

A strategic framework for salmon stock identification and age sampling program review in Pacific Region with case studies on key stocks and fisheries

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A STRATEGIC FRAMEWORK FOR SALMON STOCK IDENTIFICATION AND AGE
SAMPLING PROGRAM REVIEW IN PACIFIC REGION WITH CASE STUDIES ON KEY
STOCKS AND FISHERIES

by

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ABSTRACT

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Importance

Salmon stock identification and ageing are required to estimate fishery impacts, determine stock status, forecast abundances, and inform enhancement and habitat actions across Pacific Region. The marking and sampling programs that yield these data thus enable Fisheries and Oceans Canada to sustainably manage salmon populations and to meet its *Pacific Salmon Treaty* commitments. Under evolving management priorities and fiscal constraints, it is pivotal that scientific advice is generated efficiently and at relevant scales. The institutional value of sampling programs is therefore highest when efforts are coordinated and streamlined.

Proposed Framework

This paper proposes a three-step strategic review framework to evaluate and modernize marking, stock identification, and age sampling programs:

1. Documentation
2. Review & analysis
3. Forward planning

Reviews following this framework will provide an inventory of current programs and data pathways, highlight information gaps relevant to management priorities, and outline practical options to improve program efficiency and management relevance. The strategic framework emphasizes aligning sampling activities with fishery, enhancement, and habitat management.

Recommendations

Improving the efficacy of salmon marking, stock identification, and age sampling programs in Pacific Region requires stronger coordination grounded in the kind of strategic reviews demonstrated in this paper. Focusing on southern BC chinook fisheries as a case study revealed redundancy between using otoliths versus genetic methods for stock identification, suggesting it could be prudent to begin winding down the chinook otolith program in this area. Further efforts should focus on other opportunities to harmonize marking and sampling paradigms across fisheries or species, standardize metadata, and improve database interoperability. Establishing standardized annual marking and sampling plans and streamlining data management systems will enable analysts to develop new information products with high management value, such as coastwide annual catch estimates for all BC salmon stocks.

RÉSUMÉ

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Importance

L'identification et le vieillissement des stocks de saumons sont nécessaires pour estimer les impacts des pêches, déterminer leur statut, prévoir les abondances et informer les actions d'amélioration et d'habitat dans la région du Pacifique. Les programmes de marquage et d'échantillonnage qui fournissent ces données permettent ainsi à Pêches et Océans Canada de gérer durablement les populations de saumons et de respecter ses engagements du Traité du Pacifique sur le saumon. Face aux priorités de gestion évolutives et aux contraintes budgétaires, il est essentiel que les conseils scientifiques soient générés efficacement et à des échelles pertinentes. La valeur institutionnelle des programmes d'échantillonnage est donc maximale lorsque les efforts sont coordonnés et rationalisés.

Cadre proposé

Cet article propose un cadre d'examen stratégique en trois étapes pour évaluer et moderniser les programmes de marquage, d'identification des stocks et d'échantillonnage d'âge:

1. Documentation
2. Revue et analyse
3. Planification prospective

Les examens suivant ce cadre fourniront un inventaire des programmes et voies de données actuels, mettront en lumière les lacunes d'information pertinentes aux priorités de gestion et présenteront des options pratiques pour améliorer l'efficacité des programmes et la pertinence en gestion. Le cadre stratégique met l'accent sur l'alignement des activités d'échantillonnage avec la pêche, l'amélioration et la gestion de l'habitat.

Recommandations

Améliorer l'efficacité des programmes de marquage des saumons, d'identification des stocks et d'échantillonnage d'âge dans la région du Pacifique nécessite une coordination renforcée, fondée sur le type d'examens stratégiques démontrés dans cet article. En se concentrant sur les pêcheries chinook du sud de la Colombie-Britannique, en tant qu'étude de cas, a révélé une redondance entre l'utilisation des otolithes et les méthodes génétiques pour l'identification des stocks, ce qui suggère qu'il pourrait être prudent de commencer à réduire le programme des otolithes chinook dans cette région. D'autres efforts devraient se concentrer sur d'autres occasions d'harmoniser les paradigmes de marquage et d'échantillonnage entre pêcheries ou espèces, de standardiser les métadonnées et d'améliorer l'interopérabilité des bases de données. L'établissement de plans annuels standardisés de marquage et d'échantillonnage ainsi que la rationalisation des systèmes de gestion des données permettront aux analystes de développer de nouveaux produits d'information à forte valeur de gestion, tels que des estimations annuelles de captures à l'échelle de la côte pour tous les stocks de saumons de la Colombie-Britannique.

INTRODUCTION

PURPOSE

The purpose of this paper is to provide a structured framework for evaluating and updating salmon marking, stock identification, and age sampling programs, including:

- Characterizing current marking, stock identification, and age sampling paradigms;
- Characterizing management and assessment needs pertaining to marking and sampling; and
- Recommending options to improve efficacy of marking and sampling programs

RATIONALE

Several factors merit a broad review of current salmon sampling programs within Fisheries and Oceans Canada (DFO):

- **Shifting management context:** Pacific salmon stocks have generally declined in British Columbia over the last 3 decades and the management context has evolved in response: there has been a significant reduction in mixed-stock fishing, more emphasis on terminal (or individual stock) harvest, increasing interest in selective fishing, and a move to modernize hatchery and enhancement operations. However, not all marking and sampling programs have adapted to meet the related assessment needs.
- **Emerging opportunities for program efficiency:** New analytical tools and technologies offer opportunities to improve the breadth of information collected and cost-effectiveness of program delivery.
- **Imminent applications:** As salmon resource management shifts to align with the Fish Stocks provisions, sampling programs will need to support data-driven, stock-specific status assessments and harvest control rules. While the coastwide coded-wire tag (CWT) program allows Canada to uphold its Pacific Salmon Treaty commitments, these data are increasingly disconnected from domestic fishery management, reinforcing the need for parallel programs that satisfy domestic priorities.

SCOPE

In this report, the term ‘biological samples’ (or ‘biosamples’) refers broadly to any physical material collected from individual salmon. However, the scope of this review is limited to the subset of biological samples used for stock identification and age determination. For clarity, these are collectively referred to as ‘stock ID and age samples’ throughout the document. Our report also covers juvenile marking or tagging programs that are used for subsequent stock identification and/or age determination. Other types of biosamples (e.g. size, sex, fecundity, or other demographic traits) are mentioned occasionally when relevant but are generally outside the scope of this paper. Similarly, marking or tagging programs used to estimate population abundance (i.e. mark–recapture programs) or those associated with shorter-term research studies are not included.

A COHESIVE FRAMEWORK FOR SALMON SAMPLING PROGRAM REVIEW

CRITICAL PATHWAY APPROACH

In 2019, Canada's *Fisheries Act* was amended to include the Fish Stocks provisions (FSP), which provide a legislative obligation to manage prescribed major fish stocks in accordance with the Precautionary Approach (PA) framework (Fisheries and Oceans Canada 2009, 2022). As Pacific salmon stocks are batched and prescribed under the FSP, current management frameworks must evolve to realign with the updated legislation. Work is currently underway within Pacific Region to develop and implement 'critical pathways' that describe the necessary steps to implement PA management for all Pacific salmon stocks. Reviewing assessment programs available to support management is thus a key step within the critical pathways. Here, we outline a framework for such reviews and apply it to two case studies.

Current assessment and sampling programs have arisen over decades to address various needs, including *Pacific Salmon Treaty* updates, *Wild Salmon Policy* implementation, First Nation treaties and agreements, and multifarious domestic fishery management scenarios. Likewise, solutions for data storage and management have developed across technological eras and often on an ad hoc basis, such that the current data environment lacks unifying principles and structure. This has resulted in an inconsistent quality of science advice pertaining to sample results across the region. Considering the current state of affairs, it is clearly important to begin by inventorying existing programs and describing where and how resulting data are stored and accessed.

The framework for sampling program review follows three steps that mirror the broader critical pathways:

1. Documentation: describe current sampling programs, data management practices, and the applicable management context and decision needs. Highlight how sample data are currently being used by management.
2. Review & analysis: evaluate whether the current sampling portfolio enables management advice at the decision scale required, including alignment with the FSP.
3. Forward planning: outline practical options for improving alignment between sampling programs and management procedures, highlighting trade-offs and fiscal constraints where applicable.

We do not recommend that this framework be applied as a single comprehensive exercise intending to cover all salmon stocks and fisheries. Such an approach is likely to yield results and recommendations that are too general to be useful. Instead, it will be important to take a detailed, iterative approach focusing on interrelated groups of stocks and fisheries. Early iterations can focus on areas where management needs are most clearly not being met, such as mixed-stock fisheries that are constrained by incidental harvest on stocks of concern. However, note that in this document we have taken a more convenient approach and instead selected case studies based on availability of sample data for fulsome reviews.

Accordingly, it is worth noting that tracking down and understanding all relevant sample data will be necessary for future program reviews. In some cases, management decisions are not expressly constrained by lack of samples, but rather by data shortcomings, such as incomplete metadata, poor database interoperability, or nebulous accountability for data stewardship. Thorough reviews will allow these structural issues to be brought to the surface and addressed before considering whether sampling programs or management frameworks should be altered.

Inevitably, some sampling programs, analytics, and management systems will need to adjust to align with the PA framework, and in these cases it will be particularly important to discuss the inherent trade-offs. For example, in some areas, sampling programs may be overachieving what is required for PA management, indicating the possibility for fiscal streamlining via program reduction. However, these programs may support other DFO priorities and objectives, such as reconciliation partnerships or basic research. Such potential losses must be clearly expressed and considered in any recommendations.

A worthwhile objective of sampling program review would be to ensure that all sectors in Pacific Region that conduct salmon sampling programs operate under clearly articulated annual marking and sampling plans. These plans should be a key outcome of the critical pathway approach, such that activities are regionally coordinated and reflect a prioritization scheme based on management decision relevance. Likewise, sample data management must be organized regionally or nationally to ensure all applicable data can be mobilized to provide necessary advice. Efforts to do so are currently underway via STAMP (see Data environment, below), which should continue to be prioritized.

CLASSIFICATION OF PACIFIC REGION SALMON STOCKS AND FISHERIES

Stock ID and age sampling programs for Pacific salmon predominately focus on either spawning populations or fishery catches. Spawning populations (and thus associated sampling programs) can be easily aggregated into stock groups. However, mixed-stock fisheries cannot be attributed to any one stock group and thus neither can their associated sampling programs. For the purposes of sampling program review, it is therefore important to categorize sampling programs into stock and fishery groups—Stock Management Units and Fishery Management Units, respectively.

Stock Management Units

Stock Management Units (SMUs) are defined in annual Salmon Outlook and Integrated Fishery Management Plan (IFMP) documents and correspond to the definition for major fish stocks under the FSP. The 2025 Salmon Outlook document identifies 69 Pacific salmon SMUs (Fisheries and Oceans Canada 2025a). SMUs are groups of Conservation Units (CUs) that are managed together to achieve a joint status under Canada's Precautionary Approach framework (Fisheries and Oceans Canada 2009). CUs are defined in Canada's *Wild Salmon Policy* as the granularity at which wild salmon stocks must be protected to preserve biodiversity (Fisheries and Oceans Canada 2005).

Fishery Management Units

Fishery Management Units (FMUs) are groupings of salmon fisheries defined in IFMP documents under "Species Specific Salmon Fishing Plans." Collectively, there are 41 FMUs across the most recent IFMPs from each of the four Pacific subregions (Yukon, Transboundary, Northern BC, and Southern BC; Fisheries and Oceans Canada 2024, 2025b, 2025c, 2025d). Some FMUs arise from clearly delineated fishery groupings outlined in the *Pacific Salmon Treaty* (Pacific Salmon Commission 2019) and the rest have been defined domestically based on overlapping fishing areas and target stocks or species.

KEY QUESTIONS AND EXERCISES

Table 1 outlines specific questions to advance marking, stock ID, and age sampling program review through each step on the critical pathway along with the exercises required to address each question. These exercises are demonstrated in the Case studies below.

Table 1. Guidelines for strategic review of salmon stock ID and age sampling programs.

Step	Key questions	Strategic review exercises
1. Documentation	What are the current marking sampling programs and their respective authorities?	Sampling programs and data flowchart + discussion
	What data are collected and where are metadata and results stored?	Sampling programs and data flowchart + discussion
	Which guidelines are fishery management currently operating under?	Management decision inventory
	What decisions are made in relation to stock enhancement and habitat stewardship?	Management decision inventory
2. Review & analysis	What spatial, temporal, and stock resolution arise from marking and sampling programs?	Data–management alignment matrix
	What spatial, temporal, and stock resolution is required for fishery and enhancement management and habitat stewardship?	Data–management alignment matrix + discussion
	Is there overlap or conflict in the types of sample information required for fishery, enhancement, or habitat decision-making?	Management decision inventory + discussion
	Are there key gaps or bottlenecks in sample data management that impede timely analysis and advice?	Data gap inventory
3. Forward planning	What is required to align marking and sampling programs with each decision-making information gap identified in step 2?	Options & trade-offs table
	How could marking and sampling programs be tapered and still meet management needs?	Options & trade-offs table + discussion
	What trade-offs exist for each proposed alteration to current marking and sampling programs?	Options & trade-offs table

The third step, forward planning, would be best achieved through an annual group process comprised of all sectors involved in sampling and management, generally: area stock assessment, area resource management, Salmonid Enhancement Program (SEP) operations,

and regional science. Managers should review and update the management decision inventory and ensure the time, area, stock, and age strata required for decision-making and performance review are clearly defined. Sampling program leads should communicate annual sample allocations, program funding, and logistical constraints so available resources for sampling can be strategically deployed. Regional science staff should assist in data management planning by ensuring program staff adhere to best practices for data interoperability. Regional science and/or resource management should also provide farsighted guidance on sampling programs to ensure any disruptions to valuable, longstanding time series are well-justified.

