SEP Biological Assessment Framework

Salmonid Enhancement Program
Fisheries and Oceans Canada
Pacific Region

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Glossary

Biostandards – Average values for assessment outputs such as release-to-recovery survival rate.

Escapement – The number of returning adult salmon that "escape" the enroute fisheries, predation, and other impacts, to survive and spawn.

Exploitation rate – The ratio of total catch relative to total production.

Indicator stocks – Stocks deemed to be representative of other stocks in the area as they are comparable geographically and in life history features.

Production line – A release group defined by the production facility name, species, run, stock, brood year, release stage and release location.

Stratum – Each recovery component, such as a recreational fishery or river escapement, collectively known as **strata**.

Survival rate – The ratio of juveniles released relative to total production is known as overall survival rate.

Total adult production – An estimation of the number of enhanced fish that survive to the adult stage comprised of those enhanced fish that contribute to fisheries and those in the escapement back to the river and hatchery of origin.

Glossary words are highlighted in **bold** when first used in the document.

1. Executive Summary

Biological assessment is fundamental to evaluating the performance of the Salmonid Enhancement Program (SEP). It is the means by which SEP measures program contribution to fisheries and rebuilding of populations; fish production levels; the effectiveness of enhancement strategies; and effects of hatchery salmon on wild populations. SEP assessment is also a key component of Fisheries and Oceans Canada (DFO) work in the Pacific Region. It supports regional DFO stock assessment and harvest management planning and evaluation, and it is inextricably tied to meeting obligations under the Pacific Salmon Treaty (PST).

SEP biological assessment involves specific assessment activities, such as juvenile marking and analytical techniques (e.g. mark recovery analysis to determine contribution of enhanced salmon to a fishery). This framework sets out a baseline program for such assessments and describes how they aggregate and integrate with other DFO salmon stock assessment programs to meet domestic and international commitments such as the PST. SEP assessment objectives are divided into those that support SEP's core assessment program and those that are linked through SEP to other essential Pacific Region assessment objectives (Figure 2).

The assessment framework is also essential to national reporting requirements. As a stand-alone regional program, SEP must maintain its own nationally credible performance measurement and reporting system, independent of the broader performance measurement infrastructure that is available to department-wide or more broadly-based DFO programs. A logic model, which is a component of the national performance measurement framework, guides the program (Appendix 1). The model depicts the outcomes, or results, that the program works to achieve in support of broader government outcomes such as enhanced salmon supporting harvest, stock recovery, rebuilding and assessment. The assessment framework connects these larger government performance measurement requirements with program and regional assessment needs.

This document is one of a number of integrated planning tools that SEP has developed to guide program management and decision-making (Figure 1). Companion documents are the *SEP Production Planning: A Framework* (DFO 2017) and *A Biological Risk Management Framework for Enhancing Salmon in the Pacific Region* (DFO 2013), which together provide cohesive program-level strategic management. Operational guidelines will also form part of the SEP assessment approach.

This framework applies to SEP managed or supported hatcheries and incubation projects for which SEP holds the Pacific Aquaculture Regulations (PAR) licence, and to managed spawning channels (where spawn timing and density are controlled) operated by SEP in the Pacific Region. The focus of the framework is on the assessment of Chinook, Coho, Sockeye, Pink and Chum Salmon produced from such facilities, of which there are about 150 throughout British Columbia and the Yukon. Projects range in size from spawning channels releasing nearly 100 million juveniles annually to school classroom incubators releasing fewer than one hundred juveniles. The framework does not address SEP habitat restoration or lake enrichment projects, assessment of Steelhead and Cutthroat produced at SEP facilities, or non-SEP funded facilities that culture and release Pacific salmon.

1.1. Methodology

Adult production from every enhancement project is assessed in some form for each release group, with the method dependent on the species, project size, and enhancement technology employed. The key assessment outputs are **total adult production**, **survival rate**, **exploitation rate**, biological metrics, such as age composition, and metrics of the effects of hatchery salmon on wild salmon.

Assessments may be direct or indirect. Direct assessments are those where the juvenile and adult data used for estimating the assessment outputs of a stock are obtained directly from the released production of that stock. They frequently involve statistical analyses that are based on the marking of juvenile salmon and their subsequent recovery as adults in fisheries and the **escapement** (Figure 3). Marking may entail removal of a fin, insertion of a coded-wire tag, manipulation of water temperatures during incubation to produce unique ear-bone patterns, or utilization of natural occurring genetic markers. The choice of mark depends on the: objective of marking; number of fish or proportion of the population to be marked; life stage at which they are to be marked; planned recovery method; and costs of marking and subsequent recovery and sampling. Direct assessment may also involve analysis of the rate of return to fisheries and the escapement (Figure 5). Some directly assessed stocks are designated as **indicators** and are deemed to be representative of other stocks in the area as they are comparable geographically and in life history features.

Indirect assessments, in contrast, are calculated estimates using **biostandards** from directly assessed **indicator stocks** of the same species (Figure 6). Indicator stocks are essential constituents of indirect assessment methodology as they provide data that can be used to estimate production for projects that are not directly assessed. They are also fundamental to overall program assessment as the production from both directly and indirectly assessed projects must be aggregated to provide a program-wide view of production. Juvenile production is directly assessed for all facilities but it is not possible to directly assess adult production from every facility because some projects are too costly to assess relative to data quality or because of site-specific logistical reasons. For example, some facilities release only small numbers of fish and the statistical analyses used for assessment are not valid for such small releases.

Assessment of the effect of hatchery salmon on wild salmon is also a key component of the assessment framework. There are numerous pathways through which hatchery programs can affect wild salmon populations, including genetic traits, life history alterations and ecological interactions. The effects may be within and outside enhanced populations. Some effects can be mitigated through the SEP production planning process, such as utilizing release strategies that minimize competition with wild rearing juveniles or that reduce the likelihood of adult straying. Others are addressed through application of guidelines and best practices. SEP is working to assess and manage the level of genetic risk to hatchery-influenced wild salmon populations through the application of the "proportionate natural influence" (PNI) index. The PNI, developed and applied through the American Hatchery Scientific Reform Group process (HSRG 2009, HSRG 2014), is the most widely applied metric to assess the genetic risks of hatchery production on natural populations and represents an index of gene flow between the natural

and hatchery environment. SEP will use a classification system based on the PNI for assessing, designating and managing the degree of influence of hatchery programs on individual salmon populations (DFO 2018).

1.2. Planning, Integration, and Priority Setting

There is extensive interface between DFO Science Stock Assessment, Fisheries Management and SEP because SEP assessment activities support wild salmon stock assessment and harvest management. Enhancement assessment data, especially for Chinook and Coho, are widely used for assessing wild salmon stock status, developing forecasts, monitoring in-season abundance, and PST analysis. Coordination of the activities in a manner that supports both SEP and other regional DFO needs involves pre-season and in-season planning to ensure that core activities are identified, funded and implemented. Table 2 describes these responsibilities in more detail.

The annual assessment cycle includes a series of milestones connected with both the production planning and business planning processes (Figure 8). Effective execution of the assessment cycle is critical to ensuring successful planning, implementation and integration within SEP and across other branches. Linking assessment planning requirements to the business planning cycle matches assessment needs with available resources, highlights potential funding gaps, and works to ensure the prioritization of key assessment components for funding. Similarly, by linking the assessment cycle to the production planning process, assessment analyses are used to establish, inform, and adaptively manage production levels and enhancement strategies The management and analysis of data generated by assessment activities is critical to the timely provision of reporting products required by SEP and other branches and programs in the region. Additionally, data analysis supports assessment and production planning for the next cycle year.

Good business practices require SEP to prioritize these activities and to follow a structured decision-making process that clearly documents the rationale for the allocation of resources. Priorities therefore are a key determinant in the annual SEP planning process and rely on characterizing and determining which assessment activities best address the assessment objectives depicted in Figure 2.

2. Introduction

2.1. Purpose

Biological assessment is fundamental to evaluating the performance of the Salmonid Enhancement Program (SEP). It is the means by which SEP measures program outcomes (e.g. contribution to fisheries and rebuilding populations), fish production levels, enhancement strategies and effects on wild populations. SEP assessment is also a key component of Fisheries and Oceans Canada (DFO) work in the Pacific Region (British Columbia and the Yukon) as it supports regional DFO stock assessments, harvest management planning and evaluation, and the Pacific Salmon Treaty (PST).

This document describes the SEP biological assessment program, the framework for which provides a predictable and systematic means of organizing the assessment projects managed or supported by SEP in the Pacific Region. An operational guidelines document will also form part of the SEP assessment approach. SEP has carried out extensive biological assessment from its inception, and this framework situates those activities in the current setting while providing the foundation from which future decisions can be made from a planning and priorities perspective.

At its root, SEP biological assessment involves assessing the production from individual enhancement projects using a variety of analytical techniques to establish production levels and enhancement strategies. This framework sets out a baseline program for such assessments and describes how they aggregate and integrate with other DFO salmon stock assessment programs to meet domestic and international commitments such as the PST. The framework also takes into account implementation of the *Wild Salmon Policy* (DFO 2005) through the assessment of effects on wild salmon.

This framework is designed for SEP staff and community partners, primarily those who work in or with fish production facilities, and those who collect, manage and analyze fish production and program biological assessment data. It is also designed for DFO staff in Fisheries Management (FM) and Science Stock Assessment programs who rely upon or provide input to SEP biological assessment. It can be ultimately linked to any overall DFO integrated stock assessment framework that may be developed in the region.

This document is one of a number of integrated planning tools that SEP has developed to guide program management and decision-making (Figure 1). Companion documents are the *SEP Production Planning: A Framework* (DFO 2017) and *A Biological Risk Management Framework for Enhancing Salmon in the Pacific Region* (DFO 2013). These products provide a cohesive program-level strategic management framework. The production planning framework outlines the process and considerations that SEP utilizes to set the production targets for each facility. The biological risk framework provides detail on the guidelines, practices and tools that SEP utilizes to manage risks to wild salmon as well as approaches to assessing biological effects.

