NORTH PACIFIC ANADROMOUS FISH COMMISSION

TECHNICAL REPORT 13

Report of the Proceedings for the IYS Workshop
International Year of the Salmon Workshop on Salmon Status and Trends

Technical Editors: James R. Irvine, Kelly Chapman, and Jeongseok Park

Vancouver, Canada, 2019
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Report of the Proceedings for the IYS Workshop

*International Year of the Salmon Workshop on Salmon Status and Trends*

*Vancouver, BC, Canada, January 23–24, 2019*

**Location:** Morris J Wosk Centre for Dialogue 580 W Hastings St., Vancouver, BC, Canada

**Sponsors:** Fisheries and Oceans Canada (DFO), North Pacific Anadromous Fish Commission, North Pacific Research Board

**Conveners:** Jim Irvine (DFO) and Mark Saunders (NPAFC IYS)

**Steering Committee:**

- **Gérald Chaput** (DFO Science; SAG of IASRB)
- **Sue Grant** (DFO Science; DFO IYS/State of Salmon)
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Preface

The International Year of the Salmon (IYS) is an international framework for collaborative outreach and research that seeks to increase understanding and raise awareness of the challenges facing Pacific and Atlantic salmon and the measures to support their conservation and restoration against increasing environmental variability. The overarching theme of the IYS is “Salmon and People in a Changing World”, and the research themes are (1) status of salmon; (2) salmon in a changing salmosphere (the current and future geographic range of salmon); (3) new frontiers; (4) human dimension; and (5) information systems.

Fisheries and Oceans Canada (DFO) and the North Pacific Anadromous Fish Commission (NPAFC) co-hosted an IYS workshop on Pacific and Atlantic salmon status and trends in Vancouver, BC, on 23–24 January 2019. The workshop was attended by 25 international salmon experts and scientists with expertise in salmon in the Pacific, Atlantic, and Arctic oceans. Support staff from NPAFC also attended. Overview presentations on state changes and trends were provided for Sockeye, Pink, Chum, Chinook, and Atlantic Salmon with incidental information provided for Steelhead, Coho, and Cherry Salmon. Legacy datasets were identified, temporal patterns documented, state changes and trends discussed in relation to potential drivers and mechanisms, and future work needs identified.

The Workshop Steering Committee consisted of Gérald Chaput (DFO Science, Moncton), Sue Grant (DFO Science, Vancouver), Carrie Holt (DFO Science, Nanaimo), Kim Hyatt (DFO Science, Nanaimo), Jim Irvine (Steering Committee Chair, DFO Science, Nanaimo), Martha Robertson (DFO Science, St. John’s), and Mark Saunders (NPAFC IYS, Vancouver). Kelly Chapman facilitated the workshop.

On behalf of the Workshop Steering Committee, we thank all presenters and participants for sharing information and addressing the topics related to the IYS research themes at the workshop and for submitting materials for this volume. Financial support was provided by DFO, NPAFC, and the North Pacific Research Board. Technical Report No. 13 includes a compilation of extended abstracts submitted by workshop presenters and documentation and summaries of discussions and research priorities identified at the workshop. Material in this report has not been peer-reviewed and does not necessarily reflect the views of NPAFC, member countries, or authors’ agencies. The assistance of Stephanie Taylor (NPAFC IYS Coordinator), Nathan Bendriem (2019 NPAFC Intern), and Jennifer Chang (Administrative Officer) leading up to and during the workshop was greatly appreciated.

James Irvine
Steering Committee Chair
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International Year of Salmon (IYS) Workshop on Salmon Status and Trends

1 BACKGROUND

1.1 Problem Statement

In recent decades, the productivity of salmon has become increasingly uncertain with many populations experiencing extremes related to changes in timing, abundance and size with serious social, economic and conservation impacts. Much has been learned in previous workshops (e.g., NPAFC 2018, 2019a) but a lack of consistency in approaches to categorize biological status and trends, terminology to indicate status, requirements and standards for different types of data, spatial and temporal scales for comparison and aggregation, and ways of communicating findings significantly impedes the timeliness, efficiency and effectiveness of scientific investigations. Our data systems do not match our technological capacity and social/scientific inquiry needs. Many agencies have a commitment to open data but are challenged to achieve it given the significant costs associated with bringing historic data online. Increasing variability in a rapidly changing environment demands rapid access to integrated data for comparative and mechanistic studies of the distribution and productivity of salmon across life history stages and associated eco-regions.

1.2 International Year of the Salmon (IYS)

The International Year of the Salmon (IYS) is a five-year outreach and research initiative of the North Pacific Anadromous Fish Commission (NPAFC) and the North Atlantic Salmon Conservation Organization (NASCO). IYS seeks to inspire/motivate/activate a new hemispheric-wide partnership of government, academia, stakeholders, non-governmental organizations, Indigenous Peoples, and industry that will drive an intense burst of outreach and research to create a well-informed community of decision-makers who can establish the conditions necessary for the resilience of salmon and people in an uncertain future (see Table 1-1). Specifically, the IYS will stimulate an investment in research and leave a legacy of knowledge, data/information systems, tools, and a new generation of scientists better equipped to provide timely advice to inform the hundreds of decisions made daily by private individuals, conservation organizations, businesses, fisheries, and environmental managers that affect salmon.

The IYS Information Systems outcome (Table 1-1) of “freely available information systems contain historic and current data about salmon and their environment” is foundational to further achieving the Status of Salmon and Salmon in a Changing Salmosphere outcomes. A series of workshops, each building on the previous, are proposed to establish at the hemispheric scale, standardized approaches of defining metrics for salmon status and trends and their associated environments. Participation and leadership at individual workshops will vary depending on the specific goals of each workshop.

1.3 IYS Workshop on Salmon Status and Trends

The International Year of Salmon January 2019 Workshop on Salmon Status and Trends (hereafter, referred to as ‘the workshop’) was held from January 23–24, at the Morris J Wosk Centre for Dialogue in Vancouver, BC, Canada. The primary goal of the workshop was to bring together salmon ecologists interested in working with others on representative times series of data and associated metadata to understand salmon status and trends. The specific objectives of the workshop were to: 1) identify a series of legacy datasets (and associated standards where possible), 2) look at broad temporal patterns for salmon data categories, and 3) link observed state changes and trends to potential drivers and mechanisms. The workshop builds on one held in 2018 (NPAFC 2019a) and
immediately preceded one developing an International Salmon Data Laboratory (NPAFC 2019b).