IMPORTANCE OF STOCK IDENTIFICATION AND AGE DETERMINATION

Stock ID and age samples provide critical scientific information that supports DFO's responsibilities under the *Fisheries Act* and *Species at Risk Act* (SARA) to sustainably manage fisheries and protect aquatic species. These samples enable estimation of key salmon population parameters that cannot be derived from abundance data alone, such as survival, recruitment, exploitation rates, migration routes, and marine distribution. Stock ID and age samples are also used to estimate mixed-stock fishery impacts, information that is obligated under the Canada–USA *Pacific Salmon Treaty* and also supports domestic fishery management. In practice, these samples fulfill a broad range of management and research priorities that are detailed below.

MANAGEMENT REQUIREMENTS

The core management needs served by stock ID and age sampling programs are: estimating fishery stock compositions, informing stock status and management plans, informing COSEWIC assessments and SARA listing decisions, forecasting future stock abundance, and informing hatchery production programs. While these needs are conceptually distinct, they collectively define the scientific advice required for DFO to sustainably manage salmon resources.

The major policy frameworks guiding salmon fishery management in Canada dictate that fish stocks should be managed on an individual basis. However, most fisheries in BC harvest salmon originating from multiple populations or stocks, necessitating stock ID sampling to estimate stock composition and thereby monitor catch and exploitation rates for each SMU. Precise stock composition estimates are especially important for fisheries that are highly mixed-stock, that intercept stocks from distant watersheds in Canada or the USA, or that intercept stocks of concern at low but consequential rates. In such fisheries, insufficient sampling results in large uncertainty around impacts to constraining stocks, eliciting more precautionary management than might otherwise be required. Consequently, fisheries differ considerably in importance of stock ID sampling, with mixed-stock fisheries warranting higher sampling intensity than more terminal fisheries.

Stock ID and age sampling also provide important information for determining management reference points and stock status. Both sample types enable run reconstruction analyses, where salmon returns are apportioned among component populations and age classes. The resulting run reconstruction data can be used to organize abundances by contributing brood years and thereby estimate stock–recruit relationships, the recommended basis for biological status and fishery reference points under the WSP and PA framework (Fisheries and Oceans Canada 2009; Holt et al. 2009). Age data (and other demographic data arising from biosampling, such as sex and size) can also provide independent indicators of stock status, such as shifting maturation rates or fish sizes (e.g. Lewis et al. 2015; Fisheries and Oceans Canada 2025e). Where stock ID and age sampling are scarce, management must adjust to accommodate

data-limited or data-deficient conditions, often through more conservative harvest controls or broader aggregation of stocks.

Salmon fishery management also benefits considerably from more accurate forecasts of future stock abundance. Run reconstructions (based on stock ID and age sampling) greatly improve forecast accuracy by allowing return abundances to be temporally linked to environmental covariates and by enabling sibling correlations (Peterman 1982; Ovando et al. 2022; Burke et al. 2026). Inaccurate or absent forecasts can lead to precautionary early-season decisions that forsake harvest opportunities in strong years, or conversely to increased risk of over-harvest when abundance is overestimated. Forecasting supports estimation of stock-specific impacts needed to manage mixed-stock fisheries and, for chinook, to determine Canada–USA allocations under the *Pacific Salmon Treaty*. Some forecasts are also used to support other management needs, such as setting hatchery broodstock targets or anticipating interactions between salmon and freshwater habitat activities, particularly where stocks of concern are present.

In fact, SEP relies heavily on marking, stock ID, and age sampling for assessing and managing hatchery operations. Objectives and applications are described in detail in the SEP Biological Assessment Framework (Fisheries and Oceans Canada 2019), but broadly include using biosamples to:

- estimate total adult production by hatchery and production line;
- estimate survival rates from release to adult return (i.e. marine survival);
- estimate exploitation rates and the contribution of hatchery production to fisheries;
- identify hatchery-origin fish in broodstock, escapement, and spawning populations;
- assess straying rates and interactions with wild populations, including implications for Proportionate Natural Influence (PNI) targets; and
- orchestrate indicator stock programs that use hatchery-origin fish to infer marine distribution as well as survival, maturation, and exploitation rates for same-stock natural-origin fish

These applications impose distinct sampling requirements that may differ in scale, timing, and sample type from those needed solely for fishery management or stock assessment.

RESEARCH VALUE

Research applications of stock ID and age sampling programs extend well beyond their immediate role in management. These samples enable profiling and monitoring of salmon biodiversity and provide foundational datasets for emerging methods and analyses. As such, stock ID and age sampling must be valued not only in terms of immediate management utility, but also in their capacity to support long-term objectives.

Genetic samples formed the basis upon which salmon were originally grouped into “Conservation Units” (CUs) under the *Wild Salmon Policy* (Fisheries and Oceans Canada 2005; Holtby and Ciruna 2007). It was recognized from the outset that CU definitions would not be fixed and should be updated in accordance with new information (Holtby and Ciruna 2007; e.g. Fisheries and Oceans Canada 2013). Widespread genetic sampling is therefore needed to support ongoing monitoring of salmon population diversity. Genetic samples from escapement are particularly relevant for this function whereas they are often not required nor routinely collected in smaller single-stock watersheds for run reconstruction purposes. In such cases, it is still important to sequence tissue samples every decade or two to update the genetic baselines.

Age samples also have relevance in delineating and refining CUs. Holtby and Ciruna (2007) identified life history types (largely based on freshwater and marine age classes) as an important basis for diversity among sockeye and chinook salmon. In Fraser chinook CUs, for example, dominant freshwater and total age classes are core distinguishing characteristics (Fisheries and Oceans Canada 2013; Government of Canada 2020; Weir et al. 2022).

Beyond their importance in profiling salmon diversity, stock ID and age samples support a range of research endeavours with promising applications. For example, whole-genome analyses, based on the expansive historic record of tissue samples across the region, are being explored to describe markers of adaptive potential among salmon populations in response to climate change (Fisheries and Oceans Canada 2025f; Metzger et al. 2026). Stock ID and age samples (predominately CWTs) have also been employed to ground-truth parentage-based tagging, an emergent genetic tool that could be used to streamline stock assessment programs coastwide (Satterthwaite et al. 2015; Beacham et al. 2020, 2021, 2022).

In summary, stock ID and age samples constitute a durable asset whose value increases through time as requirements for management advice evolve. Maintaining broad, representative, and well-documented sample collections therefore supports both current management needs and future priorities that cannot always be anticipated. Recognizing this breadth of application is important when evaluating existing sampling programs, and reinforces the need for a strategic approach that respects long-term information value alongside cost-efficiency.

OVERVIEW OF STOCK IDENTIFICATION AND AGE SAMPLING IN B.C.

SAMPLE TYPES

Stock identification and marking

Various stock identification and associated marking and tagging methods are used and the application of these techniques has evolved with changing technology and management requirements. The most widespread program is the coastwide Coded-Wire Tag (CWT) program, which involves application of CWTs to salmon smolts from hatchery and wild indicator stocks and subsequent detection, recovery, and analysis of tags from adult salmon in catch and escapement programs. Genetic stock identification (GSI) methods are also used extensively, either as a primary source of stock identification for mixed-stock sockeye and chum fisheries or to augment CWT information for chinook and coho. Parentage-based tagging (PBT) is a more recent technique that allows stock ID and age determination for any fish whose parents were genetically profiled (generally via hatchery broodstock programs).

Table 2. Marks or methods commonly used by DFO for stock identification and/or hatchery-origin determination.

Type	Purpose	Description	Resolution	Recovery Method
Coded-wire tags (CWT)	Stock origin; aging	Small wire with a binary code inserted into the snout of juvenile salmon	Brood Year Origin Stock (most commonly hatchery stocks, but also naturally spawning populations in some cases)	Lethal for stock ID and aging (although CWT presence can be detected electronically with the combination of an external adipose fin clip)
Genetic stock identification (GSI)	Stock ID, predominately for natural-origin fish	Genetic markers that are characteristic of distinctive population groups	CU for most stocks in BC. In some cases, salmon can be assigned to a natal watershed	Non-lethal tissue sample that is sequenced in a salmon genetics lab
Parentage-based tagging (PBT)	Stock ID from a parental baseline database	Genetic markers profiled from salmon spawners (typically hatchery broodstock) are used to identify their progeny	Family of origin	Non-lethal tissue sample that is sequenced in a salmon genetics lab
Otolith thermal marks	Stock (hatchery) origin	Hatchery water temperatures are manipulated to create unique otolith 'marks' on salmon during their early stages of development	Brood Year Origin Stock Hatchery rearing and/or release strategy	Lethal (need to remove otolith bone, external detection is not possible)
Passive Integrated Transponders (PIT tags)	Individual salmon tracking	≈10-mm capsular tags implanted in salmon body cavities that emit unique radio frequencies when stimulated by an electromagnetic field	Individual salmon with unique tags	Non-lethal (tags are detected and read through external wands or fixed arrays)
Adipose fin clips (AFC)	Identify hatchery-origin	The adipose fin is removed from juvenile salmon in hatcheries	Hatchery- versus natural-origin; sometimes indicates presence of a CWT, but not for mass-marked stocks	Non-lethal visual inspection of intact fish

Age determination

Scale analysis is the most common method used to age natural-origin or wild salmon, with analysis of growth rings on otoliths providing an alternative method that is more rarely employed. Scale analysis is also commonly used to age hatchery-origin fish and PBT is becoming an increasingly common method as well. CWT information (CWT codes are unique to brood year and stock) is the preferred method for aging hatchery-origin fish, when available.

Table 3. Aging methods commonly used by DFO

Type	Description	Resolution	Recovery Method
Scale	Individual salmon scales or smears of scales collected from the posterior half of fish, ideally just above or below the lateral line between the pelvic and anal fins	Total and freshwater age in years	Individual scales are collected from salmon using forceps or scale smears (typically for juveniles with very small scales) are collected using a scalpel
Otolith	Otoliths are small calcareous structures that grow in the heads of salmon; growth rings are visible in otolith cross-sections	Total and freshwater age in years	Dissection of salmon heads allows retrieval of otoliths using forceps
Coded-wire tags (CWTs)	Small wire with a binary code inserted into the snout of juvenile salmon	Total age in years; freshwater age can be determined from associated release group information	Dissection of salmon heads allows retrieval of CWTs
Parentage-based tagging	Age determined based on genetically linking sampled salmon to parents of a known spawning year	Total age in years; freshwater age can be determined from associated release group information, if available	Non-lethal tissue sample that is sequenced in a salmon genetics lab

COLLECTION METHODS AND LOGISTICS

All methods covered in this paper for salmon stock ID and age determination require physically handling fish and the difficulty of accessing fish to collect samples varies considerably among programs. For example, some salmon fishery catches are delivered to processing facilities in cities, such as Nanaimo or Vancouver, that DFO staff, PSC staff, or contractors can travel to and from in one working day. Likewise, large numbers of salmon across Pacific Region are sampled in swim-in hatchery broodstock programs, where salmon swim near or into hatchery facilities and can be readily netted, spawned, and sampled in bulk. In contrast, some fisheries operate within complex supply chains that include at-sea buyers and sales to international markets, necessitating extensive coordination with individual vessel captains to intercept catch at remote offload sites or even at sea. It can be even more difficult to access and sample fish

from populations of conservation concern; in some cases less than 100 fish return to the spawning grounds, which are often difficult to reach (sometimes requiring helicopter travel), and may yield only a few (if any) carcasses to sample. Due to such complexities, DFO often relies on contracts or collaborative arrangements with First Nations and other partners who are better located or equipped to access fish.

Once target fish are reached, collecting samples and metadata for stock ID and aging is generally a rapid process, spanning from a couple of seconds to a couple of minutes per fish. The bullets below individually summarize the collection process for the different sample types pertinent to this review, but in practice these activities tend to occur simultaneously or might be repeated across groups of fish in a rapid sequence.

- CWT: fish are either scanned with an electronic device that can detect the CWT in the fish's head, or—in fisheries with high incidences of paired hatchery adipose fin clipping and CWT'ing—CWT presence might simply be inferred based on an absent adipose fin. Samplers then cut off the fish head and attach a barcoded “E-label” using a zip-tie through the jaw that can be used to subsequently link the CWT information to the sample collection event.
- GSI or PBT: samplers use a hole punch to extract a tissue plug from the adipose or caudal fin. The tissue plug is then knocked free and positioned on a particular cell of a “Whatman sheet” (Pacific Salmon Commission 2022) or into individual or bulk vials of ethanol. Whatman cells and ethanol vials generally carry unique IDs that can be used to link the genetic results to the sample collection event metadata.
- Scale: samplers use forceps to extract 2–5 scales from the “preferred area” close to the lateral line (depicted in Maclellan 1987), carefully examining them under good lighting to reject damaged or regenerate scales. Each scale is mounted in a particular cell on a scale card, whose unique “scale book” ID and cell ID are used to subsequently link the age results to the sample collection event.
- Otolith: samplers use a knife to cut a section into the fish's head (details in Maclellan 1987), exposing the cranial otolith sockets, then use forceps to retrieve both otoliths. Otoliths are cleaned of blood and membranous tissue and then deposited into small vials as pairs. Vials are then slotted into trays, such that tray ID and vial ID can be used to subsequently link otolith results to the sample collection event.

In practice, there are innumerable logistical hurdles that can impede the quality or success of sample collection, such that achieving sample targets for particular programs is sometimes an incredible feat of perseverance. Rather than striving for comprehensiveness, we provide here one anecdotal narrative of a fishery sampling event to give a flavour of how a seemingly straightforward task is rarely so (Box 1).

Box 1

A sampling team is tasked with collecting 100 stock ID and age samples from an upcoming salmon fishery opening. The opening is authorized overnight from 20:00–06:00h, with a possible extension. The sampling team plans to travel to the dock and arrive at 05:30, when most fishers are expected to be offloading their catch. During the opening, several vessels are quite successful in the first 6 hours and decide to hail out early; their catch is offloaded and trucked away by 02:00 and is therefore not sampled. Meanwhile, the rest of the fleet is steadily grinding through the night with less success, such that by 05:30 the fishery is authorized for a 2-h extension. The sampling crew arrives at the dock at 05:30 as planned and waits for vessels to begin hailing out and offloading. The bulk of the fleet hails out at 07:30 and by 08:00 the dock is bustling with cranes hoisting totes from vessels and forklifts loading them into trucks. The samplers are careful to intercept several totes originating from different vessels to ensure a representative sample is collected. It is raining, making it difficult to visually inspect scales and to keep paper data sheets, scale cards, and Whatman sheets dry. After collecting the sample of 100 fish, the team leaves the site and puts the tissue samples in the mail, addressed to the corresponding labs where they will be processed, then proceeds to scan and digitize the field data collection sheets.