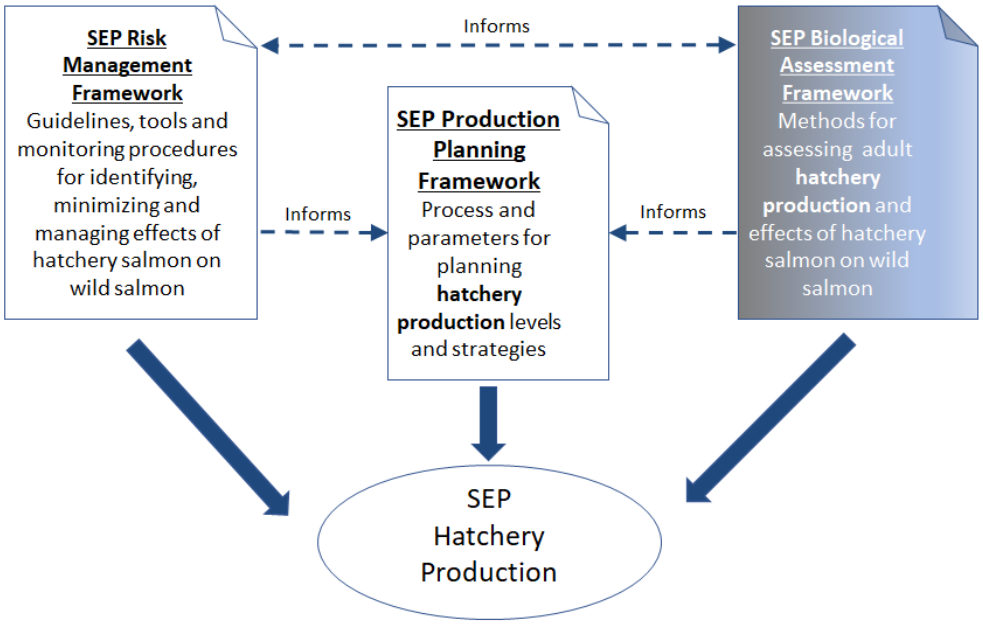

Figure 1 - SEP Integrated Framework Documents.

2.2. Program Background

SEP produces Pacific salmon and Pacific trout[1] at enhancement facilities, restores habitat, and undertakes projects that include public participation by local communities and First Nations in fisheries and watershed stewardship activities. Enhanced salmon enable economic, social, and cultural harvest opportunities for commercial, recreational, and First Nations harvesters; support vulnerable stock rebuilding; and contribute to stock assessment commitments within DFO's Pacific Region and under the Pacific Salmon Treaty with the United States. Projects with community partners include stewardship activities and the development of integrated local and area watershed plans. SEP also supports salmonid related school education and public awareness projects.

SEP enhances Chinook, Coho, Chum, Pink, and Sockeye Salmon, as well as small numbers of Steelhead and Cutthroat Trout. Project types include hatcheries, fishways, spawning and rearing channels, habitat improvements, flow control works, lake fertilization, and small classroom incubators. Projects are operated by SEP staff or contracted with some SEP support to First Nations and community and volunteer groups. Of these, about 150 are fish culture projects that release fish annually from sites throughout British Columbia and the Yukon. These projects range in size from spawning channels releasing nearly 100 million juveniles annually to school classroom incubators releasing fewer than one hundred juveniles.

A logic model (Appendix I), which is a component of the larger performance measurement framework, guides the program. The model depicts the outcomes,

[1] Pacific salmon and Pacific trout are within the genus *oncorhynchus*, but were each a separate genus (*oncorhynchus* and *salmo*) under the family *salmonidae* at time of the program initiation, hence "Salmonid" in the name.

or results, that the program works to achieve in support of broader government outcomes, identifying the linked activities, inputs and outputs. The logic model provides the program-planning framework for setting priorities and desired outcomes. As part of this model, SEP has defined the following four program outcomes:

- **Enhanced salmon support harvest** – This outcome addresses the direct economic, social, and cultural benefits generated from harvest opportunities.
- **Enhanced salmon support stock recovery, rebuilding and assessment** – The recovery and rebuilding of vulnerable populations addresses conservation objectives and can address harvest objectives in cases where vulnerable populations may constrain fisheries. Assessment supports regional stock assessments that enable harvest management and creates data sources for fisheries management and stock assessment.
- **Restored habitat and community stewardship support salmon sustainability** – First Nations, local communities and external parties participate in cooperative fisheries and watershed stewardship activities.
- **Partnership and volunteerism support salmon rebuilding and stewardship** – This outcome includes Community Involvement Program arrangements, as well as initiatives such as watershed planning.

SEP has further identified five specific fish production objectives that flow from the logic model: harvest, assessment, conservation, rebuilding, and stewardship and education (defined in Appendix II). Each SEP **production line** (a release group defined by the production facility name, species, run, stock, brood year, release stage and release location) must address at least one of these fish production objectives.

Production targets (the maximum number of eggs to be taken and juveniles released) for each production line are developed through a cross-sector integrated planning process that involves establishing juvenile release targets and strategies that will produce the number of adults desired to meet specific objectives. The production planning process also considers hatchery-wild salmon interactions, exploitation rates that minimize impacts of abundant enhanced salmon on wild salmon, habitat capacity, project capacity, and assessment requirements.

2.3. Scope

This framework applies to SEP managed or supported hatcheries and incubation projects for which SEP holds the Pacific Aquaculture Regulations (PAR) licence. It also applies to managed spawning channels (where spawn timing and density are controlled) operated by SEP in the Pacific Region. It does not address the assessment of SEP habitat restoration or lake enrichment projects, nor does it consider assessment of Steelhead and Cutthroat produced at SEP facilities, as their assessment and management are a provincial responsibility. The framework does not speak to non-SEP funded facilities that culture and release Pacific salmon.

The focus of this document is on the assessment of hatchery-produced Chinook, Coho, Sockeye, Pink and Chum Salmon after they are released from the facility, specifically their production and contribution to fisheries and the escapement and

their potential effect on wild populations. The framework does not consider routine in-hatchery juvenile operational assessment requirements such as growth sampling.

3. Objectives of SEP Assessment

SEP assessment is critical to operational and management functions within the program while at the same time supporting associated regional and international programs (Figure 2).

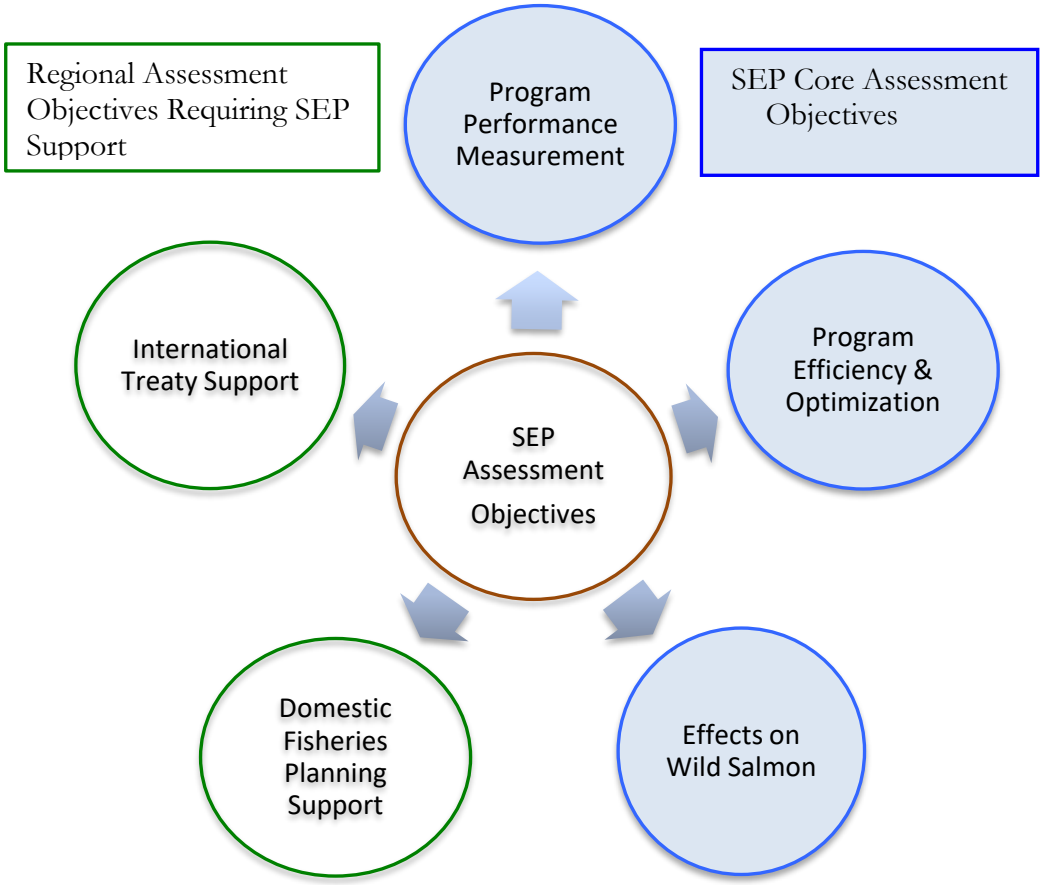

Figure 2. SEP assessment objectives and the key relationships SEP assessment has with program operational and management functions.

Reviews in other jurisdictions, albeit often with a primary focus on hatchery salmon interactions with wild populations, continue to emphasize the importance of assessment for proper management of hatchery programs (Hatchery Scientific Review Group 2009; Hatchery Scientific Review Group 2015). In the case of SEP, the importance of assessing enhanced production extends far beyond the hatchery program itself. SEP assessment for DFO is a key component of wild salmon stock assessment and fisheries management in the Pacific Region, extending into adjacent international jurisdictions. SEP assessments carried out for program purposes are integrated with, and integral to, domestic and international fishery management and tied inextricably to meeting obligations under the PST.

SEP is a unique program within DFO because of its focus on species existing only in the Pacific Region, buttressed in its formative years by a partnership with the government of British Columbia. As a stand-alone regional program, SEP must maintain its own nationally credible performance measurement and reporting system, independent of the broader performance measurement infrastructure that is available to national or more broadly based DFO programs. Because such reporting is key to program integrity, SEP has always had an intensive assessment and reporting component (DFO 2009, DFO 2015), designed to provide information to address national evaluation requirements. In addition to national and program requirements, SEP assessment also integrates other assessment priorities such as PST commitments and metrics for assessing effects on wild salmon. SEP assessment objectives can be broadly divided into those that support SEP's core assessment program and those that are linked through SEP to other essential Pacific Region assessment objectives (Figure 2). These objectives are described in the sections that follow. Appendix III provides a figure that illustrates in more detail how these objectives are met and linkages between them and the important role of **biostandards**, as discussed in a following section.