The report that follows documents the proceedings of the workshop and results from a questionnaire following the workshop. It also provides recommendations for research programs and projects to improve our ability to understand salmon status and trends.

Table 1-1. IYS Outcomes.

<table>
<thead>
<tr>
<th>IYS Outcomes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Status of salmon</td>
<td>The present status of salmon and their environments is understood.</td>
</tr>
<tr>
<td>Salmon in a changing Salmosphere</td>
<td>The effects of environmental variability and human factors affecting salmon distribution and abundance are understood and quantified.</td>
</tr>
<tr>
<td>New frontiers</td>
<td>New technologies and analytical methods are advanced and applied to salmon research. Research is carried out to fill gaps in poorly studied regions of the salmosphere.</td>
</tr>
<tr>
<td>Human dimensions</td>
<td>Communities, Indigenous Peoples, youth, harvesters, scientists and resource managers across the Northern Hemisphere share knowledge and collaborate in the development of new tools and approaches to restoring, managing and sustaining salmon.</td>
</tr>
<tr>
<td>Information systems</td>
<td>Freely available information systems contain historic and current data about salmon and their environment.</td>
</tr>
<tr>
<td>Salmon outreach and communication</td>
<td>People understand the value of healthy salmon populations and engage to ensure salmon and their varied habitats are conserved and restored against the backdrop of increasing environmental change.</td>
</tr>
</tbody>
</table>

1.4 Workshop Structure and Objectives

1.4.1 Introductory Session

The two-day workshop was chaired by Jim Irvine, Research Scientist with the Department of Fisheries and Oceans Pacific Biological Station, who began Day One by reviewing the workshop objectives and agenda (below and Appendix A, respectively).

Primary objective:
1. identify a series of legacy datasets and where possible, associated standards (e.g., accuracy and reliability)

Secondary objectives:
2. Day 1—look at broad temporal patterns:
   a. for three salmon data categories:
      i. catch and pre-fishery abundance (i.e., catch plus escapement),
      ii. survival, distribution, and productivity (including stock and recruitment, recruits/spawner, freshwater and marine survival), and
      iii. biological trait information (e.g., size at age, age at maturity, age and sex composition), and
   b. three spatial scales:
      i. Ocean Basin (i.e., Atlantic vs. Pacific (all species); trends among species within Pacific)
ii. Regional (broad regions within Atlantic and Pacific)
iii. Population (or Conservation Unit) specific

3. Day 2—link state changes and trends from Day 1 to potential drivers and mechanisms (hypotheses) and identify data requirements for more thorough evaluation

4. Identify additional datasets, data providers, and other information necessary to better understand how natural environmental variability and human factors affect salmon status and trends, and

5. To achieve IYS outcomes, identify next steps including a) improved documentation of data standards (accuracy, precision, metadata), and b) coordinated data assembly, integration, storage, processing, analysis and communication of findings.

A roundtable of introductions followed (see participant list in Appendix B). Mark Saunders, IYS Director for the Pacific Region (NPAFC), then gave an overview presentation of the International Year of the Salmon (Appendix C).

1.4.2 Overview Presentations

Dr. Irvine chaired a series of overview presentations on trends in selected salmon species at basin-wide to local-area spatial scales. Extended abstracts from these presentations are located in Section 2. The overview presentations were followed by a lunchtime presentation by Scott Akenhead (Appendix D) introducing the International Salmon Data Laboratory (ISDL) Workshop held on January 25, 2019.

1.4.3 Plenary Discussions

Dr. Kelly Chapman facilitated a series of three plenary discussions on data, drivers and mechanisms, and next steps. The outcomes of these discussions are detailed in Sections 3 to 5. Following the workshop, participants were sent a questionnaire to further refine and synthesize their views from the plenary discussion on data. The results from this questionnaire are located in Appendix F and summarized in Section 3.2.1.

1.5 References Cited


2 OVERVIEW PRESENTATIONS: TRENDS IN SELECTED SALMON SPECIES AT BASIN-WIDE TO LOCAL-AREA SPATIAL SCALES
An Overview of Sockeye Salmon Trends at Basin-wide to Local-area Spatial Scales in the North Pacific Ocean

Kim D. Hyatt, Fisheries and Oceans Canada, Science Branch, Pacific Biological Station, Nanaimo, B.C., Contributions by: M. Stockwell¹, H. Stiff², P. Rankin¹, R. Ferguson¹, B. Hanslit¹, S. Cox-Rogers¹, C. Carr-Harris¹, A. Ogden¹, J. Irvine¹, S. Grant¹, B. MacDonald¹, D. McQueen², E. Hertz³, H. Wright⁴, D. Machin⁴, R. Alexander⁴, J. Fryer⁵, and A. Munro⁷

¹Fisheries and Oceans Canada, ²York University (emeritus), ³Pacific Salmon Foundation, ⁴Okanagan Nation Alliance, ⁵LGL Ltd, ⁶Columbia River Intertribal Fisheries Commission, ⁷Alaska Department of Fish and Game

A central problem in understanding how species respond to global changes exists in parsing the effects of local drivers of population dynamics from regional and global drivers that are shared among populations (Ohlberger et al. 2016). Uncertainty regarding the relative importance of productivity factors operating at different spatial scales hinders the prioritization of science and management activities (Zimmerman et al. 2015). Here, we examined time series observations of annual production variations for Sockeye Salmon populations originating from freshwater systems around the rim of the North Pacific Ocean. Historic production patterns were considered within a hierarchy of spatial scales including aggregated returns of adult Sockeye Salmon to (1) the entire north Pacific basin; (2) the north-central coast of British Columbia; (BC), (3) the south-coast of BC; and (4) disaggregated adult returns to several local-area watersheds representing southern, central, northern and Alaska transboundary areas of BC.

Adult returns aggregated at a Pacific basin scale indicated that between 1980–2015, total production of Sockeye Salmon in the Pacific was far above the 50-year average observed from 1925–1975 (Figure 1). Ruggerone and Irvine (2018) documented the average contribution to total Sockeye production for 1990–2015 by area of origin which indicated that Sockeye returns to Bristol Bay Alaska alone accounted for 48% of the basin-wide total and that stocks originating from BC contributed the second largest proportion at 16% of total production. By contrast, sub-basin scale trends exhibited by aggregated returns of adult Sockeye to BC’s north-and-central coast (Fig. 2a) and BC’s south-coast (Fig. 2b) areas revealed a relatively constant decadal-scale level of average production in 1950–1990 followed by a 30–40% decrease in average returns to both areas between the early 1990s and present (Connors et al. 2018). This pattern is markedly different from the basin-wide aggregate and is consistent with the observations of the existence of a north-south inverse production pattern for salmon (Mantua et al. 1997, Hare et al. 1999).