LABORATORY PROCESSING

While numerous teams and programs across Pacific Region collect stock ID and age samples, only a few labs process them (Table 4).

Table 4. Laboratories in Pacific Region that process salmon stock ID and age samples.

Data type	Sample Type	Laboratory(ies)
Stock ID & age	CWT	J. O. Thomas and Associates, Ltd., Vancouver, BC.
Stock ID & age	PBT	Molecular Genetics Laboratory, Pacific Biological Station, Nanaimo, BC
Stock ID	GSI	Molecular Genetics Laboratory, Pacific Biological Station, Nanaimo, BC
Stock ID	Otolith	Yukon Stock Assessment Otolith Thermal Mark Laboratory, Whitehorse, YT <i>kt̓ cp̓əl̓k̓ st̓im̓</i> Laboratory, Penticton, BC (not covered in this paper) Uchucklesaht Tribe Government Otolith Laboratory, Port Alberni, BC (closed in 2025)
Age	Otolith	Sclerochronology Laboratory, Pacific Biological Station, Nanaimo, BC

Data type	Sample Type	Laboratory(ies)
Age	Scale	Sclerochronology Laboratory, Pacific Biological Station, Nanaimo, BC Pacific Salmon Commission Laboratory, Vancouver, BC A-tlegay Scale Laboratory, Campbell River, BC <i>kt̓ cp̓əl̓k̓ st̓im̓</i> Laboratory, Penticton, BC (not covered in this paper)

Individually, these labs process anywhere from a few thousand to nearly one hundred thousand salmon stock ID and age samples per year (Figure 1).

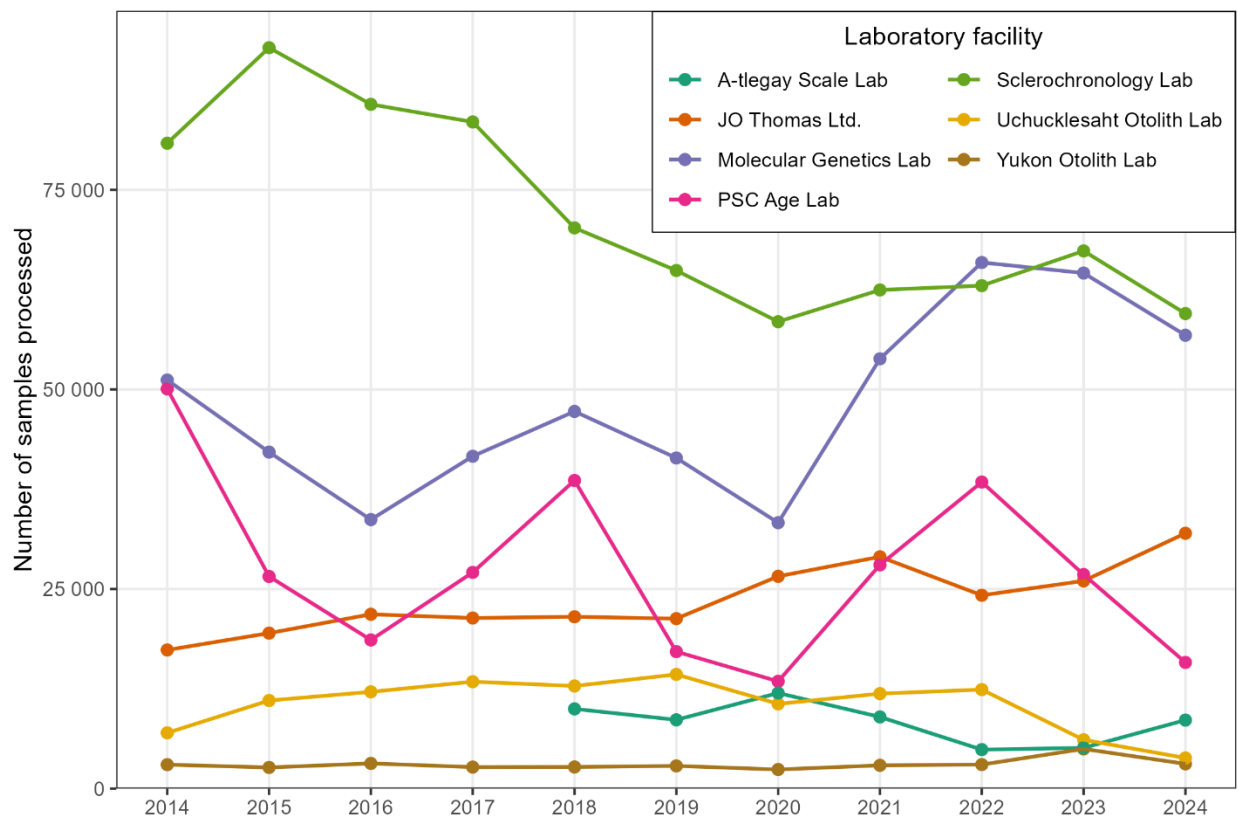


Figure 1. Annual Pacific salmon sample processing volumes for each laboratory facility operating in Pacific Region. Data from [PSBI database](#).

DATA ENVIRONMENT

Biological samples have been collected by DFO for many decades, well before the advent of modern digital data systems. As a result, biosample data management has evolved incrementally and largely on a program-by-program basis, rather than through regional or national coordination. Within Pacific Region, different sectors and teams have independently developed solutions to similar challenges, with varying degrees of success.

Broadly, the evolution of biosample data storage followed a common trajectory: paper field records were stored in physical archives, then came early electronic storage (e.g., floppy disks), followed by spreadsheet-based systems on shared hard drives, and eventual migration (for some programs) to relational databases. While early adopters of relational databases benefitted from having larger portions of the historical record consolidated in a single system, many of these databases were designed for narrow purposes that do not align with current management needs and reflect legacy architectures that do not align with more modern systems.

Today, salmon biosample data in Pacific Region are distributed across at least nine distinct databases (Table 5) with overlapping but discrete scopes (e.g. differing in temporal and geographic coverage, sample types, or program mandates). The most robust databases are supported by DFO's Chief Digital Officer Sector (CDOS) and the rest are "client-supported" by individual programs within or even external to DFO. In some cases, no database solution exists at all, and sample data persist only in spreadsheet files stored on shared regional hard drives. Collectively, this has resulted in a highly heterogeneous data environment characterized by data silos, inconsistent metadata, no common vocabulary, and variable data quality.

A central consequence of this heterogeneity is the absence of a consistent, automated pipeline for linking field collection data to laboratory results. Therefore, analysts frequently assemble the datasets they require by exporting queries from separate databases, collating spreadsheets, and manually joining records using sample identifiers (often with disparate variable names). This process is repeated on a use-case basis and results in bespoke, one-off datasets that are not reusable but often overlap in scope with other analyses.

These challenges are widely recognized and have been the subject of several streamlining initiatives over the years. Most recently, the Sample Tracking and Management Program (STAMP) has been advanced as a conceptual framework for a coordinated solution. While this work represents an important step toward improving sample data stewardship, its eventual scope, implementation timeline, and degree of national integration remain uncertain. In the meantime, analysts and program staff continue to expend substantial effort compensating for structural limitations in the existing data environment.

PACIFIC SALMON BIOSAMPLE INVENTORY

To support this paper and to establish a basis for broader sampling program review in Pacific Region, we compiled a database containing counts of all stock ID and age samples accessioned in regional DFO or PSC databases, which we titled the [Pacific Salmon Biosample Inventory \(PSBI\)](#). The PSBI records the numbers and types of samples collected across stocks and fisheries from 2014–2024.

Sample count data

Numerous databases currently house information related to stock ID and age samples, and these vary widely in scope, structure, and available metadata. Broadly, applicable databases fall into two data domains:

1. *Collection*: data that are recorded during the physical sampling event, such as time, date, location or fishery, biometrics (e.g. size or sex), and identifier labels for tissue or tag samples that will be submitted for laboratory processing.
2. *Laboratory*: results of laboratory analyses pertaining to individual fish. These records often contain some but never all metadata associated with a physical sampling event and must be linked back to the original collection records via identifier labels to yield a fulsome dataset.

Some databases contain only collection records, others only laboratory records, and a few integrate both, with back-end workflows that automatically link field-collected identifiers to some associated laboratory results. Table 5, below, lists all databases contributing data to the PSBI along with their corresponding domains and scopes.

Table 5. Databases that contributed records to the Pacific Salmon Biosample Inventory.

Source database	Data domain	Scope	Hosting organization
CREST (Catch and Release Estimate Tool)	Collection ¹	Samples collected from South Coast Area recreational fishery programs, including creel surveys, fishing lodge partnerships, and individual angler voluntary submissions	DFO South Coast Stock Assessment
E-Pro (Enhancement Program)	Collection ²	Samples collected from Salmonid Enhancement Program (SEP) activities, plus some adjacent escapement programs in enhanced systems	DFO SEP
FOS (Fishery Operations System)	Collection ¹	Samples collected from Pacific Region commercial and test fisheries, plus some First Nation fisheries	DFO CDOS
PSC (Pacific Salmon Commission)	Collection & laboratory	Fraser River sockeye and pink samples collected or assimilated by the PSC, including test fisheries, commercial fisheries, First Nation fisheries, recreational fisheries, and escapement programs	PSC
A-tlegay	Laboratory	Scale samples analyzed by the A-tlegay Fisheries Society laboratory in Campbell River, BC; primarily chum	A-tlegay
CWT (Coded-Wire Tags)	Laboratory	CWT samples collected from all sources (fisheries, escapement, hatcheries, research) in Pacific Region and analyzed by the J.O. Thomas laboratory in Vancouver, BC.	DFO CWT program
MGL (Molecular Genetics Lab)	Laboratory	Genetic sample results from all sources (fisheries, escapement, hatcheries, research) in Pacific Region and analyzed by the MGL in Nanaimo, BC. These data are managed internally by MGL, with an outward-facing "Genetic Results Database" (GRD) currently in active development.	DFO Molecular Genetics Lab

Source database	Data domain	Scope	Hosting organization
Otomanager	Laboratory	Otolith samples collected from all sources (fisheries, escapement, hatcheries, research) in Pacific Region and analyzed by either the Uchucklesaht Otolith Lab in Port Alberni, BC, or the Yukon Otolith Lab in Whitehorse, YT.	DFO CDOS
Salmon aging	Laboratory	Scale samples collected from all sources (fisheries, escapement, hatcheries, research) in Pacific Region and analyzed by the Sclerochronology Lab in Nanaimo, BC.	DFO CWT program

¹ These databases include backend workflows that retrieve some sample results; most notably, all age results are automatically paired to collection data.

² EPRO includes a toolkit for users to manually import laboratory results.

Collectively, these databases (PSBI variable name = source_db) cover most Pacific salmon samples collected in Pacific Region. We queried each of these databases for record counts (PSBI variable name = n_samples) across all available variables containing metadata on salmon species, sample collection program, sample location or fishery, and sampling or fishing date.

We then attempted to categorize all resulting records into an SMU and/or FMU. However, successful categorization depended on available metadata (Table 6). In some instances, metadata were sufficient to categorize records into both a single SMU and a single FMU (e.g. pink salmon samples from any fishery in the Fraser River are assumed to belong to SMU = FRASER PINK SALMON and FMU = Fraser Pink Salmon). More commonly, records could be ascribed to only an SMU or an FMU, but not both (e.g. samples from mixed-stock fisheries could be ascribed to an FMU but not an SMU). And some records lacked sufficient metadata to determine FMU or SMU.

Table 6. Numbers of samples (N; materials or tissues collected) recorded in each database for 2014–2024, with subtotals indicating the numbers ascribed to both Stock Management Unit (SMU) & Fishery Management Unit (FMU), just SMU, just FMU, or neither, respectively. Note.—considerable numbers of sampled fish are duplicated across databases and thus ‘Total N’ is not discrete between rows.

source_db	Data domain	N SMU & FMU	N SMU	N FMU	N not assigned	Total N
CREST	Collection	24405	0	130752	0	155157
E-Pro	Collection	0	285227	0	0	285227
FOS	Collection	144132	0	138258	0	282390

source_db	Data domain	N SMU & FMU	N SMU	N FMU	N not assigned	Total N
PSC	Collection & Laboratory	106778	167375	130982	3275	408410
A-tlegay	Laboratory	9120	20205	28599	176	58100
CWT	Laboratory	58309	134694	49819	17865	260687
MGL	Laboratory	116288	926	224147	82531	423892
Otomanager	Laboratory	25167	96320	3702	23745	148934
Salmon aging	Laboratory	241406	421723	112098	13609	788836

¹ The data available for this report were indexed by project name and did not contain actual genetic results for each sample, thus precluding assignment of all genetic samples to SMU in the PSBI.

Note that failure to assign samples to SMU and/or FMU through this exercise is not an indication that these samples are not accessible to or used by the programs that collected them. Rather, it reflects the current necessity for program staff to link (often manually) sample results across databases using field-identifier labels.

Due to diffusion of sample data across multiple databases and insufficient project metadata, it was not possible to identify and prune out duplicates among the query results. To mitigate this issue, we organized the database into discrete tables that largely isolate duplicate records from one another. At the highest tier, records are categorized by either SMU or FMU, and are then further divided between the two database domains—collection or laboratory data (Figure 2). Under this structure, the only level at which records can be duplicated is between individual databases (e.g. fish whose samples were submitted for GSI and scale aging will be counted in both MGL and salmon aging database records); analysts can therefore avoid any potential duplication errors by grouping sample results under either source_db or (for laboratory data only) sample_type.

Within the constraints of the current DFO salmon sample data environment, the PSBI thus offers a comprehensive and robust system for investigating salmon sampling activities in Pacific Region across the last decade.