3.1. SEP Core Assessment Objectives

3.1.1. Program Performance Measurement

Government programs such as SEP must routinely report on performance indicators (i.e. percentage of enhanced salmon that directly supports the objectives of harvest, stock assessment and conservation (DFO 2016a)) as part of their national performance information profile. SEP is also subject to periodic comprehensive evaluation (e.g. DFO 2015) to assess its ongoing relevancy, effectiveness, and efficiency and its alignment with key DFO strategic outcomes In recent years, program performance measurement tools such as the SEP logic model and a SEP performance measurement strategy have been favoured for assessing program performance over direct overall program production and contribution measures. Direct measures of total adult and juvenile production and contribution to fisheries and the escapement continue to be used for internal reporting, and external reports to the public and other agencies, such as the North Pacific Anadromous Fish Commission (NPAFC) (North Pacific Anadromous Fish Commission 2016).

3.1.2. Program Efficiency and Optimization

Beyond assessment requirements for national and public reporting, production lines are assessed to support hatchery studies and project/program optimization. Optimization enables limited resources to be directed to the most efficient delivery of priorities that maximize return on investment. For example, assessment programs that provide data on release sizes and dates can be used to maximize **survival rates** and minimize operating costs, leading to cost savings and efficiencies. Project specific assessments may also be undertaken to compare different enhancement strategies, or to solve specific concerns identified for an individual stock. Optimization at the project level can often be applied across the program to multiply efficiency gains. Production lines are also assessed for performance relative to the enhancement objective using an assessment approach appropriate to the objective. For instance, where the production objective for a

production line is a local harvest, the performance may be assessed by evaluating the occurrence or size of that harvest. Specific assessment approaches by enhancement objective will be outlined in an assessment guidelines document.

3.1.3. Effects of Enhanced Salmon on Wild Salmon Populations

Monitoring, assessing and managing the effects of enhanced production on wild salmon populations have been and continue to be high priorities. SEP utilizes intensive production planning that takes into account potential effects on wild salmon. SEP also utilizes operational guidelines (DFO 2016b) and a biological risk management framework (DFO 2013) and is currently developing indices to monitor potential effects of hatchery salmon on wild salmon in target and adjacent streams (described in a later section).

3.2. Regional Assessment Objectives Requiring SEP Support

3.2.1. International Treaty Support

Data from many SEP stocks are fundamental to PST harvest management and sharing arrangement commitments, particularly for Chinook and Coho, and for managing key fisheries. Priority for assessment is placed on those stocks that meet both SEP and regional stock assessment requirements. Most Chinook and Coho PST groups in Pacific Region that are used for estimating survival and **exploitation rate** are hatchery stocks, and as such act as surrogates for wild salmon populations. Chinook hatchery exploitation rate indicator stocks are specifically named in the PST. Hatchery information in these instances results in positive effects for wild salmon as harvest measures that protect wild salmon can be implemented based on the assessments of hatchery salmon.

Assessment programs and methodologies conducted by SEP and Science Stock Assessment on a number of systems are closely intertwined; removing any component would significantly undermine, and in some instances eliminate, assessment capacity unless alternative programs were developed and funded.

3.2.2. Domestic Fisheries Planning Support

Fisheries that target or involve significant numbers of enhanced salmon require pre-season estimates of available production in order to plan management measures that allow harvest of enhanced salmon. Where applicable, this aids in protecting wild salmon and providing sufficient returns of river spawners and sufficient hatchery broodstock. Where enhanced salmon are marked, pre-season estimates of the abundance and potential catch distribution of marked salmon are necessary to plan mark recovery sampling requirements (effort and distribution) in fisheries. These programs support management and conservation of wild salmon.

Some BC fisheries are involved in the Marine Stewardship Council (MSC) process, through which fisheries are assessed for sustainability certification. Where fisheries include hatchery salmon, there are specific criteria related to their management and assessment that must be addressed. SEP assessment programs at current levels support certification, but MSC criteria may result in the need for different or more rigorous assessment approaches in the future.

Hatchery salmon assessment is necessary to address other national requirements such as status assessments for populations under review by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

4. Methodology - Assessment of Production

4.1. Background

Adult production from every enhancement project is assessed in some form at the production line level, with the method dependent on the species, project size, and enhancement technology employed. There are a number of outputs from assessments with their application dependent on the specific assessment objective. Key outputs include:

- **Total adult production** – An estimation of the number of enhanced fish that survive to the adult stage comprised of those enhanced fish that **contribute to fisheries** and those in the **escapement back to the river and hatchery of origin**.
- **Survival rate** – The ratio of juveniles released relative to total production is known as overall survival rate. Survival rate may be used to assess the performance of a release group or applied to other unassessed groups to estimate their production.
- **Exploitation rate** – The ratio of total catch relative to total production. Exploitation rate may be used to assess the performance of a release group with a harvest objective.
- **Proportionate natural influence (PNI)** – a metric that represents an index of gene flow between the natural and hatchery environment to assess the genetic risks of hatchery production on natural populations (discussed in detail in section 4).

Assessments may be direct or indirect. Direct assessment is where the data used for estimating assessment outputs of a stock are obtained directly from that stock using the tools and methodologies described in the following sections. In contrast, indirect assessment uses biostandards, average values for assessment outputs such as survival rate, from another stock of the same species (an indicator) to estimate production. Indicators are deemed to be representative of other stocks in the area as they are comparable geographically and in life history features.

Biological sampling is a key part of direct and indirect assessments and of the assessment of hatchery effects on wild salmon. It is used to characterize the enhanced population with respect to the size, age, sex ratio and genetic origin (DNA) of individuals, and hence is an integral part of assessment analyses.

Hatchery staff undertake biological sampling of both hatchery and wild salmon in SEP facilities and sometimes nearby watersheds as part of the hatchery escapement and broodstock management programs. Science Stock Assessment carries out sampling in some fisheries and watersheds to support stock assessment and related fisheries planning and for research-specific purposes. Fisheries Management also conducts biological sampling in some fisheries (i.e. vessels, boat ramps, etcetera).

Depending on the species, assessment requirements and enhancement technology, sampling may consist of any or all of the following biological attributes, with the specific requirements identified in the annual escapement assessment plan and the methodology consistent with the DFO biological sampling manual (Shaw 1994).

- **Scale/otolith sampling** – To determine the age composition of the population, and to detect thermal marks. Where otolith marking has been used to mark experimental groups for facility specific assessments, results contribute to project assessment.
- **Sex ratio** – To determine the overall proportion of each sex in the population. Sex ratio is linked to productivity, since the proportion of females in the population is a predictor of natural spawning and hatchery egg availability.
- **Length** – Post-orbital hypural length is related to age and sex of the fish.
- **DNA** – To characterize the overall genetic structure of the population. DNA samples are also used for Parental Based Tagging (PBT) – described in the next section.

4.2. Direct Assessment

Direct assessment entails a suite of juvenile and adult data collected directly from the released production of a specific stock. It frequently involves statistical analyses that are based on the marking of juvenile salmon and their subsequent recovery as adults in fisheries and the escapement (described in the following sections and as per the sequence shown in Figure 3). It may also involve analysis of the rate of return to fisheries and the escapement, including spawning channels (i.e. Babine Sockeye). This approach is described more fully in Section 4.2.4 and illustrated in Figure 5. The specific methodology depends on the species and the enhancement technology.

Those stocks for which most strata (recovery components such as various fisheries and the escapement) can be sampled and which are also representative of other area stocks may be used as indicator stocks. Some stocks may have direct assessment of only one or two **stratum**, (each recovery component, such as a recreational fishery or the river escapement, is known as a stratum, collectively strata) with such data used for project specific issues such as performance relative to an objective.

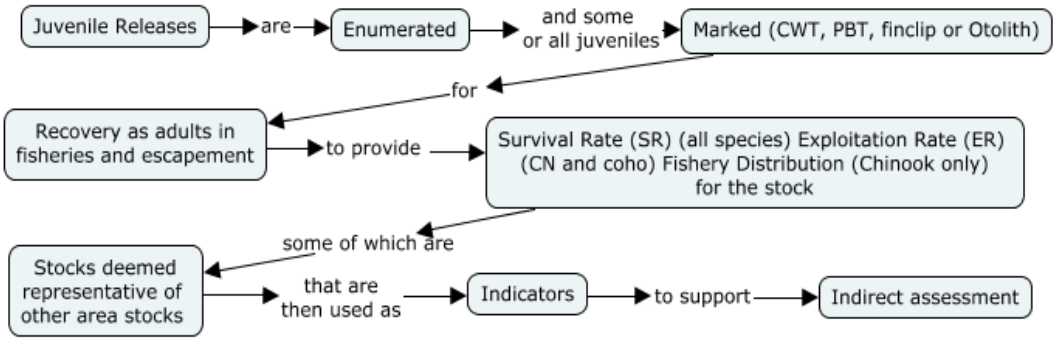

Figure 3. Direct Assessment - Mark and Recovery Methodology

4.2.1. Mark Recovery Methodology

One of the fundamental methodologies for direct assessment of enhanced salmon production involves identifiably marking some or all of a specific group of juvenile fish for later recovery as adults in the fisheries or escapement. Marking is currently the primary direct assessment method for Chinook, Coho, and Chum stocks but is also used for some Pink and Sockeye stocks.

SEP uses four types of marking methods: fin clip marking, coded wire tag (CWT) marks, thermal otolith marks and PBT. The marking method depends on a number of factors, including: the objective of marking; the number of fish or proportion of the population to be marked; the life stage at which they are to be marked (which can be species determinant); the planned recovery method; and costs of marking and subsequent recovery and sampling. Some kinds of marks are used to simply identify that the fish is of hatchery origin while others are used to support complex statistical analyses respecting the production and contribution of adults to coastwide fisheries. Marking of all juveniles released from a hatchery is termed mass-marking and is done so that all hatchery fish can subsequently be identified for objectives such as hatchery mark-selective fisheries or managing the number of hatchery fish in the broodstock. The following provides more detail on marking tools and applications, with additional information in Appendix IV.

Fin Clip Marks

The clipping of one or multiple fins in various combinations, and sometimes in combination with other types of marking such as the thermal otolith mark, allows identification of various differently treated groups of fish within a stock. Current practices predominantly use adipose fin clips since a higher post-marking mortality is associated with clipping other fins.

