 Specific Guidelines

The success of an enhancement program hinges on several major factors. First, more adults must return to the system than would have been produced in the wild by allowing the fish to spawn naturally. Second, where the goal is rebuilding a stock for conservation purposes, the returning fish must reproduce successfully to increase the productivity of the natural population. Additionally, the program should maintain the long-term genetic fitness of the fish population being enhanced, and keep the adverse genetic and ecological interactions with non-target species or stocks within acceptable limits.

Enhancement of populations of local, wild salmon in British Columbia's SEP hatcheries has involved a strategy that attempts to mimic the optimal natural conditions and life history characteristics of each species as much as possible (MacKinlay et. al. 2004) in a program that utilizes both wild and hatchery-produced components of target wild stocks. Such a strategy endeavours to mitigate risks and has been designed to follow current scientific thought on minimizing negative effects from fish culture operations (Miller and Kapuscinski 2003) on natural salmon populations.

9.1 Disinfection

Disinfection protocols are vital to prevent the movement of pathogens both within and between facilities. Movement of equipment within and between sites provides easy access for pathogens to migrate to facilities in different geographical regions thus equipment must be kept clean at all times to limit pathogen spread.

Regardless of the apparent health of any fish, the potential exists that any animal may be carrying pathogens that could threaten the production at a facility. Egg disinfection has been utilized successfully for decades to reduce the incidence of disease and loss of eggs and fry.

Eggs can be safely disinfected following fertilization, during or after water hardening. The purpose of egg disinfection is to minimize the pathogen load which may have come from the broodstock and decrease subsequent spread of pathogens between eggs or egg batches. Disinfection should not been done within 5 days of hatch, as it can stimulate premature hatching with increased mortalities.

Ovadine™ is commonly used at fish hatcheries for equipment disinfection. It has also been safely used for over two decades as an egg surface disinfectant during water hardening. Current concerns have been raised regarding the use of iodophores, but these have not been substantiated for use in hatcheries. The benefits of using disinfectants far outweigh the dangers and it is highly recommended that all facilities practice disinfection measures.

Ovadine™ is currently (2008) under review by the Veterinary Drug Directorate for approval as a fish egg disinfectant. Until approval is received, it is available only by prescription from a licensed Veterinarian, through Health Canada's Emergency Drug Release (EDR) program

Eggs should be treated with a 100 ppm iodine solution for 10-15 minutes. A 100 ppm concentration of Ovadine™ is made by adding 10 mls of Ovadine™ to each litre of water. The exception to this is when sockeye are being cultured. In this case, the Alaska protocols must be followed stringently and eggs disinfected in separate containers for 60 minutes (McNeil et.al. 1994).

Ovadine solutions will be a rusty brown colour when fresh, but as the iodine degrades, the solution will start to lighten in colour to yellow indicating a loss of activity and effectiveness. If the colour lightens before time has expired, additional Ovadine can be added and mixed gently to ensure even distribution.

Local waste management regulations regarding safe disposal should be followed. Diluting spent Ovadine™ bath solutions with the rest of the effluent from a facility is considered sufficient before discharging to a stream; however, if dilution is not possible, it can be safely disposed to ground.

9.2 Genetic Management

The objective of genetic guidelines is to preserve, as much as possible, the entire range of genetic diversity of a given population. Appropriate broodstock selection and spawning practices can minimize chance events and maximize the genetic variability of the population. Sufficient broodstock which adequately represent the entire donor population and its genetic characteristics are essential in order to minimize undesirable genetic effects, such as inbreeding and loss of alleles.

These guidelines apply to broodstock collection and spawning for hatcheries and incubation facilities using standard hatchery techniques. They are not applicable to captive broodstock programs or production spawning channels.

9.2.1 Selection of Brood Stock Source

Certain natural life history traits may be lost in hatchery stocks through the process of selection. For example, selective breeding for early-run adults may result in a shift in spawning timing. In order to conserve the natural genetic integrity of a stock, hatchery broodstock need to represent adequately the entire donor population and all its genetic characteristics, including broodstock collection over the entire duration of the run. Regardless of enhancement objective, the first choice of brood stock source should always be the native stock, every attempt should be made to utilize the gene pool that has evolved naturally in the system of interest.

At SEP hatcheries, where broodstock are collected from fish that swim into a hatchery holding area through a fishway or other access point, spreading effort throughout the run is relatively easy. Where run timing may extend over several months, some fish may require additional months to reach maturity and prophylactic treatments may be required to maintain fish health. Where fish return to the hatchery several months before they are ready to spawn, a portion of each run segment is held until fish are mature and ready to spawn to ensure broad representation.

Where broodstock are collected directly from a river, spreading effort throughout the run is more difficult as accessibility to fish throughout the run may not be ensured, and the exact end of the run cannot be forecast. However, fish captured in the river are generally sufficiently ripe to spawn either immediately or soon after capture.

A major component of genetic management guidelines is that broodstock be collected over the entire run timing. With the exception of very small egg targets, this guideline is fully implemented within the operating context of the facility. However, for reasons outlined in the following, the collected fish will not necessarily be proportionately representative of the total run.

Expected run timing and abundance in a given year are estimated from historical run timing and abundance. However, these parameters are difficult to predict accurately as run timing can change, depending on annual weather conditions.

In attempting to conduct egg-takes throughout duration of the run, a hatchery program must necessarily choose one of several options:

1. collect all the required eggs before the end of the run and accept a possible bias towards the early run segment
2. take eggs throughout the run and potentially exceed production targets (with the proviso that some surplus production from early egg-takes may be planted as eyed eggs in river gravel)
3. take eggs according to expected run timing and accept a shortfall to target production if the run ends sooner than expected.

Where duration of the run is greatly protracted, some hatcheries have egg targets that are specific to particular periods of the run; for example, 30% from the first 2 weeks of return, 40% from the next 2 weeks etc.

Some shortfalls in production may occur through logistical necessity e.g. balancing production targets with duration of the run. As stated above, there are inherent uncertainties in estimating run timing and abundance. Where abundance is low and or the run ends sooner than expected, egg targets will not be met. This is a particular concern where broodstock are collected from a river, not from a hatchery rack.

Application of the guidelines is affected by the operating strategy for the facility. For example, projects with small egg targets and readily available broodstock may require only a few broodstock fish. These are sometimes collected by volunteer labour, over a very short period, such as a single weekend – ideally at or near the peak of the run but are not representative of the entire run. Other facilities may be constrained by a lack of staff available to collect broodstock over the entire run duration or delays in approvals to begin operations can curtail broodstock collection over the early part of the run.

In at least one instance, SEP has deliberately altered run timing of a hatchery stock at the request of fisheries managers for harvest management purposes. Conversely, SEP has used specific broodstock collection and spawning strategies to restore the natural run timing of a population (e.g. Capilano coho) that had lost its early timing component because of a dam.

9.2.2 Broodstock Collection

9.2.2.1 For all enhancement objectives

As many spawners as possible should be utilized. This is the single most important strategy for minimizing inbreeding effects and maintaining genetic diversity in an enhanced population. A total of 100 spawning pairs is generally considered to be an effective breeding population (i.e. the minimum number of successfully reproducing adults at which most rare gene combinations are maintained) (Allendorf et al 1987). Fewer than this inserts a high probability of a founder effect and loss of genetic material from the population. Where there are less than 100 of each sex available, a breeding strategy, such as matrix spawning, should be employed to increase genetic exchange (Allendorf et al 1987).

Lower numbers of spawners may be used when rebuilding a historically small stock as these small natural populations appear to be genetically stable at low escapement levels. The recommended minimum number varies from 25 to 100 pairs, depending on the availability of broodstock, historical stock size and/or carrying capacity of the receiving environment.

Note: When rebuilding an extremely depressed population a Stock Recovery Plan is recommended (see Spawning Broodstock of Fewer than 50 Pairs - Conservation Enhancement).

The collected broodstock should represent the entire range of run timings, growth rates, age groups, body sizes, etc and should include both hatchery and natural fish. Collect broodstock in a stratified, random manner unless there are specific harvest strategy reasons which are part of an approved plan.

Historical data may be able to identify the average duration of any given run of fish. Every attempt should be made to utilize fish from the entire run period to ensure that genetic diversity has been maximized.

Attempt to use jacks in numbers proportional to their abundance in the total stock rather than their abundance in the river escapement, or if unknown at the rate of 10-15% of males. These precocious males may contain genetic material important for the long-term fitness of the population.

Do not collect broodstock on the basis of physical characteristics. Avoid artificial or intentional bias in the selection of spawners. Do not exclude small, unattractive or sexually precocious fish. The objective is to preserve and maximize genetic diversity, and minimize artificial selection. Collect broodstock randomly from the entire population.

Where egg targets are small or when weather or logistical circumstances confine broodstock collection to a short time period (e.g. one weekend), strategies to improve representativeness should be employed. These could include choosing different dates each year to collect broodstock collection in order to collect a different portion of the run timing and collecting broodstock from as many sites as possible within the river.

What about when supplementing historically small stock (25-100 pairs?).

9.2.2.2 Where the enhancement objective is rebuilding, recovering, or habitat mitigation

When mitigating for habitat loss (where minimal natural habitat remains) or for "enhanced systems" maintain a minimum return of 500 fish to the hatchery, over the course of the run, for spawning purposes. This should maximize the genetic diversity of the hatchery broodstock.

When supplementing or re-building where a natural stock contains greater than 100 pairs do not remove more than one third of the escapement for hatchery use. Allow the remaining fish to spawn naturally to maintain a viable, naturally spawning population.

When collecting brood from a fence or rack, collection can be implemented by retaining about one third of the fish handled, stratifying by sex. When collecting brood stock without a fence or rack (angling, seining etc.), it may be difficult to estimate one third of the total return. Broodstock collection in these instances should be conservative if it appears that returns are limited.

Release targets will result in hatchery-origin adults comprising approximately 50% of the target escapement_and should be adjusted as conditions change. During the rebuilding phase, returns of hatchery-origin adults will usually be greater than 50%. This strategy should moderate hatchery impact on the natural population. How so?

For depleted, but not critically depressed stocks, do not remove more than 1/3 of returning females for hatchery use. This may mean that production targets will not be achieved. Allow the remaining fish to spawn naturally to maintain a viable, naturally spawning population.

Special protocols that allow for brood stock removals of up to 50% of the returning spawners have been used for the use of fish culture to assist rebuilding of populations of conservation concern where a stock has been severely depressed (<100 spawners and below 5-20% of historic escapement). To avoid negative effects from inbreeding in very small populations (fewer than 30 individuals), all fish should be taken for brood rather than every third fish as per standard protocols. All fish captured should be retained to achieve the egg target. These protocols should be employed only when specific programs have been developed between Fisheries

Management, HEB and Science Branch and this strategy must be part of an approved recovery plan. From a genetics perspective, it would be preferable to use all available spawners as broodstock. However, this strategy carries too much risk of catastrophic loss of the entire population.

9.2.2.3 Where the enhancement objective is sustaining a fishery.

Where there are both natural and hatchery fish in the return, include both natural and hatchery fish as available in the broodstock. However, sound broodstock collection methods that include all run timings and body sizes should ensure a balance of hatchery and natural returns that represents the population. For large hatcheries where hundreds of animals are spawned, targeted inclusion of natural fish is not as critical. Under these circumstances, broodstock collection may not be constrained to a specific proportion of return; appropriate levels should be established when production targets are set.

9.2.3 Mating and spawning

Genetic material is selected and passed on during spawning. In order to ensure the full genetic make-up of a population and its long-term fitness, appropriate mating strategies are critical. The HSRG (2004) recommends that the mating of hatchery fish should be designed to achieve two principal objectives:

1. Maximizing the genetic effective number of breeders
2. Ensuring that every selected adult has an equal opportunity to produce progeny. This is particularly critical in conservation programs, where populations are small or have experienced significant declines. Strategies must also take into account the enhancement objective, and must be suitable for a given population size.

During egg-takes, specific strategies are available for pairing males and females, and for mixing eggs and sperm to ensure the maintenance of genetic diversity. Seemingly inconsequential acts, such as pooling sperm from a number of males before mixing with eggs, can reduce the genetically effective population size.

Spawning guidelines are part of the genetic management guidelines. Spawning of a single male with a single female, a key practice in maintaining genetic diversity, were first indicated by guideline in 1985 and pooling of milt was identified as an undesirable practice in 1986. Current spawning guidelines include specifications on the inclusion of jacks in broodstock and mating protocols that are specific to spawning population-size and program objective. For example, spawning protocols to maximize the generic diversity when rebuilding stocks of significant conservation concern involve some form of matrix spawning whereby eggs from a single female are divided into a number of egg lots, each lot fertilized by a separate male.

Modified mating practices that diverge from “best practices” as stipulated in SEP guidelines, are sometimes used for very large broodstock populations because of logistical issues and in some instance for very small broodstock targets where the population is not at risk. All fully mature broodstock that have been collected should be spawned without regard to age, size or other physical characteristics. No fish should be excluded for any reason except disease.

9.2.3.1 All Broodstock Population Sizes

Wherever practical all carcasses should be returned to rivers due to their value as nutrient enrichment.

Do not release live males back to their systems of origin after spawning in the hatchery. If a higher freshwater survival rate of hatchery progeny over wild fish is assumed, each of these males will already have contributed a disproportionate amount of genetic material to the stock relative to wild fish, and, if released, would have the opportunity to contribute even more. What about streamside egg takes?

Under exceptional circumstances, such as those where males make up a disproportionately small proportion of the overall return (<30%), it may be prudent to return some of those used for broodstock alive to ensure an adequate number for mating with natural female spawners. This approach should be a part of plan developed with the input of area assessment biologists.

Maintain a record of all breeding activities. Include dates of adult capture and egg takes, number and origin of males and females used in daily spawning, condition of milt and eggs, spawning procedures used, etc. Complete broodstock history is essential to fully evaluate the broodstock program.

9.2.3.2 Spawning Broodstock of More than 50 Pairs

When spawning more than 50 pairs and the sex ratio is approximately 1:1, mate each female with an individual male (single pair mating). This produces approximately similar family size for each male / female crossing and helps maximize genetic diversity.

When spawning large numbers of animals i.e. greater than 1000 independent crosses, pooling of milt and eggs may be considered but at a ratio of not less than 2 males: 4 females. However, where at all possible, one to one spawning is most desirable.

When spawning more than 50 pairs but the sex ratio is very disproportionate (e.g. only 30% males) males may be re-used in one to one spawnings. Milt should not be pooled.

9.2.3.3 Spawning Broodstock of Fewer than 50 Pairs - Conservation Enhancement

The objective of genetic guidelines is to preserve as much as possible the entire range of genetic material of a given. Stocks which are at levels well below their historic size (< 100 spawners and below 5-20% of historic escapement) are at greatest risk of losing genetic variability, and may in fact, have already lost important genetic material. These are referred to as Stocks at Risk. Because of the additional risks, enhancement needs to be incorporated into a Stock Recovery Plan. The main difference when working with severely depressed populations is the term of enhancement. The goal should be to rebuild the stock to target levels or self sustaining population size (how is this defined?) and discontinue enhancement, typically after one cycle.

The broodstock collection and spawning practices recommended for enhancing medium or large populations should also be used when working with depressed stocks. These include using native stock and collecting broodstock to represent the entire range of run timings, growth rates, age groups, body sizes, etc.

Additional guidelines specific to conservation enhancement are:

1. Enhancement may use up to 50% of the returning spawners or a graduated collection plan scaled to return levels. When trying to rebuild an extremely depressed stock (< 100 spawners and below 5-20% of historic escapement), do it as quickly as possible. From a genetics perspective, it would be preferable to use all available spawners as broodstock. However, this strategy carries too much risk of catastrophic loss of the entire population.

2. Consider cryopreservation (freezing and storage) of milt if the remnant stock is very small.

    a. Collecting milt from more than one brood year expands the genetic base.

    b. Harvest milt from captured males (before and after spawning with females) and cryopreserve it for future use.

    Note - cryopreserved milt is viable but may show a reduced level of successful fertilization compared to unfrozen controls.

For a small broodstock population, matrix spawning is recommended (see below). That is, eggs from each female are split into approximately equal groups, and each group is fertilized with sperm from a different male. As a result, each male and female contributes to more than one family, and the number of family groups is increased.

9.2.3.4 Matrix Spawning

When spawning fewer than 50 pairs, regardless of sex ratio, use matrix spawning. Matrix spawning involves the crossing of gametes from a single male with the gametes from several individual females. This strategy allows the use of all broodstock, even when the sex ratio is unequal, and maximizes genetic combinations and each parent's contribution to the next generation.

Table 1 outlines the principles of matrix spawning, and facilitates the selection of an appropriate matrix structure. The basic concept is to divide eggs of each female into lots, each lot to be fertilized by a different male. In general, if males are more abundant than females, use a higher total number of males than females. If there are fewer males than females, split the milt of each male among the same number of fractioned females maintaining an overall 1:1 ratio. Males may be re-used under these circumstances to ensure all females are utilized.

Select the appropriate matrix structure that will be workable throughout the entire spawning season, based on the number of broodstock and sex ratio.

Matrices may be adjusted at the end of the spawning day for remaining males or females to compensate for uneven sexual maturation or mortality.

A minimum of 2 of the least available sex is recommended for each matrix. When the sex ratio is even, eggs from each female may be split into two approximately equal groups and each group fertilized with milt from a different male (2 x 2). When the sex ratio is unequal, use a 2 x 3 or 2 x 4 design.

Avoid milt competition; do not pool milt from several males. This strategy ensures that each male makes an equal genetic contribution. Effectiveness of fertilization in pooled milt may differ considerably among males, resulting in a reduction in the effective number of breeders.