SMU and FMU Profiles

In addition to collating counts of samples, we also aggregated summary metadata for each of the 69 SMUs and 41 FMUs, referred to as SMU and FMU Profiles. These data are stored as PSBI tables called smu_meta and fmu_meta (Figure 2).

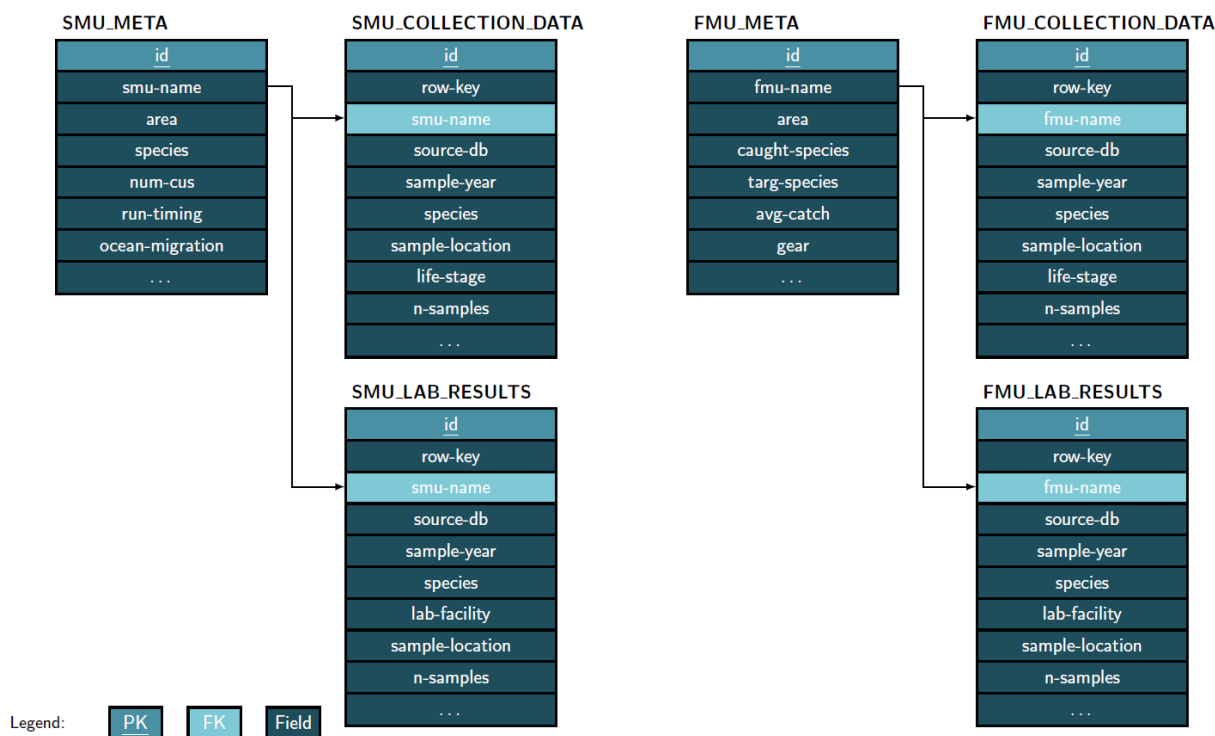


Figure 2. Pacific Salmon Biosample Inventory (PSBI) table relationship diagram. Only the first 7 or 8 fields in each table are listed (“...” indicates the presence of additional fields).

SMU profiles list the component CUs, as well as CU counts by *Wild Salmon Policy* status (red, amber, or green), basic life history information, SMU status, and Precautionary Approach reference points, where data are available. SMUs are also partly linked to FMUs via the `fmu_list` variable, which contains concatenated lists of all FMUs that actively target fish from the focal SMU.

FMU profiles list the Pacific Fishery Management Areas (PFMAs) spanned by the fisheries, decadal average catch (in numbers of salmon), participating sectors, and several variables that broadly categorize the catch monitoring, sampling, and harvest management frameworks. FMUs are linked to SMUs via the `targ_smu` variable, which contains concatenated lists of all SMUs targeted by the focal FMU.

Classification of monitoring, sampling, and management frameworks

Using information from recent IFMP documents (Fisheries and Oceans Canada 2024, 2025b, 2025c, 2025d), we summarized and classified the harvest management context for each FMU. Two complementary classifications are reported in the PSBI: the harvest management framework and harvest management constraints. Harvest management framework classification encompasses four attributes: management scope (i.e. domestic versus international), management plan increment structure (e.g. continuous, categorical), the variable that determines management measures (e.g. run size), and the regulated or managed variable (e.g. catch, opportunity, timing) (Table 7). Harvest management constraints classification encompasses three attributes: management scope, the constraining factor (e.g. Southern Resident Killer Whales), and the restriction type applied (e.g. time or area closures) (Table 8).

Table 7. PSBI harvest management framework example: Domestic-Cont-RunSize-ER

Management scope	Management plan increment structure	Determining variable	Regulated/managed variable
Domestic	Continuous	Run size	Exploitation Rate
International	Categorical	Escapement	Total Allowable Catch
	Binary	Marine Survival	Number of days or openings (opportunity)
	Undefined	International fishery	Number of vessels or fishers (effort)
		Not applicable	Not applicable

- Management scope = domestic, i.e. fisheries targeting the SMU are managed exclusively within Canada by DFO
- Management plan increment structure = continuous, i.e. fisheries are regulated by a continuous HCR that is mediated in fine increments by the determining variable
- Determining variable = run size, i.e. fisheries are managed according to a forecast total annual run size of the target SMU
- Regulated/managed variable(s) = exploitation rate, i.e. fishery openings and catch quotas are orchestrated to achieve a target total catch year exploitation rate

Table 8. PSBI harvest management constraints example: Domestic-LocalStocks-time+area

Management scope	Constraining factor	Restrictions
Domestic	Southern Resident Killer Whales	Time
International	<Stock><Species>	Area
	International stocks or treaty considerations	Gear
	Local stocks of concern of any salmon species	Effort
		Opportunity

- Management scope = domestic, i.e. constraints affecting the fishery(ies) are regulated within Canada by DFO
- Constraining factor(s) = local stocks of concern of any salmon species, i.e. local salmon populations, are assessed to be of poor status and require additional fishery management precautions
- Restriction(s) = time & area, i.e. affected fishery(ies) are subject to time and area restrictions designed to minimize impacts on the constraining factor

Some FMUs received multiple classifications, such as in cases where fisheries are subject to both domestic and international management under the PST (e.g. Skeena–Nass Pinks, Fraser Chum) or where a single FMU bundles discrete fisheries that operate under different

frameworks (e.g. Inside Southern Chum Terminal Fisheries, Central Coast Chum). Likewise, several FMUs carry multiple harvest management constraints, such as Northern AABM Chinook, which is managed to mitigate impacts on WCVI, Fraser, and Skeena–Nass chinook.

Although harvest management plans are prescribed for SMUs under the FSP, they are implemented within FMUs. Thus, to characterize SMU-level harvest management contexts, we mapped each SMU to the FMUs that target it (or for which it is constraining) and assigned the corresponding harvest frameworks and constraints.

Catch monitoring frameworks are also summarized for each FMU in the IFMPs, with activities listed by sector. For classification, we grouped like activities and recorded their presence (e.g., creel surveys, dockside validation, fisher-reported conditions of licence).

In contrast, stock ID and age sampling programs lack consistent documentation at the FMU or SMU level. As an initial approximation, we concatenated unique `sample_type` entries from PSBI by FMU and SMU and joined them to the profile tables. This necessarily omits samples that were not assigned to an MU, so some routinely collected sample types may not appear in the profiles. This shortcoming further underscores the need for a comprehensive sampling program review. Subject matter expert review and updates to PSBI records to finalize FMU and SMU attributions would be a worthwhile starting point.

CASE STUDIES

BARKLEY SOUND SOCKEYE SALMON

Scope

Barkley Sockeye salmon comprise a single SMU with three component CUs. Barkley Sockeye are targeted by a single FMU, WCVI – Barkley/Somass Sockeye, whose fisheries are prosecuted solely in PFMA 23, predominately within the narrow coastal fjord of Alberni Inlet (Figure 3). Despite its small fishing area, Barkley Sockeye is currently the fifth largest salmon fishery in British Columbia, as measured by average mass of fish harvested per year over the last decade (Figure 3). These fisheries target the abundant Somass Sockeye run, which is comprised of the Great Central and Sproat CUs; fisheries generally avoid harvesting the third CU, Hucuktlis Sockeye, which is less abundant. Participating fishery sectors include First Nation Treaty, First Nation Rights-Based, First Nation Commercial, Recreational, Commercial (license areas D and B), and Test.

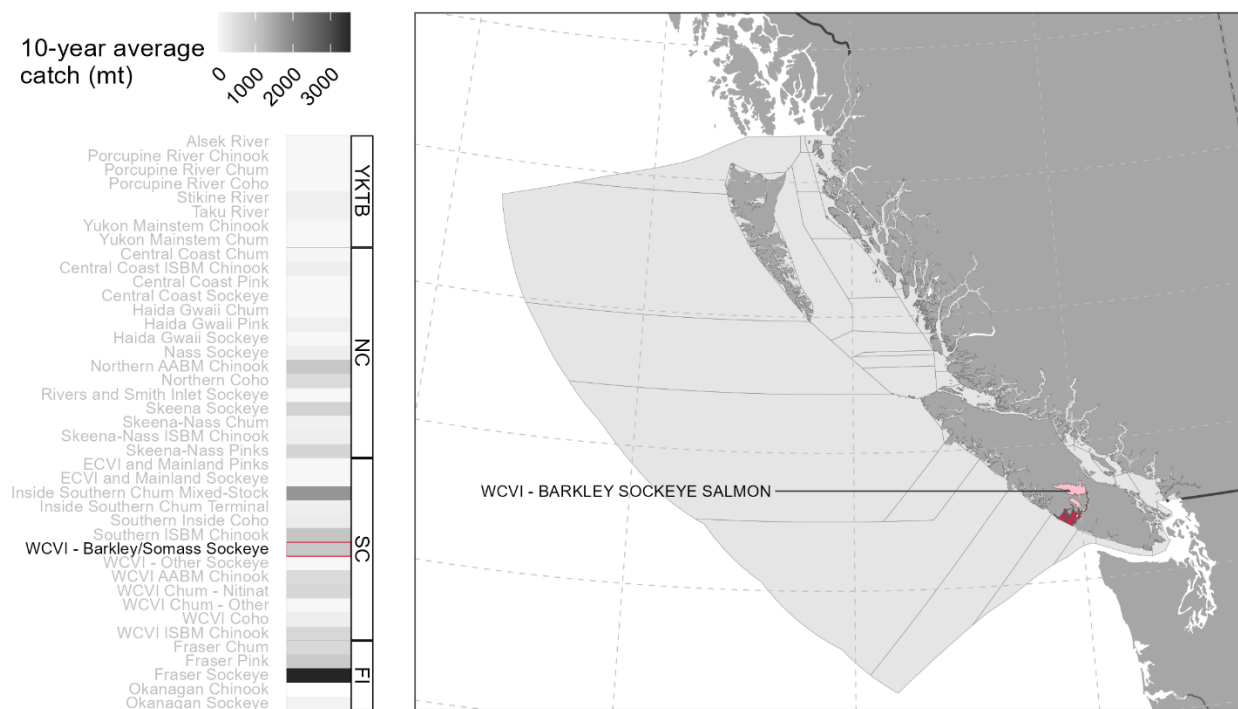


Figure 3. Geographical extent and magnitude of Barkley Sockeye fisheries and spawning grounds. The labeled and shaded bands on the left show the magnitude of 2014–2024 average Barkley Sockeye catch (approximate weight) in relation to all other Fishery Management Units (FMUs). The map on the right shows all Pacific Fishery Management Areas (PFMAs; light grey polygons) with red showing PFMA 23, where Barkley Sockeye are fished. The labeled pink areas show the extent of spawning watersheds encompassed in the Stock Management Unit (SMU).

1. Documentation

Marking, sampling, and data management programs

There are no marking programs for Barkley Sockeye. Stock identification is achieved using single nucleotide polymorphisms (SNPs; Beacham et al. 2002) extracted from fin tissue samples.

Sampling of Barkley Sockeye fisheries is orchestrated by DFO South Coast Stock Assessment in collaboration with the Hupacasath and Tseshahat First Nations and the Uchucklesaht Tribe Government. Each year, plans are prosecuted to representatively sample from the following sources:

- Escapement: Sproat, Stamp, and Hucuktlis rivers
- Catch: First Nation commercial (gillnet and seine), First Nation Food Social and Ceremonial (FSC; gillnet and seine), First Nation Treaty (gillnet), commercial (gillnet and seine), and recreational (rod & reel)
- Fry & smolt: Sproat, Great Central, and Hucuktlis lakes (midwater trawl for fry; downstream trapping for smolts)

Stock ID and age samples are collected from all catch sources, but only age samples are collected from adult escapement, fry, and smolt sources (it is presumed fish are 100% native to the system they are sampled in).

Barkley sockeye sample data are housed in five different databases, including both CDOS- and client-supported databases:

- CDOS -supported: FOS
- Client-supported: salmon aging, CREST, VidEsc (maintained by Hupacasath First Nation for escapement count and biosample data), Molecular Genetics Lab internal files (with a potential client-facing option, the “Genetic Results Database,” in development).

Sampling event metadata, which include sex and length data, from the Hucuktlis Fence escapement program, Maa-nulth Treaty catch sampling, First Nation FSC catch sampling, and all fry and smolt programs do not fall within the scope of any extant databases and are instead stored in unmanaged spreadsheets on shared network drives. Figure 4 shows the general trajectories taken by various parcels of Barkley Sockeye stock ID and age data between collection and database accession (or lack thereof).