Coded Wire Tag Marks

A key juvenile marking tool is the CWT, a one-millimeter binary-coded tag inserted in the nose (see Appendix IV for more details), used primarily for Chinook and Coho but sometimes for other species. In Canada, removal of the adipose fin (Figure 4) indicates the presence of a CWT for Chinook Salmon. For

most Southern BC hatchery Coho, its removal identifies the fish as of hatchery origin, regardless of whether it carries a CWT.

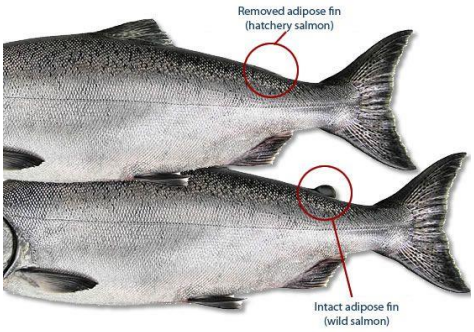

Figure 4. Adipose fin clip

Thermal Otolith Marks

SEP utilizes thermal otolith (ear bones of the fish) marks to mass mark juveniles, whereby water temperatures are manipulated during incubation to form specific patterns on the otolith or ear bone, similar to tree rings. The pattern can be used to identify the origin of adults recovered and for comparative in-hatchery studies. Otolith marking may be applicable where juveniles are too small for CWT/finclip application (i.e. emergent Chum fry) or where release groups are too large to practically mark all juveniles. Otolith marks are generally less expensive to apply than CWTs or finclips but recovery costs may be comparable. Since otolith marks are not externally visible their utility is restricted in those situations where hatchery fish must be outwardly identifiable.

Parental-Based Tagging

SEP is also utilizing parental-based tagging as a marking and mass-marking tool. PBT involves genotyping all hatchery broodstock, thereby resulting in genetic tagging of all hatchery fish. Sampling programs for all strata produce recoveries of fish from PBT release groups via statistical matching of genotypes of sampled individuals to two genotyped hatchery parents (mother and father – offspring trios) or to single parents (parent-offspring pairs) for estimation of survival rates.

Currently SEP is utilizing PBT for all Coho in Southern BC. Recovery sampling is appended to the existing fishery and escapement sampling and is feasible because all hatchery Coho can be identified through their missing adipose fin. PBT has also been used in a more limited way for specific Chinook and Sockeye stocks for applications such as heritability studies. Application beyond Coho is not as broad because other hatchery produced salmon are not all externally identifiable with adipose clips and thus not readily sampled.

Cost and feasibility analyses will determine the future application of PBT in assessment but the maintenance of fishery and escapement sampling programs are a key component to any continued use. Although SEP is now using PBT routinely, coastwide application is still in the conceptual stage.

4.2.2. **Recovery**

Regardless of mark type, recoveries of marked mature fish take place in various fisheries (First Nations, commercial and recreational) or in river and hatchery escapement sampling. A key precursor for any marking program is the certainty that a good quality assessment (count of number of fish sampled, statistically sufficient number of mark recoveries) of at least one, and ideally most, significant recovery strata can be completed in a relatively cost effective manner.

For CWT-marked Chinook and Coho, a coastwide CWT sampling and data exchange program was established under the PST (Nandor et al. 2010). Catches and escapement are sampled from Alaska to California, so that tagged fish can be followed from release to catch or spawning grounds, making possible a complete assessment of ocean distribution, exploitation and marine survival.

No such coastwide recovery and data exchange program exists for other species that are marked with CWTs or otherwise marked. Instead, catch sampling and mark recovery is managed domestically and targeted at fisheries with a high likelihood of mark recovery. Intensive escapement sampling programs may also be involved.

Because marking resources are finite (i.e. most CWTs are reserved for SEP indicators and PST requirements and sampling resources are limited), marks must be allocated to those production lines that will yield the highest value information that can be applied most broadly. Priority is greatest for those stocks that function as indicators. In most situations, this precludes application of marks to release groups that will have limited recovery potential or very low statistical analytical power. The process for determining which production lines are to be marked is described in the later section on planning and priorities.

4.2.3. **Indicator Stocks**

Indicator stocks are directly assessed and deemed representative of other stocks in the area that are not directly assessed. They are essential constituents of indirect assessment methodology as they provide biostandards, average values for outputs such as survival rates that can be used to estimate production for projects that are not directly assessed. The methodology is described in section 4.3. They are fundamental to overall program assessment as the production from both direct and indirectly assessed projects must be aggregated to provide a program wide view of production.

The usage of indicator stocks differs between species. Chinook and Coho indicator stocks provide survival rate and exploitation rate data for both species and catch distribution information for Chinook. These are used as biostandards for SEP analyses and as part of statistical models for PST analyses. Chinook and Coho indicators have been selected based on the need to represent significant SEP production and/or PST stock groupings (Chinook) (Figure 7) or management units (Coho). They meet the requirements for PST statistical methodology and provide data that address both SEP and regional assessment objectives.

Chum, Pink and Sockeye indicator stocks are specific to SEP requirements although Chum and Pink data may be used opportunistically by Fisheries Management and Science Stock Assessment to support harvest analyses and MSC

certification. There is more limited indicator coverage of stock groupings and release stages for these species partly because DFO's overall assessment approach is less intensive for Pink and Chum than that for Chinook and Coho and partly because most Sockeye production originates from spawning channels and is directly assessed. The bulk of program investment and production, and hence potential effects, involve Chinook and Coho in southern BC, and renders the current focus on assessment of Chinook and Coho prudent.

Logistically, indicators that involve marking (CWT or fin clips) must be production groups of sufficient numerical size to meet statistical requirements for mark and recovery programs. To produce statistically sound results, the number of marks required is determined by survival and recovery rates and purpose of assessment. Indicators are most effective for sites where all, or at least some, of the most significant recovery strata (e.g. coastwide and/or domestic commercial harvest) can be sampled in a cost effective manner. Activities required for direct assessment of exploitation rate and survival rate, including marking and sampling of the harvest and escapement, are coordinated as much as possible to ensure optimization of resources across branches.

4.2.4. Return Rate Analyses

Direct assessment of spawning channel production is done through enumeration of the juvenile releases and assessment of the catch and escapement components of the run, including adult fish returning to the facility. Returns to the river escapement, where sampled, and to the facility, are assigned to the brood year based on otolith and scale ages and growth period patterns, and stock specific scale and otolith patterns, as are fish from fisheries where hatchery salmon can be differentiated. Attribution of adult data to juvenile data allows calculation of survival rates (Figure 5).

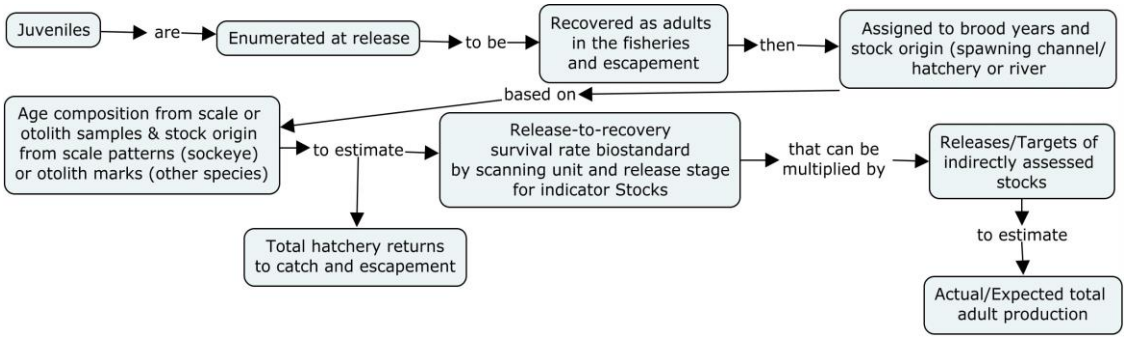

Figure 5. Direct Assessment - Return Rate Methodology

4.3. Indirect Assessment

In order to assess aggregate total production of the overall program, juvenile and adult production must be assessed for every project. Juvenile production is so assessed but it is not possible to directly assess adult production from every facility because some projects are too costly to assess relative to data quality or because of site-specific logistical reasons. For example, some facilities release only small numbers of fish and the statistical analyses used for assessment are not valid for such small releases. Where production cannot be directly assessed, total

production is estimated using data from a directly assessed indicator stock (Figure 6).

The method involves matching each production line, by species and release stage, to the best available biostandard survival rate indicator in the scanning unit (SU) (Figure 7), with the rationale documented. Where there are no indicators for the specific SU or release stage, data from adjacent SUs may be utilized, or biostandards for other release stages may be scaled up or down. Other biostandards for characteristics such as age composition or fecundity may be also be used in some analyses, where available and appropriate. Notably, there are limited current survival rate biostandards for some areas and release stages.

Expected or actual production is estimated by multiplying the production target or the actual releases respectively by the biostandard survival rate. Chinook production estimates can be further partitioned into contribution to fisheries and fishery distribution by gear type and area. This is further illustrated in Appendix V, Figure A1. The estimated production from a production line can then be aggregated to the desired level (e.g. SU or program).

