The primary objective of NPAFC is to promote the conservation of anadromous stocks in the North Pacific Ocean. The role of NPAFC’s Working Group on Stock Assessment is to assess and provide the best available information on the status of Pacific salmon and steelhead trout.

Understanding the status of salmon stocks and the factors (e.g., climate) influencing Pacific salmon production requires long-term monitoring of salmon populations. Assessment and management of Pacific salmon demand accurate and precise information about spawner abundance in order to estimate escapement goals, regulate harvest, evaluate management performance, and determine population status and stock-recruitment relationships (Walters and Ludwig 1981).

Given the large number of salmon streams in British Columbia (BC) and the Yukon and expense of monitoring salmon populations, CDFO has been utilizing more cost-effective alternatives for improving the accuracy and precision of escapement estimation. This paper explores three examples of technological alternatives being pursued by CDFO. These improvements are specific to each of the areas discussed. One is for monitoring Chilko Lake sockeye salmon, another is for Skeena River Chinook salmon, the third one addresses Somass River stocks (Fig. 1).

Background

The diversity and magnitude of Canada’s Pacific salmon populations makes assessing and monitoring both complex and expensive. Under Canada’s Wild Salmon Policy (http://www.pac.dfo-mpo.gc.ca/fm-gp/species-especes/salmon-saumon/wsp-pss/docs/wsp-pss-eng.pdf), the CDFO is moving increasingly towards the assessment and management of Conservation Units (CUs), which are defined as ecologically and/or genetically distinct groups of salmon (DFO 2005). Holtby and Ciruna (2007) identified at least 420 salmon CUs in BC. Within the CDFO Pacific region (BC and the Yukon Territory), the Salmon Stock Assessment Section is responsible for monitoring the status of stocks, impacts of fisheries, and trends in productivity. The stock assessment program is organized into four operational areas: South Coast, Fraser River, North Coast, and the Yukon, with analytical support provided by science staff from the Pacific Biological Station, Nanaimo.

Coast-wide, CDFO and its partners (other departmental branches, First Nations, universities, and local community organizations) expend considerable effort to monitor salmon escapements (the number of salmon that reach the spawning grounds after “escaping” marine and freshwater fisheries). The regional Salmon Escapement Database (NuSEDS) currently reports salmon spawning observations for 7000+ individual stream populations, but escapement estimates are available for 1200+ populations. Individual population estimates often go back as far as the early 1950s, but there can be huge variation in the methodology used and in their reliability. Estimation quality has generally improved over time as regionally consistent escapement survey/analysis methodologies and data standards were applied.

Fig 1. Relative location of the three largest salmon-producing rivers in British Columbia (BC): Fraser, Skeena, and Somass rivers
The collection of salmon escapement information involves a diverse set of methodologies with a range of accuracy and precision. The methodology used depends on the stream characteristics, hydrological conditions, the behavior of the fish, and available resources. Visual surveys (walk, snorkel, boat) including aerial counts (helicopter, fixed wing aircraft) are commonly used to provide an index of escapement from year to year. Mark-recapture studies, fixed weir, and fence counts generally provide escapement estimates of higher accuracy and precision, but also require more effort and resource expenditures to implement than simpler visual survey methods.

Chilko Lake Sockeye Salmon Adult and Smolt Enumeration Programs

Chilko Lake is a large (185 km²), high elevation (1175 m) natural lake located in west-central BC (Fig. 1). The lake is drained by the Chilko River (Figs. 2 and 3), which flows northeast 82 km to its confluence with the Chilcotin River, 106 km upstream from the junction with the Fraser River. The Chilko Lake system supports three distinct sockeye salmon populations that spawn at the north and south ends of Chilko Lake and in the Chilko River. Juveniles of all three populations rear in Chilko Lake prior to seaward migration.

Adult enumeration program

Starting in 2009, dual-frequency, identification sonar (DIDSON) replaced large-scale mark recapture studies to estimate total escapement of sockeye to the Chilko system (Figs. 4 and 5). DIDSON systems record near ‘video-image’ of individual fish as they swim through the ensonified area, allowing staff to manually count and record numbers of migrating fish during discrete time periods. DIDSON imaging is not affected by water clarity or the amount of daylight, making 24-hour observation of the migration possible. The use of DIDSON technology to enumerate Chilko sockeye salmon has resulted in increased precision of escapement estimates, while greatly reducing project costs owing to the reduction in field staff required to conduct a DIDSON assessment.
Securing an accessible location with a suitable channel profile is essential for obtaining reliable escapement estimates using DIDSON technology. The Chilko River contains an ideal location for DIDSON operation 10 km downstream of Chilko Lake and downstream of the Chilko River spawning area. Current speed at this location restricts sockeye migration to the shoreline. Two DIDSON units, one on each shore of the river, enumerate sockeye as they migrate upstream along the shoreline. Field crews also conduct carcass recovery surveys in major spawning areas in Chilko Lake and in the Chilko River throughout the spawning period to provide estimates of sex ratio, female spawning success, age, and length-at-age. DIDSON operations span the entire period of arrival of returning adults (early August – early October), while recovery surveys begin in late August and extend to mid- or late October.