Table 1 - Matrix spawning protocols

<table>
<tr><th>No. Females & Males</th><th>Sex Ratio</th><th>Proper Spawning Protocol</th><th>Examples of Different Number of Broodstock and Rationale for Selecting a Given Spawning Protocol</th></tr>
<tr><td>≥100 F
≥100 M

Large broodstock</td><td>1:1</td><td>No matrix used
Spawn 1x1<table><tr><td></td><td>Female
X</td></tr><tr><td>Male A</td><td>AX</td></tr></table></td><td>150 Females +150 Males
Large broodstock size -- sufficient to protect genetic diversity.
Even sex ratio allows 1x1 spawning.
No matrix is required.
Single pair mating is appropriate for this broodstock.</td></tr>
<tr><td><50 F
<50 M

Small broodstock</td><td>1:1</td><td>Use matrix spawning
Spawn 2x2<table><tr><td></td><td></td><td colspan="2">Female</td></tr><tr><td></td><td></td><td>X</td><td>Y</td></tr><tr><td>Male</td><td>A</td><td>AX</td><td>AY</td></tr><tr><td></td><td>B</td><td>BX</td><td>BY</td></tr></table></td><td>40 Females + 40 Males
Small broodstock size -- need matrix spawning to preserve or increase genetic diversity.
Since have a small broodstock, include a minimum of 2 of the least available sex per matrix .
Even sex ratio allows an even-sided matrix.
2x2 matrix is appropriate for this broodstock.</td></tr>
<tr><td><50 F
<50 M

Small broodstock</td><td>Not 1:1</td><td>Use matrix spawning
Matrix structure depends on sex ratio (usually not more than 2x4).
(e.g. 2x3 matrix)<table><tr><td></td><td></td><td colspan="2">Female</td></tr><tr><td></td><td></td><td>X</td><td>Y</td></tr><tr><td>Male</td><td>A</td><td>AX</td><td>AY</td></tr><tr><td></td><td>B</td><td>BX</td><td>BY</td></tr><tr><td></td><td>C</td><td>CX</td><td>CY</td></tr></table></td><td>20 Females + 35 Males
Small broodstock size -- need matrix spawning to preserve or increase genetic diversity.
Also, uneven sex ratio requires matrix spawning to ensure that all broodstock are used.
Since the number of the least available sex (females) is well under 50, include a minimum of 2 females per matrix.
2x3 matrix is appropriate for this broodstock.</td></tr>
</table>

Do not re-use males, except as follows:

1. As part of a matrix spawning protocol males may be used to fertilize more than one female.
2. If male infertility is a concern, two males may be used sequentially per female (as recommended by R. Withler). Each male should be the first male used for only one female (as below).

Male 1 Male 2	**Male 2 Male 3**	**Male 3 Male 4**	**Male 4 Male 1**
\ /	**\ /**	**\ /**	**\ /**
Female 1	**Female 2**	**Female 3**	**Female 4**

3. At the end of the run where there a few females but no new males collected for broodstock (if there are males but no females there is nothing that can be done), males may be reused to ensure all females have been spawned.

What about historically small stock enhancement. i.e. 10 k eggs. What matrix should be used? Is it better to divide all eggs & fertilize with all males (maximize crosses but more siblings) or not?

9.3 Captive Breeding Programs

In captive breeding, gametes from wild spawners are crossed and the resulting progeny propagated artificially to maturity. Once the captive raised fish reach maturity, their gametes are again crossed, but the resulting progeny are released into the natural habitat as juveniles. Alternatively, wild juveniles may be captured and reared to maturity in captivity but this practice carries increased risks of pathogen importation with it. In either case, the objective is to maximize juvenile production from a limited broodstock source to overcome external factors limiting survival to adult.

Since this technology greatly magnifies the overall egg-to-adult survival, it has the potential to rapidly increase broodstock numbers and avoid the imminent extinction of critically depressed stocks. Fisheries and Oceans Canada has reviewed the captive brood technology (see Quickstart Initiative, DFO 1996 – can someone provide me with this reference??), and concluded that in order to minimize genetic impacts, such programs would be conducted for one generation only.

Captive breeding should only be used to hasten the recovery of a wild population that may not recover without intervention and/or to reduce the likelihood of extirpation. A wild population will not stay "rebuilt" unless the sources of mortality that originally led to its decline are ameliorated. Because captive breeding is still considered experimental, it should only be used where no other options exist.

9.3.1 Risks

1. The captive brood technology remains unproven as to whether it can produce a stable increase in the abundance of natural populations.
2. Several technical and logistical problems remain unresolved (e.g., methods to ensure adequate health and survival to maturity, issue of gamete viability, choice of fresh or salt water for rearing).
3. Significant loss of genetic diversity is possible (compared to other more conventional approaches) due to multiple genetic risks (e.g., domestication, genetic drift, inbreeding)
4. Behavioural conditioning due to prolonged hatchery rearing may be a problem.
5. Competitive inferiority of captive broodstock to wild adults may be expected during spawning.
6. Risk of a catastrophic failure of cultured population is a possibility (e.g., severe disease losses).

The risks are considerable and a failed program has the potential to hasten the extinction of a remnant stock (e.g., through mining of broodstock and/or undesirable genetic changes). For these reasons, a captive brood program should be undertaken very cautiously and only as part of a Stock Rebuilding Plan.

Captive brood technology for Pacific salmon is still in experimental stages, with no guarantee of a stable increase in wild stock abundance. While captive breeding programs carry risks, the obvious benefit of potentially salvaging a population of fish on the brink of extinction must be considered.

9.3.2 Benefits

Captive breeding may be the only option available to save some critically depressed populations from imminent extinction.

A one-generation captive breeding program with careful attention to broodstock collection and pedigrees, may have fewer adverse genetic impacts than more conventional long-term supplementation programs.

Small breeding population size is the most serious threat to the genetic diversity of any population. Captive breeding endeavors to maintain a population at or above a minimum numerical level that conserves genetic adaptability and diversity. To minimize genetic effects such as hybridization, inbreeding depression and artificial selection, each year class of fish should only be used for one generation.

The negative effects of inbreeding and hybridization can be avoided by careful choice of broodstock and carefully designed mating schemes.

9.3.3 Broodstock Collection

Selection of broodstock should seek to capture as much of the spatial and phenotypic diversity as possible. If the numbers of adults in the population is more than 50, no more than 30% of the available broodstock should be taken. Gametes should be taken from as many individuals as possible, up to the 30% limit, or the egg-take target, whichever is less. Collect equal numbers of wild males and females, if possible. However, beware of unacceptably skewing the sex ratio in the remnant wild population. So is it better to have a skewed sex ratio in the captive brood adults or the river?

In populations where there are between 30 and 50 individuals, no more than 30% should be taken for broodstock, irrespective of the egg target.

Where there are fewer than 30 fish no broodstock should be taken (Bonnell, 1999). In these circumstances, a portion of outmigrating juveniles (how many?) may be captured to be reared to maturity as potential broodstock. Trapping of migrants should extend over the entire outmigration period. This provides a random sampling of the entire brood year and hence a broad genetic base for the captive breeding program.

Where juvenile trapping fails, eyed eggs or swim-up fry may be collected from redds.

Wild adults may be captured and a portion of the gametes may be stripped in the field if the above methods fail. Partially stripped adults are to be released back to their natal stream to allow natural spawning.

A combination of the above methods may also be employed.

The following key factors should reduce potential genetic problems and increase the chances of program success when using captive brood technology to supplement Pacific salmon.

1. Conduct aggressive programs to resolve those issues that caused the stock decline in the first place (e.g., habitat destruction, overharvesting). Do this concurrently with the captive brood program.

2. Assess the magnitude / scale for the captive brood program against possible risks. While the risk of extinction may increase when most of the remnant stock is removed for culture, at imminent extinction, captive breeding programs will decrease the risk of extinction
3. Consider the age structure of the remnant stock when defining duration of the captive breeding program (inbreeding problems will increase if only part of a generation is used for hatchery broodstock).
4. Follow a rigorous hatchery protocol that addresses genetic concerns, especially inbreeding problems due to the small initial gene pool.
5. Limit the duration of captive breeding programs to one generation only (or to a single generation per year class). This should minimize genetic impacts, such as domestication, and preserve genetic diversity and adaptability to native habitat.
6. Ensure that the natural population is sufficiently large after the termination of the captive breeding program. This is essential to prevent subsequent erosion of genetic diversity and possible population crash.
7. Determine the effective number of spawners required per year so as not to exceed the acceptable level of genetic risk from inbreeding (this risk increases when few captive breeders are used).
8. Do not use returning adults from previous releases of captive brood progeny for broodstock.

9.3.4 Spawning

Basic spawning procedures are the same as for normal programs (see *Mating and spawning*) with the following modifications.

When mating adults reared from juveniles produced from the original wild x wild crosses, the following precautions are recommended:

1. If possible, rear juveniles from individual crosses separately to reduce the risk of inbreeding (i.e. Genetically screen to prevent crosses between closely related families).
2. Do not sort before fish are fully mature. Sorting Kilbella/Chuckwalla Chinook after 3 years of rearing led to significant losses (Hilland, 2002).
3. If possible reintroduce milt from wild males if the timing of spawning wild fish and captive fish permits.
4. Practice matrix spawning, especially in the first year of the program when very few spawners may be available.

   Note that matrix spawning is superior to pair-wise matings because it provides a greater genetic diversity in the resulting progeny, and reduces losses due to inviable gametes (e.g., if one female is crossed with two males one of which is infertile, only half the eggs will be lost).
5. Mate each adult to two or more individuals of the opposite sex
6. For very small populations, mate each adult to all individuals of the opposite sex.
7. If the numbers of breeders in later years reaches greater than 100, conduct random one-to-one matings

8. Avoid sibling matings. This reduces the risk of inbreeding and, as such, is superior to random mating.
9. Cross individuals of different ages (i.e., brood years) whenever possible.
10. Keep track of individual family groups where the number of spawners is small, so that sib-matings can be avoided. This generally requires separate rearing of families, at least until the juveniles can be differentially marked
11. Consider setting up a gene bank that includes cryopreserved sperm from several males in the remnant stock.
12. Fertilize with cryopreserved sperm from other generations where possible. The use of cryopreserved sperm will help increase effective population size and possibly reduce inbreeding. It will also facilitate crosses between brood years.
13. Note: cryopreserved sperm generally shows a loss in fertility.
14. Consider taking milt from wild males that have already spawned.
15. Consider alternative methods for spawning captively reared broodstock (e.g., spawn these fish with fish captured from the wild, or release cultured adults to spawn naturally).

9.3.5 Disease Management

All eggs should be disinfected thoroughly prior to planting in incubators.

If the program involves sockeye salmon, the Alaskan Sockeye Culture Manual (McDaniel et. al. 1994) must be adhered to in order to minimize risks associated with IHN.

http://www.cf.adfg.state.ak.us/geninfo/research/patho/pdf/sockeye_salmon_culture_manual.pdf

The eggs from individual females should be segregated, at least to the eyed stage of development, and incubated in a disease free water source. Adult broodstock should be screened for viral and bacterial pathogens (e.g.. IHN, BKD).

Incubating eggs that test positive should be destroyed, disinfected and disposed of immediately, to prevent horizontal and/or vertical transmission of the pathogen. At the Veterinarians recommendation, eggs may be transferred to an isolated incubator (True or False?).

9.3.6 Rearing and Release

Salmon have been reared to maturity in freshwater successfully on many occasions. Transfer to salt water is not a necessary component of maturation in a captive brood program and can risk valuable broodstock by exposing them to marine pathogens. Because ground water is generally pathogen free, it is preferable to rear captive brood salmon from egg to adult in a facility that has pathogen free well water available in sufficient quantity.

Flagg et al (1998) found that husbandry methods producing the highest survival to maturity for Redfish Lake sockeye ranked as follows:

1. Circular tanks supplied with pathogen free surface water
2. Circular tanks supplied with pumped, filtered, ultraviolet sterilized seawater

3. Seawater net pens

Hilland (2002) found fresh water rearing of captive brood Kilbella/Chuckwall chinook provided higher juvenile to adult survivals and increased gamete viability than did seapen rearing.

Specific problems encountered during seapen rearing of captive brood Kilbella/Chuckwall chinook were:

1. Stress from low oxygen levels associated with a mini plankton bloom was killing 50 -6 0 fish a week (Sep 98).
2. Inappropriate diet and ration caused bloating and reduced egg and sperm viability.
3. Marine anaemia, possible lymphoma (J. Brocklebank), *A. Salmonicida* (St Hilaire) and "suspected BKD" were reported in 94 and 95 broodstock (June 98).
4. At least 30% became "jacks", which reduced the number of males available in subsequent years.
5. Some or all of the fish were treated for BKD during their captivity. Details of groups treated, method of treatment and frequency of treatment are unavailable.

Take extra care when rearing progeny of captive broodstock. Rear families (groups) separately unless juveniles can be marked with group-specific tags.

Mark all reared progeny prior to release. To reduce probability of inbreeding, do not use marked returns for subsequent broodstock where possible.

A detailed Fish Health Management Plan must be written for the program. Strict adherence to the 'Required Elements of a Fish Health Management Plan for Public and Commercial Fish Culture Facilities in British Columbia' (MAL 2003) is recommended to reduce or eliminate these types of problems.

9.3.7 Assessment

Because captive breeding is still considered experimental it is extremely important to vigorously assess results. Mass marking followed up with an aggressive recovery program is recommended whenever this strategy for population recovery is used.

Fin clipping and CWT's are options. Dye marking is an experimental method in trial. The protocol can be found in the Appendix section of this document.

9.4 Incubation

A basic understanding of egg development can be of great use in understanding the incubation requirements of those eggs. Salmon and trout eggs become progressively more fragile during a period from roughly 48 hours after water hardening until they reached the eyed stage. The eggs should not be handled during this extremely sensitive life stage.

Once the eggs reach the eyed stage, they are quite resilient and can withstand handling. This is the point at which egg shocking and egg picking generally should take place. Regardless of their less delicate nature at this stage, eggs should still be treated with care to avoid undue stress or damage.

Eggs are a delicate life stage and there are a number of factors that affect their health and development. Light, temperature, and oxygen are the three primary considerations in incubation. In nature, salmonid eggs are buried safely in redds, in cool, flowing, oxygen rich waters. In culture, it is important to attempt to mimic these conditions as closely as possible to ensure high quality fry and good survival rates. In nature, the water in which eggs rear is exposed to many different pathogens and mortality rates to hatch are often high. In culture, the eggs can be protected during incubation from this early mortality through simple defensive methods and appropriate disinfection procedures to prevent the introduction and/or spread of disease. Billard and Jensen (1996) estimate embryonic development time to different stages for the five species of Pacific salmon and steelhead trout, these are outlined below in Table 2. (taken from Clarke 1997). These models have been used to develop 2 software programs that can be used to model specific conditions at a facility (Clarke 2000).

IncubWin (*http://www.pac.dfo-mpo.gc.ca/sci/aqua/sirp/incubwin_e.htm*) is based on relationships between incubation temperature and embryonic development rates for eggs of Pacific salmon and steelhead trout. One hundred and fifty mathematical models for embryonic stages, for median hatching, and for maximum alevin wet weight (MAWW), ponding, or emergence have been incorporated into the program allowing the user to easily determine the time (i.e., in hours, days, or °C-days) it takes eggs or larvae for any of the six species to attain a specific stage of development at various temperatures. Also included in the program are digitized colour photographs of the various developmental stages.

WinSIRP (*http://www.pac.dfo-mpo.gc.ca/sci/aqua/sirp/sirp_e.htm*) uses predictive models to assist salmonid fish culturists and biologists with a wide range of fish culture problems. These models focus on incubation, dissolved oxygen during rearing, and excess total gas pressure and are incorporated into a package of computer programs for PC-compatible computers titled SIRP (i.e. Salmonid Incubation and Rearing Programs) that was easy to use (Jensen et al., 1992). Additional features include information on ammonia excretion rates, mechanical shock egg sensitivity, temperature warnings as well as a module that calculates the quantity and flow rates for chemical treatments in circular and raceway rearing ponds.

9.4.1 Large scale enhancement operations

The guidelines below focus on avoiding artificial selection, preserving genetic variability and reducing the possibility of disease transfer.

1. Sockeye should not be co-cultured in the same facility with other salmonid species. If sockeye are to be cultured on the same geographical site, facilities must be isolated and strict biosecurity measures put in place. See Sockeye Protocols – just refer to Alaskan or do separate ones for SEP?
2. To reduce the risk of disease transfer, incubate and rear satellite stocks (stocks from a different watershed) using ground water where possible.
3. To reduce the risk of disease transfer when culturing more than one stock at a facility, segregate each stock.
4. To avoid artificially inducing selection pressures which will reduce genetic diversity, do not exclude or cull slow growing or small juveniles for whatever reason, and avoid selection of the "best" juveniles.
5. Minimize opportunities for competition among rearing juveniles.
    a. Feed in a manner that permits sub-dominant juveniles to obtain food.
    b. Rear juveniles at lower densities to avoid development of aggressive behaviour.

6. Avoid rearing losses due to poor culture conditions (high density, poor water quality, etc.) or disease. Such losses may create artificial selection.
7. Develop and implement innovative rearing strategies that provide more natural rearing conditions. Consider:
    a. pond rearing
    b. rearing over natural substrate with variable flows and shade cover
    c. lower density rearing
    d. predator training
    e. supplemental feeding with natural prey items
    f. more natural feeding / growth schedules
    g. supplemental aeration systems
    h. minimum fish handling, etc

These strategies should help improve the quality of hatchery releases and their performance in the natural environment.

8. Maintain a record of all disease outbreaks and treatments during the culturing and stocking of juveniles in accordance with Fish Health Management Guidelines.
9. Additionally, when working with small populations at conservation risk,
    a. Keep hatchery rearing time to a minimum. The potential for culture-induced problems increases with the length of time spent under artificial conditions. Reducing rearing time should reduce the probability of artificial selection, domestication, losses to disease, genetic drift, etc.
    b. Use smaller containers to reduce overall impact of dominance.

9.4.2 Small scale enhancement for educational opportunities or assessment purposes

Classroom incubators are useful educational tools. They provide an opportunity to learn about the development and biology of salmon, as well as stewardship and enhancement. The principles regarding classroom incubators are:

1. The incubators are for educational purposes
2. Generally, the function of classroom incubators is not stock rebuilding, even though a few fish may return
3. Enhancement may have a role in the rebuilding of some stocks but it must be part of an overall recovery plan for that stock and watershed
4. There are guidelines and protocols for enhancement projects to ensure that the stocks are rebuilt in a way that minimizes risks associated with disease, loss of genetic diversity, and ecological effects

    The operation of incubators must follow the guidelines for enhancement projects as well as some that are specific to classroom incubators. These include:

1. Chum fry should be used wherever possible because they have no juvenile in-stream residency period and therefore minimal impact on resident juveniles
2. All classroom incubators are limited to 100 eggs or less
3. Introductions and transfers guidelines restrict the transfer of fish from one stream to another limit ecological, genetic and disease risks. Therefore, the natal stream is the most desirable release location.

Table 2- Predicted embryonic development times for five species of Pacific salmon and steelhead trout, using the models listed in Table 3 from Billard and Jensen (1996). Taken from Clarke 1997.