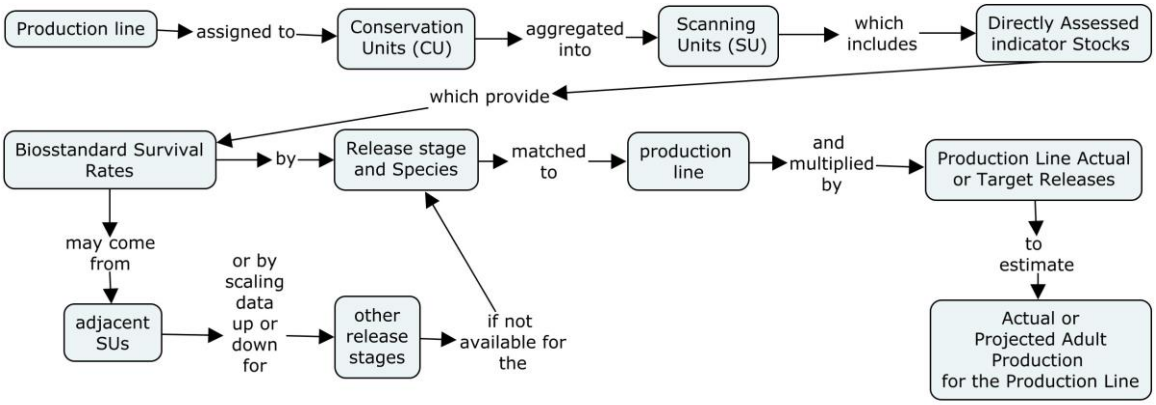

Figure 6. Indirect Assessment Methodology

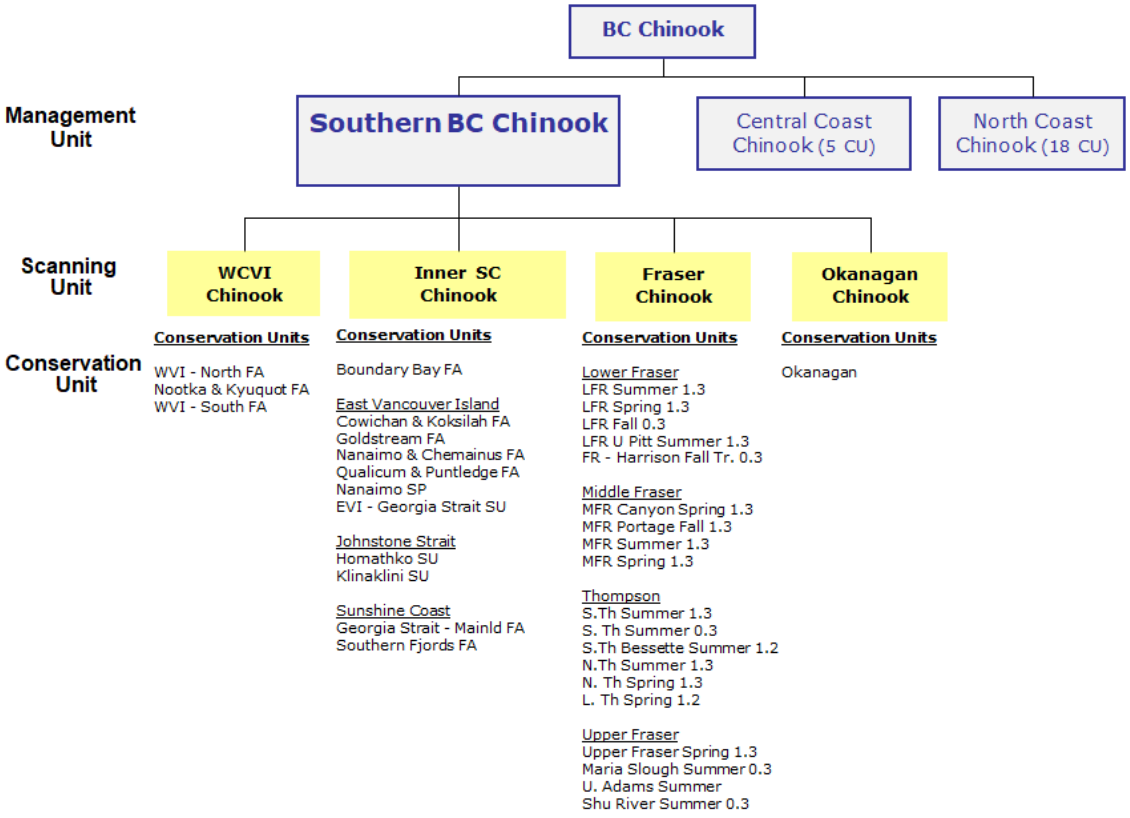

Figure 7. Chinook population structure.

5. Assessment of the Effects of Hatchery Salmon on Wild Salmon

Canada's Policy for the Conservation of Wild Pacific Salmon (WSP) (DFO 2005) defines "*wild fish*' as those "*that have spent their entire life cycle in the wild and originate from parents that were also produced by natural spawning and continuously lived in the wild*". The WSP notes that "*the requirement in the definition that a wild salmon must complete more than one full generation in the wild safeguards against potential adverse effects resulting from artificial culture.*"

As such, there are numerous pathways through which hatchery programs can affect wild salmon populations, including genetic traits, life history alterations and ecological interactions. The effects may be within and outside enhanced populations. Some aspects of effects are mitigated through the SEP production planning process, such as utilizing release strategies that minimize competition with wild rearing juveniles or that reduce the likelihood of adult straying. Others are addressed through application of guidelines and best practices. SEP has mitigated the influence on genetic traits through broodstock collection and mating guidelines and best practices since 1987 and has updated them regularly over time. However, the potential for undesirable genetic effects is still present through the spawning of hatchery salmon with wild salmon, both naturally and in the hatchery because SEP's hatchery programs are based on an "integrated" model whereby native broodstock are used and hatchery origin spawners are allowed to spawn with co-migrating natural origin spawners within the population.

One tool SEP uses to assess and manage the level of genetic risk to hatchery-influenced populations and the surrounding wild populations is the "proportionate natural influence" (PNI) index. The PNI, developed and applied through the American HSRG process (HSRG 2009, HSRG 2014), is the most widely applied metric to assess the influence and genetic risk of hatchery production on natural populations and represents an index of gene flow between the natural and hatchery environment. In brief, the PNI gauges the relative influence of natural and hatchery selection through calculation of a value between 0 and 1 based on the proportions of natural-origin parents in the hatchery broodstock and hatchery-origin fish on the natural spawning grounds. A *PNI* value >0.5 indicates a gene flow favouring the adaptive influence of the natural environment, and a *PNI* value of <0.5 indicates a gene flow where the adaptive influence of the hatchery environment is dominant.

Upon the request of SEP, the Canadian Science Advisory Secretariat provided scientific advice for DFO on genetically based targets for enhanced contributions to Canadian Pacific Chinook Salmon populations (DFO 2018). This advice utilizes the PNI metric, a population classification system for Chinook informed by the WSP, to reflect the adaptive state of integrated Chinook hatchery populations based on proportions of natural- and hatchery-origin fish. Implementation guidelines provide more detail on how the PNI, in conjunction with the population designation system defined by CSAS, will be utilized to achieve the principles and objectives of genetic management of all species of enhanced Pacific Salmon. Guidelines developed for Chinook Salmon are considered highly appropriate for Coho and Sockeye Salmon, and applicable but more conservatively so for Pink and Chum Salmon.

The focus of the assessment on the effects of hatchery salmon on wild stocks will be to characterize the population with respect to their designations and to continue to support broodstock collection, management and mating design. In practice, the population biological objectives will serve as both a goal and an assessment of current status.

The population biological designations with associated descriptions and PNI metrics (DFO 2018) are shown in Table 1.

Table 1. Population biological designations with associated descriptions and metrics.

Designation	PNI	WSP Wild Fish[1] (%)	Description
Wild	n/a	> 97	Designated wild populations that do not have hatchery programs; straying from out-of-basin hatchery production is limited to <3% per year.
Wild-stray influenced	n/a	< 96	Populations that receive strays from hatcheries outside the watershed at rates that exceed limits specified for *wild* designation. A very large fraction of fish is wild but gene modelling suggests a long term decline in PNI.
Integrated-wild	$\geq$ 0 .72	> 50	Populations with an integrated hatchery program managed to achieve conservation and genetic goals while contributing to production. Hatchery production is managed to keep WSP defined wild fish >50%.
Integrated transition	> 0 .5	> 25 - < 50	Populations retaining PNI> 0.5, indicating a gene flow from the natural-origin component to the hatchery component. PNI > 0.5 ensures natural-origin influences predominate but wild fish are in the minority.
Integrated -hatchery	< 0.5	< 25	Populations where hatchery fish dominate both broodstock and the natural spawning components. Net gene flow is from hatchery environment and most fish are hatchery origin and <25 % of fish are wild.

[1] The WSP Wild Fish column shows the expected proportions of natural origin to natural origin mating that would result in production of salmon qualifying as wild under the WSP.

6. Roles and Responsibilities

Because SEP assessment activities support wild salmon stock assessment and harvest management, there is extensive interface between Science Stock Assessment, Fisheries Management and SEP. Enhancement assessment data, especially for Chinook and Coho, are widely used for assessing wild salmon stock status, developing forecasts and monitoring in-season abundance.

A primary task of Science Stock Assessment is to advise Fisheries Management and other groups (e.g. First Nations and stakeholders) on the status of fish stocks. The assessment of stocks is quantitative and data intensive, with SEP data components figuring prominently in many analyses. Correspondingly, SEP assessment requires data from Science Stock Assessment assessment activities, such as escapement assessment and fishery sampling (Table 2). Coordination of the activities in a manner that supports both SEP and other regional DFO needs involves pre-season and in-season planning to ensure that core activities for indicator stocks are identified, funded and implemented (Table 2). Production of hatchery stocks as indicators for assessment requirements is also a planning requirement and is addressed through the production planning process led by SEP

staff, with participation by Fisheries Management and Science Stock Assessment. Planning and coordination of regional stock assessments is led by Science Stock Assessment with the participation of SEP and Fisheries Management.

Table 2. Responsibilities for annual SEP assessment planning and implementation.

Task	SEP	Science Stock Assessment	FM
Develop regional stock assessment frameworks and requirements	C	A	C
Develop annual SEP production plan	A	C	C
Develop annual juvenile/adult stock assessment plan	C	A	C
Provide direction on regional stock assessment priorities and commitments (e.g. PST)		A	
Develop regional mark plan for SEP facilities	A	C	C
Develop regional adult sampling plan for SEP facilities	A	C	
Implement juvenile marking/sampling and adult sampling plan for SEP facilities	A		
Fund and implement escapement assessment programs*	C	A	
Fund and implement fishery sampling and assessment programs*	C	A	C
Provide area SEP/ Science Stock Assessment requests/ requirements for SEP regional assessment plan	A	C	C
Provide annual SEP assessment projects input to annual regional Stock assessment framework	A		
SEP - assessment data analysis management and reporting, regional program data standards, RHQ/Area data integration, sharing of program data with region	A		
REGIONAL DFO - assessment data management, regional data standards, sharing and integration, and reporting requirements/timelines	C	A	

A = Accountable to deliver
C = Contribute
* SEP covers some of these activities to obtain data for indicators even though regional accountability resides elsewhere.

Indicator stock assessment activities may be funded and implemented by Science Stock Assessment, SEP, or both. Hatchery marking programs are coordinated between the branches to ensure optimization of resources for each. For indicator stocks, Science Stock Assessment utilizes data from SEP-funded hatchery CWT marking programs directly "as is" or by supplementing the number of tags for increased analytical capacity. In a few instances, stocks are enhanced only to provide a marked release group for regional or Science Stock Assessment purposes.

