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# Salmon Assessment and Monitoring in British Columbia and Yukon


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## Abstract

The purpose of salmon stock assessment is to provide the information on stock status, trends and productivity needed to inform and guide management of salmon fisheries. Understanding the status of salmon stocks and the factors (e.g. climate) influencing Pacific salmon production requires long-term monitoring of biological data. Stock assessment data are required to address issues related to conservation, fisheries management, biodiversity, fish habitat, and the effects of climate change. Stock assessment research conducted by Canadian Department of Fisheries and Oceans Pacific Region includes freshwater sampling activities to determine abundance of returning adults and juvenile production and marine sampling activities to determine stock composition of catch.

## Assessment Framework

Assessing and monitoring Pacific salmon in Canada is a complex and expensive endeavour because of the diversity and magnitude of the resource and the interactions between salmon, their ecosystems and a wide variety of resource users. Slaney et al. (1996) identified more than 8,000 natural spawning salmon streams by species in British Columbia and the Yukon.

The Department of Fisheries and Oceans (CDFO) is the lead Canadian agency responsible for conservation and management of salmon resources. The Pacific region is one of six administrative regions within the Department and includes the province of British Columbia and the Yukon Territory. Within the Pacific region, the Salmon and Freshwater Ecosystem Division (SAFE) has an active freshwater and marine research program, with science activities conducted in various locations. The Department also collaborates with a variety of partners on science, including other government departments, universities and non-government organizations.

Canada's Policy for the Conservation of Wild Pacific Salmon (WSP, DFO 2005) guides Pacific salmon management and assessment in Canada. The goal of the WSP is to restore and maintain healthy and diverse salmon populations and their habitat for the benefit and enjoyment of the people of Canada in perpetuity. This goal is to be achieved by fulfilling three objectives: safeguard genetic diversity, maintain habitat and ecosystem integrity, and manage fisheries for sustainable benefits. Under the WSP, salmon are managed and assessed as biologically-based Conservation Units (CUs), aggregate populations based on similar characteristics of freshwater and marine ecology, life history, and molecular genetics. The WSP recognizes 450+ Conservation Units of Pacific Salmon. A key requirement of the WSP is ongoing monitoring and assessment of the status of wild salmon populations at the CU level. The biological status of a CU will normally be based on the abundance of spawners in the unit, or some proxy thereof. This policy also considers habitat and ecosystem indicators, and provides guidance on the standardized monitoring of salmon.

Monitoring the status of 450+ salmon CUs is not feasible. Since not all salmon populations or CUs can be practically monitored, annual monitoring programs are determined based on species-specific Assessment Frameworks that incorporate a risk-based approach. The primary objective of a framework approach is to foster a process that efficiently and transparently provides objective, defensible, timely and useful advice to resource managers and credible information about their public resources to all Canadians. Groups of CUs exposed to common threats, are monitored based on abundance and status indicators within units that can be monitored. Generally, CU status and risk will determine the frequency and intensity of the assessment effort. Stock assessment work plans are updated annually taking into consideration CU status, major risk factors, resource management objectives, assessment strategies, and enhancement activities. CDFO maintains databases for information on catch and spawning escapement and regularly reports to NPAFC on catches and hatchery releases (e.g. Irvine et al. 2012).

The Salmon Stock Assessment section of SAFE is responsible for monitoring the status of stocks, impacts of fisheries, and trends in productivity. The regional Stock Assessment operational program is organized into four delivery areas: South Coast (Nanaimo), Fraser River (Kamloops), North Coast (Prince Rupert), and Yukon / Transboundary (Whitehorse) (Fig. 1). Core Science staff located at the Pacific Biological Station in Nanaimo play a policy & developmental role, and provide coordination, advice, & support to area staff.