However, as was the case for the basin-wide pattern of returns, aggregated patterns of returns to both sub-basin scale areas in BC were dominated by a few large Sockeye populations in the north-and-central coast area (i.e., Nass-Meziadin and Skeena-Babine) as well as in the south-coast (i.e., less than a dozen large Fraser River populations such as Chilkco, Adams and Quesnel).

Although aggregate patterns of returns at both Pacific-basin and sub-basin scales are revealing with respect to trends in the biomass variations of adult fish available for harvest at relatively coarse geographic scales, the dominance of contributions from relatively few stocks or populations of fish (i.e., no more than a couple of dozen out of hundreds of Sockeye populations) to the aggregate of numbers or biomass will conceal a wider variety of return trends associated with environmental variations at finer spatial scales of resolution. For example, productivity (R/S) residuals from either Ricker or Larkin S-R models fitted to each of 18 Sockeye populations from the Fraser River suggest the general occurrence of relatively low levels of productivity covariance among stocks (Grant et al. 2017). This should not be surprising given that these stocks originate from climatologically disparate areas scattered throughout the broad geographic extent of the Fraser basin spanning seven degrees of latitude and six bio-geo-climatic zones.
Over the past 90 years, Sockeye Salmon numbers of originating from North Pacific rim countries have varied from a low of roughly 30 million to a high of almost 125 million fish.

Between 1980 and 2015, the North Pacific has sustained total returns averaging roughly 85 million fish as opposed to significantly lower average returns of 45 million fish between 1925–1980.

Yellow color shows a portion of hatchery-origin sockeye.

**Fig. 1.** Basin-scale Trends: Total Production of Sockeye Salmon in the North Pacific from 1925–2015 (adapted from Ruggerone and Irvine, 2018).

Catch (jade green) and escapement (gray) making up total returns of which >70% of the North and Central Coast aggregate originate from the Meziadin (Nass) and Babine (Skeena) Sockeye CUs.

Total returns (catch plus escapement) of which >70% of the South Coast aggregate originates from the less than a dozen productive Fraser R. CUs.

**Fig. 2.** Sub-basin-scale Trends: Total abundance trends for adult Sockeye Salmon stock aggregates returning to BC’s North and Central Coast and South Coast. The NCC aggregate abundance decrease of 30% after 2000 and for south-coast aggregate by >30% after 2005 have raised fisheries management concerns (source: Eric Hertz and Pacific Salmon Foundation [http://data.salmonwatersheds.ca/data-library/default.aspx](http://data.salmonwatersheds.ca/data-library/default.aspx)).

However, Grant et al. also observed relatively short periods during which the majority of Fraser River Sockeye stocks did register similar productivity anomalies (e.g., lower than projected productivity for brood years 2005, 2011 and 2012) suggesting sporadic dominance of powerful overarching environmental drivers of salmon production patterns. Similarly, Hyatt et al (2011, 2018) found that temporal trends in total production of Sockeye Salmon populations or stocks originating from local areas representing the
entire BC coast (Fig. 3) exhibit relatively low levels of covariance suggesting that local-scale rather than basin-scale drivers exert much of the control over annual variations in production (and productivity). Populations frequently co-vary over multi-year intervals at local area scales (i.e., 300 km or less) and especially if they share a common sea-entry domain (e.g., Somass and Okanagan Sockeye both make sea entry into the northern California Current system, Fig. 3 bottom panels). By contrast, even though Somass River Sockeye and Fraser-Chilko Sockeye points of sea entry are geographically closer together than those of Somass and Okanagan Sockeye, the former exhibit relatively weak co-variation (Hyatt and Stiff, unpublished analysis). This is likely related to their sea-entry into different marine domains (i.e., Salish Sea versus California Current system). In common with results of Grant et al. (2017), there are occasional return years in which regional scale synchrony of anomalously high or anomalously low production (and productivity) occurs across virtually all stocks (e.g., Fig. 3: high 1990, 2010; low 2005, 2017).

Fig. 3. Local area, decadal-scale trends: Total Sockeye returns (1000s) by index stock and area, 1975–2017 (Hyatt et al. 2018).

Analyses of recruit-per-spawner (R/S) indices of salmon productivity have provided considerable insight into the spatial and temporal patterns associated with salmon production trends in the eastern Pacific in particular (Mueter et al. 2002a,b; Pyper et al. 2005, Peterman and Dorner 2012, Malick et al. 2015, Ohlenberger et al. 2016, Dorner et al. 2017). However, the majority of these studies have provided only weak inferences that much of the variation of interest is driven by marine as opposed to freshwater processes because R/S observations by definition reflect cumulative effects on all life stages of salmon between their parental stock and subsequent adult recruitment phases. Further, correlation analysis between R/S indices and various sets of independent environmental data series in the majority of these studies implicate not only effects associated with the time of early marine entry but also with preceding intervals in freshwater (Mueter et al. 2002, Peterman and Dorner 2011, Ohlenberger et al. 2016; but also see Malick et al. 2015).

Stronger inferences about the location and identity of mechanisms driving annual production variations of salmon are possible through development and analysis of relatively data rich “index stocks” for which time series observations of relative contributions of freshwater and marine productivity variations to overall production outcomes are tracked. For example, the spectacular decline in Smith Inlet (and River’s Inlet) Sockeye Salmon stocks on the B.C. central coast (bottom left panel, Fig. 4) in the early 1990s (McKinnell et al. 2001) clearly had marine origins as indicated by the order of magnitude decline in
smolt-to-adult return rates beginning with the 1990 brood year and extending to present (top right panel, Fig. 4). Some of the post 1990 production variations appear to be associated with biophysical changes in Hecate Strait that favour covariance of both salmon survival and fledging success of rhinoceros auklets (Borstad et al. 2011). By contrast, the occurrence of small production event increases centered on the 2002 return year appear attributable to density-dependent compensation in freshwater survival rates (bottom right panel, Fig. 4) of 1999–2000 brood-year spawners in response to very low escapement levels that likely situated Sockeye reds in the highest quality spawning areas in the system. However, we are unable to clarify additional details of either the marine or freshwater mechanisms controlling trends in Smith Inlet (and River’s Inlet) production due to the scarcity of well documented, independent variable time series data and especially meta-data (e.g., frequency and magnitude of landslides in freshwater; temporal aggregation of marine mammals etc.) associated with annual productivity indices. The availability of supplementary time series data and meta-data is frequently required to determine cause-and-effect associations between salmon production variations and natural or human-origin events and regimes (e.g., see Akenhead et al. 2016, Hyatt and Stockwell 2019).