Species	Temperature ° C	Yolk plug closure		Eyed stage		50% hatch	
		Days	ATUs (°C-days)	Days	ATUs (°C-days)	Days	ATUs (°C-days)
Chinook	5.0	26.7	133.5	51.5	257.5	102.4	511.8
(O. tshawytscha)	7.5	17.9	134.5	34.2	256.6	70.3	527.5
	10.0	13.4	133.5	24.9	249.2	52.6	526.4
	12.5	10.6	132.1	19.2	240.5	42.1	525.7
Chum	5.0	31.9	159.6	50.1	250.3	99.6	498.2
(O. keta)	7.5	19.3	145.1	32.4	243.3	72.3	542.3
	10.0	13.3	133.0	22.9	229.0	54.4	544.5
	12.5	9.9	123.2	17.1	214.1	42.7	533.2
Coho	5.0	22.8	114.1	46.1	230.6	93.6	467.8
(O. kisutch)	7.5	16.3	122.1	31.5	236.6	63.1	473.6
	10.0	12.0	119.7	22.8	227.8	45.9	459.5
	12.5	9.0	112.9	17.1	214.4	35.6	444.8
Pink	5.0	36.7	183.4	51.4	257.2	109.0	545.0
(O. gorbuscha)	7.5	22.2	166.2	32.3	242.5	80.9	606.4
	10.0	15.1	151.5	23.1	231.4	63.0	629.6
	12.5	11.2	139.4	17.8	222.7	54.0	674.9
Sockeye	5.0	27.3	136.4	48.2	240.9	122.8	613.8
(O. nerka)	7.5	18.3	137.0	34.3	257.2	90.5	679.0
	10.0	12.6	126.0	25.0	249.6	69.3	693.2
	12.5	8.9	111.4	18.5	231.7	55.4	692.5
Steelhead	5.0	17.6	88.0	34.3	171.4	70.7	353.4
(O. mykiss)	7.5	11.7	87.5	23.9	179.5	47.2	354.0
	10.0	8.5	84.6	17.1	171.0	32.9	328.6
	12.5	6.5	81.1	12.5	155.9	24.8	309.8

9.5 Egg fungal treatments

Dead eggs serve as growth media for saprophytic fungal infections. Once a fungal infection has started, it rapidly spreads to adjacent eggs and can result in poor survival to hatch. Egg disinfection and picking are the first steps in preventing fungal infections. However, depending on water source, temperature and hardness, preventing and controlling fungal infections of eggs may be best accomplished by administering chemotherapeutants.

If fungal problems arise, culture operators should contact the staff Veterinarian for advice on how to proceed as treatment will be site-specific according to treatment capabilities, water quality criteria etc.

Fungal treatments contain chemicals that may be hazardous to personal health and anyone administering chemical treatments to eggs must be aware of WHMIS safety information and must employ appropriate personal protective equipment.

Approved chemotherapeutants for egg disinfection include: Parasite-S™, also known as formalin (a liquid solution containing 37% formaldehyde), and Perox-Aid™ (a 35% hydrogen peroxide solution). Formalin is generally the preferred treatment. Information on both compounds can be found at the manufacturer's website (Syndel Chemicals - *http://www.syndel.com*)

9.5.1 Parasite-S ™

Formalin treatments can vary in concentration from 1000 to 2000 ppm. The duration of exposure is generally 15 minutes, applied as a constant flow to incubation water supply. The scheduling can be repeated as needed to control fungal infections. The standard treatment for eggs is 1670 ppm formalin for 15 minutes twice weekly. Formalin should be metered in with a reliable delivery system.

Treatments can be started a day or two after fertilization and may be continued throughout incubation; however treatments should be stopped at least 5 days before anticipated hatch to reduce the risk of stress-induced premature hatching. Alternatively, treatments can be discontinued after shocking, if egg picking alone can prevent fungal infections from developing.

When calculating the treatment dose of Parasite-S, the product is considered 100% active. 1670 ppm (or 1.67 ml/L) is the equivalent of a 1:600 dilution. This can be calculated as:

1000 ml//600 = 1.67ml/L

Formalin effluent restrictions: Depending on temperature and species, concentrations of formalin > 200 ppm can be toxic to fish. Effluent target concentration is < 25 ppm formalin; this dilution should be achieved by combining incubation flows with the discharge from other rearing units prior to release into a natural watercourse.

Users should review WHMIS information prior to handling this product and employ appropriate personal protective equipment. Formalin must be handled with care. It is harmful if inhaled, and can seriously irritate eyes and skin after contact. Formalin should only be handled in well ventilated areas, preferably while wearing a respirator and safety glasses.

9.5.2 Perox-Aid ™

Hydrogen peroxide treatments can vary from 250 – 500 ppm. The standard treatment regime to prevent fungal infections of eggs is 500 ppm for 15 minutes every other day. To treat existing fungal infections, 500 ppm for 60 minutes every other day may be used. However, existing fungal infections will be better controlled with Parasite-S.

PeroxAid volume calculations are based on a 35% active ingredient (hydrogen peroxide concentration). So to obtain a final concentration of 500 ppm:

$$\text{Volume of PeroxAid per litre} = \frac{\text{recommended dose}}{\text{active ingredient}}$$

$$= \frac{\text{500 ml/L}}{\text{35 \% or 100/35}}$$

= 143 ml PeroxAid per litre

In its concentrated form, Perox-Aid is a strong oxidizer that can burn skin or membranes. Staff should review WHMIS information and use appropriate personal protective equipment when handling this product.

9.6 Egg shocking and picking

Fertilization is rarely 100% for a given batch of eggs. Those eggs which were not successfully fertilized and any eggs that died during early incubation should be removed from the incubation system once the fertilized eggs can withstand manipulation. These eggs are removed to reduce fungal growth and disease transfer and this potential for fungal growth necessitates frequent and routine observations for mortalities in incubators.

Different species of salmon display different degrees of sensitivity to shocking and it should not be carried out before eggs are eyed (Jensen and Alderice 1983, Jensen and Alderice 1989, Clarke 1997). Once the eggs have reached the eyed stage, they can be physically shocked to allow the discrimination between viable and unviable eggs. Shocking will rupture the yolk (vitelline) membrane of eggs which are undeveloped or infertile and result in an influx of water turning the egg white. Dead eggs may be removed, or picked, as required to keep the proportion of dead eggs in the incubators to a low level.

The term shocking or addling trout and salmon eggs is applied to the process of turning the infertile eggs white so they can be separated from the fertile ones. Actually, this amounts to nothing more than agitating the eggs enough to rupture the yolk membrane in the infertile eggs, which causes them to turn white. Shocking can be carried out using one of several methods that result in a physical shock that is not so excessive that it ruptures those eggs that are alive.

Pouring eggs from one container into another, water filled one, from a height of approximately 12-24 inches is a commonly utilized method. Another commonly utilized method involves siphoning the eggs through a section of hose approximately 4-5 feet in length from an egg container to a second container at a lower level. The container the eggs are siphoned into should be perforated near the top edge, to allow the water to run off without carrying away the eggs. The distance from the end of the hose to the water surface in the pail will determine the degree of shock being given and can be varied until the desired results are obtained.

Yolk coagulation is visible within seconds after shocking, involving as much as 50% of the yolk material within 5 min of shocking (Jensen and Collins 2003). Since shocking ruptures eggs, it allows fungal spores access to proteins that were previously contained within the eggs, providing substrate for excessive growth. For this reason, it is important that eggs are picked shortly after shocking, this is generally carried out within 1-24 hours post shocking. Eggs may be picked by hand using modified tweezers or through the use of mechanical pickers. The volume of eggs to be picked will dictate the requirements. Regardless of method, equipment should be sterilized between batches of eggs to mitigate any opportunity for pathogen transfer.

9.7 Rearing

Rearing constitutes the period immediately following ponding when feed is first offered until fish are released. This is obviously an important period, particularly in light of the fact that this is the period when the single most costly factor arises in hatchery production of fish, namely feed. If fish are not maintained in the healthiest manner possible, feed will be being wasted as the fish partition energy into process other than growth.

Stress is a major factor in fish health and factors that result in stress to fish should be mitigated to reduce incidence of disease on any facility. Stress can result from many factors. Inadequate water quality accounts for more disease outbreaks than any other factor. High water temperatures, low dissolved oxygen levels, excessive suspended solids, nitrogenous waste build-up and a host of other factors can result in physiological stress which can funnel energy reserves away from the immune system reducing disease resistance in favour of maintenance of homeostasis. Improper protection of fish through the use of covers, predator netting or other deterrents may result in losses to predation and associated stress in surviving fish. Inadequate cleaning of enclosures can lead to biofilm development and may provide harbour for potential pathogens. These represent a fraction of the potential stressors that can occur on a fish culture facility and merely serve to highlight the importance of reducing stress during rearing.

While it is preferable to handle fish as little as possible, some handling is required to ensure appropriate daily rations and to avoid waste and associated reduction in water quality. To facilitate this, regular determination of average fish weight in an enclosure is necessary. It is important that representative samples are taken, thus it is important to take samples in a random manner with fish crowded to resolve any bias in the process.

In most cases, hatchery fish are marked as such through the use of fin clips and, in some facilities, the use of coded wire tags. Again, this is another handling procedure and in this case anaesthesia will be required to reduce the degree of stress on the fish during the process. As in all handling procedures, care should be taken to minimize stress and any possible damage to the mucus coat of the fish, both of which can lead to an increased susceptibility to pathogens present in the water system.

Rearing represents the greatest time and energy investment during the entire process of fish culture at an enhancement facility and as such, it is a period that requires care and attention to details that may seem relatively minor, but may well determine the overall health of the population.

The release guidelines below cover fish health at release, size and age at release, time of release and release conditions, release sites, stocking densities and method of stocking.

1. Conduct site-specific determination of the best release strategy for a given stream / project. Strive to minimize ecological disruption (through competition, predation, etc.) to the native fish community and minimize straying.
    a. Releasing younger fish (fry) should reduce selection of hatchery adapted traits and conditioning (domestication), encourage natural genetic and environmental selection and improve imprinting. However, consider also that survival generally increases with the size at release. Also, because they immediately migrate to the ocean, smolt programs generally have less of an impact on natural populations than fry programs.
    b. The presence of naturally produced fry also needs to be considered. Fry stocking programs should only be considered for productive under-seeded habitat, taking into account all species of fish present.
2. Conduct health-checks on cultured juveniles prior to release. (should there be a standard checklist of what constitutes a health check?) Ensure that fish health status complies with the DFO health standards (again, is there a document somewhere that could be appended?).

3. Avoid large differences in body size between wild and cultured juveniles where competition and predation may be expected when fry are released.
4. Release fry at night or during periods of high water / turbidity / velocity to avoid visual predators (e.g., birds, fish). Fish should not be released if there is a potential for extreme conditions in the river.
5. Release hatchery juveniles at the same migration timing as wild juveniles. Studies have shown that there is an optimal migration timing window for each stock, during which conditions for survival are maximized (reference??).
6. Select release sites to minimize possible negative interactions (e.g., predation, competition) with local salmonid populations
    a. Stock fry into productive under-seeded habitats
    b. Reduce straying of returning adults to other systems by
        i. Locating sea-pens used for rearing close to the river mouth of the receiving stream.
        ii. Imprinting satellited stocks on their natal stream before release.

Coho rearing:

Coho are held for a greater rearing period than other species of salmon. Juvenile coho have been faring poorly in the ocean environment and evidence suggests that release at a greater target size may assist them in surmounting environmental hurdles they currently face (Beamish and Mahnken 2001). These authors hypothesise that early natural mortality is mostly related to predation, which is followed by a physiologically-based mortality and that juvenile salmon that fail to reach a critical size by the end of their first marine summer do not survive the following winter.

9.8 Release strategies

For decades, hatcheries have released vast numbers of juvenile salmon in an attempt to compensate for numerous human insults to their populations, yet the ecological effects of this effort are poorly understood (Levin and Williams 2002). A study in Oregon indicated that the density-independent rate of reproduction of wild coho salmon that correlated negatively with the average number of hatchery coho salmon smolts released in each system (Nickelson 2003). It was hypothesized that productivity of wild populations can be reduced by the presence of large numbers of hatchery smolts in lower rivers and estuaries that attract predators. Based on time series of hatchery releases and rates of smolt-to-adult survival, a study by Levin and Williams (2002) suggested that the survival of wild chinook salmon may negatively associated with hatchery releases of steelhead in the Snake River. Nickleson (2003) stated that *"… the operation of hatcheries must be changed to reduce interactions of juvenile hatchery fish with wild fish."* Alterations suggested that could encourage the recovery of wild populations included:

7. avoiding release of large numbers of smolts in areas with high concentrations of wild fish
8. decreasing the overall number of smolts released
9. using a volitional release strategy or a strategy that employs smaller release groups spread temporally

9.8.1 Volitional Release

Volitional release is practiced by many of the SEP facilities and allows juvenile salmon the opportunity to move into the associated water when they are prepared.

Spawning channels are at the extreme end of volitional release as little to no intervention is practiced. Regular checks of traps positioned at the outflow allow facility staff to regulate flow rates in the channels to ensure fry receive the most appropriate flows to deliver necessary oxygen when metabolic requirements are high and to facilitate outmigration.

Some facilities are positioned such that volitional release is easily managed. When fry are deemed prepared for release according to regular assessment of growth, condition, and behaviour, outflow screens are removed and fry are allowed to migrate into the natural system. Fry should be permitted several days to migrate out to allow for variation in development of cohorts. After approximately one week, flows should be increased and water levels lowered to encourage stragglers to move out of the artificial environment.

What is the optimal target size for each species? Is it different at each facility or is there a standard that everyone is shooting for?

I assume historical assessment of the fish in the systems are what formed the basis for size at release? But have these assessments been continued or is SEP still running on what happened X number of years ago? I would think regular assessments of natural populations would be prudent?

9.8.2 Non-volitional release

Not all facilities have the option to release volitionally. Many facilities are satellite facilities and several stocks of fish from different systems are reared on site. Fry must be returned to the system of origin. These fish may be released by several means, but all involve transportation to the originating system.

Transportation mechanisms involve varying degrees of intensity, from simple buckets to transport tanks on trucks and trailers, to helicopter movement in large capacity containers. Irrespective of the method of movement, several guidelines apply.

1. Fish should be held in containers for the minimum amount of time possible
2. Densities should be kept at or below (what – check FHMP)
3. Water should be supplemented with oxygen where travel is to be more than a few minutes and densities are greater those noted above
4. Temperatures in the containers should be as close as possible to that of the receiving waters

9.8.3 Temporary Freshwater & Marine Net Pen Rearing sites

Any plans for net pen rearing, freshwater or marine must be part of an integrated management plan with DFO – OHEB, Resource Management – Fisheries management & Stock Assessment, and local community consultation. Rearing facilities are deemed to be either temporary or not and different regulations apply to each category (see

Table 3).

Considerations should include, but may not be limited to:

- who will be involved
- who will be affected
- what species will be used
- what technology will be used
- where will the net pens be located
- what is the justification for using net pens
- what life stage will be held in net pens
- how long will fish be retained in the pens

Table 3 - Temporary and non-temporary rearing criteria for net pen rearing facilities

The following are considered to be temporary rearing:

Net Pen use	Duration	Activity	Species	Permitting/Approval Required
Juvenile Rearing	4-6 weeks annually	Securing pens, transport of fish, feeding, mort picking, cleaning, changing nets, removal	Chinook, chum, coho, pink	NWPA, Transplant approval DFO, Fisheries Act –Habitat Management, Water Lot lease, Tenure secured
Adult Broodstock Holding	4-6 weeks	Securing pens, sorting for brood, mort picking, cleaning/changing nets, removal	Chinook, chum, coho, pink	NWPA, Transplant approval DFO, Fisheries Act –Habitat Management, Water Lot lease, Tenure secured

The following activities are **<u>not</u>** considered to be temporary as activities extend over period of several months:

Net Pen use	Duration	Activity	Species	Permitting/Approval Required
Juvenile rearing 1+	Extended rearing to smolt	Securing pens, transport of fish, feeding, mort picking, cleaning, changing nets, removal	Chinook, coho	Longer term – requires additional review to aquaculture standards. NWPA, Transplant approval DFO, Fisheries Act –Habitat Management, Water Lot lease, Tenure secured
Captive Brood Rearing	Long term smolt to adult		Chinook, sockeye	Treated like finfish aquaculture site – Long term
Captive Brood Holding	Long term adults		Chinook, sockeye	Treated like finfish aquaculture site – Long term

1. Determine numbers of fish to be reared or held
2. Estimate net pen footprint area
3. Survey area (underwater)- to ensure appropriate depth, identify substrate, ensure no critical or sensitive habitat in area of impact – include anchoring. (To 10 m perimeter from footprint net pen/anchoring or based on currents). Method ?
    - **Critical Habitat:** Anadromous spawning areas (include the intertidal area associated with pink or chum streams), kelp beds, eelgrass beds, lingcod spawning habitat (<30 m depth), herring spawning area and abalone habitat

- **Sensitive Habitat:** Anadromous rearing areas (including the intertidal area associated with salmon bearing streams), rockfish rearing/nursery areas, shellfish beds, unique feature and sponge complexes.

4. Estimate deposition potential – fish faeces and feed - from net pen configuration and loading densities expected. Determine if reduced density necessary (Calculation Program ?)
5. Monitoring – survey area (10 m perimeter) post release immediate, one month post release, 6 months post release.
6. Also consider cumulative effects if the same area is to be used annually
7. The following communications are required to ensure approval and permits are in place:

a. Navigable Water Protection Act

http://www.tc.gc.ca/pacific/marine/nwpd/applicationguide.htm

The *Navigable Waters Protection Act (NWPA)* provides a legislative mechanism for the protection of the public right of marine navigation on all navigable waterways of Canada. This is accomplished through authorization of the construction of works built or placed in, over, through or across navigable waterways, and through a legal framework to deal with obstacles and obstructions to navigation. The NWPA is administered by Transport Canada. (NWPA 2006)

b. Canadian Environmental Assessment Agency

http://www.ceaa.gc.ca/index_e.htm

An Environmental Assessment may or may not be required depending on the nature of the project. Generally, enhancement projects are felt by the CEAA to impact the fish and fish habitat environmental components but to a much smaller extent than industry facilities due to their smaller scale (<10 pens) and timing (<2 months/yr and juvenile fish only).

c. Water Lot Lease - Can't find this!!

http://ilmbwww.gov.bc.ca/

Land Act Permits grant the right to carry out specific activity(s) for a short term, but do not allow for the construction of permanent improvements on the land.

d. Upland Owner

Contact the upland owner directly to advise of planned activities

e. DFO Transplant Committee

http://www-heb.pac.dfo-mpo.gc.ca/intro_trans/transfers_e.htm

The Federal-Provincial Introductions and Transfers Committee is an intergovernmental body that consists of members from the Department of Fisheries and Oceans, the B.C. Ministry of Environment, Lands and Parks and the Ministry of Agriculture, Fisheries and Food. The Transplant Committee is a technical committee whose primary role is to advise the above agencies on fish introduction and transfer issues.

f. DFO Habitat Branch

http://www-heb.pac.dfo-mpo.gc.ca/default_e.htm

Under the Fisheries Act, contact must be made with the local DFO Habitat Management staff to inform of planned activities

g. DFO Resource Management

The Stock Assessment office and local Fisheries Management contacts must be informed of planned activities

h. Provincial Government (Ministry of the Environment)

http://www.env.gov.bc.ca/wsd/water_rights/licence_application/section9/index.html

Where activities will result in changes in the freshwater environment, the Provincial Misistry of Environment must be contacted.