## *Escapement*

Escapement data derived directly from enumeration of adult spawners are essential to compute the annual abundance estimates needed to track stock status and trends. Escapement estimation activities are delivered at three levels of intensity: indicator, intensive, and extensive programs, in order of monitoring effort, and accuracy and precision of estimates. Both indicator and intensive programs are delivered at a high level of intensity and provide quantitative estimates of abundance but indicator programs have additional monitoring requirements used for developing estimates of productivity, survival and exploitation rates. Additional biological information such as age and sex composition, body size, fecundity, egg size, genetic diversity, and disease may be monitored at some systems to help determine the biological status of key populations. Generally, indicator programs are core programs delivered by the agency. Information generated from extensive programs is of lower accuracy and precision, but useful for generating indices of abundance and for discerning trends. Some intensive and extensive programs may be delivered by partners (First Nations, stewardship organizations, etc).

The Salmon Escapement Database (NuSEDS) is CDFO Pacific Region's central database that stores individual spawner survey data records, spawner abundance estimates and the linkages between the two. Annual abundance estimates are maintained by population, as defined by freshwater location and run timing. Data were collected through surveys using various methodologies including ground level observations (walk, snorkel, boat), aerial counts (helicopter, fixed wing), mark recapture studies, and fixed weir and fence counts. Individual population estimates often go back as far as the early 1950s, but there can be huge variation in the methodology used and their reliability. Estimation quality generally improved over time as regionally consistent escapement survey/analysis methodologies and data standards were applied.

The NuSEDS database currently reports salmon spawning observations for 7000+ individual populations but escapement estimates (all levels of survey intensity) are available for 1200+ populations. NuSEDS is not a spatial database but each population is referenced to the location of the stream mouth. Figure 2 identifies individual populations where 2010 escapement estimates are recorded for all five species of salmon (Chinook, chum, coho, pink and sockeye).

## *Production*

**Salmon in Regional Ecosystems Program**

Canada also monitors key salmon populations as indicators of regional salmon production. The Salmon in Regional Ecosystems Program monitors primary productivity and conducts annual juvenile and adult surveys of sockeye salmon at selected lakes throughout the region (Fig. 3). These data sets allow partitioning of freshwater and marine effects in order to better understand factors controlling regional production variations of sockeye salmon. These results are reported annually in the State of Ocean publications (e.g. Hyatt et al. 2011). This data set has permitted the comparison of coast wide trends in marine survival for juvenile sockeye salmon originating from the Fraser, Smith Inlet and the Columbia Rivers relative to ocean temperatures at the time juvenile sockeye entered the ocean. Results indicate that varying ENSO-like conditions, anticipated by sea surface temperature changes, appear to induce predictable oscillations from higher to lower marine survival for all stocks.

**CWT / Mark Recovery Program**

Productivity is also assessed for some Chinook and coho salmon stocks based on data from the Coded Wire Tag (CWT) indicator program. The CWT and Salmonid Head Recovery Programs were established in the early 1970s with the primary purpose to tag salmonids and collect samples used to estimate stock-specific catch contributions in coast-wide fisheries. CWTs are small pieces of magnetized wire that are inserted into the nasal cavity of juvenile salmon, generally hatchery indicator stocks, prior to ocean migration, and used to track groups of salmon from release through to maturity. A core component of the program includes sampling 20% of the Chinook and coho salmon caught in all fisheries. The major assumption of the CWT program is that the hatchery indicator stocks represent natural origin or wild fish from the same region, i.e., have the same migration timing and distribution. CWTs provide data to assess fishery and stock-specific exploitation rates and changes in productivity, evaluate hatchery production, determine migratory paths, estimate and forecast abundance, and regulate fisheries in-season. The CWT system has been invaluable in the coast-wide management regime of Chinook and coho under the Pacific Salmon Treaty. The parties developed a coast wide stock assessment and data management system, incorporating catch, effort, escapement, and CWT data.

The CWT program is closely associated and coordinated with the Salmonid Enhancement Program (SEP) which produces Chinook, coho, chum, pink, and sockeye salmon, as well as small numbers of steelhead and cutthroat trout (Sandher et al. 2012). Currently 28 hatcheries and facilities release CWT marked salmon (Fig. 4). CWT indicator stocks tagged to represent wild stocks include:

- Coho: Louis / Lemieux / Dunn, Eagle River, Coldwater, Inch, Black Creek, Biq Qualicum, Quinsam, Robertson, Goldstream, and Toboggan Creeks

- Chinook: Lower Shuswap, Middle Shuswap, Nicola, Chilliwack, Harrison, Cowichan, Big Qualicum, Quinsam, Puntledge, Robertson, Kitsumkalum, and Atnarko Rivers.