The region-wide network of Sockeye index stock observations assembled annually for DFO’s State of the Pacific Ocean Reports (Hyatt 2005, Hyatt et al. 2018) serves as an important source of information against which to verify or reject speculation about the frequency, magnitude and potential source of major Sockeye production events or the emergence of regimes. For example, this data set served as a source of internal advice to DFO that the record low returns of Sockeye Salmon to the Fraser River in 2009, that resulted in the multimillion dollar Cohen Commission of Enquiry, were not part of a pattern exhibited by our regional network of Sockeye Index Stocks (e.g., compare 2009 returns to Chilko versus remainder of index stocks in Fig. 3). By contrast, the unexpectedly, near record, high returns to the Fraser that followed in 2010 were apparently part of a regionally coherent positive response of Sockeye populations to a common environmental driver (Fig. 3) associated with the 2008 “cold-ocean”, La Niña event in our region (Hyatt et al. 2011).

**Fig. 4.** Data-rich index stocks: Productivity indices at local area scales in freshwater and marine systems identify where mechanisms driving trends originate and offer clues to their identity (e.g., Smith Inlet Sockeye).

Of more immediate concern, our Sockeye Index Stock series is currently indicating a downturn in returns beginning in 2016 progressing to anomalously low production of total returns throughout our region (and
as far as south central Alaska, Andrew Munro, pers. comm.) in 2017 (Fig. 3) and 2018 (Hyatt et al. unpublished observations). This suggests the recent emergence of unusually powerful basin-scale drivers in the Pacific that warrants further investigation (e.g., Peterman and Dorner 2012) in order to provide timely advice to fisheries managers regarding the near-term need to adopt precautionary management actions. Additional support that we may be witnessing initiation of an unusual set of production events for Sockeye stocks along the eastern rim, or possibly the entire Pacific basin, is available from biological trait attributes of recent year returns of adult Sockeye salmon. Anecdotal reports, of which two confirmed examples are presented here (Fig. 5; A. Munro (ADF&G) and S. Cox-Rogers, (DFO), pers. comm.), suggest the widespread occurrence of sudden and relatively large declines in the average size and/or the size-at-age (7 to 12 % length and weight reductions respectively) of adult Sockeye Salmon in returns across a large geographic area in 2015–2018 (i.e., south central AK-Copper River to at least the BC North Coast-Nass and Skeena rivers). Additionally, Sockeye returns to the Nass and Skeena rivers on BC’s north coast were 10–17 days later than average in 2015–2017 (data not shown). Changes of this frequency and magnitude in adult Sockeye size and return timing are largely unprecedented in the 30 plus year time series of observations considered here and, taken together with anomalously low productivity, may indicate important changes in oceanic rearing areas, migration distances, food webs supporting good growth, age-at-maturity, or all of these.

![Biological Trait Indices: Provide supplemental clues to processes controlling Sockeye Salmon abundance trends](image)

**Fig. 5.** Biological trait indices provide supplemental clues to processes controlling Sockeye Salmon abundance trends. Yellow circles indicate the river-mouth locations of a subset of British Columbia Sockeye stocks for which annual assessments of smolt-to-adult survival have been conducted.

Although the examples provided here are limited, they suggest further immediate coordinated assembly of information would be beneficial to characterize the geographic extent, magnitude and management implications of asynchronous to synchronous production and biological trait variations exhibited by Sockeye stocks over various spatial and temporal scales. Uncertainty regarding the relative importance of productivity factors operating at different spatial scales hinders the prioritization of science and management activities (Zimmerman et al. 2015). To this end, we intend to invite agency personnel,
involved in annual assessments of relatively data rich Sockeye populations in Washington State and Alaska, to contribute observations on annual production, productivity indices and biological traits to supplement those currently assembled annually for Sockeye Index stocks returning to BC to form an international network of Sockeye Index Stocks (INSISt). International collaboration for annual assembly, analysis and reporting of the time series data on total production, productivity and biological traits from the INSISt would represent a highly cost effective means to facilitate the rapid identification of region-wide versus local area salmon production trends in the Pacific as a basis for improvements in timely advice to fisheries managers and stakeholders regarding future production prospects and the origins of either past or developing Sockeye population trends.

References


An Overview of Pink Salmon Trends at Basin-wide to Local-area Spatial Scales in the North Pacific Ocean

Sue C.H. Grant, Fisheries and Ocean Canada, Vancouver, British Columbia

Life-History and North Pacific Trends

Pink Salmon (*Oncorhynchus gorbuscha*) are the most abundant species of salmon in the North Pacific Ocean and Bering Sea (Ruggerone and Irvine 2018). Wild and hatchery origin Pink Salmon contribute 67% to the total numbers of Pink, Sockeye and Chum salmon in the North Pacific and Bering Sea and 48% in biomass in recent decades, from 1990–2015 (Ruggerone and Irvine 2018) (Fig. 1). In the Western North Pacific, Pink Salmon spawn in freshwater from North Korea to Russia. In the Eastern North Pacific, Pink Salmon spawn in freshwater from central California, up to the Mackenzie River in the Canadian Arctic (Heard 1991). This species matures at two years of age, and for this reason are also the smallest of Pacific salmon species ranging from three to ten pounds. Because of their fixed two year ages, there are two distinct brood lines of Pink Salmon, an odd and even brood line (Heard 1991). The odd brood line dominates Pink populations in southern British Columbia (B.C.) in Canada, Washington State in the United States (U.S.), Hokkaido in Northern Japan, and the East Coast of the Kamchatka Peninsula of Russia. The even year brood line dominates Pink populations in northern B.C. in Canada, and the West Coast of the Kamchatka Peninsula of Russia (Irvine et al. 2014).