Section 9 of the Water Act requires that a person may only make "changes in and about a stream" under an Approval; in accordance with Part 7 of the Water Regulation, including Notification where required; or under a Water Licence or Order.

Under the Water Act, "changes in and about a stream" means

i. any modification to the nature of the stream including the land, vegetation, natural environment or flow of water within the stream, or
ii. any activity or construction within the stream channel that has or may have an impact on a stream

Approval requires approximately 75 days

i. First Nations

http://www.bced.gov.bc.ca/abed/map.htm

Prior to commencement of any activities, it is important to identify the territory the operation will be taking place in and to communicate accordingly with the appropriate First Nations

j. Conservation Data Centre

http://srmwww.gov.bc.ca/atrisk/toolintro.html

The BC Species and Ecosystems Explorer can be used to identify:

- Provincial species and ecological communities
- Red- and Blue-listed species/ecological communities
- All ecological communities and Red- and Blue-listed species by Forest District and/or Biogeoclimatic unit.
- Species and ecological community status, legal designation, distribution, life histories, conservation needs, recovery plans etc
- Ccological communities by ecoregion and ecosection.
- Direct links to relevant publications about species and ecological communities

8. Identification of Environmental Component and Mitigation Required

A number of environmental components of siting must be considered and mitigative actions taken where required.

a. Impacts on Water Quality

Water quality impacts in the area near a pen can be a result of fish faeces and food in the water column and a related reduction in dissolved oxygen in the water column. This can be mitigated through feeding rate adjustment to ensure fish are taking up the feed and fallout is reduced. Densities of fish can also be reduced.

b. Impacts on Fish and Fish Habitat

Increased sedimentation through increased faeces and feed deposition can result in decreased benthic productivity which can impact fish in the area as well as fish habitat. The impacts can be mitigated by siting pens well away from critical or sensitive habitats, fine tuning feed rate to maximize growth- feed conversion and minimize wasted feed and ensure records of water temperatures are maintained. Additionally, a simple depositional model can be applied to predict grams of carbon deposited/day (should be <1gC/m^2/day)(where can this model be found?).

Anchoring systems can be damaging to the benthic habitat. Ensure that no sensitive or critical habitat exists in the vicinity of where the anchoring system is to be installed.

Net pens can attract wild fish to the vicinity due to feed fall-out. To minimize the potential for wild to hatchery disease transfer, ensure optimal feeding practices and vaccinate fish for marine pathogens (i.e. *Vibrio*)

c. Impacts on Aquatic Vegetation

Pens have the capacity to produce shading impacts on aquatic vegetation in the subtidal and intertidal region and can occur during pen and anchor installation, deposition from feed, faeces, and net cleaning. Impacts can be mitigated by keeping rearing periods short, spacing the net pens to allow light penetration, and siting in deeper water such that lower densities of aquatic vegetation are affected.

d. Impacts on Wildlife Habitat

Net pens are enclosed by predator nets to protect the smolts during the sea water culture phase. Predator nets have the potential to entrap other species particularly during tidal fluctuations where the outer predator net may ground. Invertebrates and fish may also swim into the net and become entangled. To reduce potential impacts, ensure predator nets are kept well above the substrate by ensuring adequate depth during tidal fluctuations.

e. Impacts on Landforms and Soils

Construction of docks to access net pens can lead to erosion and sedimentation at the shoreline. Construction materials may also contain detrimental chemical compounds as preservatives. Mitigate any potential effects by avoiding products with chemical preservatives and ensure erosion control during excavation. Revegetate the shoreline for stability.

f. Impacts on Aesthetics

The public is sensitive to the aesthetics of facilities on or near waterways. Scattered feed and carcasses can result in an increase in pests and scavengers and result in offensive smells. Sites should be cleaned regularly and feed should be stored in secure bins.

9.8.4 Pre-Smolt Coho Outplanting Guidelines

Preliminary Considerations:

- Any eggs to be taken for releases as fry must be part of a production plan agreed to by HEB support and assessment biologists, HEB Area chiefs, Science Branch Stock Assessment staff and Operations Branch fisheries managers.
- Any releases requiring a transplant permit must have received approval from the federal – provincial Transplant Committee before eggs are taken.
- The release of fish must not exceed the stocking criteria (see below). If marking assessment is conducted, the numbers of marked fish must be large enough to result in sufficient returns to allow acceptable confidence limits to be put on the estimates of survival, catch and escapement (95% confidence, +/- 25% error). This can be determined by the HEB Assessment Biologist (Program Co-ordination and Assessment Division)(there was a comment here that asked for a decision on an acceptable number as well as numbers for marking based on stage at release and SEP guideline)
- Egg targets for releases prior to smolting are determined by the following four factors. The target is the lowest number which results from an assessment of the following:
    1. No more than one third of the escapement may be removed for brood stock.
    2. For fry release strategies (any juveniles not expected to migrate immediately to the ocean), the number of eggs to be taken and subsequent release targets will be determined by the amount of habitat accessible to adult coho but demonstrated to be barren or severely under-utilized.

       Release numbers must be reduced according to the amount of habitat estimated to be occupied by existing juveniles at appropriate densities. Note that for northern and up river populations, a significant number of juvenile coho spend more than one winter in fresh water. Release of age 0+ hatchery fry must be reduced by the available habitat occupied by age 0+ wild fry and age 1+ (or older) juveniles from natural production and previous hatchery fry releases. Densities of naturally produced juveniles and stocking densities for hatchery-produced juveniles should be determined in consultation with HEB and Science Branch Stock Assessment biologists.
    3. The final rearing densities at the hatchery must be at or under those shown to result in excellent fish health and survival.
    4. For rebuilding populations in the short term, no more than 50% of the target escapement for the population in question may be from enhanced production.
- Preference in collection of brood may be given to returns from natural production providing these make up more than 40% of the escapement. If the proportion of "wild" fish in the returns is less than 40%, inbreeding may become a concern and brood stock is to be collected as adults are captured (i.e. randomly without selection). If no hatchery returns are expected, this provision does not apply. Broodstock should be collected both temporally and spatially from all portions of the run.

9.8.4.1 Stocking densities

Where an outplanting program has been agreed upon among enhancement, assessment and management staff, the following (

Table 4) are suggested initial stocking densities. Did these numbers below ever get decided on? Is there a current version with numbers?

Table 4 - Stocking Densities

Area	**Streams**	**Source**	**Lakes (and wetlands)**	**Source**
South Coastal	___ g/m2 ___ #/m2 ____ #/m		___ kg/ha, or ___kg/ha of littoral area	
North Coastal	___ g/m2 ___ #/m2 ____ #/m		0.5 kg/ha, or ___kg/ha of littoral area	
up river (Thompson, Skeena)	1.0-1.5 g/m2 ___ #/m2 ____ #/m	B. Finnegan (StAD), G. Bonnell (HEB)	___ kg/ha, or ___kg/ha of littoral area	
Yukon	___ g/m2 ___ #/m2 ____ #/m		___ kg/ha, or ___kg/ha of littoral area	

9.8.5 Release from small scale enhancement for educational opportunities

Releases to non-natal streams must be approved by the Transplant Committee and should conform to the following approach:

1. Area stock groupings will be established by the area within which fish of that grouping may be released. Does this mean they can move them around from creek to creek or are you only talking about barren habitat (see next bullet)?
2. Unless there is previous, lengthy enhancement history, stocks should not be released to systems which contains a native stock of that species
3. Streams may be designated to which no releases will be permitted
4. Where possible, fish should be released to systems where this in an existing enhancement program utilizing the classroom incubator stock and an active transplant approval
5. For coho, total aggregated releases will conform to *Pre-Smolt Coho Outplanting Guidelines*

6. Releases should be made in such a way as to minimize impacts on in-stream resident populations

9.9 Transplant/transfer guidelines

See *Approvals and licenses* also

A transplant can be defined as any movement, by humans, of eggs or fish outside their current range. It may, but does not necessarily, involve artificial propagation at some life stage. All movements of eggs and fish between rivers or projects require that a transplant application be submitted to the Fish Transplant Committee (FTC) for review. Programs requiring a transplant application include:

Stock transplants where broodstock are collected from one river and the progeny released into another river

Range extension where broodstock are collected from one river and the progeny outplanted into the same river but in a section above an impassable barrier

Temporary movement of fish for incubation and/or rearing at one or more facilities not located on the natal stream of the stock (stock satellite).

A stock transplant may be considered in order to:

Rebuild a self-sustaining, naturally reproducing population that is virtually or totally extinct

Introduce a new stock / species into an area that had previously not supported that population, where the objective is to establish a self-sustaining, naturally reproducing population

Create a new fishing opportunity in an area (put-and-take or terminal fishery), especially where the habitat is limited. Such populations may be hatchery-sustained

Allow the temporary movement of eggs or fish to an incubation or rearing site removed from the stream of origin.

Transplants of salmonids, if not carefully managed, can pose risks to wild fish populations, particularly in the areas of fish health, genetics and ecology. The potentially severe problems inherent in some transplants and the pressure to allow transplants where other approaches may not be feasible, prompted the formation of the Fish Transplant Committee in 1980 and the development of the present transplant guidelines. The Fish Transplant Committee (FTC) is an interdepartmental committee with representation from DFO and the Province of B.C. whose mandate is to assess the risks imposed by transplants. The FTC consults with area experts on management and stock assessment issues associated with any transplant.

The present transplant guidelines and the review by FTC of a transplant application are designed to:

Minimize the risk of introduction and spread of infectious disease agents and parasites

Prevent undesirable genetic changes in native wild stocks

Minimize negative impacts from ecological interactions within and between species.

The guidelines presented here apply to anadromous salmonids within the province of British Columbia. Transplants from outside B.C. are not considered.

9.9.1 Pre-Transplant Assessment and Transplant Application

Site-specific information, rather than general standards, should be used when planning a transplant program. Where a transplant may be appropriate, a biophysical assessment of the receiving system must be conducted using field reconnaissance data and other available information. The information should include: purpose of the transplant; species to be enhanced; project location; donor stock status; status of stocks in the receiving stream, concerns over disease / genetic / ecological issues; release strategies proposed; anticipated production etc. (see Append-Assessment for details). Based on the compiled data, a decision will be made by the appropriate agencies on whether a transplant is appropriate.

9.9.2 Initial Transplant Application

When submitting a new application to the FTC for rebuilding, or establishing or extending the range of a stock, the following steps must be undertaken:

Conduct feasibility and assessment studies including a full inventory of the receiving system

Determine whether transplanting is the desired option for stock rebuilding. Transplants of non-native fish are considered a last resort for stock rebuilding, and will be permitted only if the native stock is virtually or totally extinct. It is advised to monitor the escapement for at least one cycle (e.g., one year for pinks, three years for chinook) before transplanting, as the stock may recover naturally or through alternative actions. This applies particularly to cases where natural events, such as flooding, have affected a brood year

Determine whether the introduction of a new species/stock would impact native fish species.

If a transplant is desired, proceed as follows:

Select the best-matched donor stock(s)

Consult with the Federal and Provincial fisheries managers to determine if the transplant can be managed

Apply to the Federal-Provincial Fish Transplant Committee for approval (see Transplant Application form). Attach to this form all records of assessments and consultations with appropriated managers

Follow the appropriate enhancement guidelines (from broodstock capture to juvenile release)

Rigorously monitor the transplant program. Document the results fully and identify possible causes for transplant failure or success

9.9.3 Renewal of Transplant Application

If a transplant is approved and will be repeated under the original conditions, it is not necessary to submit another application. However, the FTC must be advised in writing of your intention to repeat the program. However, if there are significant changes from the previously approved application, a new application must be submitted. Such conditions include:

change in release number by more than 20%

change in release stage (e.g. fry instead of smolts)

change in release site

the previous approval is more that 4 years old, and has not been reviewed by the FTC since that time

9.9.4 Transplant Broodstock Selection

The protocol for broodstock selection in transplant programs is summarized below. The primary goal is to match the genetic and life history characteristics of the native and donor stocks as closely as possible.

The key points are:

9. Wild donor spawners are always preferred over hatchery fish
10. The overall fitness of fish (e.g., reproductive success, survival, growth) is generally higher for hybrid fish (i.e., transplanted x native) than pure transplanted fish
11. Transplant success increases for best matched donor stocks

Note that broodstock selection may depend on the purpose of the transplant. For example, some variation in selection criteria may be allowed if the objective is to “engineer” a totally new run for harvest purposes only.

1. Select the donor broodstock as follows (in order of decreasing desirability) if the native wild stock is totally or virtually extinct:
    a. If the native stock is not available, transplant the best-matched wild donor stock
    b. If no such wild donor stock is available, transplant a combination of suitable wild donor stocks
    c. If no adequate combination of suitable wild donor stocks is available, transplant a combination of best available wild and hatchery stocks (i.e., pure stocks and their hybrids)
    d. If no suitable wild donor stocks are available, transplant a single best suited hatchery stock
    e. Finally, if none of the above options is possible, transplant a combination of suitable hatchery stocks
    f. Avoid using the same stock(s) to supplement different populations in the area as this will lead to reduced genetic variability. Davis et al. (1985) recommended that a single donor stock should not be used to establish or contribute to more than three hatchery broodstocks.

Note that the multi-stock approach (options 1c, 1d and 1f above) may be taken when the best-matched wild donor stock is not available. Such an approach will provide a broad genetic base from which the fish best suited to the new environment will be selected naturally. However, the selected stocks should be closely matched genetically to avoid problems of outbreeding depression in subsequent generations.

2. Select the best-suited wild donor stock. Match life histories, and biological and morphological characteristics of the donor and native stocks. The greater the similarity between the stocks, the greater their genetic compatibility and the greater the chance for transplant success. Matching of stocks should include the following:
    a. Incubation period and fry emergence timing,

b. Life history type of juveniles (e.g., stream-rearing vs lake-rearing forms of sockeye and coho, immediate versus delayed migration to sea of chinook juveniles),

c. Duration of freshwater residency,

d. Freshwater migration route of juveniles (length, complexity and orientation, where orientation refers to stream and lake orientation based on compass direction of water flow). For sockeye and cutthroat trout, match migratory direction of newly emergent fry from the inlet and outlet spawning streams to rearing areas.

e. Adult migration route (length, complexity and orientation). When selecting within the same system, the donor stock should come from an upriver rather than a downriver site in order to reduce straying. If a donor stock has to make an extensive journey upstream to the new site, select also for that characteristic.

f. Adult migration and spawning timing,

g. Adult age and size at maturity.

If the biological and morphological characteristics of the original native stock are not known (since resident stock may be totally or virtually extinct) or if historically there had been no native stocks, use as broodstock fish from a nearby river that has similar stream habitat characteristics as the receiving stream (see below). In particular, match water temperature regimes in the donor and receiving streams since temperature greatly affects migration and spawning timing. Such matching should ensure successful fertilization and incubation, as well as favorable emergence timing for the fry.

3. Match habitat characteristics (freshwater and early marine) at donor and receiving sites. Also provide a general description of estuarial and near-shore marine habitat at both the native and donor sites (e.g., available rearing area, temperature and salinity profiles, abundance of food resources). Include the following:

a. Water temperature and flow regimes,

b. Water depth and stream gradient,

c. Spawning habitat and gravel size (e.g., sockeye donor stock that will be spawning primarily on lake beaches (compared to tributaries) should be selected for that trait),

d. Presence of stream cover and channel stability,

e. Presence or absence of a lake,

f. pH and water quality,

g. Available food resources for rearing fish (e.g., for a successful sockeye transplant, the receiving nursery lake should have an adequate seasonal timing of preferred forage items, and sufficient density and body size of forage species to allow for efficient fry growth rates.

h. When matching habitat types:

- Do not mix stocks from large stable and small unstable rivers
- Do not mix stocks from fast-flowing and slow-flowing streams
- Do not mix stocks from glacial and non-glacial systems
- Do not mix stocks from systems with different water temperature regimes, water quality parameters, stream gradients or substrate types

4. Select geographically closest donor stocks. Where two potential donor stocks have equal ratings on the life history and habitat profiles, select the one stock that is geographically closest to the receiving stream. Avoid introduction of distant stocks because of high and unpredictable risks posed to native stocks, increased straying and reduced survival of transplanted fish. The use of the nearest neighbour population should generally result in greater genetic and environmental compatibility, lower risk of disease transfer (since similar disease profiles and disease resistance can be expected for geographically close stocks), and better adaptation and homing to the new site. Even with subsequent straying, the use of nearby donor stocks should reduce the genetic impact on adjacent fish populations.

5. Consider the abundance of donor stock. Do not use a depressed population for donor stock.

6. Consider disease risks. Disease profiles of donor and native stocks and sites should match or at least not place either system at risk.
   a. Use pathogen-free donor stock, if possible.
   b. Do not transplant fish from a watershed which carries a given disease into an area where that disease has never been detected.

9.9.5 Transplant Stage

1. Transplant only surface-disinfected eggs.
2. Transplant younger fish stages (eggs or fry) where possible
3. Younger stages have a reduced chance of carrying disease agents and parasites from their original habitat. Transplanting younger stages should also enhance natural genetic and environmental selection, improve imprinting to the new site, and hence improve transplant success
4. Transplant a combination of life stages (eggs, fry, presmolts, adults), especially when introducing a new species into an area. This should increase the chances of transplant success since survival of different life stages can vary greatly
5. Select eggs or fry (destined for transplants) randomly from as many fish as possible in the donor population. This will allow the full genetic range of the donor stock to be represented
6. Do not export progeny of entire families to other facilities as this will lead to reduced genetic diversity in the donor population

9.9.6 Duration of Program

Once returns from transplants have been observed:

1. During the first cycle of returns, numbers are likely to be low (<25). Allow these fish to spawn naturally and supplement the system with an additional transplant. While this will slow the adaptation of the population to the new environment it will also increase the effective breeding population
2. Once there are sufficient broodstock returning, discontinue further introductions. Continued outplanting of non-native fish will keep these populations perpetually biologically mal-adapted to their new stream

9.10 *Feeding practices*

Proper nutrition aids in growth and health, addition of immunomodulators may give an important boost to fish, especially during periods of stress such as handling, marking, higher than average water temperatures etc. The best foods available may lose their value through improper storage, therefore it is important that feed is maintained in a pest free, cool environment to ensure that fats and oils do not go rancid and that vitamins remain biologically available to fish. There is little point in spending money on fish feed if it is not cared for in a manner that ensures it meets the nutritional requirements of the fish.