Fishery monitoring and mark recovery sampling of commercial and recreational fisheries are regionally coordinated and generally funded by Fisheries Management

and Science Stock Assessment. Estimates of total harvest in First Nations food, social and ceremonial fisheries are available, but mark sampling is limited.

For escapement strata, information is needed for both river and hatchery escapement. At the hatchery rack or fence, escapement enumeration and mark sampling is conducted by hatchery staff. Escapement programs for natural spawners (total escapement estimates, mark sampling and biological sampling) are generally funded by Science Stock Assessment, sometimes with in-kind support from SEP.

There is limited investment in Pink and Chum Salmon assessment regionally. Because SEP enhances both species, SEP plans and funds assessment activities that are specific to SEP requirements where necessary (e.g. domestic harvest sampling or escapement sampling).

7. Assessment Planning Cycle

While previous sections have described the many components of SEP assessment, understanding the timing and constitution of the assessment cycle (Figure 8) is critical to ensuring successful planning, implementation and integration within SEP, and across other branches. The cycle involves a series of milestones connected with both the production planning and business planning processes.

Linking assessment planning requirements to the business planning cycle matches assessment needs with available resources and highlights potential funding gaps while working to ensure the prioritization of key assessment components for funding. Similarly, by linking the assessment cycle to the production planning process, assessment analyses are used to establish production levels and enhancement strategies, essential outcomes of assessment. The management and analysis of data generated by assessment activities is critical to providing reporting products required by SEP and other branches and programs in the region. Additionally data analysis supports assessment and production planning for the next cycle year.

The following are key activities and their respective timing in the assessment cycle as illustrated in Figure 8.

- **Mark Planning** – Critical SEP and Science Stock Assessment requirements are considered, such as PST marking and outcomes from adult assessments that may suggest the need for specific study marking. Science Stock Assessment staff provide input and review. Mark planning culminates in the production of an initial marking plan that identifies the marking requirements for specific production lines including the stock, stage and species to be marked, the mark type, the number of marks to be applied, funding sources and other relevant details. The business planning process informs funding availability for marking, with funding prioritized for core assessment activities and processes (see Section 3.1). A final plan that accounts for the availability of funding, tags, staff and marking infrastructure and timing, is distributed to all facilities and to Science Stock Assessment staff, with some components shared with other agencies.

- **Marking Implementation** – Marks are applied at facilities with mark quality validated. Depending on the facility, marking may be done by DFO staff, contractors or volunteers. Data are recorded on standardized templates and include the number of marks applied, the mark type or code, tag retention checks, and the number of unmarked fish represented by the mark.

- **Mark Data Management, Validation and Integration** – Facility staff provide mark data to SEP core assessment staff after the marked group is released. The data are validated and entered into SEP databases from which they are integrated with Science Stock Assessment databases and through them, other agencies.

- **Fishery and Hatchery Escapement Sample Planning** – Fisheries that target or involve significant numbers of enhanced salmon require pre-season estimates of available production so that FM can develop management measures that allow, where applicable, the harvest of enhanced salmon, while protecting wild salmon and allowing sufficient escapement of river spawners and hatchery broodstock. Where enhanced salmon are marked, pre-season estimates of the abundance and potential catch distribution of marked salmon are necessary to plan effort and distribution of mark recovery sampling requirements in fisheries management measures. FM identifies these measures in the appropriate Integrated Fisheries Management Plans.

  For ***escapement*** sampling, factors such as expected mark types, mark rates, numbers of fish returning and sex ratios must be considered. Biological and mark sample requirements for SEP and Science Stock Assessment programs must be identified and consolidated and sampling supply requirements (e.g. scale books, otolith vials) established. The planning process culminates in an annual escapement assessment plan for each facility that addresses sampling objectives for both SEP and Science Stock Assessment and that specifies sampling requirements for marks and biological characteristics.

- **Hatchery Escapement Sampling Implementation** – Hatchery staff implement escapement assessment plans for hatchery facilities and, in some cases, river escapements. Data are recorded in template formats and include total count, number of fish sampled for marks, number and type of marks found and biological data as required. Heads of adipose-clipped fish are removed for CWT sampling and sent to off-site labs for CWT analysis. Scales, DNA and otolith samples are also collected and sent for off-site analysis. Results of CWT, scale and otolith analysis are returned to the hatchery, where they are consolidated with mark samples to provide a complete record.

- **Escapement Data Management, Validation, and Analysis** – Facility staff provide consolidated escapement records to SEP core assessment staff who validate and analyze data for entry into SEP managed databases.

- **Escapement Data Integration – Regional Databases and Processes (PST)** – SEP escapement data are provided to Science Stock Assessment for inclusion in their databases, and through them to other agencies. SEP escapement data are integrated with other relevant data components (e.g. fisheries, mark data) in regional databases and processes such as the PST analytics and shared with other agencies.
- **Data Analysis, Reporting and Application** – The integrated data are analysed by SEP and Science Stock Assessment staff with results utilized to address assessment objectives and applied to the mark planning and production planning processes. For example, an assessment might indicate that rebuilding goals are not being met for a population, or that there is excess escapement. These outcomes could suggest that a change in the production targets or production strategies may be appropriate and that additional or specific marking assessments could be undertaken and cycled back into the process. Moreover, the results collectively will be utilized for program optimization and to develop scientific advice.
- **Production Planning Process** – (November to February) Provides information on production available for marking and incorporates assessment data for developing enhancement strategies.

- **Business Planning Process** – (December to April)) Identifies and provides assessment resources and incorporates assessment results for program optimization.

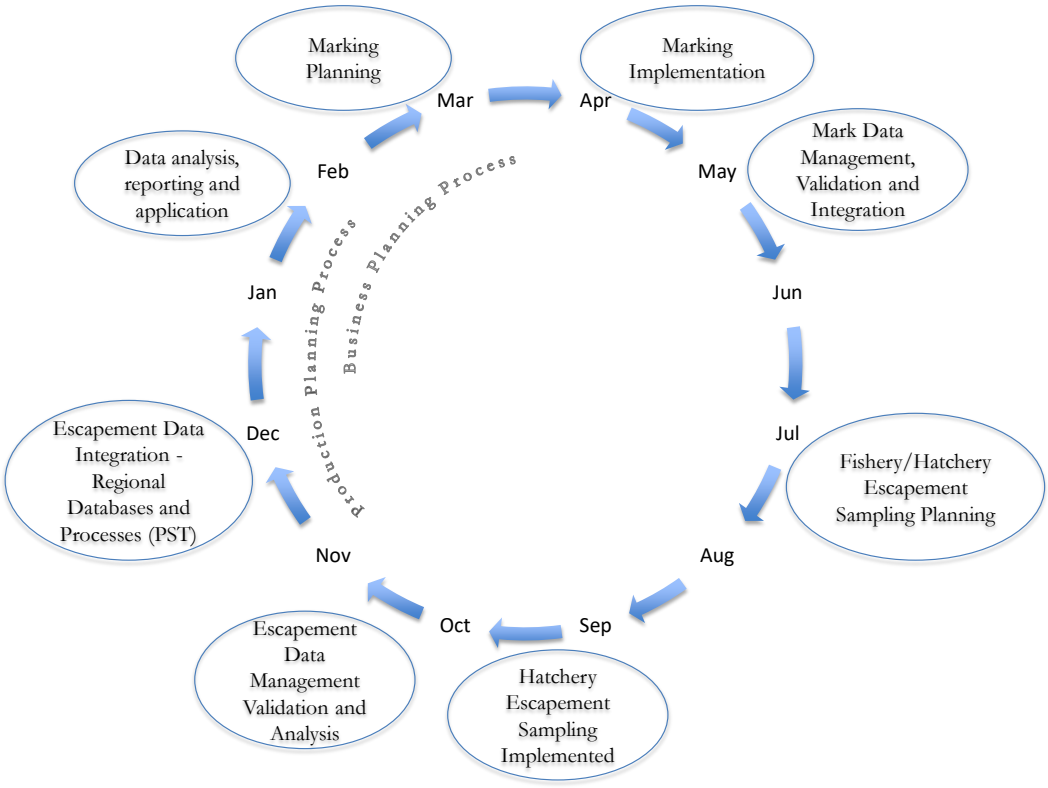

Figure 8. Example of an Annual Assessment Cycle.

8. Assessment Priorities for Decision Making

Essential decisions in operating and funding the SEP assessment program tend to manifest at the marking and resultant sampling program development stages, with the marking plan essential for direct assessments. Good business practices require SEP to prioritize these activities and to follow a structured decision-making process that clearly documents the rationale for the allocation of resources. Priorities therefore are a key determinant in the annual SEP planning process, and for development of the annual marking plan in particular. This assumes that infrastructure and program operations costs are relatively fixed.

The key factor in setting assessment priorities is characterizing and determining which assessment activities best address the assessment objectives outlined in section 3.1 of this document. The following principles are utilized to guide development of assessment program priorities, a process that is ongoing and dynamic.

1. Priorities are established based on the requirement to meet assessment objectives and are delivered on a production line basis. Assessment activities that address multiple objectives are generally a higher priority than those that address only a single objective.
2. Assessment activities that support indicator stocks and the maintenance of biostandards (including updating and filling gaps) are the highest priorities for assessment investment.
3. Mark planning is based on a rating and ranking approach that considers how well marking programs meet key priorities. Investments in marking obligates follow-up with requisite sampling since not following through would constitute a loss of benefits and invested marking resources.
4. Marking and sampling programs must meet the corresponding sample design objective in a statistically sound manner to be a priority.

In order to identify assessment gaps or weaknesses, SEP periodically grades assessment projects on a production line basis by rating, weighting, and scoring objectives and sub-objectives to rank production lines or assessment programs in priority order . This is supplemented with updates necessitated by introducing new initiatives or program re-scaling.

Wild salmon assessments will be prioritized through biological designation of populations as the approach develops. This in part takes into account the level of production, which can be a factor in potential risks to wild salmon populations.

There are known data gaps with respect to geographic coverage and release stages, and some data are not current. The representativeness of indicator stocks also requires investigation. SEP is reviewing and assessing these data gaps to support limited resource allocation to priorities.