Fig. 1. (A) Abundance (millions of fish), (B) adult biomass (thousands of metric ton), and (C) adult and immature biomass (thousands of metric tons) of Sockeye Salmon, Chum Salmon, and Pink Salmon in the North Pacific Ocean, 1925–2015. Reprinted with permission from Ruggerone and Irvine 2018.
Regional Pink Salmon trends are broken out by country and geographic area (Fig. 3). Starting in the Northeast Pacific, from Washington State, Southern British Columbia, Alaska, and Arctic and then moving into the Northwest Pacific, including Japan and Russia.

Fig. 3. The approximate geographic locations of regional stock groups. Region 1, the West Coast of the United States, includes the Columbia River. Region 2 includes southern British Columbia (BC) south of the BC central coast (~51°N). Region 3, northern BC, includes central and northern BC. Region 4 encompasses Southeast Alaska (AK), including the Yakutat coast. The central Alaska region extends from the Bering River (~60°N), near Prince William Sound in region 5, westward to Unimak Island (~166°W), thereby including regions 5–8. Western Alaska includes regions 9–12 (that is, all North American drainages flowing into the Bering Sea from Unimak Island to Kotzebue). Data for east Kamchatka and west Kamchatka (regions 14 and 15) are separated from data for the Russian mainland and islands, which include the Okhotsk coast, Amur River, Primorye, Sakhalin and Kurile islands, and relatively small runs to the Anadyr River. Region 20, Japan, includes the islands of Hokkaido and Honshu. Reprinted with permission from Ruggerone and Irvine (2018).
The southern extent of the Pink Salmon range is Washington State. No persistent populations have been reported in Oregon or California (Hard et al. 1996). Washington State Pink Salmon are dominated by the odd year brood line. These salmon exhibited relatively low abundances early in their time series, from 1985 to 2001, and subsequently improved. Numbers were relatively high from 2009 to 2013 with an average of 8 million and declined most recently in 2015 to 3.7 million and 2017 to 500,000 (Fig. 4) (data provided by M. Litz and A. Dufault, Washington Department of Fish & Wildlife). Hatchery contributions to Washington State stocks are negligible.

In British Columbia, Pink Salmon assessments have declined over time. Therefore, there are more gaps and data are generally poorer quality for this species. In BC, odd year Pink Salmon have been relatively stable or increasing. In contrast, many even year Pink Salmon populations have decreased (Irvine et al. 2014) (Fig. 5). Hatchery contributions to BC Pink stocks are negligible.
In Southern BC, the Fraser River odd year brood line dominates total Pink Salmon production in this area. No directed assessments are conducted on the even brood line. Fraser Pink Salmon returns have averaged 13 million fish from 1969 to 2017 (Fig. 6a) (Grant et al. 2014). Returns have been quite variable during this period, ranging from 3.6 to 24 million fish (Fig. 6a). Similar to Washington State Pink Salmon, Fraser River Pink Salmon numbers were relatively high from 2009 to 2013 with an average of 19 million and declined most recently in 2015 to 6 million to 2017 to 4 million (Fig. 6a). The methods to enumerate Pink Salmon returns over time have varied, so some caution must be made interpreting these trends (Grant et al. 2014). Freshwater survival, measured as recruits-per-juvenile were variable over the time series, and particularly low in the last two brood years in 2015 and 2017 (Fig. 6b). Juvenile assessments have been consistently assessed since the late 1960s (Grant et al. 2014).

**Fig. 6.** Fraser River Pink Salmon abundances from 1969 to 2017. These salmon are predominantly odd-year brood lines and data are presented for these odd years only; and b) freshwater productivity (recruits-per-juvenile). In both graphs the dashed line represents the time series average. Source: Grant et al. 2014 and J. Tadey, DFO.

In Northern BC, abundances have been variable (Fig. 7). Unlike southern BC Pink Salmon, Northern BC stocks have not exhibited similar declines in recent years (Fig. 7).

In Alaska Pink Salmon are comprised of both odd- and even-brood lines. Numbers have increased since 1970, from under 40 million fish to up to 200 million in the last decade. Numbers were low in 2016 at approximately 40 million fish (Fig. 8). Populations in Alaska are considered healthy and there are no stocks of concern (Fig. 9) (source: A.R. Munro and W.D. Templin, Alaska Department of Fish & Game). Hatchery contributions are highest for Alaska, compared to southern U.S. and Canada.
In the U.S. and Canadian Arctic (Beaufort Sea Region) Pink Salmon abundances have increased over the past decade, as reported in subsistence catches. Since there are no self-sustaining Pink Salmon populations in the U.S./Canadian Arctic, these increases are likely from straying from southern populations. Pink have also been reported upstream in the Mackenzie River, and off the east coast of Greenland (source: E. Farley, K. Cieciel, K. Dunmall, and T. Sformo). In the North Bering Sea Pink Salmon appear to be increasing, given observations of juvenile pink salmon abundances (Fig. 10) collected during integrated ecosystem surveys (Murphy et al. 2017). Pink Salmon increases in the Arctic, might be an indicator of Arctic change (Dunmall et al. 2013).
Fig. 10. Northeastern Bering Sea Pink Salmon biomass in metric tonnes. Source: Farley et al. (2018).

Fig. 11. Trends in Russian Pink Salmon catch in tones for A) East (blue line) and West Kamchatka (red line), with Western Kamchatka data offset by one year behind to demonstrate the correlation between these coasts; and B) East Kamchatka and Sakhalin Coast. The data include predominant brood lines only: even year brood line for the Western Kamchatka coast, and odd year brood line for the Eastern Kamchatka and Sakhalin coasts. Catches in the other brood line are not presented. Reprinted from Klovach et al. (2018).
In Russia, Pink Salmon comprise 55–75% of the total salmon catch in the far East. Kamchatka Pink Salmon increased in 2015 to 2017, coinciding with warmer Northeast Pacific Ocean in these years (Krovinin et al. 2016) (Fig. 11a). Pink catches in the East and West Kamchatka are strongly correlated when the data series for Western Kamchatka is moved one year back relative to Eastern Kamchatka (Fig. 9a). Sakhalin Coast Pink Salmon catch also increased in the early 2000 associated largely with an increase in marine survival (Fig. 11b). Sakhalin Coast Pink Salmon declined from 2015–2017 (Fig. 9b) coincided with cooler sea surface temperatures in the southern Okhotsk Sea.

**Fig. 12.** Japanese inshore Pink Salmon catch numbers (millions). These catches exclude offshore and Russian coast data. Source: S. Sato, Salmon Resources Research Department, Hokkaido National Fisheries Research Institute, Japan Fisheries Research and Education Agency.