Feeding is both an art and a science. A site-specific, customized feeding program coupled with appropriately sized, high quality feed will fulfill the nutritional requirements needed for the growth and health maintenance of the fish. Fish should be fed at appropriate intervals with a nutritionally adequate feed. Feeding and feed size-sorting should be optimized to ensure all fish have the opportunity to feed. The amount fed will be influenced by many factors including: water temperature, species, body size, age, type of feed and different feed delivery methods. Fish should be observed regularly during feeding to determine if they are responding as expected and if the volume of ration is sufficient or if overfeeding is occurring. When automated feeders are used, the equipment should be serviced regularly and the rate of intake of the fish checked frequently.

Proper storage of feed is essential to maintain its nutritional value. Feed stored under improper conditions will result in rancidity and degradation of essential nutrients. Feed should be stored in secure buildings such that wildlife is excluded and spillage is prevented.

Proper delivery of feed is imperative. Uneaten food generates an ammonia cloud as it breaks down and this can be detrimental to fish. Additionally, uneaten fish food generates suspended solids and these can lead to bacterial gill disease. If a maximum ration is fed to small fish, these constraints can be more restrictive than oxygen criteria. That is, more water is required to flush away particulates than is required to maintain dissolved oxygen levels. Low concentrations can be equally detrimental if sustained for long exposure periods.

Feed should be obtained from a feed mill that has been inspected by the CFIA. (EWOS and Skretting) and it should be stored in a secure location (e.g. a freezer) such that wildlife is excluded and feed is kept protected from extremes of heat, light and humidity. Dry feeds should be stored at temperatures $<20^{o}C$ and humidity <75%.

Feed for immediate use and feed in feeders should be similarly protected in sealed top containers to protect it from humidity and light, and should be replaced frequently with feed from storage. These feed buckets should be cleaned, disinfected and put away after use.

Feed bags should be labelled with the date of manufacture and guaranteed analysis information and should be rotated so that newer lots of feed on site are fed out last and any spilled feed is cleaned up immediately. Medicated feed must be clearly identified and used immediately.

Failure to begin feeding or to acquire a sufficient amount of food is considered a major cause of death of larval fish. In the event of food refusal or failure to gain weight (as determined by routine bulk sampling of newly ponded alevins), Support Biologists, the Veterinarian and the feed manufacturer should be informed.

Note: if a feed-related problem is suspected, a sub-sample of food from the lot in question should be bagged, labelled and frozen in case analysis is indicated.

9.11 *Marking fish*

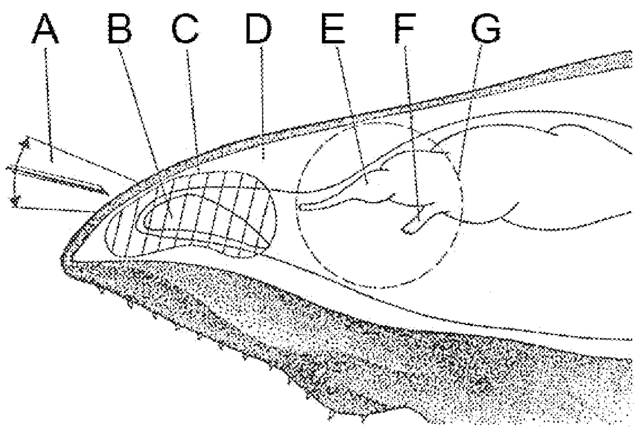
Marking fish is a valuable identification tool for accurate stock assessment. The species, number of fish to be marked and method of marking should be reviewed annually during this facility's production planning meetings. Marking should be done in a manner designed to result in minimal injury and stress to the fish. Appropriate anaesthesia and monitoring for adverse effects, both during the procedure and for several days following, are standard, as the stress of the procedure and resulting wound can compromise the immune response of the fish.

9.11.1 Coded wire tag (CWT)

Northwest Marine provides guidelines on planning and conducting projects using CWT and associated equipment (Solomon 2005). The CWT is a small length of stainless steel wire 0.25 mm in diameter and typically between 1 – 1.5. The tag is coded with a series of factory-etched decimal numbers, which allow identification of the spool of wire (typically 10,000 tags) from which it was cut (standard format) or particular batch or even individual fish (sequential format). The tag is cut, magnetized and implanted into suitable tissue with an injector. The usual target tissue in small salmonids is an area of muscle, connective tissue and cartilage in the snout (see below).

The tag is detected in live or dead fish using one of a range of magnetic detection devices from highly portable handheld wand detectors, to tunnel detectors for detecting tagged fish in large groups. However, the tag must be recovered from the fish for code identification. Most often this is done by dissecting the tag from a dead fish after collection, it is a widespread protocol with salmonids to remove the adipose fin as the coded wire tags are implanted in the rostral cartilage time of tagging to indicate the presence of a CWT.

Do we want to go into details on this or other marking techniques?



A. Usual range of tagging needle angles
B. Muscle, adipose and fibrous tissue
C. Tag target area 
D. Cartilage

E. Olfactory lobe and nerve

F. Optic nerve

G. Position of eye

9.11.2 Adipose fin clipping

It is widely felt that the most appropriate mark suitable for a mass marking program is the removal (clip) of the adipose fin. This mark offers the advantages of simplicity and ease of removal, low injury and mortality, low rate of regeneration, and easy visible detection. Adipose clipping has several purposes when applied to fish of hatchery origin: determining fishery exploitation rates in conjunction with Coded Wire Tag (CWT) recoveries, determining marine and freshwater distribution, determining overlap with wild fish in spawning areas, broodstock management, and identification for selective fisheries (Schmidt 2001). Historically, the adipose clip has been used to identify fish that have been marked with a CWT as a visual “flag” for recovery purposes.

Same question as above, do we want to go into detail on methodology, particularly when most facilities seem to contract this out?

9.11.3 Otolith marking

Otolith marking is performed during incubation by varying the temperatures that the fertilized eggs or alevins are exposed to. It is a conceptually simple process that requires no specialized equipment, so long as there is an ability to manipulate the temperature of the water bathing the eggs. No permits are required for this form of marking and it does provide 100% marking (i.e. it is a true mass marking technique) that appears to result in no harm.

A specified temperature change over a predetermined amount of time creates a life-long mark with no known adverse effects on hatching success or subsequent fish survival, health, behaviour or social interactions. However, this mark can only be judged through lethal means and is therefore more of a tool for stock assessment purposes. As the samples must be sent out for analysis, and this analysis can take a considerable amount of time, it should not be considered to be a visual tool for hatchery staff (Volk et. al. 2005).

9.11.4 Calcein Marking

To assess survival rate to smolt of summer releases, since brood year 2003, up to 250K fry per year have been mass marked with the fluorochrome dye calcein (SE-MARK™ – Western Chemical, Ferndale WA.). Calcein functions as an accessory mark, with an adipose clip indicating hatchery origin and release stage. In addition to the Ad/Calcein summer lake release, and “adipose-only” fall lake release, an “adipose-cwt” yearling smolt release (below the counting fence at the outlet of Cultus Lake) have been conducted.

Calcein is an experimental product under the jurisdiction of the Canadian Veterinary Board and applications must be submitted one year in advance of intended usage. Calcein is purchased in solution and is diluted 1:1 with water prior to usage.

Calcein marking is performed following adipose clipping. Calcein is a fluorescent dye that affixes to calcium and therefore predominantly attaches to bony tissue. Subsequently, the observation of fluorescing colour is able to be visualized though the use of a proprietary viewer utilizing a black light and yellow lens.

Calcein marking involves brief exposure to a salt solution followed immediately by a brief exposure to the SE-MARK™ solution. An important first step is to run small "trial lots" in order to determine the preferred salt concentration that results in a high quality dye mark but does not cause excessive stress to treated individuals. Salt tolerance varies depending upon species, fish size, water quality (especially pH), temperature, etc. and needs to be checked before each marking program.

Although calcein breaks down under UV light, it has a known visible retention of minimum 10 months on sockeye smolts. It is thought that it will persist in otoliths and other bony tissues to allow microscopic detection on adult return.

Materials:

- Calcein ("SE"-Mark) – from Western Chemical in Ferndale.
- Salt – Non Iodized / "pickling type".
- Baking Soda – to raise calcein bath pH if required.
- Vinegar – to lower calcein bath pH if required.
- Blue recycling bins
- Modified blue recycling bins (2 bins with perforated bottoms)
- Oxygen
- Tubing
- Old marking tank used to set bins in and flow water through to keep bins cool
- pH meter
- buckets
- nets
- timer
- graduated measuring cylinder/flask
- DO meter
- Fry netter
- Batch measurer
- Lot dipper
- Air stones
- Crew of at least three staff

Notes:

Salt functions as an "osmotic pretreatment" to dehydrate the fish slightly and increase the osmotic uptake of the calcein marker dye

A pH differential greater than 0.3 pH units is thought to increase the risk of mortality.

Prior to any production marking, it is important to determine "optimal concentration" on a small sample of test fish. The concentration needs to be strong enough to result in high quality mark, but not so strong as to cause undue stress. This concentration will vary by species, fish size, location and brood year. For this reason, test lots of 20-30 fry (~2.0 kg each for a total of 4.0 kg fry tested) should be run 24 hours in advance of any production marking. Any sign of mortality should result in an additional test lot being run with a reduced salt concentration. Only once a well tolerated salt concentration is identified via the test lot methodology should production marking be initiated.

3.0 % salt is the assumed maximum salt concentration for Cultus Sockeye. This concentration will be reduced if necessary as evidenced by fish behaviour and, resultant 24 mortality (if any).

Method:

1. Starve fish being marked for 48 hours prior to treatment.
2. Ensure protective clothing, gloves and eye protection are worn during all Calcein procedures to eliminate staining of the skin and possible injury.
3. Make up the predetermined concentrations of hyperosmotic salt solution and calcein solution in separate blue bins.

a. Salt bath – 2.5 – 3.0%

   i. In general, the salt solution will be changed 3-4 times per day

b. Calcein solution bath – 0.5% (1% stock solution diluted 1:1 with water)

   i. 1 litre of stock solution can mark 10 kg fish

   ii. Change bath solution once the calculated "extinguishment point" is reached

   iii. In general, the solution will be changed 4 times per day

4. The pH of the bath solution should be within 0.3 of the water at the hatchery. Vinegar or baking soda is used to lower or raise the pH of the treatment bath.

5. Add airstones to each container, monitor the dissolved oxygen levels throughout the treatment and bubble oxygen as required .

6. Locate the blue bins containing the respective treatment solutions into the flowing water immersion bath to keep the solutions cool.

7. Place a perforated insert box into the saline treatment container

8. Immerse fry into the hyperosmotic saline solution to dehydrate them by netting out the appropriate measure of fry from the rearing container and place into the perforated container within the saline solution

9. Lots of fry should be approximately of 2 kg of ~ 1 gram fry per treatment batch. This works out to about 80 grams of fish per litre of bath solution in 25-30 litres of salt solution

10. Time for 3.5 minutes duration in the salt solution bin.

11. Drain the fry of the salt solution by lifting out the perforated container. Tilt the bin to ensure all the salt solution has been drained to avoid diluting the calcein solution

12. Place the perforated container with the fry into the calcein solution

    a. The first third of fish treated with a single solution batch are placed into the calcein bath for 3 minutes

    b. The second third of fish are exposed to the calcein bath for 3.5 minutes

    c. The last third of fish is exposed for 4 minutes.

Note: Lengthening the exposure time for each subsequent third of each batch of fish is an attempt to equalize calcein uptake in the face of decreasing concentration of calcein due to uptake by previous fish in the batch.

13. Monitor the fish at all times for any excessive stress response (flared gills, loss of orientation, etc). Occasionally an "immobile response" or stasis has been observed on placement of fry into Calcein solution, and if observed, the corners of the bath bin are agitated or swirled slightly by hand.

14. Remove the perforated bin from the calcein bath and tip bin to allow as much solution to drain back into the treatment container as possible. At end of each batch, it is important to conserve calcein solution. Use a garbage can lid to catch draining solution as the fish are walked to the recovery container

15. Place fish into the recovery container

16. Check for any mortality after 24 hour period.

Notes:

A downstream trapping program is operated at the outlet of Cultus Lake over a three month period each spring, with peak sockeye smolt migration occurring in late April/early May.

As all hatchery releases into the lake are adipose fin clipped, clipped smolts need to be checked for the presence/absence of accessory marks in order to apportion numbers by strategy.

To allow for rapid processing, calcein marks needed to be readily obvious and, fortunately, this has been the case.

Detection is performed through the use of a specialized hand-held scope which functions via combination of long-wavelength light and a tinted lens.

Even though marked fry have experienced twelve-fold growth increases in-lake, the calcein marks have persisted well to the smolt stage.

Upon inspection, locations of significant dye accumulation include the lower jaw, cartilaginous pectoral fin “anchors” and branchiostegals.

9.12 Fish Movements

See *Transplant/transfer guidelines* also

The SEP operating practice is to use native, locally adapted populations as far as possible for rebuilding populations, but there are intentional movements of non-native salmon to re-establish extirpated or non viable populations, or to develop a new and discrete population for harvest purposes. Carefully evaluated transfers or introductions may be utilized to address specific objectives, such as re-establishment of an extirpated stock. All transfers, whether long- or short-term, are reviewed by the Introductions and Transfers Committee. The transfer review process requires that transfers of non-local stocks not be made arbitrarily. As noted, movements are reviewed as part of the production planning process and reviewed by the Introductions and Transfers Committee. Non-native broodstock are not used for “top-up” if egg targets are not achieved.

The range of percentages of total release by species that transferred to other sites for release for the 1992 – 2002 brood years was: sockeye <1%, Chinook 5 – 12%, Coho 5 – 11%, chum 2 – 4% and pinks - up to 35%. (these data are still being confirmed) Transfer rates for pink appear high as there is only one pink significant pink population enhanced, Quinsam on the east coast of Vancouver Island, and it is used to support a number of local pink enhancement projects. The population is treated as an aggregate as there are no other East Coast Vancouver Island pinks.

Some facilities are designed to accommodate a number of stocks from outside the local watershed (satellite facilities) or generally lend themselves to flexible operation. These facilities have a variety of adaptable container options and multiple water sources (surface water, disease free ground water) of varying temperature regimes. This flexibility provides the best opportunity to produce juveniles appropriate to the life history of the systems and with the greatest potential for survival. It also allows the enhancement of multiple populations without the need for facilities on every stream. Salmon from each population are kept separately and returned to the natal stream at the appropriate timing. All fish movements, both to the intermediate facility and back to the natal stock, are reviewed by the Introductions and Transfers Committee to ensure that there are no disease concerns.

As part of this approach, eggs and juveniles may be moved from one facility to another that is out-of-basin for incubation or rearing purposes, with the juveniles returned to the natal system for release. Production in these instance can be best secured by bringing native broodstock, particularly those of serious conservation concern, to a proper facility. Risks associated with such movements are minimized by a review by the Introduction and Transfers Committee, and by using disease protocols or health testing, as required.

9.13 Coho fry salvage guidelines

An ad hoc Fisheries and Oceans technical committee was formed as a result of a request by the Area Chief to develop fry salvage guidelines for community groups to follow with regard to the Coastal BC South area. Committee consisted of Kent Simpson (Coho Stock Assessment Biologist), Mel Sheng (HEB Support Biologist), Gregory Bonnell (RHQ Assessment Biologist)) and Barry Cordocedo (Community Advisor Nanaimo).

It is common in many streams on Vancouver Island for fish habitat to be dewatered during the dry summer months; causing salmonid juveniles to be trapped in isolated pools. Significant mortality results from intense predation, crowding, lack of food, temperature stress and eventually, loss of water. The stranding of fry is a natural phenomenon that the species has had to deal with throughout their evolutionary history.

Public concern for these losses has prompted many individuals and groups to capture the stranded fry and relocate them to other habitat that remain wetted throughout the dry period. Fry salvaging can have a positive influence on stock restoration if it does not "overload the system" and does not have any negative impact on existing wild populations. Unfavorably high densities can adversely affect growth and survival rates leading to a need for general fry salvage guidelines which will minimize the impact on existing wild fry populations and yet also satisfy public concern over stranded fry.

There is an important need for good planning and communication when working on salmon populations in streams; particularly at present time when Fisheries and Oceans has placed a greater emphasis on the assessment of coho populations in streams through its Science Branch, Stock Assessment.

A. Fry Salvage Plan

A fry salvage plan should be developed prior to any fry salvaging and should include

- A list of candidate streams
- A review of existing data on current stock abundance and habitat inventory (including total wetted area during low flow period)
- Some level of stream reconnaissance/monitoring
- Identification of release sites
- A list of participants and their roles
- A list of operational equipment and vehicles that will be needed
- Notification of appropriate landowners and permission for access
- Notification of and discussions with DFO and Provincial Fisheries staff about fry salvage activities and providing contact names and phone numbers
- Acquisition of necessary permits
- Completion of report data requirement
- Ensuring safety measures are being met (informing where crew will be, cellular phone /two way radio on hand, first aid kit available etc)
- Ensuring training needs are met if required (i.e. fish ID, First aid, fry collection/transfer etc)
- Appointment of a fry salvage coordinator (preferred)

B. General Guidelines

1. Stay in the same system and preferably in the same tributary. Failing that, place planted fry as near as possible to the originating location, either downstream or upstream
2. Outplant into large habitat area that remains wetted throughout the summer. Do not plant into small isolated pools.
3. Attempt to salvage fry when water temperatures are below 16 °C and exercise caution if the temperature is above this
4. Do not plant fry above any barriers if this is not an ongoing program (i.e. transplant approval in place)
6. Do not place fry into pools where high densities already exist (i.e. 2 fry/m^2)
7. Avoid cobble size habitat
8. Do not plant fry into Black Creek. In the case of other study streams contact Community Advisor and Coho Stock Assessment Biologist. Stock Assessment will provide CA's with a list of streams that are being surveyed
9. Avoid temperature shock when moving fry. The difference in temperature should not exceed 4 °C (2 °C/hr)

C. Salvage Sites

Community groups to identify what streams dry up, when, where and how many salvaged . This will form beginning of data base information. Data reporting sheet includes this information.

D. Release Sites

1. Plant into known accessible barren areas
2. Plant into large habitat that remains wetted during low summer flow period. Move fish up or downstream or into the main stream
3. Plant into lake where source of fry salvage is from lake tributaries or within anadromous range
4. Transfer fry to interim locations:
   a. ponds, channels
   b. hatchery (low priority); retain to smolts
   c. lake pens (low priority)
5. Plant above barrier (colonization) only if transplant approval is in place.