## *Stock Composition*

**Molecular Genetics Program**

The Molecular Genetics Laboratory at the Pacific Biological Station conducts research on the development and application of DNA-based genetic variation to discriminate among populations or stocks of Pacific salmon. Microsatellites are the main class of genetic variation employed, although single nucleotide polymorphisms (SNPs), major histocompatibility complex (MHC) variation, and gene expression are used in some management applications. The lab has the capacity to provide retrospective, post-season and in-season genetics advice.

Research is focused on applications to aid the conservation and management of Pacific salmon species. Applications include determination of population structure and appropriate assessment and management units, identification of stock compositions in mixed-stock fisheries, forensics, evaluation of hatchery and aquaculture broodstock, identification of prey items in marine mammal diets, determination of evolutionary relationships in fish, and application of biomarkers to identify upregulation and downregulation of specific gene complexes.

**Thermal Marking**

CDFO also uses thermal ototlith marks primarily for estimating stock composition in terminal fisheries, estimating hatchery contribution to enhanced stocks, and providing information on straying rates between systems. Otolith release data are reported annually to NPAFC (e.g., DiNovo and O'Brien 2012). For Canadian salmon, the relatively small number of unique otolith marks available and the limited ocean fishery sampling for otoliths, compared to CWTs or DNA, has precluded their application to ocean mixed-stock fisheries. Otolith marks are a more cost effective tool than CWTs or DNA for use in terminal area fisheries targeting enhanced fish when enhanced (marked) fish comprise a large component of the catch or spawning escapement. Otolith marks have helped to shape fisheries by identifying the areas and times when enhanced fish are present and to evaluate stock-specific fishery impacts.

## *Climate Change*

CDFO recognizes that understanding and predicting climate change and its impacts is important to the conservation, protection, and sustainability of Pacific salmon. Ongoing marine research programs have been investigating the relationships among ocean conditions, climate, and the productivity of Pacific salmon.

**High Seas Salmon Program**

The Canadian High Seas Salmon Program has been conducting integrated epipelagic ecosystem surveys from the west coast of British Columbia to Southeast Alaska (Fig. 5) to assess the effects of ocean conditions and climate change on the distribution, migration, growth and survival of Pacific salmon, and to forecast salmon returns to British Columbia (Beamish et al. 2007; Trudel et al. 2012). These midwater trawl surveys have generally been conducted in late spring-early summer and in the fall since 1998. Since 2001, winter surveys have also been conducted to assess the effects of winter conditions on the ecology, bioenergetics, and survival of juvenile salmon (Trudel et al. 2007).

**Neashore Coastal Salmon Investigations Program**

The Canadian Neashore Coastal Salmon Investigations Program has been conducting intensive epipelagic ecosystem surveys in the Strait of Georgia and surrounding inlets, since the early 1990s. The purpose of these surveys has been to determine the size, distribution, diets, mortality and migration of juvenile salmonids in this unique rearing area and the impact of climate change on these variables (Trudel et al. 2012). These surveys were initially conducted with beam trawls, but since 1998 the surveys have been conducted using mid-water trawls. Two surveys have generally been conducted in early summer and early fall following an established transect. Additional research surveys have also been conducted in Queen Charlotte Strait, Puget Sound, Juan de Fuca Strait and the west coast of British Columbia. Work in Puget Sound has been in cooperation with colleagues from the Washington Department of Fish and Wildlife and the University of Washington.

**Aquatic Climate Change Adaptation Services Program**

The Aquatic Climate Change Adaptation Services Program was initiated in 2012. This program supports research designed to understand and predict climate change impacts on Canada’s oceans and inland waters, and to develop strategies and tools to respond to these changes. This program has three components: 1, an assessment of the short and long term risks of climate change on aquatic ecosystems, 2, identification and assessment of impacts and vulnerabilities of climate change on ecosystems and implications to CDFO infrastructure and activities, and 3, the direct application of scientific knowledge in the development of ‘tools’ to incorporate climate change considerations in CDFO management and decision making. CDFO scientists are developing ecosystem models to project future trends in abundance of salmon in relation to climate change and various management scenarios Some of the research will focus on downscaling climate data from Global Circulation Models to generate data that can be used to generate regionally specific forecasts relevant to Pacific salmon in freshwater, coastal areas, and the Gulf of Alaska.