Japanese Pink Salmon are mainly captured along the Okhotsk coast of Hokkaido (Saito and Miyakoshi 2018). On average catch has been seven million fish or ten million tones. Catches of pink salmon have declined sharply since 2011; except for improved returns in 2016, and recent catch levels are comparable to those in the early 1980s and pre-1980s (Fig. 12).

**References**


Three data types were summarized for Chum Salmon: 1) catch plus escapement; 2) survival, distribution, and productivity; and 3) biological trait information. When available, these data were summarized at three scales: 1) ocean-basin; 2) regional and sub-regional; and 3) population. In general, chum abundance is increasing, productivity and body size are decreasing, and age-structure trends are mixed, though there are regional exceptions for all of these patterns.

Chum abundance (catch plus escapement), at the ocean basin-scale, is at a relatively high (Ruggerone and Irvine 2018) (Fig. 1). The number of chum returning peaked around 1995 at about 150 million fish, and has stayed relatively constant since then. When the basin-scale trends are split into three regions (Asia, Alaska, and British Columbia/Washington), it becomes apparent that the basin-scale trends are largely driven by increases in Asian chum abundance to over 100 million annually, with over half of these fish on average being generated from hatchery production (Ruggerone and Irvine 2018) (Fig. 2). The abundance of chum in Alaska, British Columbia and Washington is more stable through time, and sums to a maximum of approximately 50 million Chum Salmon in the largest years (Ruggerone and Irvine 2018) (Fig. 3 and 4). Average abundances by sub-region (e.g. Japan, Amur River etc.) exhibit some asynchrony, especially in Alaska (Fig. 5). Abundance by Conservation Unit (ecologically, genetically, and/or geographically distinct groups of wild salmon defined after Canada’s Wild Salmon Policy) also show some asynchrony, though most Conservation Units on the north and central coast of British Columbia show below average abundance from 2005–2016 (Connors et al. 2018) (Fig. 6).
**Fig. 3.** Total number of chum salmon (catch + escapement) returning to Alaska, natural- and hatchery-origin. Data redrawn from Ruggerone and Irvine (2018).

**Fig. 4.** Total number of chum salmon (catch + escapement) returning to British Columbia and Washington, natural- and hatchery-origin. Data redrawn from Ruggerone and Irvine (2018).

**Fig. 5.** Relative abundance ((yearly abundance—mean abundance) / standard deviation) of chum salmon in each region 1954–2015. Solid black line is the regional average, while faded grey lines are the sub-regions in Ruggerone and Irvine 2018. The dashed line at 0 represents average abundance.
Survival, distribution, and productivity data were not available on the ocean basin scale, but productivity (recruits-per-spawner) was available at the sub-regional scale for the eastern North Pacific Ocean from Malick and Cox (2016). These data show that most sub-regions have below-average productivity for chum, especially in the years since 2000 (Malick and Cox 2016). Conservation Units (populations) on the North and Central Coast of BC show similar trends of declining productivity, though recent years have shown a slight increase in productivity for many populations (Connors et al. 2018) (Fig. 7).

Finally, there were data available for Chum Salmon biological characteristics at various scales. At the ocean basin-scale, chum body size has declined by 20% from 1925–2015 (Ruggerone and Irvine 2018) (Fig. 8). Sub-regions show similar patterns, with declines in body size evident in Japan (Morita and Fukuwaka 2007), Anadyr (Zavolokin et al. 2009), Alaska (Fig. 9), and Puget Sound (Fig. 10). Data on age-at-maturity was also available for some sub-regions and showed increases in Japan and Anadyr (Morita and Fukuwaka 2007; Zavolokin et al.)
2012), and no trends in northern and central British Columbia (Fig. 11).

**Fig. 9.** Regional patterns in average chum body size from sub-regions in Alaska. Data provided by K. Oke and the SASAP initiative.

**Fig. 10.** Average body size of chum salmon captured in commercial fisheries in Puget Sound, Washington. Data provided by J. Losee.

**Fig. 11.** Average age-at-maturity for chum salmon from the north and central coast of British Columbia. Each point represents the average age-at-return for chum salmon in a Fisheries and Oceans Canada statistical area. Data provided by K. Beach, DFO.
Overall, Chum Salmon abundances are high and stable, largely buoyed by returns to Asia and hatchery production. In the Eastern North Pacific, productivity of Chum Salmon has declined, especially since 2000. Body size for chum has also shown declines, while age-at-maturity is more mixed. There are various datasets across regions that can be compared and initiatives underway to compile such data. Depending on research priorities, compiling common legacy data sets for chum salmon is an achievable goal.

References

An Overview of Chinook Salmon Trends at Basin-wide to Local-area Spatial Scales in the North Pacific Ocean

Mary Thiess, Fisheries and Oceans Canada, Science Branch, Pacific Biological Station, Nanaimo, B.C. Contributions by: G. Brown, J. Harding, E. Hertz, A. Munro, and B. Wells

Chinook exhibit various characteristics that distinguish them from other species of Pacific salmon and make them potentially vulnerable to different factors associated with increased environmental variability and change. In addition to growing to the largest adult size, Chinook Salmon also possess the most diverse range of life history characteristics across all ages. For example, Chinook Salmon can exhibit ocean- or stream-type life strategies at juvenile stages; are known to undertake local, northern or offshore ocean migrations; and migrate back to natal streams as adults during the spring, summer, fall or winter at a range of ages (varying from two to six years or more). Almost all combinations of these characteristics have been identified among the Chinook Salmon populations found from California through to Alaska. Typically, Chinook are vulnerable to fisheries from age 3 onwards.

Basin-scale trends for Chinook Salmon show an overall decreasing trend in abundance over time. Historical time series of Chinook Salmon commercial catch across the North Pacific aggregate show a decreasing trend (1925–2017), with the majority of the catch attributable to North America (Slide 8). Notably, when expressed as total weight, commercial catch over the same time period has declined at a faster rate than catch numbers (possibly indicating a declining trend in size at age per fish and/or a shift to increasing catch of younger, smaller fish) (Slide 9). It is important to note that changes in management regime and shifts in catch to other (non-commercial) sectors are masked in these time series. Contrary to the abundance information, hatchery production of Chinook Salmon (contributed predominantly by North American hatcheries) ramped up through the 1970s, peaked through the 1980s and has stabilized at roughly 25 million fish from the 1980s through to the present (Slide 10).