E. Stocking Densities Into Barren Areas

1. Stream plants:	2.0 fry/m^2	< 2%	stream gradient
	0.2 fry/m^2	2% to 5%	stream gradient
2. Lake plants:	2500/ hectare (of water less than 10 ft. deep)		

F. Stocking Densities Into Underutilized Areas

1. < 2% Stream gradient 1.0 fry/m^2
2. 2-5 % Stream gradient 0.1 fry/m^2

Note - If salvaged fry have been retained until November – February, densities can be increased. Possible release locations include off channel sites, upstream in apparently good habitat, or heavy weed growth areas in lakes. Any fry retained at a hatchery or lake pen are considered to be collected for enhancement and release is to follow current outplanting guidelines and should be part of a production plan discussed with the Community Advisor.

G. Transport Criteria

1. Aeration 0.1 kg/litre 2- 3 hrs
2. No Aeration 0.013 kg/litre 1 hr

H. Reporting Requirements

Although the report format should be kept as simple as possible, information should include the following:

1. date
2. exact donor and release sites
3. numbers
4. stream name/code
5. estimated average fork length
6. a map that outlines the salvage and release sites should be included

Notes

- Be as accurate as possible.
- Fish numbers can be plus or minus 20%
- Note the salvage and release with an understandable/identifiable outline of locations

Send reports to appropriate DFO and Provincial Fisheries staff including HEB Assessment RHQ

Fry that are retained should be identified separately

I. Approvals

After assisting with, or reviewing and including discussions with, appropriate DFO staff (i.e. Stock Assessment, Fisheries Management, Habitat, C&P) Community Advisors are to submit/renew/update an outline each year to HEB Area Chief (Bruce MacDonald) identifying what groups and/or individuals are involved and providing contact information for each. Also included should be the name of the stream(s) to be salvaged. This information, from all South Coast area CA's, will be attached to an Annual Licence/Permit which will be forwarded to the Provincial government. If there are no changes in the following year the only requirement is to change the date on annual licence/permit.

J. Assessment

It has been felt by some that an assessment program would be difficult and costly to do on salvage fry. It is therefore felt that at this particular time SEP biostandards could be applied as to expected survivals and productivity concerning salvaged fry.

K. Contacts/Notification

The following agency offices should be notified of proposed fry salvage activities by each CA

Groups are not to contact DFO offices and staff individually.

Fisheries and Oceans

- Fisheries Management
- Conservation and Protection
- Habitat staff
- Coho Stock Assessment

Provincial Fisheries staff

This information will be outlined in annual permit and will include names of contacts and their phone numbers.

9.14 Standard Operating Procedures

All enhancement facilities should develop standard operating procedures (SOPs) for all procedures carried out at the facility. An SOP is a set of instructions or steps that should be followed to complete a job safely, with no adverse impact on the environment (and which meets regulatory compliance standards), and in a way that maximizes operational and production requirements. The primary audience for an SOP, is the individual or group who will perform a particular job.

An SOP should contain the following information where appropriate:

1. A descriptive title that defines the purpose of the SOP. (Example: Transferring liquid chemicals safely)
2. Use document reference numbers and revision dates
3. Identify the general and specific points of activity for which an SOP has been written (Example: This SOP has been written for the safe use of the brailer system)
4. State the purpose of the SOP including the specific audience (user) in one or two sentences. Include information about process and regulatory standards, and both desirable and undesirable consequences. (Example: The purpose of this SOP is to provide instructions for the safe use of formalin solution to prevent spills, harmful vapors and injury to the worker and environment.)
5. List equipment required for following the SOP whenever they apply. Think of this list as being a "tools and parts kit" for doing a job. Use general terms for common tools and equipment. Add other categories or subcategories as desired. Sometimes a table instead of a paragraph is an appropriate format for this information.
6. Give an overview of the steps in the SOP that describes the process in terms of its major functions. Include anticipated safety, health, environmental and operational results. (Example: This SOP covers safety, health, environment and operating instructions for startup, operation, and cleanup of the automatic egg picker.)

7. Describe any machinery and major components. Complete operating instructions contain overall descriptions of the major system and its components so that readers can orient themselves to the system as a whole and to its major parts.

8. Define terms and concepts. If the SOP contains terms and concepts that readers may be unfamiliar with, define these in their own paragraph or in a glossary in a larger document that the SOP is a component of so that readers know that there are unusual words or concepts, and can find them easily for use when needed.

9. Place safety warnings, cautions and notes prominently within the SOP before the actual step to be described. Never place safety items at the end of a step. Depending on the SOP, an overall warning or caution that describes the general safety concerns may be appropriate. This should be placed at the beginning of an SOP where it is the first thing read after the title on the first page of text. If there is more than one safety warning, caution or note, list them in boldface type at the beginning of the SOP. The purpose of placing the cautions first is to alert the reader to read the warnings first. (Example: WARNING, eye hazard! To prevent eye injury from spills or splattering, wear safety goggles and face shield in this area.)

10. List and explain the process steps in sequential order in which an SOP user should perform the steps.

11. If two steps must be done at once, explain them in a sentence that clearly says so. You may wish to highlight (with italics or underlining) the first part to differentiate it from the actual step. (Example: This step has two parts that must be done at the same time. While gripping the safety lever with your left hand to keep it from slipping downward, use your right hand to remove the retaining pin.)

12. Provide a more detailed explanation if a reader needs more information to fully understand the reason for performing a step. (Example: Caution: belt can whip out! Stand behind the red warning line on the floor before reaching over to tighten the two white lock-out nuts, which hold the belt and keep it from whipping loose.)

13. When an SOP is time-dependent, indicate the times clearly. (Example: Once a week: check laboratory hood air flow to ensure it meets required specifications)

14. Decide where to use graphics (drawings, photographs and thumbnail icons) to communicate clearly. Well-labeled drawings often are better than text. Use drawings of labeled (named) parts of objects to show proper relationships and orientations among the parts or other objects. Show the positioning of hand tools, other tools and even hands and feet if applicable when work is to be performed. For example, show the positioning of a wrench or direction for turning a valve.

15. Write a reference section that includes a list of source material used for the SOP. If someone wants to confirm something, they will know where to look.

16. Include sample forms that are used when carrying out the procedure.

17. Test the SOP develop troubleshooting instructions. Anticipate problems for a reader and include them in a troubleshooting section. Also incorporate troubleshooting tips at each step in a process where they actually occur.

18. One way to anticipate safety, health, environmental and operational problems is to ask an inexperienced person to "walk through" a mock (inactive) process (under close supervision of an expert) and try the steps. Such unknowledgeable person could ask questions or demonstrate behaviors that an experienced or familiar person would not.

9.15 Fish Health Management Guidelines

Fish health is one of the single largest concerns in fish husbandry since a disease outbreak can result in decimation of stocks on a facility. The health of fish hinges on much more than just pathogens, hygienic practices, proper nutrition, adequate biosecurity measures, adherence to disinfection protocols etc. all help maintain healthy fish and provide protection from disease should an encounter with a pathogen occur. Fish culture involves the successful integration of planning, operation and production criteria to ensure the health of the population at risk. Fish managed well will be stronger, healthier, better growing and able to resist disease organisms should they be present in low numbers in the environment.

Successful fish health management begins with prevention of disease rather than treatment. Prevention is accomplished through good water quality management, record keeping, nutrition, sanitation, and a basic understanding of how your fish actually function at a biological level, what they need. Without this foundation it is impossible to prevent outbreaks of opportunistic diseases. Fish are constantly bathed in potential pathogens, including bacteria, fungi, and parasites. Even use of sterilization technology (i.e. ultraviolet sterilizers, ozonation) does not eliminate all potential pathogens from the environment. Suboptimal water quality, poor nutrition, or immune system suppression generally associated with stressful conditions allow potential pathogens to cause disease. Medications are no substitute for proper animal husbandry. Daily observation of fish behaviour and feeding activity allows early detection of problems. If treatment is indicated, it will be most successful if it is implemented early in the course of the disease while the fish are still in good health.

Ultimately, the goal of any fish health management program is to identify and manipulate risk factors in order to reduce the probability of disease. It is not necessary to remove the necessary cause to prevent disease from occurring. Diseases can be prevented from occurring by modifying the host, agent or environment. Immunization is an example in which the infectious agent that is the necessary cause of disease is not removed, but the host susceptibility is modified so that disease does not occur.

In 2005, the National Aquatic Animal Health Program (NAAHP) was implemented. The purpose of the NAAHP is to reduce incidence and transmission of infectious agents at all levels of fish culture to meet international aquatic animal health management standards that are required to protect Canadian aquatic resources (wild and farmed).

All Salmonid Enhancement Program (SEP) facilities and those facilities partially funded or associated with DFO must maintain an up-to-date Fish Health Management Plan specific to their facility. Best management practice guidelines for maintaining optimal health conditions for cultured fish to meet the current NAAHP requirements are contained within the FHMP, which is intended for use by fish culture staff at each SEP (or DFO associated facility) site for managing fish health and enabling an informed fish health decision making process. Because the FHMP consists of a series of Standard Operating Procedures that are in use at a facility that relate to fish health it will provide many obvious benefits to any fish culture program. An up to date Fish Health Management Plan will:

1. Provide guidance for preventing the introduction of disease causing agents
2. Lead to a reduction of disease occurrence in fish held in a culture facility
3. Minimize the spread of disease to stocks within and outside the facility
4. Assist staff in maintaining an environment that promotes health and productivity of fish and reduces susceptibility to disease

5. Help protect public health and minimize disease risks to cultured and wild fish through judicious use of drugs and chemicals.

6. Provide appropriate information from which rational, evidence-based fish health management decisions can be made

7. Provide individuals with all the information required to perform a procedure properly.

8. Ensure procedures are done consistently to maintain quality control, protect against failures that could harm cultured or wild fish, and ensure that approved procedures are followed in compliance with any regulations

9. Serve as a valuable training document for teaching new people

10. Provide a historical record of the how, why and when of steps in a procedure

11. Serve as an explanation of steps in a process that can be reviewed to improve practices as information and technology changes

While the underlying general principles of the FHMP will be similar for all facilities, the protocols themselves may contain many site specific details. Once completed, the FHMP should be reviewed annually by staff to ensure that it is current and changes should be made as necessary.

A standard Fish Health Management Plan will include Standard Operating Procedures for the following practices:

1. Broodstock Selection
2. Broodstock Handling
3. Broodstock Biosecurity
4. Adult Carcass Disposal
5. Gamete Collection (Egg Take and Milt Collection)
6. Egg and Milt Transport
7. Fertilization & Incubation
8. Egg Disinfection
9. Egg Fungal Treatments
10. Egg Shocking, Picking & Egg Enumeration
11. Ponding
12. Feed, Feed Storage, & Feeding Practices
13. Individual Length/Weight and Bulk Weight Sampling Protocols
14. Fish Handling Procedures
15. Marking Fish
16. Juveniles-Health Observations
17. Pre-Release or Transfer Disease Risk Assessment
18. Transporting Fish
19. Juvenile Release
20. Mortality Collection and Disposal
21. Mortality Classification
22. Outbreak Response
23. Quarantine/Isolation Procedures for Suspected Disease Outbreaks
24. Juvenile Treatments
25. Broodstock Treatments
26. Top-Coating Medicated Feed
27. Medicated Feed: Storage, Handling, and Feeding
28. Diagnostic Sampling protocols
29. Sample Shipment to a Diagnostic Laboratory
30. Anaesthesia
31. Euthanasia
32. Chemicals & Disinfectants: Supplies and Storage
33. Equipment disinfection
34. Vaccine handling, storage and administration.
35. Predator exclusion
36. Site and staff disinfection and biosecurity
37. Water quality monitoring
38. Water quality contingency plan

9.16 *Biosecurity plans*

Biosecurity refers to an integrated strategy to assess and manage the risks that threaten animal health, human health, food safety, and the environment. The key components of a biosecurity program involve the exclusion of pathogens from a site and the containment of pathogens within a site if a disease situation does occur. The nature of enhancing wild populations using gametes collected from mature salmon returning from the oceans means that it is impossible to prevent the introduction of pathogens in all cases. Nevertheless, measures are in place to minimize the introduction of pathogens at key fish culture junctions and to minimize the impacts related to the presence of pathogens.

9.16.1 Barriers

A fish culture facility should be provide a suitable, secure rearing environment. Physical barriers should be in place to prevent uncontrolled or undesirable human and animal entry and the risks involved with movement people and equipment must be assessed and managed. Physical barriers may include such structures as chain link fencing surrounding the facility, locking entrances to incubation and juvenile rearing facilities etc.

Every facility should have procedures posted for all visitors, and visitors should follow these procedures. Visitor access should exclude any areas containing sensitive life stages, i.e. incubation rooms to avoid unintentional introduction of potential pathogens.

Every attempt should be made to exclude predators such as rodents, birds, mink, otters, bears etc, from the site.

9.16.2 People movement

Personnel must adhere to biosecurity procedures for the site and, where possible, should not travel between hatcheries on the same day. If such travel is unavoidable, do not return to a clean facility after visiting a disease-suspect one, or ensure adherence to all biosecurity procedures at each facility to minimize the risk of inadvertently spreading disease between sites.

If a site has a known disease problem occurring, that site should remain isolated from other sites; the site should be visited only if absolutely necessary and the visitor should not visit any other sites that day or return to his/her normal work site.

9.16.3 Hygiene

If travel between two facilities is unavoidable, footwear should be disinfected between sites. Similarly, rain gear should not be used between facilities or should be disinfected if it must be used offsite or at another facility.

All rearing and holding units, tanks and other containers should be kept clean and tidy.

All floors in fish holding or rearing areas should be kept clear of non-essential equipment, fish food, dead fish, debris, etc.

9.16.4 Disinfection

Footbaths and hand wash stations should be placed at critical locations throughout the site, notably the entrance and exit points of the incubation and juvenile rearing units. The use of hand sanitizers and footbaths will significantly reduce the incidence of human transfer or pathogens between groups and life stages of fish.

Footbaths must be regularly refreshed to remain effective. Some disinfectants use colour as an indicator of concentration and a decrease in intensity is a sign that the bath should be changed. Examples: Ovadine, Virkon (pink formulation).

Equipment and containers should be disinfected regularly to reduce transfer of pathogens between groups of fish. Disinfectants should be used according to manufacturer's directions but as a general rule, organic matter must be removed from boots and equipment prior to disinfection to ensure efficacy. This can be accomplished by pressure washing and/or scrubbing manually using brushes and detergents if necessary/applicatble.

Disposal of chemical disinfectants should be according to manufacturer directions and following the requirements of waste management regulations. Concentrated solutions should not be disposed of into fish bearing waters, it is preferable to dispose of to ground and allow the solution to percolate through the sediment.

9.16.5 Monitoring

Regular monitoring of fish and their behaviour will often provide the first clue that something may be affecting fish in a culture situation. The most appropriate times for regular fish monitoring are during feeding, regular sampling for weights and lengths, and during cleaning of enclosures.

Several diseases do exist that can transfer from fish to humans, therefore, it is important that those working with fish take hygienic precautions to protect their own health; this includes wearing gloves while handling dead fish and washing hands after picking mortalities.

Each holding unit should have its own equipment (nets and buckets) for mortality removal. Equipment used to remove mortalities should be cleaned, disinfected and dried between uses. After mortalities have been collected they should be stored (they may be frozen) in a central location away from the fish rearing area until they can be removed from the site.

Collection of any mortalities should be performed on a daily basis and more frequently if mortalities are greater than normal. The presence of mortalities in the rearing area can contribute to horizontal transmission of disease, attraction of predators and have negative effects on water quality and hygiene in the environment. To ensure that the most sensitive life stages are protected, mortalities should be picked from the youngest and healthiest groups of fish first.

Where feasible, separation of duties should occur such that those picking mortalities are not feeding fish or cleaning holding units subsequently. Footbaths and hand wash stations should be used prior to returning to fish holding areas.

Mortalities should be counted and classified as they are collected. All mortalities should be classified and recorded in the husbandry logs. Standard mortality classifications may include:

- Background Mortality (expected background losses)
- Systems related (systems or equipment failure)
- Environmental (water quality, plankton)
- Fresh (fresh, unexpected apparently healthy losses or disease mortalities)

- Handling/transport (losses related to handling or transport)
- Matures (fish that have matured and died)
- Old (mortalities are too old and decomposed to determine cause of death)
- Predators (fish killed or injured by predators)
- Culls/Quality Control/Poor Performers (fish intentionally removed from the population

A certain degree of historical mortality is presumed but staff should record data and examine the mortality curve to observe any trends in mortalities over time. This is useful information as some hatcheries have disease signatures and these affect at different life stages etc but are specific to sites. If levels are seen to be above these then investigation should be initiated. In the event of unexpectedly high morbidity or mortality rates, the frequency of mort collection may be increased. If daily mortalities exceed 0.5%, the Veterinarian should be consulted.

9.16.6 Feed and feeding

Feeding is a critical component to proper growth, which is the most important aspect of fish culture. It is the best chance to monitor feeding behaviour and look for signs of sickness, stress, or strange behaviour, which include when the fish aredying at a higher rate than normal, swimming lethargically, flashing (showing their sides), discolouring, feeding less or improperly, breathing hard, showing no avoidance behaviour, loss of scales and fin erosion, etc. Fish should be observed regularly during feeding to determine if they are responding as expected and if the volume of ration is sufficient or if overfeeding is occurring. Overfeeding should be avoided due to its negative effects on water quality and the stimulation of potentially harmful bacterial and fungal growth.

Feeds should be obtained from a feed mill that has been inspected by the CFIA (e.g. EWOS, Skretting, Proform) and feed bags should be labeled with the date of manufacture and guaranteed analysis information.

Most feed manufacturers produce feeds with immunomodulators as an additive. These feeds use naturally occurring compounds (e.g. beta glucans) to naturally stimulate the innate immune system and provide an extra boost to the natural defences. This can provide an advantage to the fry when they are moving into a new environment and may help reduce the losses to disease on salt water entry.

To ensure that feed remains in optimal nutritional condition, it should be stored safely away from pests (rats, mice, etc) and at temperatures that reduce the chance of feeds becoming rancid ($<20^{o}$C and <75% humidity). Feed should be rotated so that newer lots of feed on site are fed out last.

When automated feeders are used, the equipment should be serviced regularly and the rate of intake of the fish checked frequently. If feed waste is observed on the bottom of the container feed rates are adjusted.

Failure to begin feeding or to acquire a sufficient amount of food is considered a major cause of death of larval fish. In the event of food refusal or failure to gain weight (as determined by routine bulk sampling of newly ponded alevins), Fish Health Management, Support Biologists (Brian Anderson is the lead on food related issues), the Veterinarian and the feed manufacturer should be informed.