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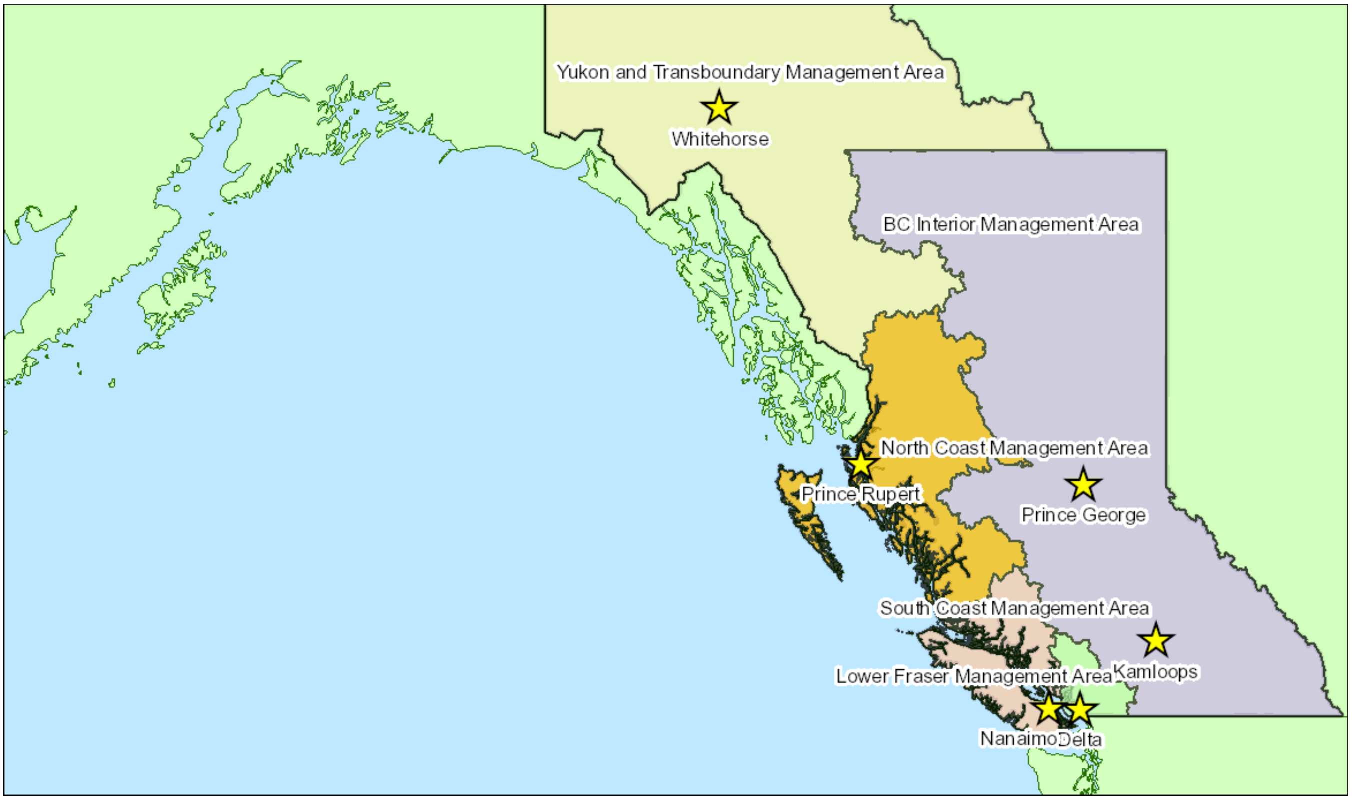


Figure 1. Canada Department of Fisheries and Oceans administrative management areas.