Regional trends for Chinook salmon can be observed through analysis of the data inputs and outputs from the Pacific Salmon Commission’s Coast-wide Chinook Model. At present, 46 indicator stocks are maintained coast-wide and provide annual estimates of abundance, marine distribution, survival rates, exploitation rates (in terms of landed catch and incidental mortality), and maturation rates by stock, brood, age and fishery (Slide 11). Many of the indicator stocks (from all regions) show decreases in abundance and increasing variability in survival across years, despite parallel declines in exploitation rates (e.g., Slides 13–16). A few notable exceptions can be found (e.g., Cowichan River Fall Chinook and South Thompson ocean-type summer runs). Generally, early-timed, stream-type populations appear to be disproportionately impacted by the observed declines.

Population-level trends can be observed through the conservation assessment-related population aggregates: Ecologically Significant Units (ESUs) in the United States, Wild Salmon Policy (WSP) Conservation Units (CUs) or Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Designatable Units (DUs) in Canada. As an example, there are 12 Chinook Salmon ESUs in California with summaries of abundance anomalies and three condition indexes (i.e., age structure diversity, proportion natural spawners and population growth rate). The most recent updates show 3 ESUs exhibit an increasing abundance trend, 8 ESUs show no abundance trend and 1 ESU shows a declining abundance trend (Slide 17). Of the 8 ESUs with condition index information, most show either no trend or a decline in age structure diversity (3 or 4 ESUs, respectively), no trend in proportion natural-origin spawners (7 ESUs), and no trend to an increasing trend in population growth rate (4 or 3 ESUs, respectively) (Slide 18). In Canada, many of CUs and DUs have been assessed in the red WSP status zone (12/35 CUs) or assessed as Endangered or Threatened by COSEWIC (15/29) (Slides 20–21). Recent work presented through the Pacific Salmon Explorer provides similar information on abundance trends and status for Canadian North and Central Coast CUs (Slide 22). Novel analyses being undertaken in the Yukon aims to extend population-level time series through the use of archived genetic material (Slides 23–28). Many of the same trends

Contributions by: G. Brown, J. Harding, E. Hertz, A. Munro, and B. Wells
in abundance and demographics have also been observed in Alaska (Slides 29–33).

Overall, Chinook Salmon abundance has demonstrated broad declines in abundance and productivity across the geographic range (with some localized exceptions). Notable demographic changes have also been observed for some populations (e.g., decreasing age at maturity, decreasing size at age, decreasing fecundity, etc.); these factors are suspected to reduce population productivity—even if survival rates and rearing/spawning environments remain unchanged. At present, finding common data sets across all regions or populations is difficult (each source has differing uncertainties and underlying assumptions), but with some work, a number of universal time series could be developed for ongoing monitoring.
Chinook Salmon
NPAFC YFS Status & Trends Workshop
January 23-24, 2019
Vancouver, BC

Acknowledgements

- Brian Wells: California
- Gayle Brown/Chinook Technical Committee: Oregon, Washington, BC, Southeast Alaska
- Eric Hertz/Pacific Salmon Explorer: North and Central Coast BC
- Joel Harding: Yukon River
- Andrew Munro: Alaska

Assignment

- Provide broad temporal patterns of:
  - Catch and escapement
  - Survival, distribution, productivity
  - Biological characteristics
- At three geographic scales:
  - Ocean basin
  - Regional
  - Population level
  ... for Chinook Salmon, noting where possible any associated standards (accuracy, reliability)

Outline

- Chinook 101
- Ocean Basin (reporting by countries)
  - Catch
  - Hatchery Releases
- Regional (Pacific Salmon Treaty stocks)
  - Abundance anomalies
  - Exploitation rates
  - Biological Traits
- Population (Ecologically Significant Units/Conservation Units)
  - Escapement
  - Productivity
  - Biological Traits

Chinook 101

- Chinook exhibit a complex range of life history strategies at all stages:
  - Juvenile rearing: ocean-type vs. stream-type
  - Ocean distribution: locally distributed, far-north or offshore migrating
  - Adult run timing: spring, summer, or fall
  - Variable age at maturity (2, 3, 4, 5, 6 or older)
- It is often difficult to estimate absolute abundance of Chinook Salmon over time and/or across their geographic range.
- Many Chinook populations have been influenced by enhancement activities since the late 1800s (US) or mid-1900s (Canada).

Ocean Basin

-
Example time series: PSC Chinook Model
Exploitation Rates

Example Time Series: PSC Chinook Model
Terminal Run & Fishery Impacts

Example Time Series: PSC Chinook Model
Brood Year Survival

Example time series: PSC Chinook Model
Maturation rate & Average generation time

Population – ESU Abundance
• Abundance indices for 12 ESUs in California
  • 3 increasing, 8 no trend, 1 decreasing
  • Sample figure:

www.integratedecosystemassessment.noaa.gov/regions/california-
current/cc-indicator-status-trends

Population – ESU Condition Indices
• 3 condition indices for up to 8 ESUs in California:
  - Age structure diversity
  - Proportion natural-origin spawners
  - Population growth rate

<table>
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<th>Age Structure Diversity</th>
<th>Proportion Natural-Origin Spawners</th>
<th>Population Growth Rate</th>
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<td>7</td>
<td>3</td>
</tr>
<tr>
<td>No trend (---)</td>
<td>3</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Decreasing (↓)</td>
<td>4</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

www.integratedecosystemassessment.noaa.gov/regions/california-
current/cc-indicator-status-trends
Population – Southern BC Chinook CUs
- Escapement time series and associated population data have been provided to inform COSEWIC (16 DUs) and WSP biological status assessments (35 CUs).

WSP – COSEWIC (November 2018)

Population - North & Central Coast CUs
- Estimates of escapement, catch, run size and recruits-per-spawner, etc. for 12 CUs

https://salmonexplorer.ca/#/!

Population - Yukon River Chinook Salmon
[B. Connors, & J. Harding]

Yuokon River Chinook sub-stock data
- Previously:
  - Genetic Stock Identification (GSI) used to assign sub-stock of origin for all Chinook sampled since 2005 (in conjunction with border sonar)
  - Data: 2005-present

- This project:
  - Analyzed genetic material from archived scales collected from fish wheels to extend data set back through time
  - Data: 1982 - present
Yukon River Chinook

Generate sub-stock run-reconstruction estimates

Yukon River Chinook

Estimate variability in sub-stock productivity

Yukon River Chinook

Next steps...