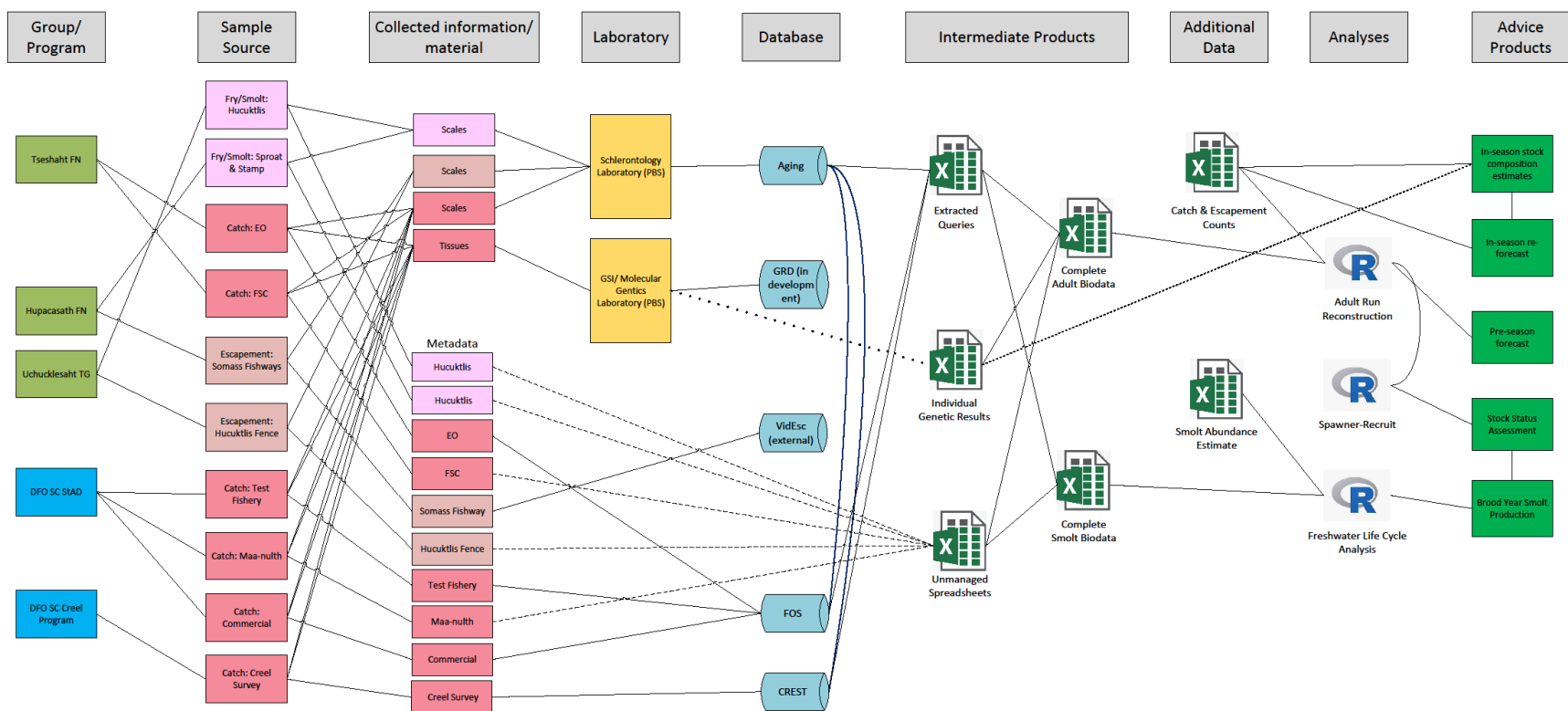


Figure 4. Flowchart illustrating Barkley sockeye annual sampling programs and data pipelines.

Management framework

At a high level, Barkley sockeye fisheries, enhancement, and habitat activities are managed in accordance with DFO's [Sustainable Fisheries Framework](#), which includes intermittent formal assessments of SMU status, inclusion in an IFMP (Fisheries and Oceans Canada 2025c), and a commitment to follow an [Ecosystem Approach to Fisheries Management](#). Decision-making relevant to these broad principles is undertaken approximately every 5–10 years based on updated science advice, and spans all DFO salmon management domains: fishery, enhancement, and habitat (Table 9).

At a finer level, Barkley sockeye fisheries are managed on an annual cycle to regulate exploitation rates. This process begins each year with a pre-season forecast that determines fishing plans during the early weeks of the run. As the run builds toward its peak, the in-season management process takes over with weekly decisions around fishing access, areas, and allocations. A water flow regulation process occurs in tandem with in-season fishery management and serves to advise Domtar Paper on spillage of water from the Great Central Lake Dam to support sockeye migration. The annual management cycle concludes with a post-season review of the fisheries and recommendations to take forward.

Stock ID and age sampling programs support management decision-making across all scales. Collection of stock ID and age samples is tailored for in-season decision-making, which requires data at the finest scale and with the fastest turnaround times. These weekly data are then rolled up and summarized at annual scales for longer-term decision-making through run reconstruction and stock-recruit analyses. Only the in-season water flow regulation process does not depend directly on stock ID and age samples (Table 9), although these data are relevant for longer term water use and infrastructure planning.

Table 9. Barkley sockeye management decision inventory.

Decision	Management domain	Frequency	Advice product(s) from stock ID and age sampling
Early-season harvest plan	Fisheries	Annual	Run reconstruction → pre-season forecast
In-season weekly fishing plans	Fisheries	Weekly	Current stock ID and age sample results → fishery stock composition estimates, weekly re-forecasts
Great Central Lake Dam in-season flow regulation	Habitat	Bi-weekly	None
Habitat stewardship activities	Habitat	1–5 years	Run reconstruction, smolt age sampling → brood year smolt production
SMU status	Fisheries, Enhancement, Habitat	5–10 years	Run reconstructions, age samples → spawner–recruit analysis → stock status assessment

Decision	Management domain	Frequency	Advice product(s) from stock ID and age sampling
Lake fertilization	Enhancement	5–10 years	Run reconstruction, smolt age sampling → brood year smolt production

2. Review & analysis

Alignment between sampling and management frameworks

Stock ID and aging samples taken from returning Barkley sockeye adults provide weekly temporal resolution and PFMA subarea spatial resolution in the run reconstruction analysis. Age samples from fry and smolt sampling programs provide annual temporal resolution and nursery lake (CU) spatial resolution in the brood year smolt production analysis. Overall, the spatiotemporal resolution provided by these samples is well aligned with management needs (Table 10; Table 11; Table 12).

In-season fishery management requires the finest spatiotemporal resolution from sampling to enable weekly adjustments to fishing allocations and areas. In some cases, fishery managers request sample resolution at finer scales than even PFMA subarea to try to understand exactly how Hucuktliis sockeye are distributed throughout Alberni Inlet. However, weekly sample sizes are generally too few to allow precise stock composition estimates within finer spatial bins. It is possible that improved geostatistical methods (e.g. kriging) could be used to achieve this, but it would require more precise location information (i.e. latitude & longitude) be recorded for each stock ID sample. This is a fruitful avenue to explore for future stock ID program development that would better align stock composition spatial resolution with fishery management needs.

While stock ID and age samples are currently collected at a 1:1 ratio in fishery samples, it might be possible to collect fewer age samples in the fisheries and still attain reasonable estimates of stock-specific age compositions. However, given that the stock ID/CU of fish is unknown when samples are collected, this would lead to fewer age samples being collected from already rarely encountered Hucuktliis sockeye. Another possibility to reduce the volume of age samples collected is to sample less frequently from escapement. In general, previous years' run reconstructions show that older fish tend to arrive earlier in the season, but by early July the age compositions are largely static over time. For this reason, some sampling effort could be spared by collecting fewer or less frequent escapement age samples from the Stamp and Sproat rivers after July, with minimal loss of information value.

Annual age sampling of smolts emigrating from each of the three Barkley sockeye nursery lakes is required for brood year smolt production analysis, which informs habitat stewardship and stock enhancement planning. During prior fiscal contraction, laboratory analysis of these samples was temporarily discontinued to ensure sustained funding for the adult sampling programs, which make the biggest contribution in terms of decision-relevant advice. However, recognizing the value of these samples, program staff continued collecting and archiving scales from fry and smolts, which were subsequently analyzed years later when surplus funds were identified. This is a prudent strategy that affords frugality during years of constrained funding but allows annual data to be updated intermittently according to habitat and enhancement planning timelines (Table 9). It is also possible that scales freed up from late-season escapement sampling (see paragraph above) could be reallocated to allow more smolt scales to be analyzed.

Table 10. Sample data–fishery management alignment matrix for Barkley sockeye.

Dimension	Current sampling provides	Fishery management requires	Notes/Gaps
Spatial resolution	PFMA 23 subarea (latitude and longitude for creel survey data as of 2025)	Latitude & longitude	Some sample sources provide finer than subarea spatial resolution, namely the creel survey and test fishery. Fine-scale stock composition estimates are used for area-based mitigation of Hucuktli's incidental catch
Temporal resolution	Weekly	Weekly	None
Stock resolution	CU	CU	None
Age resolution	Total & freshwater	Total & freshwater	Freshwater ages are used in-season to estimate proportions of “jack” sockeye, which are not counted against total allowable catch.

Table 11. Sample data–enhancement management alignment matrix for Barkley sockeye.

Dimension	Current sampling provides	Enhancement management requires	Notes/Gaps
Spatial resolution	Lake	Lake	Total smolt and adult Sockeye production by lake are required to assess fertilization efficacy
Temporal resolution	Weekly	Annual	Annual sockeye production estimates are sufficient for assessing fertilization efficacy
Stock resolution	CU	CU	None
Age resolution	Total & freshwater	Total & freshwater	Freshwater ages are required from sockeye adults and fry to enable analyses of brood year smolt and adult production

Table 12. Sample data–habitat stewardship alignment matrix for Barkley sockeye.

Dimension	Current sampling provides	Habitat stewardship requires	Notes/Gaps
Spatial resolution	Lake	Spawning reach	Understanding productivity of particular spawning habitats within lakes and tributary creeks is required to inform habitat assessments
Temporal resolution	Weekly	Annual	Annual run reconstruction and smolt production estimates are required to monitor freshwater habitat productivity
Stock resolution	CU	CU	None
Age resolution	Total & freshwater	Total & freshwater	Freshwater ages are required from sockeye adults and fry to enable analyses of brood year smolt and adult production

Data management gaps

Several structural weaknesses in the Barkley Sockeye data pipeline constrain the efficiency and quality of scientific advice. These gaps are consistent with region-wide challenges described in the Data environment section. Barkley sockeye stock ID and age data are dispersed across several databases and unmanaged spreadsheet files, each with its own schema, variable naming conventions, and metadata standards. Because these systems lack a shared ontology or common data dictionary, this fragmentation hinders interoperability, quality assurance, and analysis.

The most serious data management gap is that metadata for fry and smolt sampling programs, adult escapement, and several First Nation Treaty and FSC catch programs are not stored in any CDOS- nor client-supported databases (Table 5) and have never been formally accessioned. Instead, these data persist as unmanaged spreadsheet files stored on shared drives and thus lack oversight, version control, and protection under Government of Canada retention or security policies (Figure 4). Variable names, data formats, and file structures differ across years and programs, necessitating considerable manual efforts to harmonize and collate records.

Similar manual efforts are necessitated for all stock composition analyses by the lack of a user-facing database for genetic stock ID results. These data are maintained in internal Molecular Genetics Lab systems that are not programmatically linked to any collection-domain database. In the absence of a unifying schema, analysts must manually join genetic outputs to field records using Whatman sheet and cell numbers (Figure 4). Because Whatman sheet numbers are not always unique, linking genetic results sometimes requires linking functions to also include sampling date. (As an aside, there have even been cases outside the Barkley Sockeye context where tissue samples from different programs were mounted on the same Whatman

sheet number on the same day). This can occasionally lead to one week delays in reporting stock composition results in-season, which puts resource managers on the back foot while trying to mitigate Hucuktlis incidental catch.

Barkley sockeye data management gaps are a microcosm of the entire Pacific Region and should thus be addressed through coordinated, farsighted initiatives. Strengthening these systems (and expanding or adding components where necessary to encompass overlooked data sources) would not only resolve the immediate bottlenecks affecting Barkley sockeye but also improve consistency, durability, and reproducibility of science advice across programs.

Table 13. Barkley sockeye stock ID and age sample data gap inventory

Gap	Description of problem	Effect on advice
Sample metadata for fry/smolt programs, escapement, and First Nation Treaty and FSC catch are not accessioned in regional DFO databases	Collection metadata are not maintained to consistent standards or stored in consistent locations. Sample results need to be linked to metadata manually. Data are not properly secured against loss or corruption.	Stock and age composition estimates corresponding to these data are delayed and error-prone.
Genetic stock ID results are neither accessioned in any DFO databases nor automatically linked to any sample metadata	With no coherent database housing genetic stock ID results, these need to be linked to collection metadata manually	Stock composition estimates are often delayed by 1 week during in-season management. Estimates of age composition by stock are also delayed, which may have relevance to gear-related management decisions
Sample data are not represented geospatially	Metadata pertaining to where fish were sampled is purely descriptive and cannot be directly pinned to a geographic coordinate	Higher uncertainty in appropriate fishing boundaries to mitigate incidental harvest on Hucuktlis sockeye
Sample metadata and results are spread across multiple databases that lack a shared ontology	Databases that house some of the Barkley sockeye stock ID and age sample information are not fully linked programmatically and lack common variable names, which increases manual workloads	Run reconstruction process is slowed down and error-prone

3. Forward planning

Addressing data management gaps should be the top priority in forward planning for Barkley sockeye stock ID and age sampling. The most impactful action would be to expand extant databases so they can house the presently unmanaged datasets and connect collection records to laboratory results. This includes developing or incorporating modules within databases to accept fry and smolt, escapement, and First Nation Treaty and FSC collection metadata. Some efforts to do so are underway, including through development of KREST (a successor to the CREST database) and an Aboriginal Harvest Monitoring System (AHMS). Getting these systems into production would markedly reduce the manual integration work currently required to generate analyses for management as well as improve data security and longevity. It would also be worthwhile to consider expanding regional databases to allow geospatial encoding of sample locations (available in CREST as of 2025) and to standardize variable names, most prominently, those that link sample collection metadata to laboratory results (e.g. scale book number, Whatman sheet number, etc. that currently have different variable names in each database).