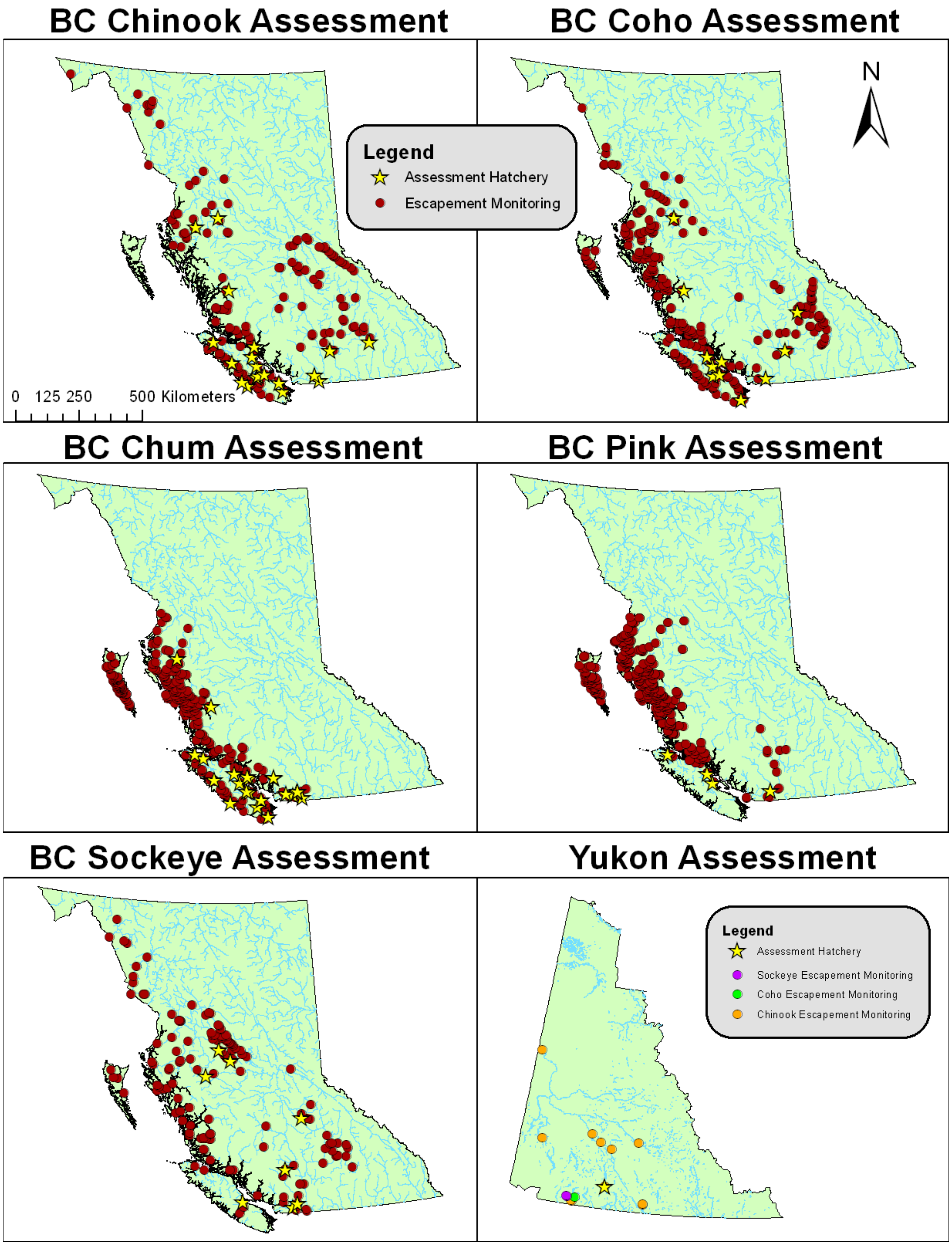


Figure 2. British Columbia and Yukon salmon escapement monitoring sites and hatchery facilities with an assessment function.