9. Conclusion

SEP biological assessment is central to evaluating program results, enhancement strategies, production levels and the effects of hatchery salmon on wild populations. It is also an essential component of regional DFO stock assessments, harvest management planning and evaluation, and the PST implementation. These outcomes are reflected in SEP's assessment objectives, which encompass both the critical operational and management functions within the program, and those required to support associated regional and international programs.

This document describes the framework that supports assessment for these objectives. The framework as structured provides a predictable and systematic means of organizing the assessment projects managed or supported by SEP in the Pacific Region. Operational guidelines also form part of the SEP assessment approach.

Because SEP assessment activities are fundamental to program and regional assessment requirements, planning and priority setting must integrate SEP needs and those of Science Stock Assessment and Fisheries Management. Further, many assessment projects and data systems are comprised of individual activities dispersed among these DFO branches and are reliant on the continuance of each component to maintain functionality of the whole. This renders knowledge of the whole and its parts as critical, and highlights the need to use integrated planning and priority setting processes and tools. At the same time, SEP must maintain program focused assessment and regularly and systematically examine enhancement assessment to ensure that coverage is sufficient.

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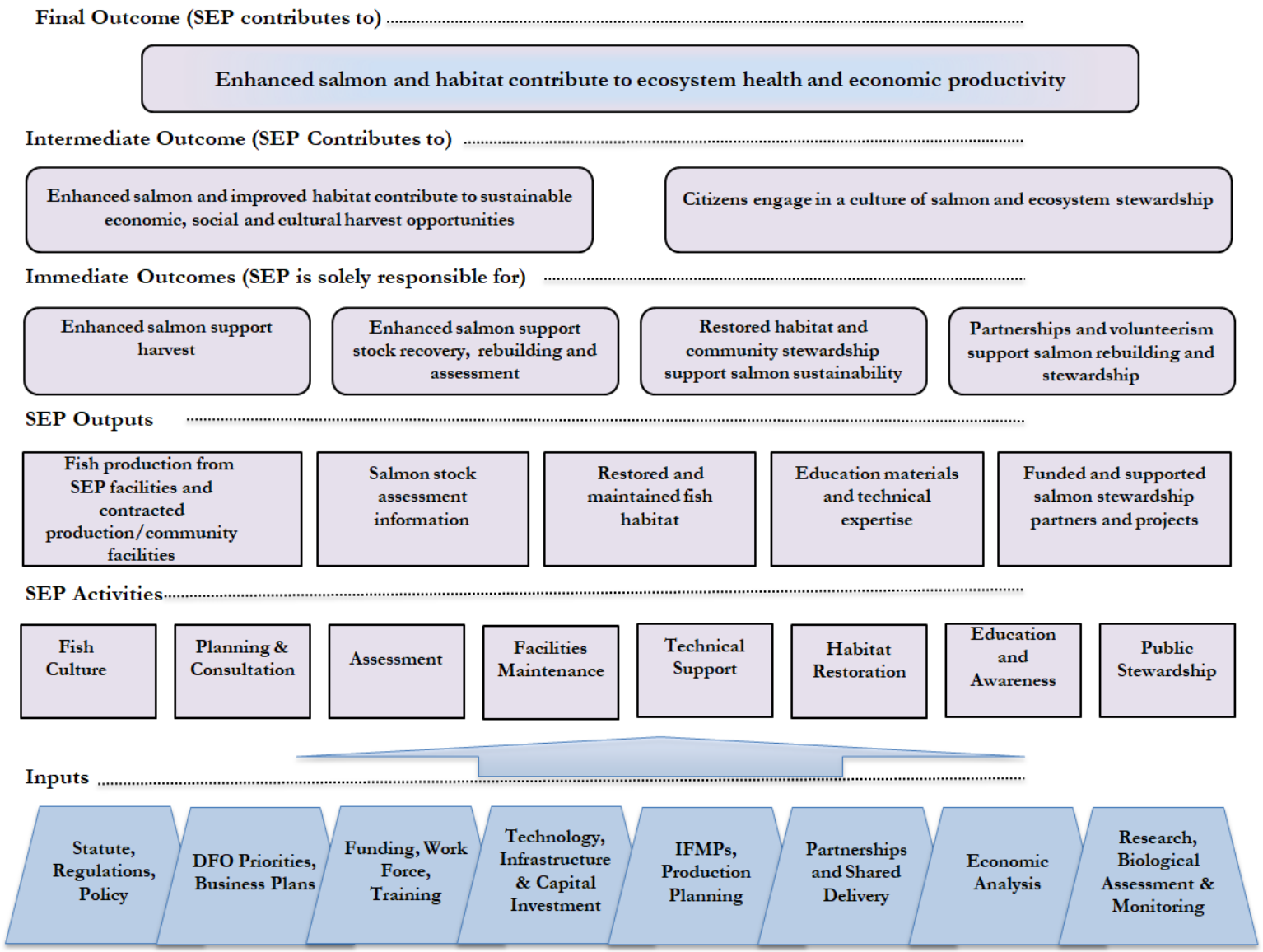
11. Appendices

Appendix I - SEP Logic Model – 2016



Appendix II - Production Planning Objectives

Fish Production Objectives

SEP has defined five specific objectives for fish production that flow from the logic model. Each production line (a release group defined by the project, species, run, stock, brood year, release stage and release location) of fish considered through production planning **must** address at least one of these objectives. They are:

- **Harvest** – enhancement for fisheries that are reliant on enhanced production, and would disappear or become severely constrained in the absence of enhancement. This includes harvest opportunities for First Nations, recreational, or commercial fisheries. When the objective is to provide a targeted-fishery opportunity, production targets may be set to consider both natural spawning and harvest requirements.

  Assessment – fish production for the purpose of achieving SEP assessment objectives[2], includes supporting Pacific region assessment priorities, such as the Pacific Salmon Treaty. Fish produced for assessment are typically part of a larger production group that also addresses another objective such as harvest. In a few instances however, fish are produced solely for marking for regional assessment purposes.

- **Conservation** – enhancement of a stock highly at risk of extirpation or extinction, or a vulnerable stock that DFO has identified as a regional priority (e.g. through development of an approved conservation/recovery strategy, or through categorization by DFO as a stock of concern). This includes re-establishing locally extinct populations and rebuilding populations at high risk of extirpation.

- **Rebuilding** – enhancement of a stock that is below apparent carrying capacity. This includes rebuilding depleted populations and mitigating for habitat loss. Rebuilding is designed with an end-goal, and does not involve ongoing supplementation for harvest or assessment purposes.

- **Stewardship and Education** - small numbers of fish produced for stewardship or educational purposes. Production levels are limited to the minimum necessary to contribute to stewardship and educational goals, unless combined with other objectives, and are considered to have a low risk of impacts to natural production or other populations.

Identification of the production objective(s) is important since the type of objective also determines the assessment and fish health requirements of a project. The objectives for fish production reflect the full array of approaches that may be applied to supporting the long-term departmental vision. However, the production plan in any given year will reflect an emphasis on objectives that address current priorities, which may shift over time. Coordinating and applying fiscal resources to the highest priorities in meeting departmental objectives is key to successful production planning. Funding enhancement initiatives or re-tooling for changing priorities usually requires a wide range of very limited fiscal sources from within the department and also depends on numerous partnering arrangements from which SEP has long benefited.

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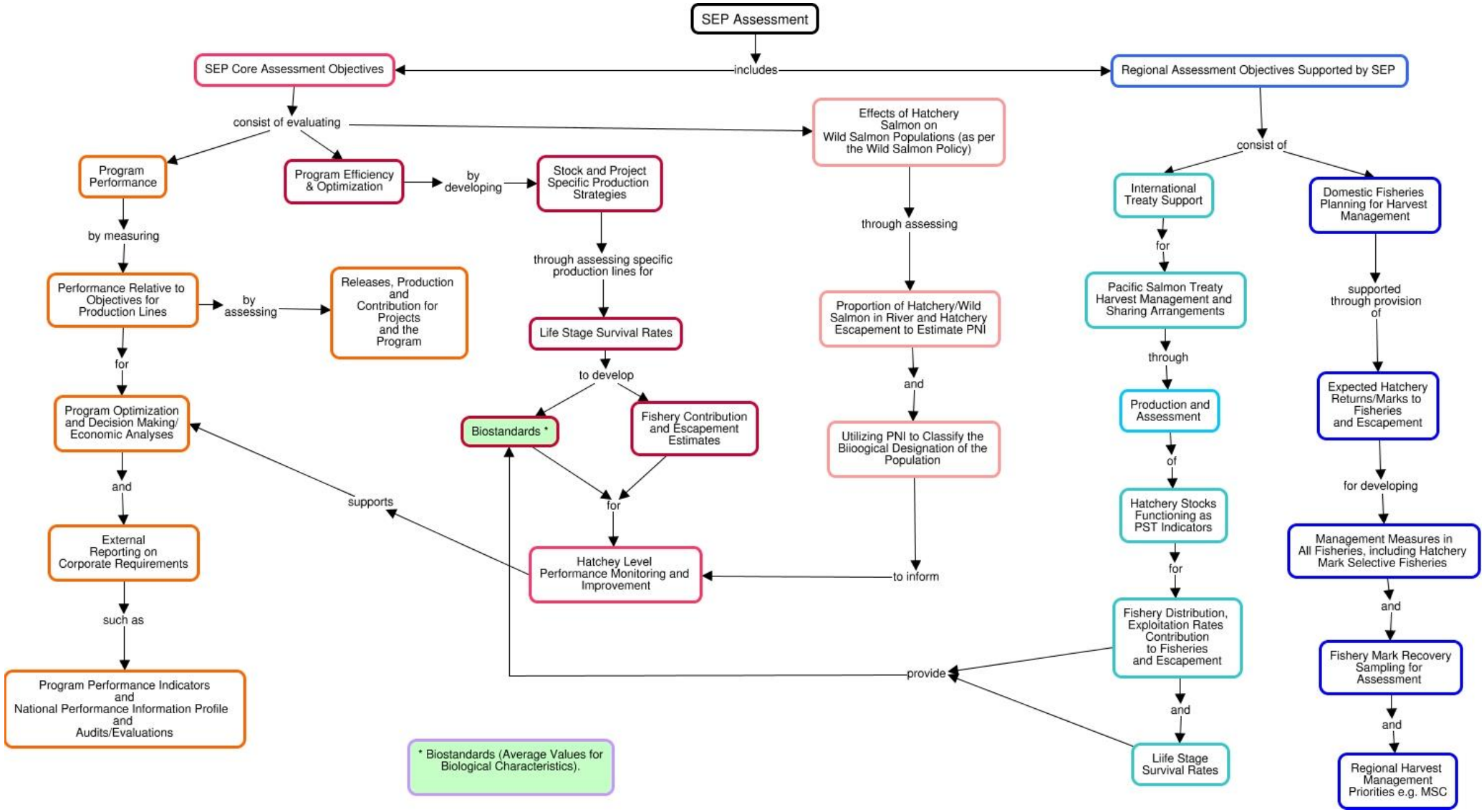
[2] As identified in the SEP Biological Assessment Framework (DFO 2017): program performance measurement, program efficiency and optimization, effects of enhanced salmon on wild salmon populations, international treaty support and domestic fisheries planning support.