There are also opportunities to taper some sampling activities without undermining management needs. Most notably, escapement age sampling could be reduced to smaller sample sizes or bi-weekly intervals once the population age structures have stabilized, freeing up sample allocations that could be redirected toward smolt ageing. Similarly, while adult fishery sampling must be maintained at high levels to support in-season decision-making, there may be situational opportunities to modestly reduce age sampling. However, because the CU of origin is unknown when fish are being sampled, any reduction risks losing valuable age data from rarely encountered Hucuktli fish. Given the importance of weekly stock composition estimates to in-season management, there is no opportunity to reduce stock ID sampling without impacting management needs.

Each of the above forward planning items for Barkley sockeye sampling carries trade-offs. Expanding regional databases to capture missing collection metadata requires financial investment, staff training, and additional work for program staff to accession historical records. This work is intensive in the short term but will yield worthwhile long-term gains. Incorporating geospatial or standardized variable conventions would likewise improve interoperability while requiring programming effort and user troubleshooting. Tapering escapement or fishery age sampling can provide cost savings or expanded capacity for smolt age sampling, but would reduce the temporal resolution of age data and risk under-sampling Hucuktli fish.

Overall, Barkley sockeye stock ID and age sampling programs are well attuned to management needs. Prioritizing improvements in sample data management will confer region-wide benefits pertinent to all management domains. Strategic tapering of age sampling could also be pursued if it does not markedly erode run reconstruction accuracy for any of the three CUs.

Table 14. Options and trade-offs for improving Barkley sockeye stock ID and age sampling efficiency.

Option	Benefits	Losses/risks	Implementation challenges	Initiatives
Develop regional database solutions for escapement and First Nation sample metadata	Reduce manual data management and errors Improve data security and longevity Address region-wide needs for improved sample data management	Transition effort	Staff training Accessioning historic data Significant financial investments are required for database development	STAMP KREST AHMS
Incorporate geospatial capabilities into sample databases	Allows spatial modelling of stock composition data and potential for improved area-based management	Increased burden on samplers to collect and digitize data	Significant new functionality would need to be programmed into existing databases	CREST
Standardize names of common variables across databases	Streamlines manual data collation Promotes shared vocabulary among salmon data practitioners	Breaks existing linkages to applicable database variables, all of which would need to be revised	Programming effort Data manager buy-in	DFO salmon ontology
Reduce Great Central and Sproat escapement age sampling to weekly or bi-weekly	Reduces number (and therefore cost) of escapement samples by half Scales could be reallocated to fry sampling programs, which have been under sampled in recent years	Reduces temporal resolution in escapement age data		

SOUTHERN BC ISBM CHINOOK

Scope

ISBM Chinook fisheries in southern BC include two FMUs: WCVI ISBM Chinook and (slightly confusingly) Southern ISBM Chinook. Both FMUs are reviewed in this case study because their marking and sampling frameworks are broadly congruent. These two FMUs collectively target six chinook salmon SMUs distributed across Vancouver Island, mainland inlets south of Bute Inlet, and the Fraser River watershed (Figure 5), and also regularly encounter American chinook stocks migrating into Puget Sound. These fisheries are actively managed to avoid harvesting other Fraser chinook SMUs that are poor or critical status. Summed together, these two FMUs comprise the seventh largest salmon fishery in British Columbia, as measured by average mass of fish harvested per year over the last decade (Figure 5).

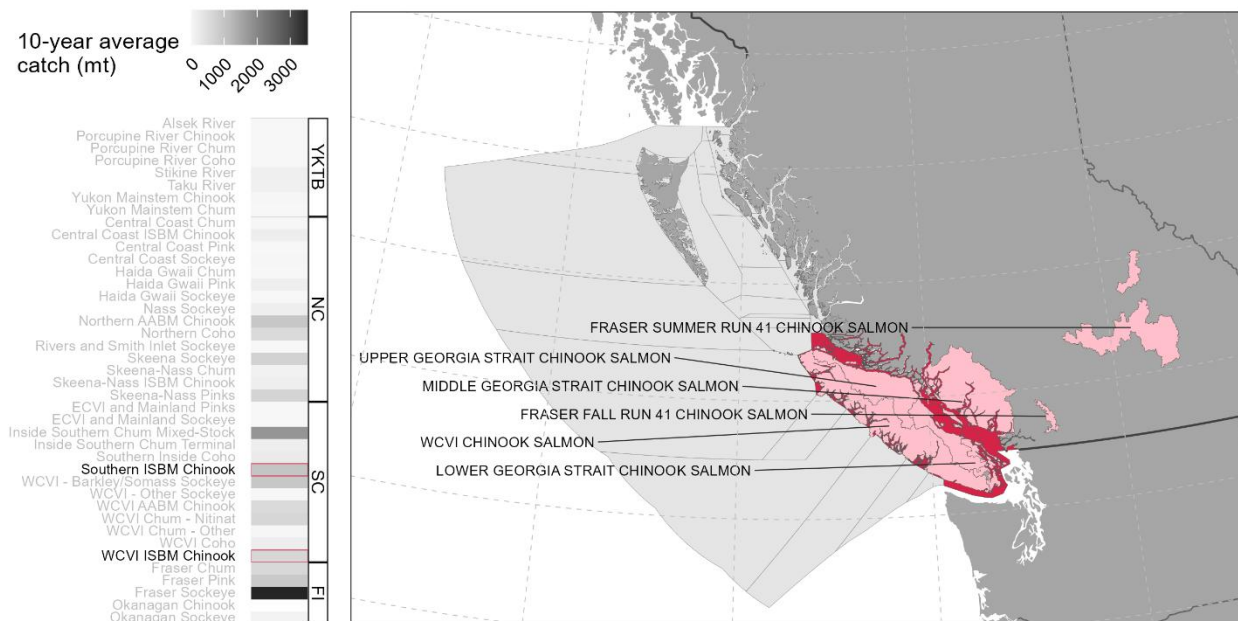


Figure 5. Geographical extent and magnitude of southern BC ISBM chinook fisheries and spawning grounds of targeted stocks. The labeled and shaded bands on the left show the magnitude of 2014–2024 average ISBM chinook catch (approximate weight) in relation to all other Fishery Management Units (FMUs). The map on the right shows all Pacific Fishery Management Areas (PFMAs; light grey polygons) with red polygons indicating the PFMAs where ISBM chinook fisheries in southern BC occur. The labeled pink areas show the extent of spawning watersheds encompassed in the Stock Management Units (SMUs) that are targeted by these fisheries; other non-targeted SMUs may also be harvested incidentally.

1. Documentation

Marking programs

Five different mark types are applied to southern BC chinook for stock identification and age determination:

1. CWT
2. Adipose fin clip
3. Genetic (PBT)
4. Otolith thermal mark

5. PIT tag

All of the above mark types, except otolith thermal marks, have been applied to both hatchery and natural-origin fish. However, while virtually all hatchery chinook release groups receive at least one mark type (Table 15), very few marking programs focus on natural-origin fish. Stock identification for natural-origin chinook in fishery samples is predominately achieved using GSI.

Across all hatchery chinook programs in southern BC, PBT is the most prevalent mark type applied, followed by otolith thermal marks, adipose fin clips, CWTs, and PIT tags, respectively (Table 15).

Table 15. Release and marking plans for 2025–2026 chinook enhancement programs in southern BC.

Regional Area	Hatchery facility/ program	Primary objective	Release target	CWT	Adipose Fin Clip	Adipose Fin Clip & CWT	PBT	PIT	Otolith mark
South Coast	Clayoquot	Rebuilding	200000	0%	0%	0%	100%	0%	0%
South Coast	Cowichan R	Production	605000	0%	0%	100%	100%	1%	100%
South Coast	Gwa'ni	Rebuilding	325000	0%	0%	0%	100%	0%	100%
South Coast	Nanaimo R	Rebuilding	717500	0%	0%	0%	100%	0%	91%
South Coast	Powell R	Production	830000	0%	0%	0%	100%	0%	0%
South Coast	San Juan R	Rebuilding	445500	0%	99%	0%	100%	0%	0%
South Coast	Sliammon	Production	100000	0%	0%	0%	100%	0%	0%
South Coast	Thornton Cr	Rebuilding	310000	0%	32%	13%	100%	0%	0%
South Coast	Gillard Pass	Production	100000	0%	0%	100%	100%	0%	0%
South Coast	Oyster R	Rebuilding	55000	0%	0%	0%	100%	0%	0%
South Coast	P Hardy/Marble	Production	1000000	0%	0%	0%	100%	0%	100%
South Coast	Sayward F&G	Rebuilding	120000	0%	100%	0%	100%	0%	100%
South Coast	Sooke R	Rebuilding	437500	0%	0%	0%	100%	0%	100%
South Coast	Tahsis R	Rebuilding	300000	0%	0%	0%	100%	0%	0%
South Coast	Tofino	Rebuilding	310000	0%	0%	27%	100%	0%	0%
South Coast	Big Qualicum R	Production	3000000	7%	0%	9%	100%	0%	0%
South Coast	Conuma	Production	3400000	0%	94%	0%	100%	0%	100%
South Coast	L Qualicum R	Production	2000000	0%	0%	0%	100%	0%	0%
South Coast	Nitinat R	Production	4100000	0%	11%	4%	100%	0%	100%
South Coast	Puntledge R	Production	2300000	0%	0%	3%	100%	0%	0%
South Coast	Quinsam R	Production	3584000	0%	0%	19%	100%	0%	100%
South Coast	Robertson Cr	Production	6475000	0%	90%	9%	100%	0%	99%
South Coast	Holberg In	Rebuilding	32000	0%	0%	0%	100%	0%	0%
South Coast	Juan de Fuca	Rebuilding	10000	0%	0%	0%	100%	0%	0%
South Coast	Kokish R	Rebuilding	45000	0%	0%	0%	100%	0%	0%
South Coast	Woss Comm H	Rebuilding	80000	0%	0%	0%	100%	0%	0%
Lower Fraser	L Campbell R	Rebuilding	50000	0%	0%	100%	100%	0%	0%
Lower Fraser	Nicomel R	Rebuilding	45000	0%	0%	0%	100%	0%	0%
Lower Fraser	Serpentine R	Rebuilding	100000	0%	0%	0%	100%	0%	0%
Lower Fraser	Capilano R	Production	560000	0%	0%	21%	100%	0%	0%
Lower Fraser	Chehalis R	Production	725000	0%	0%	55%	100%	1%	0%
Lower Fraser	Chilliwack R	Production	1500000	0%	0%	27%	100%	0%	67%
Lower Fraser	Inch Cr	Production	150000	0%	0%	100%	100%	0%	0%
Lower Fraser	Tenderfoot Cr	Rebuilding	200000	0%	0%	100%	100%	0%	0%
Interior	Kingfisher Cr	Rebuilding	40000	0%	0%	0%	100%	0%	0%
Interior	Shuswap R	Production	757000	0%	0%	92%	98%	0%	0%
Interior	Spilus Cr	Production	600000	0%	0%	42%	100%	0%	35%
Interior	N'Quatqua	Rebuilding	20000	0%	0%	100%	100%	35%	0%
Interior	Quesnel R	Rebuilding	251500	0%	0%	6%	100%	0%	0%
Interior	Spruce C	Rebuilding	94000	0%	0%	100%	100%	0%	0%
Interior	Tsilhqot'in	Production	24000	0%	0%	100%	100%	0%	0%
Grand Total:			35998000	1%	28%	14%	100%	0%	61%

Stock ID and age sampling programs

Programs that collect stock ID and age samples from southern BC ISBM chinook fisheries are orchestrated either by DFO South Coast Stock Assessment, DFO Fraser and Interior Stock Assessment, or DFO's Mark-Recovery Program.

South Coast Stock Assessment oversees the largest number of these stock ID and age sampling programs, including recreational creel surveys, commercial fishery sampling, and some First Nation fishery sampling (in partnership with local Nations) covering all marine waters surrounding Vancouver Island and southern mainland BC. Fraser and Interior Stock Assessment organize sampling programs focused on chinook fisheries occurring within the Fraser River, which include First Nation, recreational, and occasionally commercial fisheries. Both South Coast and Fraser and Interior stock assessment programs are focused on genetic, otolith, and scale samples, but occasionally collect CWTs as well.

The Mark-Recovery Program organizes systematic CWT sampling for all *Pacific Salmon Treaty* (PST)-applicable fisheries in southern British Columbia, with the exception of recreational fisheries, whose CWT sampling is accomplished through the creel program and voluntary angler submissions under the Salmon Head Recovery Program. CWT sampling is prosecuted through a contracted supply arrangement with J. O. Thomas and Associates, Ltd. (Vancouver, BC), which also provides laboratory services for extracting and reading the CWTs. CWT programs operate with the objective of attaining a 20% sample rate within PST-defined fishery groups (Pacific Salmon Commission Coded Wire Tag Workgroup 2008). This target is attainable in the CWT framework because fish can be rapidly inspected for presence or absence of a CWT either visually (in areas where all CWT fish are also adipose-fin-clipped) or using an electronic wand, such that every fish inspected adds to the total sample size whether it was implanted with a CWT or not.

Data management

Four different laboratories process stock ID and age samples from southern BC ISBM Chinook fisheries, and each of these labs delivers results in a different endpoint (database or excel; Figure 6). Sample collection event metadata are stored in two additional databases (CREST and FOS; Figure 6). There are some backend linkages among these databases that pair laboratory results to collection metadata: FOS and CREST automatically link age data from the Aging database to collection metadata; CREST additionally links otolith results directly from the Otomanager database. CREST also includes functionality to import individual genetic results files for chinook and wrap these with otolith and age results to produce a complete biodata table for all chinook sampled in South Coast creel surveys; this is known as the "Biological Data With Results" query. This query was programmed by South Coast Area biologists to assist in the substantial manual efforts of assembling complete biodata tables required for run reconstruction analyses.

Sample event metadata for First Nation FSC and Treaty fisheries do not fall within the scope of any extant databases and are instead stored in unmanaged spreadsheet files on shared network drives. Similarly, genetic results files do not currently have an operational database and are also stored in unmanaged spreadsheet files on shared network drives. A Genetic Results Database (GRD) is in active development and may become operational in the future.