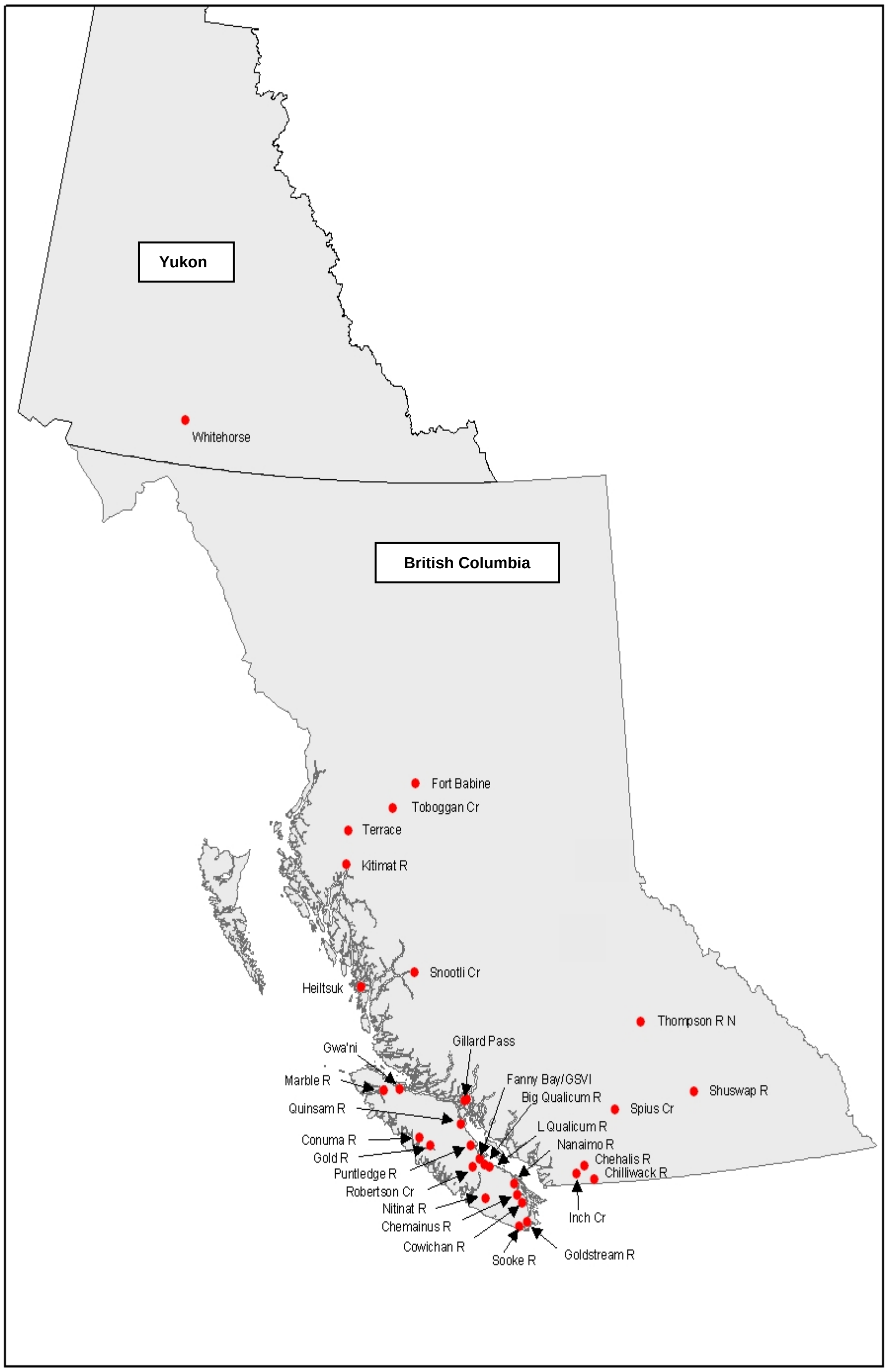


Figure 3. Hatcheries and rearing facilities in British Columbia and the Yukon that release salmonids with coded wire tags.