**Smolt enumeration program**

Enumeration of sockeye salmon smolts takes place at a smolt fence located approximately 1 km downstream from the lake (Fig. 6). The fence is typically operated from mid-April to late May depending on the timing of the smolt migration and water levels. Because of the amount of flow and the very large number of migrating smolts (e.g., > 1 million/day in some cases), smolts are allowed to migrate of their own volition through two openings (enclosed traps) in the fence. As smolts migrate through the traps, they pass over an 8 ft by 8 ft (2.4 m x 2.4 m) white board overlaid with a grid pattern (Fig. 7). Every five minutes a photo of the smolts passing over the board is taken using an overhead digital camera. The number of migrants passing through the fence is estimated daily based on counts of smolts in the photos and by measurements of travel time for individual smolts through the trap.

**Critical information to assess survival**

Annual estimates of adult escapement and smolt out-migrants provide critical information for forecasting future returns, fishery planning, and assessing trends in survival at specific life stages. Daily counts of adult sockeye salmon passing the DIDSON site are also used for in-season fisheries management. Smolt size and abundance data from Chilko Lake provide information to assess freshwater survival and carrying capacity for wild Fraser River sockeye salmon. Current collaborative research between CDFO and the University of British Columbia is investigating innovative sonar and radio tracking technology to look at migration rates, survival, bioenergetics, and environmental stressors for downstream migrating smolts and upstream migrating adults.

**Skeena River Chinook Salmon Escapement Estimation Using Genetic Techniques**

The Skeena River (Fig. 1) has the second largest aggregate of Chinook salmon spawning populations in BC. Skeena Chinook salmon are northward migrating and encountered in mixed-stock fisheries in Southeast Alaska and northern BC, as well as terminal gillnet, tidal sport, non-tidal sport, tidal First Nations’ and non-tidal First Nations fisheries.

Historically, Chinook salmon escapements to the Skeena River were represented by an index of abundance that included approximately 20 of 60 populations surveyed annually using a variety of techniques. Within the Skeena Chinook salmon complex, the Kitsumkalum River component has been estimated using a high precision mark-recapture program since 1984. Escapement estimates for other populations that contribute to the Skeena index are based on less precise methods, including fish weir counts, aerial counts, boat, and foot surveys.
The index of Chinook salmon escapement to the Skeena aggregate has averaged 50,000 fish since 1984. On average, the Kitsumkalum rivers indicator stock has represented approximately 30% of the index and the Bear and Morice River populations contributed 20% and 26%, respectively, to the index.

Since 2009 CDFO has been investigating the use of genetic stock identification (GSI) techniques on archived scale samples from a test fishery at the mouth of the Skeena River to retrospectively generate system-wide escapement estimates for Skeena Chinook salmon.

Genetic analyses of 21,044 Chinook salmon were completed from archived scales of fish sampled from a fixed effort, multi-panel gillnet test fishery conducted over 35 years (Fig. 8). The proportions of Kitsumkalum River Chinook salmon identified in the samples were expanded to the Skeena wide population using estimates of Kitsumkalum Chinook salmon escapement from an independent mark-recapture program. The Kitsumkalum stock has escapement estimates with known variance for 1984-2013. The GSI data were matched to the biological data to generate stock-specific age and timing data for large component stocks. The preliminary estimates of large Chinook salmon escapement to the Skeena River ranged from 28,398 in 1986 to 155,637 in 2001. The coefficients of variation (CV) around the escapement estimates met the data standard of 15% in half of the years examined.

Genetic-based estimates of escapement represent an improvement over existing indices because comparisons may be made among years. Escapements based on genetic techniques include estimates of variance, which cannot be produced for escapement indices of Skeena Chinook salmon because of the different estimation techniques involved. The data also make important contributions to our understanding of stock composition, timing, relative abundance, and age structure. The project has produced 30 years of escapement information with additional information for five years that is yet to be completed (1979 to 1983). The technique represents a cost effective way to estimate the aggregate of Chinook salmon returning to the Skeena River.

Somass River Salmon Adult Enumeration Programs

The Somass River, on the west coast of Vancouver Island (Fig. 1), is the third largest salmon producing system in BC after the Fraser and Skeena rivers. The Somass River drains an area of about 1,426 km$^2$ into the head of Alberni Inlet, a typical West Coast Vancouver Island fjord. The basin consists of three major sub-basins: Sproat (387 km$^2$), Great Central (651 km$^2$), and Ash (388 km$^2$).

The Somass River system supports important First Nations, commercial, and recreational fisheries in distant ocean waters, marine waters in the approach to the river, and in the river. The management of these sockeye, Chinook, and coho salmon fisheries is complex and depends on accurate accounts of catch and spawners.

Significant technological advances have been made in counting sockeye, Chinook, and coho spawner abundance in the Somass River system. The current method focuses on high-definition digital video monitoring in key areas where the fish are forced to move through fish ladders to
avoid natural barriers to migration. CDFO staff Carmen McConnell and Jeff Till worked with Hupacasath First Nations members to implement the video monitoring systems (Fig. 9). Cameras, lighting, and computers are powered by a hydro generation system designed and built with assistance from staff from the nearby Robertson Creek hatchery. Tunnels are able to handle 50,000 sockeye per day and as many as 800,000 sockeye, 40,000 Chinook, and 100,000 coho salmon, and 5,000 steelhead trout are counted on an annual basis.

The high definition video (Fig. 10) allows counting by species, determination of categorical size, detection of external marks such as adipose fin clips, and assessment of external fish condition. The video is accessed remotely by CDFO staff and they are currently working to make it available to the public over the internet. Daily counts are currently developed by sub-sampling videos at rates varying 5 to 60 minutes per hour and expanding to the full day. Total estimates are developed by summing daily estimates over the duration of the migration. Staff are investigating the use of facial recognition technologies to automate counts by species, which will further improve the salmon monitoring system.

**References**


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