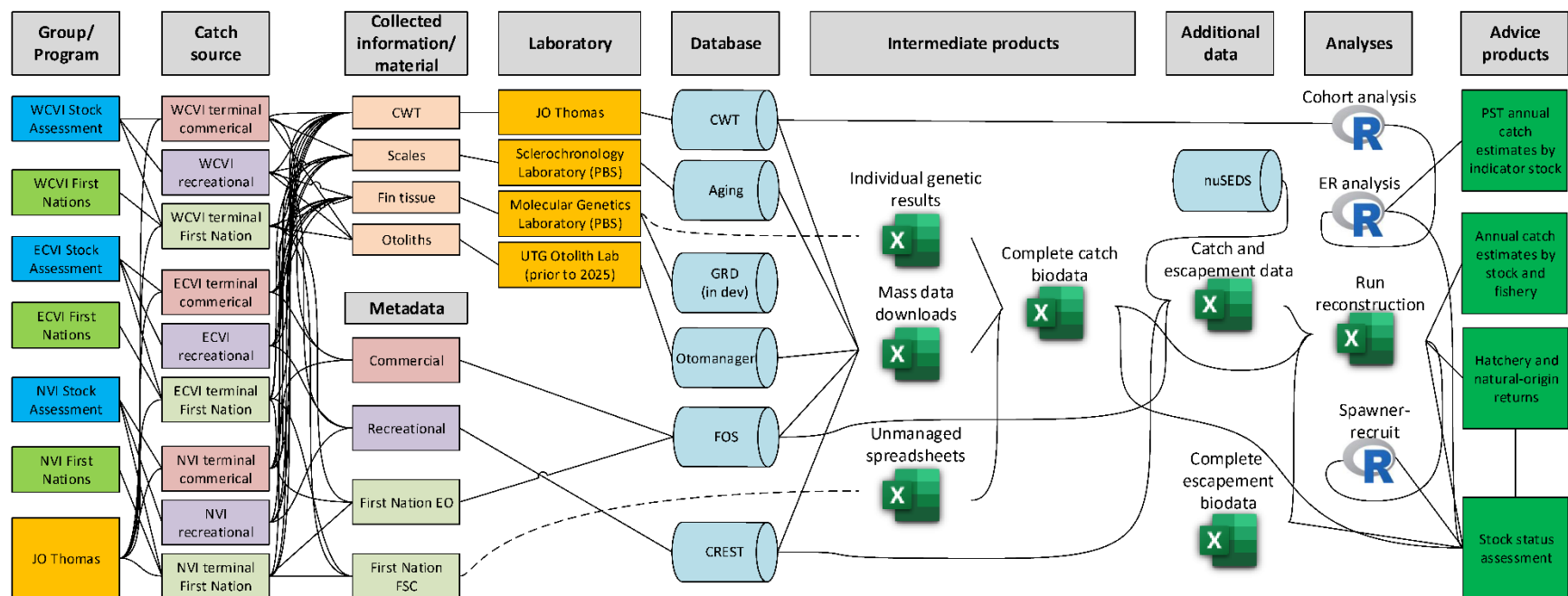


Figure 6. Flowchart illustrating southern BC ISBM chinook fisheries annual sampling programs and data pipelines.

Management framework

ISBM chinook fisheries are managed at a high level to achieve PST commitments, namely that the three-year running average calendar year exploitation rates (CYERs) on the following CWT indicator stocks are limited to 95% of their 2009–2015 base period averages: Robertson Creek & Quinsam (both adjusted to reflect natural-origin chinook), Cowichan, Nicola, Chilcotin, Chilko, Lower Shuswap, and Harrison (*Pacific Salmon Treaty*, Article XV, Annex IV, Chapter 3, Attachment I; Pacific Salmon Commission 2019).

In addition to these PST objectives, southern BC ISBM chinook fisheries are managed to address numerous domestic objectives, which can be broadly summarized:

- constrain harvest impacts on non-target stocks and species to acceptable levels;
- support rebuilding of wild chinook populations by minimizing harvest impacts;
- prioritize fishing access in accordance with the *Pacific Salmon Allocation Policy* (which is currently [under review](#)) (Fisheries and Oceans Canada 1999); and,
- maximize harvest benefits from major hatchery chinook production lines.

Domestic management operationalizes these objectives through a number of different processes. DFO organizes a BC-wide Integrated Harvest Planning Committee (IHPC) that engages First Nation, commercial, and recreational harvesters as well as environmental interests on development of the IFMP (Fisheries and Oceans Canada 2025c). At a finer scale, terminal chinook fisheries are generally managed discretely within PFMA. Annual allocations for terminal fisheries are determined based on the regional Salmon Outlook (Fisheries and Oceans Canada 2025a) or stock-specific forecasts (e.g. Brown 2024), and then managers work with local stakeholders or harvest committees to design and prosecute fishing plans. With respect to hatchery management, the Salmonid Enhancement Program operates an annual [production planning](#) process in consultation with internal and external parties to align chinook enhancement programs with sustainability and recovery goals.

Table 16. Southern BC ISBM chinook fisheries management decision inventory.

Decision/ accountability	Management domain	Frequency	Advice product(s) from stock ID and age sampling
Early-season harvest plans	Fisheries	Annual	Run reconstruction → pre-season forecast
In-season weekly fishing plans	Fisheries	Weekly	Current stock ID and age sample results → fishery stock composition estimates, weekly re- forecasts
Management measures for stocks of concern (including time, area, gear)	Fisheries	Annual	Run reconstruction → fishery mortality indices (FMI), fishery stock composition estimates (including % hatchery)

Decision/ accountability	Management domain	Frequency	Advice product(s) from stock ID and age sampling
Hatchery production plans	Enhancement	Annual	CWT recoveries → expanded returns by brood year, expanded catch by release group Run reconstruction → fishery stock composition estimates
PST reporting	Fisheries	Annual	CWT recoveries → Exploitation Rate Analysis → Calendar Year Exploitation Rate (CYER) by indicator stock
Mark-selective fisheries implementation	Fisheries	Annual	MSF reference fishery, stock ID sampling, visual adipose fin clip rates → mark rate analysis, stock and age composition estimates from kept and released fish
SMU status assessments	Fisheries, Enhancement, Habitat	5–10 years	Run reconstructions, age samples → spawner–recruit analysis → stock status assessment

2. Review & analysis

Alignment between marking, sampling, and management frameworks

Marking and sampling programs relevant to southern BC ISBM chinook fisheries are generally aligned with management needs (Table 17), although there are some notable discrepancies. The discussion below considers the CWT program separately from other stock ID and age sampling programs (focused on genetics, otolith, and scale) because its mandate is exclusively driven by Canada's PST commitments.

Table 17. Sample data–fishery management alignment matrix for southern ISBM chinook fisheries.

Dimension	Program	Current sampling provides	Fishery management requires	Notes/Gaps
Spatial resolution	CWT	PFMA, sometimes PFMA subarea	PFMA	
Spatial resolution	Other stock ID and age sampling	PFMA	PFMA	In areas where MSF implementation is being considered, finer than PFMA resolution may be required

Dimension	Program	Current sampling provides	Fishery management requires	Notes/Gaps
Temporal resolution	CWT	Daily	Monthly	Each CWT recovery is associated to a catch date or range of dates, which are rolled up by month for analysis
Temporal resolution	Other stock ID and age sampling	Weekly – monthly	Weekly – monthly	
Stock resolution	CWT	Indicator stocks	Indicator stocks	Some southern BC chinook stocks do not currently have an associated CWT indicator program (e.g. the Fraser Spring and Summer 5 ₂ SMUs; Dobson et al. 2020)
Stock resolution	Other stock ID and age sampling	Population (hatchery-origin) Population or CU (natural-origin)	Population (natural- & hatchery-origin)	Population-level resolution is available for all hatchery fish from all mark types (except visual adipose clips alone). GSI can provide population-level resolution for natural-origin fish when the genetic baseline is strong enough, but more typically it provides CU-level resolution.
Age resolution	CWT	Total	Total	Freshwater ages can be inferred from CWT data by interrogating the release strategies, but are not calculated programmatically
Age resolution	Other stock ID and age sampling	Total (PBT) Total & freshwater (scale)	Total	

CWT program

The chinook CWT program has two primary objectives: 1) implant sufficient numbers of CWTs in PST hatchery indicator stocks to ensure adequate tag recoveries across all relevant fishery strata, and 2) representatively sample and recover CWTs from fisheries, targeting per-fishery sample rates of 20%. These objectives support the Chinook Technical Committee's (CTC)

annual cohort and exploitation rate analyses, which yield CYER estimates for all Canadian and USA indicator stocks. The CTC also uses CWT data to forecast abundances and stock compositions of chinook indicator stocks in upcoming years, which fishery managers rely on to adjust fisheries to remain compliant with PST commitments. Thus, the CWT program functions well to support management needs within the PST framework.

However, there are shortcomings in the CWT mark-recovery paradigm, which have been recognized, debated, and workshopped both within and beyond the Pacific Salmon Commission for the last two decades (Hankin et al. 2005; Pacific Salmon Commission Coded Wire Tag Workgroup 2008; Satterthwaite et al. 2015; Pacific Salmon Commission Selective Fishery Evaluation Committee 2016; Beacham 2021). Below is a cursory summary of the issues:

- Statistical uncertainty in the cohort and exploitation rate analyses increases substantially when CWT recoveries dwindle. This has occurred previously due to poor marine survival and low ocean abundances of chinook in the mid 1990's and early 2000's, which were accompanied by extensive fishing restrictions (Hankin et al. 2005). Program reductions arising from fiscal constraints further compounded the issue. Such uncertainty hinders evaluation of harvest outcomes relevant to PST objectives.
- Fisheries and fishery management have been evolving in ways that are increasingly incongruent with the CWT program. Recreational salmon fishing has been expanding in magnitude and priority, leading to higher proportions of total salmon catch (and CWTs) occurring in diffuse fisheries that are more difficult to sample (Hankin et al. 2005). Selective fishing practices and non-retention measures are also expanding, leading to higher proportions of total mortality affecting non-landed fish (Hankin et al. 2005). Likewise, hatchery mass-marking programs are increasing, as is the demand for mark-selective fisheries (MSFs), which erode the ability to visually detect CWT-implanted fish and violate the assumption that exploitation rates on marked CWT fish are representative of unmarked natural-origin fish, respectively (Pacific Salmon Commission Selective Fishery Evaluation Committee 2016). Finally, salmon fisheries are being managed at finer geographic and temporal scales to mitigate harvest impacts on various stocks of concern. The CTC has updated its exploitation rate model to reflect these shifting scales, but CWT recoveries are being spread thin across strata as a result, leading to higher uncertainty and weaker management advice.
- There are issues with the representativeness of CWT indicator stocks for wild populations. First, CWT indicator stocks exist for only about one quarter of Chinook CUs identified in Canada (Beacham et al. 2021). Many CUs without a direct indicator thus rely on data from a nearby proxy, which may differ significantly in abundance and migration timing (Dobson et al. 2020). Second, the assumption that hatchery CWT populations accurately represent exploitation rates of natural chinook (or even nearby hatchery chinook) is not robust (Peterson et al. 2016; COSEWIC 2020). This assumption breaks down when hatchery and natural chinook differ in maturation rates and marine migration or distribution patterns.

The CWT program continues to be refined to address these issues. Following the CWT Action Plan (Pacific Salmon Commission Coded Wire Tag Workgroup 2008), indicator stock programs, fishery sampling, data management systems, and equipment were all improved or expanded to some degree (Pacific Salmon Commission Joint CWT Implementation Team 2015). Work is also underway to account for mark-selective fisheries analytically (Pacific Salmon Commission Calendar Year Exploitation Rate Working Group 2024). However, other issues persist: unsatisfactory representativeness of CWT indicator stocks, proliferation of mass marking, and management requirements for finer-scale data. PBT has been advanced as a viable and possibly preferable alternative (Satterthwaite et al. 2015; Beacham 2021), but carries its own

challenges (Hankin et al. 2015; Beacham 2021). Given the breadth of these issues and their relation to the PST, resolution lies outside the scope of this review and should continue to be advanced through the Pacific Salmon Commission.

Other stock ID and age sampling programs

All non-CWT southern BC ISBM chinook fishery sampling is conducted to support domestic management needs. These programs primarily target tissues (for PBT & GSI), otoliths, and scales, but also collect CWTs opportunistically if feasible. Spatial and temporal coverage is generally strong (Table 17), though some small or diffuse fisheries (e.g., certain First Nation FSC or freshwater recreational openings) inevitably elude sampling. The main tension between marking/sampling paradigms and management frameworks arises from stock-identification resolution for natural-origin chinook (Table 17).

Stock ID for chinook in southern ISBM fisheries is the most complicated among all salmon species and fisheries in BC. CWTs, otolith thermal marks, PBT, and GSI can all be used to determine chinook stock ID, and some or all of these methods are often available for each individual fish. However, information value varies among these methods. CWT and PBT both provide highly accurate stock ID and age data for hatchery chinook, although PBT error rates can increase due to incomplete or contaminated broodstock baseline sampling. Otoliths provide accurate stock ID data for hatchery chinook but error rates are subject to the quality of applied marks. GSI provides stock ID data for hatchery- and natural-origin chinook, with assignment accuracy varying according to the quality of available baseline samples and the degree of genetic differentiation among nearby populations.

Sampling programs have been shaped by these information value considerations as well as the regional prevalences of mark types and hatchery chinook. In general, chinook stock ID methods are prioritized accordingly: CWT > PBT > otolith mark > GSI. However, to avoid redundancy in stock ID methods, programs select methods heuristically on a case-by-case basis. Heads are collected for CWT extraction from adipose-fin-clipped fish in areas where hatchery chinook are not mass-marked, albeit these CWT'd fish are generally rare. Prior to the recent expansion of PBT, otolith marks were the best stock ID method available for unmarked hatchery chinook, as they are both cheaper and more accurate than GSI. Otoliths have thus been broadly collected in sampling programs, particularly on the WCVI, where hatchery chinook comprise the vast majority of landed catch in ISBM fisheries (Fisheries and Oceans Canada 2025e). GSI is the only stock ID method for natural-origin chinook and has been widely collected in creel programs, but GSI sampling is often waived in terminal fisheries that tend to harvest very high prevalences of hatchery-origin chinook (*circa* 90%).