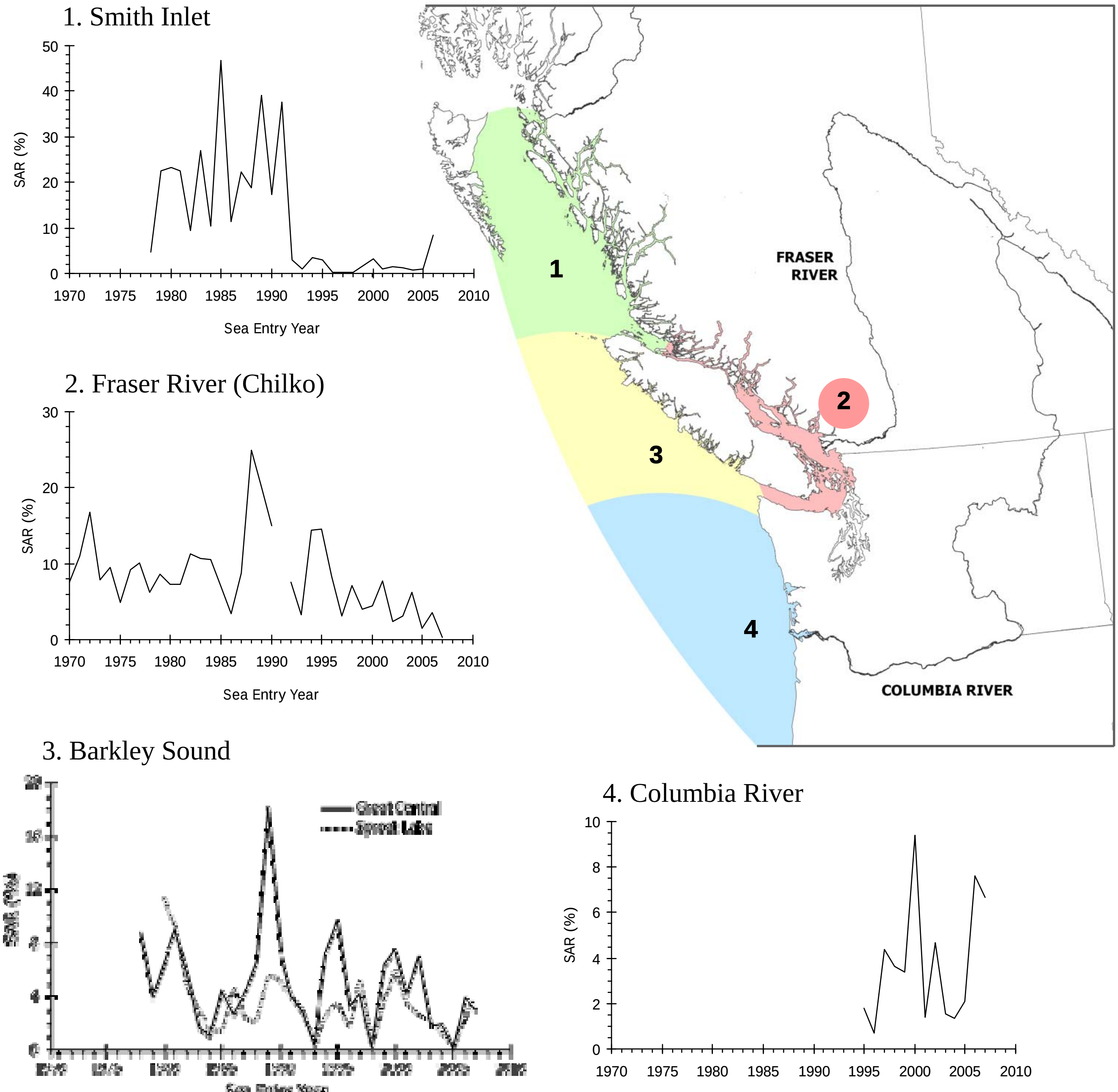


Figure 4. Marine survival variations exhibited by sea-entry year, for five indicator stocks of sockeye salmon, originating from freshwater ecosystems tributary to: 1) Smith Inlet on the B.C. Central Coast (Long Lake), 2) The Fraser River and Georgia Basin (Chilko Lake), 3) Barkley Sound on West Coast Vancouver Island (Great Central and Sproat lakes) and 4) Upper Columbia River (Okanagan River-Osoyoos Lake). By permission from Hyatt et al. 2010.