Note: if a feed-related problem is suspected, a sub-sample of food from the lot in question should be bagged, labeled and frozen in case analysis is indicated.

9.16.7 Vaccination

Vaccination is a proactive defence against potential pathogens. It provides an effective barrier to many, known, problematic diseases and boosts the likelihood of survival in the face of disease. To be effective, vaccines do need to be handled and stored appropriately. Manufacturer's directions will dictate appropriate use, handling, and storage. In general, however, vaccines are kept refrigerated (2-8°C) in transport and storage and should be protected from light and freezing. Once opened, a bottle of vaccine should be used within 24 hrs. Any open vaccine older than 24 hrs must be discarded. The vaccine should be a uniform cloudy suspension. If the vaccine appears abnormal it should not be used. The lot number of the vaccine should be noted in the records and the expiry date checked prior to use; expired vaccine is discarded.

Fish showing signs of illness should not be vaccinated and fish should not be vaccinated at water temperatures of less than 1°C. Vaccination should also be avoided during smoltification and the four weeks prior to seawater entry

Fish should be taken off feed for a maximum of 72 hours prior to vaccination. Determination of the time off food includes consideration of fish size, diet, water temperature and existing knowledge of gut emptying times. Vaccination should not occur if water quality is questionable. Once it has been determined that fish are healthy enough for vaccination, large enough to respond to the vaccine and the

Vaccines used in enhancement are delivered in a bath treatment and the water quality in the bath should be monitored closely for the duration of the procedure, particularly dissolved oxygen and temperature. Supplemental oxygen should be bubbled into the vaccine bath to maintain optimum dissolved oxygen levels.

Fish should be fed the day following vaccination if their behaviour and appearance is normal. Fish should be monitored closely for two weeks following the vaccination procedure for signs of illness. Fresh mortalities should be closely examined and sampled.

9.16.8 Suspected disease

If a disease is suspected to be present and causing mortalities in a population of fish, every effort must be made to isolate those fish from other groups on site. Equipment in the affected enclosure must not be used elsewhere without appropriate disinfection. Access to affected fish should be limited and the Veterinarian should be notified immediately. Any movements of fish into or out of the affected containers should be stopped. Depending on overall morbidity rate, all sick, slow swimming or moribund fish should be removed from the environment. Mortality removal should be done at least twice daily.

Mortalities should be collected into spill proof containers with secure lids and transported to a composting landfill for disposal. Equipment and containers used to collect mortalities should be disinfected after each use.

Deciding when diagnostic support is needed can often be difficult. Shipping samples is time consuming and costly. If mortalities are unexpected, clinical signs are suggestive of a disease of concern (eg. popeye and/or swollen abdomens at a facility with a history of recurrent BKD infection), or if the daily mortality rate exceeds 0.5% of the population, a sample should be forwarded to the Fish Pathology Laboratory at the Pacific Biological Station.

The Veterinarian will most likely request a sample of affected, and apparently healthy, live fish to be sent to the laboratory for diagnostic purposes and may suggest some temporary mitigative measures. In order for accurate diagnoses to be obtained, fish samples must arrive at the laboratory in suitable condition. Instructions for collection and shipment will be provided. Shall we include?

Ensure that a complete fish history information, including: population size, clinical signs, mortality and morbidity rate, diet and feed consumption, water quality conditions, records of recent stressful events (e.g. low water event, marking), vaccination status, disease and treatment history, accompanies the shipment.

9.17 Record Keeping

Records are valuable tools for managing and interpreting production on any facility. Records allow historical productivity to be investigated, and assist in tracking down problems.

Records that should be maintained on a regular basis at any enhancement facility include, but are not limited to:

- Inventory records (including source, number, location, and age of fish at the site)
- Fish movement records
- Mortality records including clinical signs and mortality cause if known
- Diagnostic sampling records and diagnostic results
- Water quality records (temperature, flow, dissolved oxygen, etc.)
- Therapeutics and medication records
- Records of actions taken to prevent or mitigate disease, e.g. refused shipment of potentially infected eggs
- Records of reporting to Provincial or Federal authorities, in accordance with existing regulations

Many of these records are computerized and form part of the integrated operator record keeping system. SEP will provide adequate system training and documentation to authorized site personnel including data entry and reports, e.g. ENPRO for DFO. Backups should always be maintained.

Paper records not entered into a computerized system should be well organized, easily accessible and protected from damage, e.g. kept in binders.

Records should be kept for the duration of time the fish are on site and archived records should be maintained at a suitable location such as DFO's head office or securely stored off site. Records should be available for inspection upon request by BC MAFF and should be reviewed on a routine basis by the DFO Veterinarian and/or Fish Health Management Team to look for patterns in fish health and disease.

Records allow ease of reporting to the BCSFA Fish Health Database on a monthly basis. Reporting to the BC Fish Health Database is required of enhancement hatcheries and this data is also subject to audit by the BC MAFF. There is a shared responsibility to report what is occurring in fish culture regardless of the nature or purpose of culture. Wild and cultured fish share similar resources and compliance with the reporting requirements ensures that the maximum information is available to lead to informed and appropriate aquatic environmental and health management decisions.

9.18 Maintenance of water quality and contingency planning

Maintaining good water quality is vital to good fish health. Every facility should maintain a regular program for monitoring and recording water quality at hatchery sites. Monitoring will vary between sites depending on location and the specifics of the aquatic environment and the frequency of monitoring will depend on available equipment and type of facility water use (i.e., flow through or recirculation). In-line monitoring may be applicable in some cases.

The facility should maintain a contingency plan in the event of acute deterioration of water quality (for example due to loss of flow or contamination of supply). Failure of pumps requires an immediate response. Systems should be suitably alarmed to indicate a water supply failure and the site should have backup systems to ensure water supply is not interrupted and quality is maintained.

9.19 Habitat improvement

9.19.1 Guidelines for in-Stream Placement of Salmon Carcasses for Nutrient Enrichment

Available online: *http://www-heb.pac.dfo-mpo.gc.ca/publications/carcass_guide_e.htm*

Historically, large numbers of salmonid carcasses provided entire watersheds with abundant nutrients and organic matter derived from the ocean. Recent research strongly supports the hypothesis that salmon carcasses play a key role in maintaining the productivity of salmonid systems and benefiting the aquatic and terrestrial ecosystem as a whole. Specifically, salmon carcasses provide a significant portion of nitrogen in plants and animals inhabiting streams where salmon returns are abundant. Rearing juveniles consume salmon eggs, feed directly on spawned-out carcasses, and benefit from increased abundance of invertebrates and algal growth. The presence of carcasses in streams has been related to increased juvenile density, growth rate, body size, improved fish condition, improved over wintering survival and ultimately increased marine survival.

While the deliberate distribution of hatchery salmon carcasses into watersheds for nutrient-enrichment purposes, can provide ecological benefits to natural salmonid stocks, this practice may also pose fish health risks to native stocks if the carcasses carry live pathogens.

Accordingly, appropriate disease risk-aversive measures must be followed (e.g., pathogen-free certification) to prevent the possible transmission of disease organisms within salmon carcasses to living salmonid. DFO has developed guidelines for in-stream distribution of hatchery carcasses. SEP first developed these guidelines in 1999 and they have been routinely updated since then. Because there is not widespread disease screening of hatchery fish, the risk of introducing disease organisms is managed by allowing distribution of carcasses only to the immediate watershed of origin.

Distribution to nearby streams outside the watershed may be considered in exceptional circumstances, where the fish disease history is known and the receiving stream is within the zone of influence (i.e., significant straying of natural fish may be expected to that zone). Carcass distribution rates are also specified.

The guidelines have been developed to regulate the in-stream placement of hatchery salmon carcasses from Fisheries and Oceans Canada enhancement facilities where there is a desire and the capacity to distribute carcasses. The guidelines are not intended to enforce the distribution of carcasses, nor to replace harvest under an Excess Salmon to Spawning Requirements (ESSR) authorization.

These guidelines are meant to increase the overall benefits from carcass placement by minimizing disease risks and other concerns, providing general management strategies for carcass placement, and highlighting the interagency process to avoid conflicts with potentially affected groups and agencies. Numerous factors affect the benefits of carcass placement in streams. These include ambient nutrient content in treatment streams, abundance of native salmon spawners, presence of fish disease agents in carcasses, retention and distribution of carcasses in waterways, water temperatures, flow levels, light penetration, and predator / scavenger activity on carcasses by insects, fish, birds and mammals. These factors have been considered in the development of the guidelines The guidelines were developed utilizing current relevant literature, input from DFO fish health specialists and ecological research scientists, and guidelines prepared by the Washington Department of Fish and Wildlife.

9.19.1.1 Planning, Review, And Awareness

Carcass placement plans must be reviewed by a DFO member of the Introductions and Transfers committee. Projects that meet the terms of the carcass placement guidelines will be issued a letter from the Department allowing the transport and deposition of carcasses. This letter must accompany all carcass movements. Carcass placement plans should be discussed with all relevant groups and agencies. These groups will include DFO local area staff in stock assessment, habitat, and resource management, and Conservation and Protection (Fishery Officers), as well as local First Nations, stewardship groups, affected landowners or any other affected groups. It is also important to contact the regional Ministry of Environment office to ensure that carcass placement is coordinated with inorganic nutrient enrichment projects. The Ministry of Environment should also be contacted if placement is considered in non-anadromous waters.

Under the Water Act, downstream water users (primarily local municipalities), must be advised of activities that may potentially impact water quality of their withdrawals. Accordingly, Water Licensees on treatment streams should be advised prior to placement programs. Carcasses should be distributed in such a way so as to avoid or minimize impacts on domestic and other types of intakes or water supplies. Background material and signage may be provided to advise members of the public of carcass placement activity and its benefits.

9.19.1.2 Carcass Management and Condition

The placement of salmon carcasses in streams may pose a risk of disease transmission if carcasses of infected fish are used, if carcasses are moved to areas within the watershed that are normally not accessible to salmon, or if carcasses are moved to streams outside the watershed. Streams that receive carcasses are referred to as “treatment” streams and those that provide carcasses are referred to as “donor” streams. In general, no carcasses may be moved outside their natal stream because of concerns regarding disease transmission. However, in specific circumstances, movement of carcasses from the watershed to nearby streams may be considered if all of the following conditions are met: donor and treatment streams are geographically proximate and, treatment stream is within the zone of influence of the donor stock (i.e. adults may be straying from donor to treatment stream), and current disease history is available. If sufficient information is not available, health testing of fish in the donor stream and treatment stream may need to be undertaken. Historical information can be obtained by searching the Pacific Biological Station (PBS) Fish Health Database; the Fish Pathology Program may be contacted at (250) 756-7057. Please note that wild fish surveys have not been conducted in many locations in recent years so that information contained in the database does not include current disease status for many salmon stocks.

Only those fish killed with CO_2 or blunt trauma that show no visible evidence of serious disease should be used for carcass placement. Carcasses of recently dead salmon from managed spawning channels may also be considered for placement.

Because of drug clearance times, and the length of holding, fish previously treated with an antibiotic or chemical anaesthetic (i.e. TMS™, Aquacalm™) must not be used for carcass placement. However, fish treated with external chemicals that do not require a withdrawal period (e.g. Parasite-S™ or Chloramine-T) are considered safe for placement. If in doubt, contact the Fish Pathology Program. Carcasses may be frozen for later use. However, as freezing will not significantly reduce disease organism loads, it should not be considered a disease management tool.

9.19.1.3 Carcass Loading Density

All salmonid carcasses are considered equal from a nutrient content basis. That is, required placement load may be calculated as biomass and then converted to fish numbers of the available species. For example, Chinook carcasses may be substituted for coho, and vice versa. Where system-specific weight data are not available, the following average weights for returning B.C. salmon are provided for weight conversion.

Suggested Average Weights for B.C. salmon *

Pink 1.5 kg
Steelhead 4.0 kg
Sockeye 2.5 kg
Chum 4.5 kg
Coho 3.0 kg
Chinook 8.5 kg

* Data sources: mean weights from B.C. catch statistics (J. Bateman, pers. comm.)

The maximum carcass placement within a stream segment (including the areas into which carcasses drift from the distribution point), over the course of a spawning season should be 1.9 kg/m^2 based on Wipfli et al. (2003) and WDFW (2002). In treatment streams with continuous escapement records, the carcass numbers may be reduced by the recent 10 year average for natural escapement to the treatment reach.

For determining total carcass deposition maximums for streams used by more than one salmon species, the area historically available to each salmon species should be used to calculate the loading rate. Spawning timing should be factored into distribution schedules.

Maximum loading densities may be adjusted to reflect the stream's carcass retention properties. Carcass retention in streams is affected by predator / scavenger activity, carcass transport during high flows, and abundance of in-stream structures to catch and retain carcasses. Accordingly, for streams with expected good carcass retention, maximum carcass densities may be reduced by the current spawner densities. For streams with expected poor carcass retention (high gradient, high flows, few pools and few in-stream structures), carcass loading densities need not be adjusted for current spawner densities.

9.19.1.4 *Carcass Distribution*

The temporal and spatial distribution of carcasses should reflect the historic spawn timing and abundance of salmon in the treatment reach. Carcasses should be placed in stream areas that are normally (or recently historically) accessible to salmon, (i.e., not above barriers). Carcass placement into inaccessible stream segments may be permitted where juvenile salmon of the same stock and species have been previously out planted (e.g., colonized upper areas above impassable barriers) but consultation with regional Ministry of Environment staff is necessary.

Placement in the riparian zone is not necessary and often results in increased numbers of blowflies. (Reimchen et al, 2003.). Natural predators will remove carcasses from the treatment stream and distribute them in riparian zones.

For streams with poor access (and low public use), a few accessible sites may be used for regular carcass placement. These sites should be inspected periodically to ensure adequate natural dispersion of carcasses. Where dispersal is poor, carcass loading should be reduced.

Carcasses should be distributed in stable stream areas, where possible. This will help avoid rapid downstream transport of carcasses. Optimal sites include shallow backwater pools, side-channels, small headwater tributaries, areas with abundant woody debris and beaver-dam complexes. However, note that placing excessive numbers of carcasses in side pools with sluggish or intermittent water exchange may cause de-oxygenation (E.A. MacIsaac, pers. comm.). Carcass placement should be avoided or delayed during high flow events, especially where anchoring and/or riparian placement is not feasible. Carcass distribution schedule should consider anticipated problems of poor stream accessibility due to snow, high water, and other constraints.

Timing of carcass placement is also important as nutrients should be made available to young salmon upon their emergence from the gravel. Placement timing may be early, mid or late, and may be used to influence the ecological response to loading within watersheds. For example, the use of carcasses from later runs of native salmon (fall and winter) may benefit the next growing season, provided that some nutrients are stored through the winter (Wipfli et al. 1999). Also, the use of carcasses from several species, each with a different run timing (e.g., early sockeye, mid-chum, late coho), will provide a longer nutrient pulse in the treatment stream than if only one or two species were used, each with a brief spawning period.

If a treatment stream has a late natural spawning timing, carcasses from earlier runs to the treatment stream may be frozen and stored for later placement. The use of frozen carcasses is also convenient for long-distance transport.

9.19.1.5 *Carcass Anchoring/Mutilation*

Carcasses may be tethered or anchored in place, especially in unstable, higher-flow areas in order to improve carcass retention. Where carcass anchoring is desirable, natural anchors (e.g., large woody debris, logjams, beaver-dams) or bio-degradable tethers such as natural-weave ropes, should be used where possible. External identification tags should be removed from carcasses prior to their placement. Non-bio-degradable tethers should be collected and removed from the stream after carcass decomposition. Where frozen carcasses are used, they should be tethered in place (frozen carcasses float and may be readily transported downstream). Where tethering is not possible, it is preferred to thaw out at least one fourth of the frozen carcasses before distributing them in order to enhance carcass retention at the point of access.

Where escapement enumeration programs will be conducted on treatment streams, carcasses should be cut in half or otherwise mutilated at placement, as directed by area stock assessment staff. This is crucial in order to avoid double-counting and ensure that enumeration programs are not affected.

9.19.1.6 Records of Carcass Placement

Records of numbers and species of carcasses placed in treatment streams should be maintained in annual data summaries, including areas and dates of placement. Summaries should be provided to the contact member of the Introductions and Transfers Committee.

Appendix 1 - Acronyms and Definitions

Captive rearing: Captive rearing programs (or captive brood programs) have been used where stocks of fish are beyond assistance by normal enhancement practices. Fish are reared through the entire life cycle in captivity. A proportion of juveniles from captive reared stocks will be released in an attempt to rebuild natural the stock while ensuring that the genetic material is not lost through a catastrophic event.

CEDP: Community Economic Development Program

Critical Habitat: Anadromous spawning areas (include the intertidal area associated with pink or chum streams), kelp beds, eelgrass beds, lingcod spawning habitat (<30m depth), herring spawning area and abalone habitat

DFO: Department of Fisheries and Oceans

Enhancement: The release of fish from a fish culture facility with the objective of increasing the size or growth of a wild fishery or other stock.

ESAU: Enhancement Support and Assessment Unit

Feral Fishes: Feral fishes refers to fishes that originated from human captivity and found their way into the natural environment that had been in captivity and originated from human introductions- intentionally or accidentally. The fishes may originate from dedicated stocking, from hatchery escapement, or from some other human action. Feral fishes can be a native species, or a nonindigenous species. Moreover, feral fishes can provide an important fishery in some waters. Besides population supplementation, they could be associated with put-and-take fisheries and put-grow-and-take fisheries. (Examples include stocked hatchery trout in west coast streams and escaped farm-raised salmon in west coast waters.) (Mudrak and Carmichael 2005).

Fishery Restoration: Propagation and stocking under a restoration plan use strategies that involve the protection and enhancement of native fish populations. Where restoration is employed, the primary goal is to increase the abundance of a particular species of fish within its historic range. Under restoration, sustainability of the population is the objective (similar to rehabilitation), but ensuring a harvestable surplus of animals for humans is the management goal. Accordingly, restoration is primarily a fishery management strategy. Under restoration, hatchery propagation and stocking might opt to use the best available genetic material that is similar to, but not specific for, the restoration river or water body. Restoration actions help to rebuild a viable fishery (Mudrak and Carmichael 2005).

Habitat improvement: Habitat improvement is achieved by SEP through aquatic nutrient enrichment. Nutrient enrichment is achieved by one of two methods.