This omission of GSI data from terminal fisheries is the first of two ways in which natural-origin stock ID data are not meeting management needs. To manage declining or threatened chinook populations, managers require accurate estimates of harvest across all fisheries that encounter each population. Even though southern BC ISBM chinook fisheries predominately harvest hatchery production stocks, the comparatively small numbers of natural-origin chinook caught can comprise significant portions of returning adults for small populations. Thus, waiving GSI sampling in terminal fisheries impedes managers from assessing where impacts on stocks of concern are highest.

The second way in which natural-origin stock ID data are not meeting management needs arises from GSI accuracy. GSI stock ID assignments are based on a panel of roughly 400 SNPs genotyped from over 100000 individuals obtained from populations spanning the entire chinook salmon range along the west coast of North America (Beacham et al. 2021). For BC chinook populations, individual GSI assignments are > 80% accurate for most individual CUs (E.

Rondeau, DFO Molecular Genetics Laboratory, Nanaimo, BC, pers. comm.). Chinook can sometimes be accurately assigned to populations (i.e. originating from a single river's watershed) via GSI, provided baseline sample sizes and the degree of genetic differentiation are both sufficient. Managers and many First Nations are increasingly interested in population-specific information to support local stewardship, harvest planning, and rebuilding objectives. However, for many southern BC chinook populations, gene flow among rivers within the same CU results in low genetic divergence, making population-level assignment scientifically indefensible despite interest in that resolution.

Data management gaps

Data management gaps relevant to southern BC ISBM chinook fisheries are more or less the same as those listed for Barkley sockeye, above: some First Nation collection metadata do not have designated databases, genetic stock ID results do not have a designated database, sample location data are not geospatially referenced or standardized to any naming convention, and databases that do store sample data and results lack a shared ontology (Table 18). In addition, there is a more minor issue of CWT stock ID results requiring an intermediate crosswalk table between E-labels and CWT codes to pair with sample metadata (Table 18). As these issues are systemic across Pacific Region salmon data, regional or national solutions are necessary.

Table 18. Southern BC ISBM chinook fisheries stock ID and age sample data gap inventory

Gap	Description of problem	Effect on advice
Sample metadata for First Nation Treaty and FSC catch are not accessioned in regional DFO databases	Collection metadata are not maintained to consistent standards and sample results need to be linked to metadata manually. It is extremely difficult to combine datasets when data are not stored in reliable locations and/or are not standardized across systems. In addition, data are not properly secured against loss or deletion.	Stock and age composition estimates corresponding to these data are delayed and error-prone.
Genetic stock ID results are not automatically linked to any sample metadata	With no coherent database housing genetic stock ID results, these need to be linked to collection metadata manually.	Stock composition data are slower to compile and assimilate, adding strain and occasional transgressions of management reporting timelines.

Gap	Description of problem	Effect on advice
Sample data are not represented geospatially	Metadata pertaining to where fish were sampled is purely descriptive and cannot be directly pinned to a geographic coordinate.	Spatial resolution on stock distributions is low, precluding advice to inform finer-scale area-based management measures
Sample metadata and results are spread across multiple databases that lack a shared ontology	Databases that house sample collection metadata and the sample analytical results are not linked programmatically and lack both common variable names and controlled vocabularies, which increases manual workloads.	Run reconstruction process is slowed down and error-prone
CWT data require two data join steps to link back to sample metadata	CWT salmon heads are given an “E-label” in the field, which is then attributed to a CWT code, which can then be linked to a stock ID. This requires an intermediate lookup table (E-label → CWT code).	Connecting to sample results can sometimes be delayed when the intermediate lookup table hasn’t been populated.

3. Forward planning

The review and analysis above identified constraints that limit the potential of genetic methods and some redundancy among stock ID and age sampling programs. Forward planning should therefore focus on two objectives: 1) expand and enhance genetic sampling, and 2) review status quo otolith and scale sampling programs that may no longer be the most efficient means of attaining stock ID and age information.

Expanding genetic sampling and enhancing GSI accuracy

While expanding sampling, particularly GSI for natural-origin fish, would bring immediate improvements to management advice, it requires additional support and resources for the MGL. MGL currently operates at the ceiling of its throughput capacity for sample processing during the busy management reporting season. In any given month, MGL can process approximately 12000–13000 samples. However, most chinook (and other species) samples are collected between August–November, with results required for management reporting by March. Thus, MGL is strained to process a huge volume of samples between the November–February surge period, and cannot absorb more.

Improving population-level GSI accuracy has potentially higher immediate feasibility. It could be achieved through collecting more baseline samples from key populations and/or exploring expanded or alternative SNP panels. Updating population baselines should be possible under current MGL resourcing provided these samples are processed outside of the surge period.

However, management expectations might need to adjust in areas where population-level accuracy is unachievable. For example, some chinook populations along the WCVI have been impacted by decades of hatchery straying to the point that these populations are now effectively

genetically homogenous (Weil et al. 2025). In such cases, the perspective of managers and stakeholders will need to shift away from managing these as individual populations.

Revaluating otolith and age sampling in light of expanded PBT

Currently, there is considerable overlap in southern BC ISBM chinook sampling programs among otolith and genetic sample collection and analysis. As PBT coverage has expanded to encompass most southern BC hatchery chinook production, the advantages of routine otolith marking and sampling have largely eroded. Otolith thermal marking began in Pacific Region in 1995, well before the development and expansion of PBT, and offered a practical, inexpensive method for mass marking hatchery chinook (O'Brien et al. 2012). However, otolith thermal marking, sampling, and processing are more challenging compared to PBT.

Applying thermal marks requires hatcheries to rapidly manipulate water temperatures by at least 4°C using a different water source or a chiller. Not all hatcheries can access different water sources and chillers are expensive. Even when hatcheries can manipulate water temperatures, numerous potential sources of error can affect the marks, occasionally leading to complete marking failure (O'Brien et al. 2012; Weil et al. 2025).

Otolith field sampling and laboratory processing also require more manual effort compared to PBT. Otolith collection requires *in situ* dissection of fish heads compared to a simple fin hole punch for PBT. In the laboratory, otoliths must be carefully ground down and individually inspected under a microscope to read marks compared to inserting batches of 100 PBT samples at a time into a sequencing machine.

On the other hand, PBT is subject to its own issues. Contamination among tissue samples or incomplete sampling of parents during broodstock operations can result in marking failure for significant portions of the resulting hatchery chinook progeny. Such issues may be more likely to arise in large production lines where broodstock operations are often a frantic endeavour involving a dozen or more staff quickly processing high volumes of fish. Thus, the strength of PBT marking should be carefully considered on an area-specific basis prior to phasing out otolith sampling.

Over the last decade, approximately 3800 otolith samples per year have been processed for stock ID from southern BC chinook fisheries (including AABM and ISBM). A portion of these samples are already also submitted to MGL for PBT/GSI analysis. Gradually switching from otoliths to PBT on a program-by-program basis could thereby provide a manageable transition pathway where the modest additional samples could be strategically worked in to the MGL stock ID workplan during surge months.

Beyond stock ID, PBT expansion also presents an opportunity to streamline age sampling for hatchery-origin chinook. Several major chinook production lines are now 100% adipose-fin-clipped and PBT'd (Table 15). Because PBT provides accurate age data in addition to stock ID (Table 3; Beacham et al. 2021), samplers encountering adipose-clipped chinook could forgo collecting scales. Compared to other species, particularly sockeye and chum, chinook scales are more difficult to read and so samplers typically collect 2–5 scales per fish instead of 1–2 (MacIellan 1987). The main trade-off with this approach is that analysts seeking freshwater age in addition to total age would need to look up or join the release strategies for each hatchery stock (Table 17). The same is true of CWT, but it is more difficult under PBT to attribute fish to individual release groups (Satterthwaite et al. 2015), so for hatcheries that produce both age-0 and age-1 chinook, freshwater age information could be lost if using only PBT for aging.

Considerations for coordinated forward planning

As outlined above, it would be strategic to begin planning for the careful, staged deprecation of southern BC Chinook otolith marking and sampling, contingent on demonstrated strength in PBT marking rates and sufficient MGL processing capacity. Rather than an abrupt transition, this would be best achieved through an annual planning process that evaluates marking success, sample requirements, laboratory constraints, and management priorities in an integrated manner. Establishing a standing regional working group attended by area Stock Assessment and Resource Management, SEP planning and assessment, and MGL staff would enable affirmative decisions on sampling strategies each year, with a clear view toward longer-term efficiency gains. Such a forum could guide when and where otolith sampling can be responsibly reduced, identify conditions (e.g. expected hatchery-origin mark rates) under which scale sampling can be forsaken in favour of PBT, and ensure that transitional risks are mitigated. This approach could meaningfully advance a more streamlined, genetics-centred sampling framework that better aligns effort, capacity, and information value across southern BC chinook fisheries.

Table 19. Options and trade-offs for improving Barkley sockeye stock ID and age sampling efficiency.

Option	Benefits	Losses/risks	Implementation challenges	Initiatives
Deprecate the otolith marking and sampling program in favour of PBT	Eliminates marking redundancy with PBT. Improves sampling efficiency in the field. PBT is a more reliable mark than otolith thermal marks. Harmonizes hatchery- and natural-origin chinook stock ID analysis pipeline.	Incorrect stock ID assignments may be more probable for PBT than for otoliths if particular hatchery production groups have poor PBT rates.	MGL would need to absorb even more samples during the challenging November–February surge period	A smaller working group in DFO South Coast Stock Assessment is pursuing alternatives to the otolith stock ID program for WCVI chinook fisheries
Cease collecting scale samples from adipose-fin-clipped chinook in favour of PBT	Improves sampling efficiency in the field. Eliminates redundancy in age sample sources, freeing up processing capacity in the Sclerochronology Lab.	PBT may not always be able to indicate freshwater ages of hatchery chinook	Requires hatcheries to PBT sample parents of all brood that w	SEP is piloting this option in some of their hatchery chinook broodstock sampling programs.

Option	Benefits	Losses/risks	Implementation challenges	Initiatives
Develop regional database solutions for First Nation sample metadata	Reduce manual data management and errors Improve data security and longevity Address region-wide needs for improved sample data management		Staff training Accessioning historic data Significant financial investment	KREST AHMS
Incorporate geospatial capabilities into sample databases	Allows spatial modelling of stock composition data and potential for improved area-based management	Increased burden on samplers to collect and digitize data For some datasets, fishing locations or names are considered DFO internal data	Significant new functionality would need to be programmed into existing databases	CREST
Standardize names of common variables across databases and adopt controlled vocabularies	Streamlines manual data collation Promotes shared vocabulary among salmon data practitioners	Breaks existing linkages to applicable database variables, all of which would need to be revised	Programming effort Program staff buy-in	DFO salmon ontology

SUMMARY AND NEXT STEPS

The strategic framework outlined in this report provides a structured, repeatable approach for reviewing salmon marking, stock identification, and age sampling programs. By organizing reviews around three core steps—documentation, review and analysis, and forward planning—the framework makes explicit the data, workflows, and decision contexts required to align sampling programs with management needs. To support these reviews, we developed the Pacific Salmon Biosample Inventory (PSBI), which consolidates regional sample records, metadata, and management classifications into a single system. However, the PSBI records are incomplete. As per Table 6, many records have still not been attributed to SMUs or FMUs. Subject matter experts undertaking sampling program reviews could improve the PSBI by

reviewing records from their areas, which would increase the data available for their own reviews and expand the resource for future users.

Applying the strategic framework to two case studies revealed consistent themes, most notably that sampling program reform will require sustained regional or national coordination in data management. Funding from the Pacific Salmon Strategy Initiative enabled formation of the Data Stewardship Unit, which drove important progress through initiatives such as STAMP, the GRD, and the DFO salmon ontology. However, these systems will require continued and predictable support to deliver their full value. Stable funding would allow for retention of experienced staff who can design data management systems with long-term vision and ensure they evolve alongside management needs. By contrast, episodic funding has historically produced short bursts of development followed by prolonged stagnation, with substantial friction arising from recurring staff turnover and unnecessary re-prioritization.

A second major recommendation concerns the need for a formal review of the chinook otolith marking and sampling program in southern BC. Evidence from the southern BC ISBM chinook case study indicates that routine otolith collection is increasingly inefficient relative to genetic methods, and future planning should pursue a phased deprecation in favour of PBT/GSI-based stock and age determination, contingent on processing capacity at the Molecular Genetics Laboratory (MGL).

The review framework should now be applied to additional case studies, prioritizing those where sampling program issues are already known or frequently raised. Focusing early effort on these “squeaky wheels” will yield high immediate value, reveal recurring structural problems, and build momentum for incremental reform. Such targeted reviews will also improve confidence in future recommendations by grounding them in accumulating evidence.

Economic assessments will be required to advance some of the recommendations emerging from this work, and likely from future reviews as well, to evaluate feasibility and long-term cost-benefits. For instance, assessing the costs and benefits associated with deprecating the otolith program would clarify where efficiencies could be realized and whether those savings could justify new investments, such as expanding processing capacity at MGL. Incorporating these economic analyses into follow-up work will help ensure that strategic decisions are fiscally advantageous.

Finally, there is a compelling opportunity for managers to view sampling program reform not merely as an efficiency exercise, but as a pathway to transformative new information products. With modernized data systems, interoperable databases, and streamlined marking and sampling protocols across regions and species, it would become possible to generate a coastwide, stock-specific reconstruction of all Canadian salmon catch, resolved at least to the SMU level and in many cases to the CU level. Achieving such a product would substantially advance Canada’s policy mandate to manage Pacific salmon on a stock-specific basis under the Sustainable Fisheries Framework and Fish Stocks provisions. Realizing this vision relies on the reforms outlined in this document, but the payoff of attaining a holistic understanding of stock-specific harvest would be profound.

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