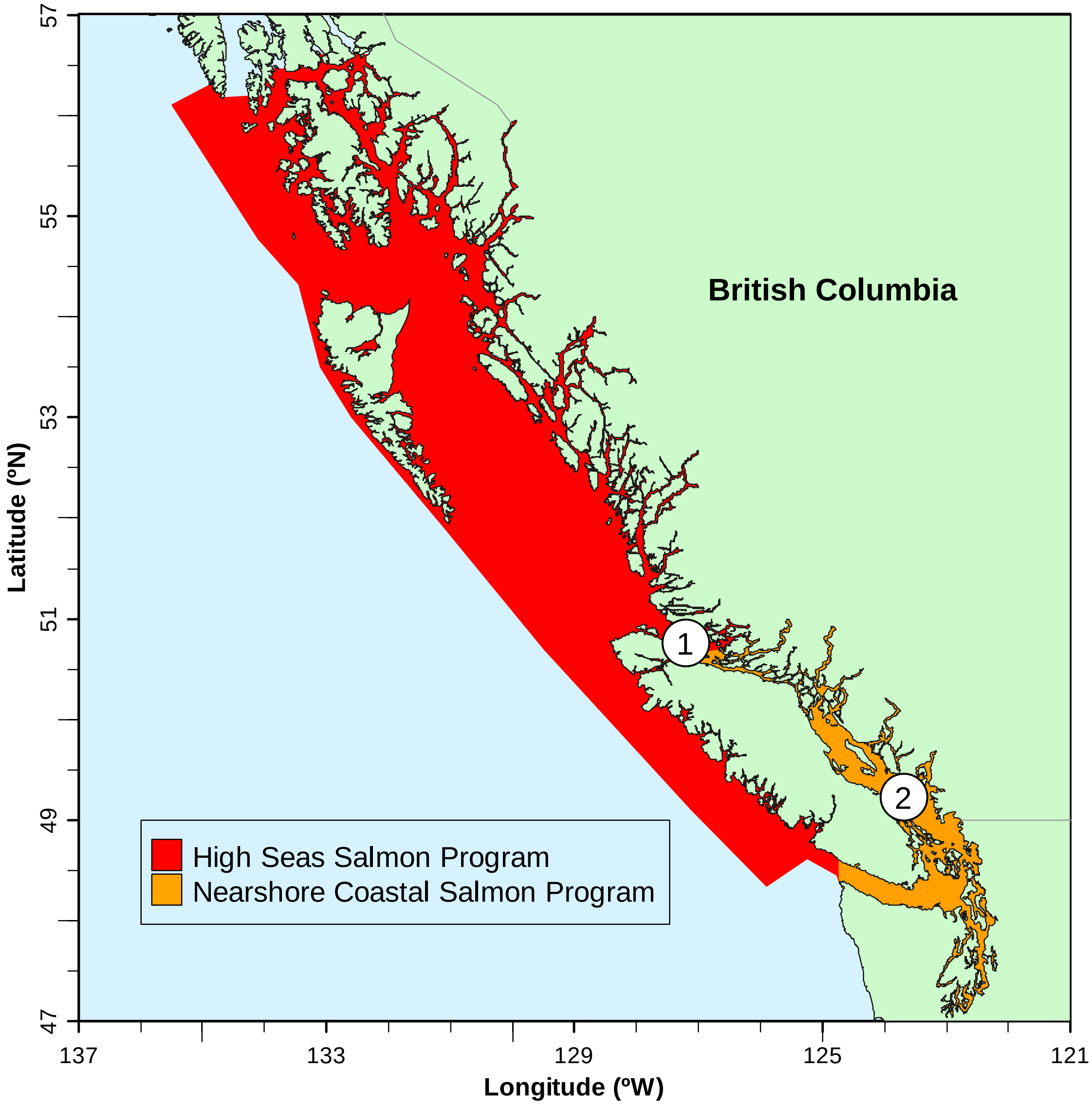


Figure 5. Canadian Department of Fisheries and Oceans high seas and nearshore coastal salmon ecosystem survey areas. 1) Queen Charlotte Strait; 2) Strait of Georgia.