> Carcass placement in rivers and streams replenishes systems by ensuring the nutrients available from naturally decomposing carcasses add necessary compounds (e.g. nitrogen isotopes) back into the stream system.
>
> Lake enrichment is a salmon habitat restoration and enhancement technique that is used to improve the freshwater rearing conditions of wild sockeye salmon. Nutrients are added to the surface waters of selected lakes during the growing season to increase the amount of plankton food for juvenile salmon. The objective is to increase the growth and survival of the sockeye salmon in freshwater, which, in turn, improves marine survival and increases numbers of returning adults. Before the advent of the commercial fishing industry, the millions of fish that

are now caught in the ocean would return to freshwater to die, and their carcasses provided a rich source of nutrients for the freshwater ecosystem. These nutrients sustained the growth of the microscopic plants and animals on which the young sockeye fed before migrating to the ocean as smolts. Historical abundance of feed organisms was therefore much greater than today, when a century of heavy fishing has reduced freshwater productivity, and many salmon stocks, to a fraction of their previous levels. Some lakes have naturally low nutrient concentrations because there is limited spawning area (and therefore carcass abundance) in their watersheds, or there is so much rainwater passing through them that the nutrients are flushed out before they can be used by feed organisms. Lake enrichment replaces some of these nutrients to partially restore or enhance the freshwater productivity of sockeye nursery lakes.

HSRG*:* Hatchery Scientific Review Group - The Hatchery Scientific Review Group is an independent scientific panel established and funded by US Congress to provide an evaluation of hatchery reform as part of the Puget Sound and Coastal Washington Hatchery Reform Project. The objective of the HSRG is to assemble, organize, and apply the best available scientific information and to provide guidance to the policymakers and technical staff who are implementing hatchery reform.

Native Species and Nonnative Species: Species native to North America are regarded as those species that resided within North America prior to European colonization in the early 1600s. And moreover, within North America, there are specific ranges for native species (e.g., eastern brook trout and west coast rainbow trout). Comparatively, nonnative species are defined as those species that were subsequently introduced by humans, deliberately or accidentally, during or post colonization. The definitions portray a static view of the world. In reality, as climate and landscapes changed over the millennia, species probably moved to latitudes and altitudes that match the conditions to which they were adapted, or the species may have remained and evolved to adjust to the changing climate and environmental conditions (Mudrak and Carmichael 2005).

Naturalized Species: A naturalized species refers to a displaced native (nonindigenous) species and/or nonnative species that has achieved self-sustaining status in the natural environment. The naturalized species may have become established outside its native range through intentional or accidental human actions. Naturalized species may provide important economic benefits for fisheries management and serve as surrogates for native species by providing functional biological benefits within natural and altered ecosystems. (An example is a self-sustaining brown trout and/or smallmouth bass in many streams and rivers of the northeast.) In many cases, the term "established" has been used as a synonym for naturalized (Mudrak and Carmichael 2005).

Navigable Waterway: The administrative definition is: any body of water capable of being navigated by floating vessels of any description for the purpose of transportation, commerce or recreation. This includes both inland and coastal waters. The authority to determine the navigability of a waterway rests with the Minister of Transport or his/her designated representative. (Transport Canada 2006)

OHEB*:* Oceans Habitat Enhancement Branch

PIP*:* Public Involvement Projects

Population Rehabilitation - Propagation and stocking under a rehabilitation plan use strategies that involve the protection and enhancement of specific native fish populations. Where rehabilitation is employed, the primary goal is to safeguard the genetic legacy of the native species within its habitat-specific historic range. Under rehabilitation, sustainability of the unique population for its ecosystem function is the primary objective, and harvest mayor may not be a secondary management objective. Accordingly, rehabilitation is generally considered a genetic conservation strategy. Rehabilitation is typically employed for enhancing the specific population, where species abundance is insufficient to meet human harvest expectations or where an imperiled population has not been given formal federal protection under the Endangered Species Act. Rehabilitation actions help to rebuild a specific natal population (Mudrak and Carmichael 2005).

Satellite Stocks: Stocks that are reared at a central facility but which originate from different watersheds

Sensitive Habitat: Anadromous rearing areas (including the intertidal area associated with salmon bearing streams), rockfish rearing/nursery areas, shellfish beds, unique feature and sponge complexes.

SOP - Standard operating procedure. Procedures that are carried out regularly (or irregularly) at any facility should be written in a standardized format that outlines the needs, steps and hazards of any procedure.

Species Recovery - Propagation and stocking under a recovery plan use strategies that involve the protection and enhancement of specific native fish populations. Where recovery is employed, the primary goal is to protect the status of the species and to ensure sustainability. Similar to rehabilitation, recovery is a conservation strategy designed to safeguard the genetic legacy of the species within its habitat-specific historic range. Under recovery, all management actions are governed by a formal species Recovery Plan, and the primary objective of the plan is to improve the population status to a measurable level that will allow the species to be de-listed. Additionally, under recovery, bycatch (unintentional harvest), as well as intentional "take," may be regulated by law. Recovery actions help to delist a federally listed species. (Mudrak and Carmichael 2005).

Supplementation: The use of artificial propagation to maintain or increase natural production while maintaining the long-term fitness of the target population, and keeping the ecological and genetic impacts to non-target populations within specified biological limits.

Wild Fishes: Wild fishes are those that originated from natural reproduction in the natural environment-as opposed to hatchery fishes or fishes derived from human intervention in the spawning process. Wild fishes might be native or naturalized nonindigenous species. Because the term "wild fish" tends to cause debate, PFIRM steering committee urges resource managers to qualify its use. (Example: the state's wilderness trout fishing program is highly successful because of management's two-tiered approach to their "wild-trout" fishery: (1) the state capitalized on the high intrinsic value of the historic native brook trout fishery; and (2) the state recognized the desire of anglers to seek out large trophy brown trout that have become naturalized in the region.) (Mudrak and Carmichael 2005).

Appendix 2 - DFO Contacts

Salmonid Enhancement Program

Vancouver (Regional Headquarters)	(604) 666-0384
Suite 200 - 401 Burrard Street	(604) 666-0417 (F)
Vancouver, BC V6C 3S4	

Support Biologists

Brian Anderson	*andersonbr@pac.dfo-mpo.gc.ca*	(604) 666-3958
R. Gregory Bonnell	*bonnellg@pac.dfo-mpo.gc.ca*	(250) 363-3484
Roberta Cook	*cookr@pac.dfo-mpo.gc.ca*	(604) 666-2879
Carol Cross	*crossc@pac.dfo-mpo.gc.ca*	(604) 666-8598
Doug Lofthouse	*LofthouseD@pac.dfo-mpo.gc.ca*	(604) 666-8646
Don MacKinlay	*mackinlayd@pac.dfo-mpo.gc.ca*	(604) 666-3520

DFO Pacific Region Animal Care Committee (PRACC) Coordinator

Louise McLennen (250) 756-7033

Pacific Biological Station Pathology Laboratory

Room T308 - 3190 Hammond Bay Road	(250) 756-7057
Nanaimo, BC V9T 6N7	(250) 756-7053 (F)

SEP Veterinarian

Dr. Christine MacWilliams *MacWilliamsC@pac.dfo-mpo.gc.ca* (250) 729-8377

Pathology Laboratory

Carl Westby *westbyc@pac.dfo-mpo.gc.ca* (250) 756-7057

Cultus Lake Salmon Research Laboratory

4222 Columbia Valley Hwy.
Cultus Lake, BC, V2R 5B6 (604) 824-4700

Introductions and Transfers

Mark Higgins *higginsm@pac.dfo-mpo.gc.ca* (250) 756-7072

A more comprehensive list of contacts can be found online at:
www.pac.dfo-mpo.gc.ca/ops/fm/toppages/contacts_e.htm
The Pacific Regional list of Fisheries Offices is located at:
http://www.pac.dfo-mpo.gc.ca/pages/offices_e.htm
The Directory of Pacific Regional Community Advisors is found at:
http://www-heb.pac.dfo-mpo.gc.ca/community/contacts/ca_e.htm

Recreational Fishing:
www.pac.dfo-mpo.gc.ca/recfish/default_e.htm

Commercial Fishing:
www.pac.dfo-mpo.gc.ca/ops/fm/Commercial/index_e.htm

24 Hour Recorded Information (Commercial) Vancouver		(604) 666-2828
Pacific Salmon Commission (PSC) Office		(604) 684-8081
PSC Test Fisheries (Recorded, In-Season Information)		(604) 666-8200

Regional Headquarters

A/Regional Director, Fisheries Management Branch	Don Radford	(604) 666-0753
A/Director, Res. Management, Program Delivery	Stephen Wright	(604) 666-6931
A/Director, Res. Management, Program Development	Vacant	(604) 666-9523
Lead- Salmon Team	Paul Ryall	(604) 666-0115
Regional Resource Manager - Salmon	Jeff Grout	(604) 666-0497
A/Salmon Officer	Kelly Binning	(604) 666-4902
Regional Recreational Fisheries Co-ordinator	Devona Adams	(604) 666-3271
A/Regional Director, Conservation and Protection	Randy Nelson	(604) 666-0604
Regional Director, Oceans, Habitat and Enhancement	Rebecca Reid	(604) 666-6532
A/Director Aquaculture Division	Andrew Thomson	(604) 666-7009

Pacific Fisheries Licensing Unit 200-401 Burrard Street Vancouver, B.C. V6C 3S4		(604) 666-0566

Lower Fraser River Area

Area Director	Mel Koytk	(604) 666-6478
Area Chief, Resource Management	Paul Cottrell	(604) 666-6512
Area Chief, Conservation and Protection	Herb Redekopp	(604) 666-2807
Area Chief, Oceans, Habitat and Enhancement	Dale Paterson	(604) 666-0315
Resource Manager – Commercial Salmon (Area E)	Barbara Mueller	(604) 666-2370
Resource Manager - Aboriginal Fisheries	Debra Sneddon	(604) 666-8426
Resource Manager - Aboriginal Fisheries	Brian Matts	(604) 666-2096
A/Resource Manager - Recreational Fisheries	TBA	(604) 666-6509
Resource Management Technician	Rob Tadey	(604) 666-2299
A/Resource Management Biologist (Sockeye, Pink)	Anne Marie Huang	(604) 666-6033
Res. Management Biologist (Coho, Chum, Chinook)	Melanie Sullivan	(604) 666-2417
Aboriginal Affairs Advisor	Jordon Point	(604) 666-8590

B.C. Interior

Area Director	Barry Rosenberger	(250) 851-4865
Area Chief, Resource Management	Les Jantz	(250) 851-4878
A/Area Chief, Salmon Stock Assessment	Timber Whitehouse	(250) 851-4833
A/Area Chief, Conservation and Protection	Stu Cartwright	(250) 851-4922
Area Chief, Oceans, Habitat and Enhancement	Jason Hwang	(250) 851-4870
Aboriginal Affairs Advisor	Barry Huber	(250) 851-4858
Resource Manager – Kamloops (AFS/Recreational)	Dean Allan	(250) 851-4821
Asst. Resource Manager – Kamloops (AFS/Recreational)	Merv Mochizuki	(250) 851-4952
Resource Manager – Williams Lake (AFS / Recreational)	Linda Stevens	TBA
Asst. Resource Manager – Quesnel (AFS / Recreational)	Al Charbonneau	(250) 992-8157
Senior Resource Management Biologist - Kamloops	Les Jantz	(250) 851-4948
A/Resource Management Biologist - Kamloops	Jamie Scroggie	(250) 851-4852

South Coast Area

A/Area Director	Wilf Luedke	(250) 756-7280
Area Chief, Resource Management	Gordon McEachen	(250) 756-7288
Area Chief, Conservation and Protection	John Lewis	(250) 756-7159
A/Area Chief, Salmon Stock Assessment	Arlene Tomkins	(250) 729-8382
A/Area Chief, Oceans - Habitat and Enhancement	Bruce Adkins	(250) 756-7261
A/ Regional Treaty Negotiator	Gordon Curry	(250) 756-7255
A/Supervisor C&P	Barrie Kanester	(250) 850-5715
Aboriginal Affairs Advisor	Al Gould	(250) 756-7267
WSP Habitat Coordinator	Mark Saunders	(604) 868-0867
A/Enhancement Operations Section Head	Gary Taccogna	(250) 287-9564
Salmon and Herring Co-ordinator	Greg Thomas	(250) 756-7103
Resource Manager - WCVI (Areas 21 to 26)	Alistair Thomson	(250) 720-4454
A/Res. Manager - Strait of Georgia (Areas 14 to 16)	Andrea Goruk	(250) 756-7287
A/Res. Manager - WCVI/Strait of Georgia (Areas 17-20)	Gerry Kelly	(250) 754-0208
Senior Management Biologist - Stock Assessment	Dick Nagtegaal	(250) 746-8290
Resource Manager - AFS (Strait of Georgia)	Jonathan Joe	(250) 756-7243
Resource Manager - AFS (WCVI)	Paul Preston	(250) 720-4452
Recreational Co-ordinator	Bill Shaw	(250) 756-7152
Resource Management Co-ordinator (Areas 11-13 & 27)	Randy Brahniuk	(250) 286-5880
Resource Manager - Campbell River (Areas 12 to 13)	Kent Spencer	(250) 286-5885
Resource Manager - Port Hardy (Areas 11, 12 and 27)	George Bates	(250) 286-5895
Community Advisor - Campbell River	Barry Peters	(250) 286-5823
Community Advisor - Bella Coola	Sandie MacLaurin	(250) 982-2663
Salmon Biologist - Johnstone Strait	Ron Goruk	(250) 286-5884
Resource Manager - Recreational Fisheries - lead- Johnstone Strait	George Bates	(250) 286-5895
Recorded Information - Nanaimo		(250) 754-0281
Recorded Information - Port Alberni		(250) 723-0417
Recorded Information - Port Hardy		(250) 949-6422

Pacific Fishery Licence Unit (250) 754-0400
60 Front Street
Nanaimo, B.C. V9R 5H7

Selective Fisheries

North Coast Project Authority	Jim Steward	(250) 627-3421
Area B and D Project Authority	Kent Spencer	(250) 286-5885
Area G Project Authority	Gerry Kelly	(250) 754-0208
Area H Project Authority	Andrea Goruk	(250) 756-7287
Area E Project Authority	Barbara Mueller	(604) 666-2370

Appendix 3 - Index of web-based information

Fisheries and Oceans Canada - General Information
Main Page (*www.dfo-mpo.gc.ca/)* Vision, Latest News, Current Topics

Acts, Orders, and Regulations (*www.dfo-mpo.gc.ca/communic/policy/dnload_e.htm*)
Canada Shipping Act, Coastal Fisheries Protection Act, Department of Fisheries and Oceans Act, Financial Administration Act, Fish Inspection Act, Fisheries Act, Fisheries Development Act, Fishing and Recreational Harbours Act, Freshwater Fish Marketing Act, Navigable Waters Protection Act, Oceans Act.

Reports and Publications (*www.dfo-mpo.gc.ca/publication_e.htm*)
Administration and Enforcement of the Fish Habitat Protection and Pollution Prevention Provisions of the *Fisheries Act,* Audit and Evaluation Reports - Audit and Evaluation Directorate Canadian Code of Conduct for Responsible Fishing Operations , Departmental Performance Reports, Fisheries Research Documents, Standing Committee's Reports and Government responses, Sustainable Development Strategy

Waves (*http://inter01.dfo-mpo.gc.ca/waves2/index.html*)
Fisheries and Oceans Canada online library catalogue

Pacific Salmon Treaty (*www.psc.org/about_treaty.htm*)
Background information; full text of the treaty.

PACIFIC REGION - GENERAL
Main Page (*www.pac.dfo-mpo.gc.ca/)*
General information, Area Information, Latest News, Current topics.

Policies, Reports and Programs
(*www.pac.dfo-mpo.gc.ca/species/salmon/policies/default_e.htm*)
Reports and Discussion Papers, New Directions Policy Series, Agreements

Oceans Program (*www.pac.dfo-mpo.gc.ca/oceans/default_e.htm*)
Integrated Coastal Management; Marine Protected Areas; Marine Environmental Quality; Oceans Outreach; Oceans Act.

PACIFIC REGION - FISHERIES MANAGEMENT
Main Page (*www.pac.dfo-mpo.gc.ca/ops/fm/fishmgmt_e.htm*)
Commercial Fisheries, New and Emerging Fisheries, Recreational Fisheries, Maps, Notices and Plans

Aboriginal Fisheries Strategy (*www.pac.dfo-mpo.gc.ca/tapd/afs_e.htm*)
Aboriginal Fisheries Strategy (AFS) principles and objectives; AFS agreements; Programs; Treaty Negotiations

Recreational Fisheries (*www.pac.dfo-mpo.gc.ca/recfish/default_e.htm*)

Fishery Regulations and Notices, Fishing Information, Recreational Fishery, Policy and Management, Contacts, Current B.C. Tidal Waters Sport Fishing Guide and Freshwater Supplement; Rockfish Conservation Areas, Shellfish Contamination Closures; On-line Licensing.

Commercial Fisheries (*www.pac.dfo-mpo.gc.ca/ops/fm/Commercial/index_e.htm*)
Links to Groundfish, Herring, Salmon, Shellfish and New and Emerging Fisheries homepages; Selective Fishing, Test Fishing Information, Fishing Areas, Canadian Tide Tables, Fishery Management Plans, Commercial Fishery Notices (openings and closures)

Fisheries Notices
(*www-ops2.pac.dfo-mpo.gc.ca/fns_reg/index.cfm*)
Openings and closures, updates, and other relevant information regarding any chosen fishery can be sent directly to a registered email.

Integrated Fishery Management Plans
(*www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/MPlans.htm*)
Current Management Plans for Groundfish, Pelagics, Shellfish (Invertebrates), Minor Finfish, Salmon; sample Licence Conditions; Archived Management Plans.

Salmon Test Fishery - Pacific Region
(*www-ops2.pac.dfo-mpo.gc.ca/xnet/content/salmon/testfish/default.htm*)
Definition, description, location and target stocks.

Licensing (*www.pac.dfo-mpo.gc.ca/ops/fm/Licensing/Default_e.htm*)
Contact information; Recreational Licensing Information, Commercial Licence Types, Commercial Licence Areas, Licence Listings, Vessel Information, Vessel Directory, Licence Statistics and Application Forms.

Salmon (*www.pac.dfo-mpo.gc.ca/species/salmon/default_e.htm*)
Salmon Facts; Salmon Fisheries; Enhancement and Conservation; Research and Assessment; Consultations; Policies, Reports and Agreements; Glossary of Salmon Terms

Fraser River/B.C. Interior Area Resource Management and Stock Assessment
(*www.pac.dfo-mpo.gc.ca/fraserriver/)*
Contact information; Test fishing and survey results (Albion, creel surveys, First Nations); Fraser River sockeye and pink escapement updates; Important notices; Recreational fishing information.

North Coast Resource Management (*www.pac.dfo-mpo.gc.ca/northcoast/default.htm*)
First Nations fisheries, Recreational fisheries; Commercial salmon and herring fisheries; Skeena Tyee test fishery; Counting facilities; Post-season Review; Contacts;

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