In making investment decisions, SEP links these objectives with those for infrastructure management as detailed in the SEP infrastructure strategy. Enhancement objectives generally drive SEP infrastructure requirements, however, it is possible that a particular stock may rank very high in the enhancement objectives, but facility logistics and costs may be prohibitive.

Appendix III - SEP Assessment Objectives Linkages



Appendix IV - Marking Tools and Respective Applications

Marking Tool	Description	Purposes/ Scale*	Species	Marking Life Stage
Coded-Wire Tags (CWT)	Small wire with a unique binary code that is injected into nose of juvenile salmon. Marked adults may be identified by missing adipose fin (Chinook) or through use of electronic tag detection equipment to locate tags in fish returning to the hatchery or natural spawning grounds. Heads sent to a lab for tag removal.	Provide ability to determine survival: i.e. enhanced contribution to fisheries and return rates to rivers and hatcheries. Must kill fish to recover.	Chinook, Coho, occasionally Sockeye and Chum	Fry and smolt
Fin Clipping	Various fins, sometimes in combination	External identifier of hatchery-raised fish. Lethal sampling not required	All species	Fry and smolt
Otolith Marks – Thermal	Manipulate water temperature to produce marks (like rings on trees) on otoliths i.e. ear bones.	Provide ability to identify hatchery fish (can mass mark easily). Must kill fish to recover.	All species	Egg
Parental Based Tagging	All hatchery broodstock are genotyped. Genotypes of recoveries, based on tissue sample, are matched to parental genotypes.	Obtains information similar to CWTs. Lethal sampling not required – tissue sample is sufficient	Coho, occasionally Chinook and Sockeye	Adult (parents)

Appendix V - Assessment Process Illustrations

Figure V - 1. Hatchery Chinook, Coho and Sockeye Assessment Process

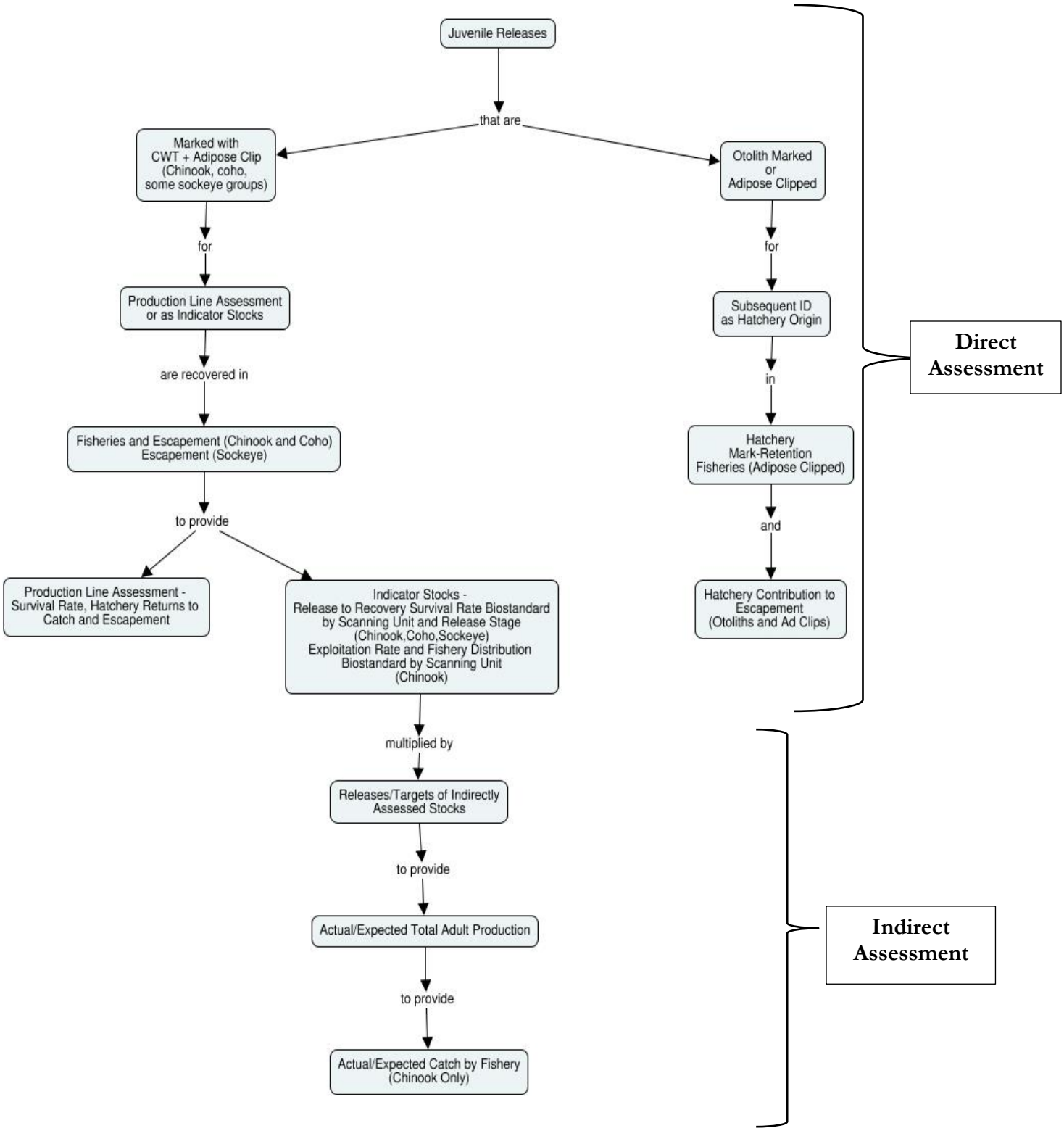


Figure V -2. Hatchery Chum and Pink Assessment Process.

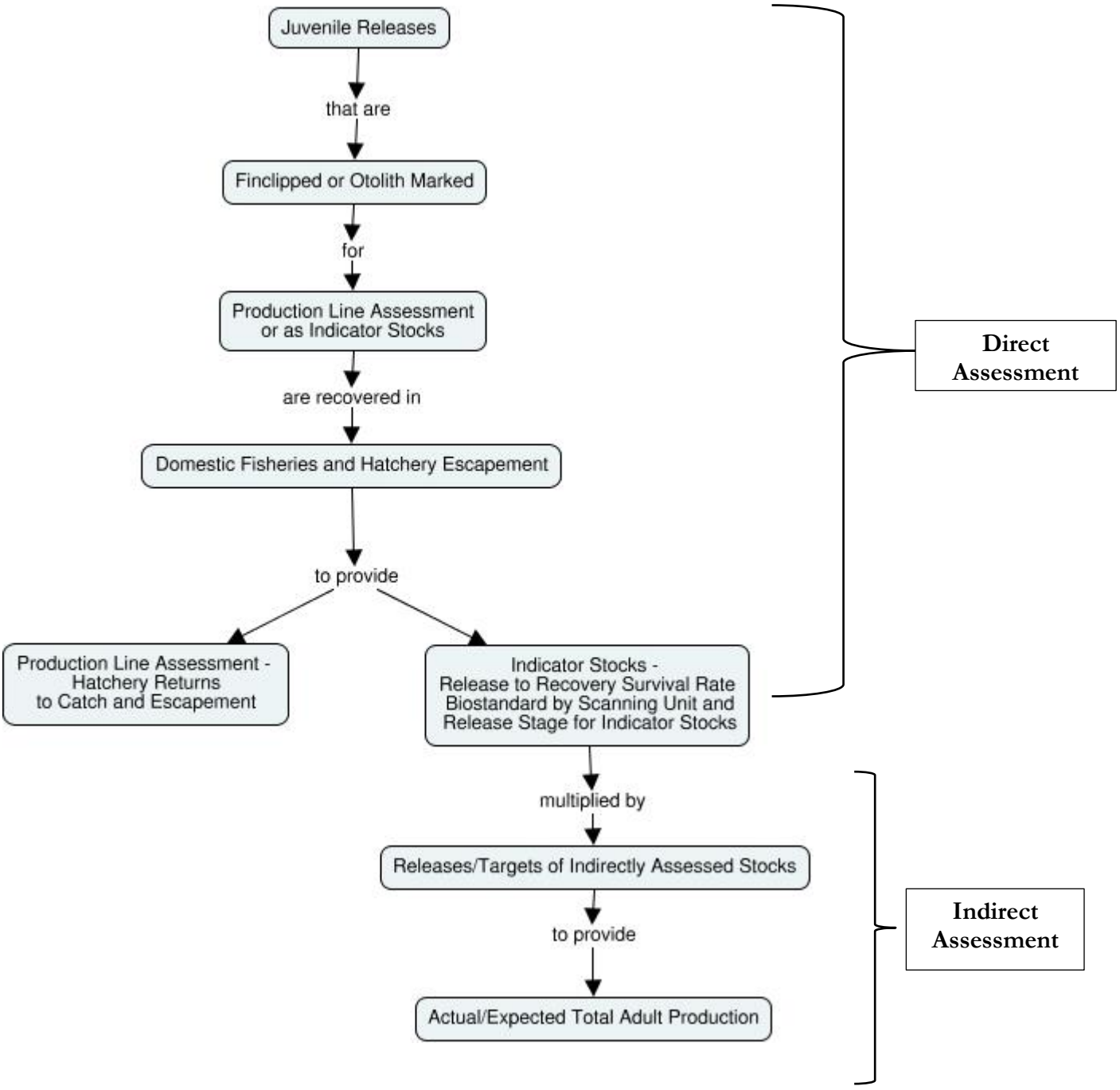


Figure V - 3. Spawning Channel Sockeye and Chum Assessment Process.