1. Characterize population diversity (e.g., productivity or carrying capacity)
2. Quantify equilibrium tradeoffs between harvest and conservation of population diversity
3. Develop closed loop simulation model to quantify fishery and population diversity consequences of a range of alternative management procedures

Yukon River Chinook

Uncertainty

- Work in progress...
  - Border assessment data (transition from fish wheel to sonar) - addressed
  - Sampling bias with fishwheels for certain sub-stocks (run-timing, size)? - underway
  - Is sub-sampling of archived scales representative? - increasing sample size
  - Bias in harvest to certain sub-stocks? - underway

Chinook Stock Status - Alaska

- recent decline in productivity
- decline in meeting escapement goals: <50% in 2017
- commercial harvests reduced
- fishery restrictions and closures throughout state
  - commercial
  - subsistence
  - sport

Chinook Stock Status - Alaska

- below average runs throughout Alaska since 2007
- improvements in western Alaska stocks
  - meeting escapement, but harvest severely restricted
- Southeastern Alaska stocks recently declined
**Chinook Stock Status - Alaska**

- Marine survival has declined for some stocks
- Related to sea surface temperature anomalies?

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**Chinook Stock Status - Alaska**

Studies suggest in some populations:
- Shift to younger age at return
- Slight decrease in length at age

**Age proportions of Chinook salmon for each state/province by brood year. (From Ohlberger et al. 2018)**

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**Chinook Stock Status - Alaska**

**Stocks of Concern**
- 13 stocks
- Located throughout state

**Arctic-Yukon-Kuskokwim**
- Yukon River – listed 2000
- Norton Sound – listed 2003
- Continued low runs

**Central**
- 7 systems
  - Listed 2010 and 2013
  - Meeting escapement goals
  - Restrictions on fisheries in area

**Westward**
- Katuk River – listed 2010

**Southeast**
- 3 listed 2017
  - Unuk, Chilkat, King Salmon rivers
  - Poor runs, not meeting escapement goals
  - Restrictions on all fisheries in area

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**Overall Summary**

- In general, Chinook Salmon abundance has declined broadly across the geographic range (with some localized exceptions).
- Observed demographic changes observed for some populations (e.g., age at maturity, size at age, fecundity, etc.) across the geographic range; likely reducing population productivity—even if survival rates and rearing/spawning environments remain unchanged in productive capacity.
- At present, finding common data sets across all regions or populations is difficult (each source has differing uncertainties and underlying assumptions). With some work, a small number of universal time series could be developed.
An Overview of Atlantic Salmon Data Sets in the North Atlantic Ocean
Gérald Chapat1, Martha Robertson1, Nicholas Kelly1, Julien April2, and Etienne Rivot3

1Fisheries and Oceans Canada, 2Ministère des Forêts, de la Faune, et des Parcs, Québec, 3UMR ESE, Ecology and Ecosystem Health, Agrocampus Ouest, INRA, Rennes, France

Special acknowledgements to the ICES Working Group on North Atlantic Salmon participants that annually provided updated information and data for Atlantic Salmon from the North Atlantic.

Introduction

Atlantic Salmon (Salmo salar) is broadly distributed in the North Atlantic, as both anadromous and landlocked (ouananiche) populations. There are three species complexes:

- North American complex—populations in eastern North America distributed from the northeastern states of the United States of America to the most northern anadromous populations of Ungava Bay (northern Quebec).
- Northeast Atlantic complex—populations located from Spain, Iceland, Europe, and to western Russia.
- Baltic Salmon—located exclusively in rivers within the Baltic Sea and anadromous salmon complete their life cycle entirely within the Baltic Sea and never migrating to the North Atlantic (similarly, salmon from the Northeast Atlantic complex do not migrate to the Baltic Sea). Baltic salmon are not considered in this overview; Baltic salmon specific information is available in the ICES Working Group Report on Baltic Salmon and Trout.

Anadromous populations mature after one to five sea winters at sea with the majority maturing after one-sea-winter and two-sea-winters at sea. Juvenile freshwater stages extend from one to up to eight years with a latitudinal cline in age at smoltification. Atlantic salmon are iteroparous spawners and can return many times to spawn; current maximum reported spawning events for an individual fish is seven spawnings.
In North America, reference is made to small salmon (< 63 cm fork length) and large salmon (≥ 63 cm fork length), convenient size groups that encompass 1SW salmon as small and multi-sea-winter (maiden 2SW, 3SW+ and repeat spawners) salmon as large. In the Northeast Atlantic, reference is made directly to 1SW and MSW salmon.

**Catch data**

Catch data beginning in 1960 has been compiled for North Atlantic Salmon (ICES 2018; Tables 2.1.1.1, 2.1.1.2). Data are available by country as well as for the mixed stock marine fisheries that occur at Greenland and in the Faroe Islands fishery. For some jurisdictions, catch data are also available by size or sea-age group for a large portion of the time series. Estimates of unreported catches (catches from legal fisheries not otherwise captured in reporting systems or illegal retentions (but not non-retained bycatch) is also available for a portion of the time series. Maximum North Atlantic reported catches of the time series were 12,670 metric tons, in 1973; reported catches in 2017 were 1,187 metric tons, the second lowest of the time series. (Fig. 1)

![graph.png](attachment:graph.png)

**Fig. 1.** Reported harvests (i.e., catches) of Atlantic Salmon in the North Atlantic for the period 1960 to 2017. Data are from ICES (2018).

**Estimates of abundance**

Estimates of spawners (also known as escapement, salmon that survive fisheries and are estimated to spawn), returns (to rivers or jurisdictional coastal areas, after marine fisheries), and pre-fishery abundance (PFA, also referred to as recruitment at an earlier age than returns due to timing of marine fisheries) are available for a subset of river populations, regional groups of rivers, and continental stock complexes (North American Complex (NAC), Southern Northeast Atlantic Complex (SNEAC), and Northern Northeast Atlantic Complex (NNEAC)).

**By individual river population—North America**

A data set of estimated returns to monitored rivers in eastern North America has been compiled based on reported values in jurisdictional assessments (Fig. 2). The returns are compiled for small salmon and large salmon. There
are data of 129 rivers in the data set. The longest time series begins in 1970 and for 73 rivers the time series $\geq$ 20 years. Annual run sizes (small and large salmon combined) across rivers range $<$ 10 fish to $> 100,000$ fish. No formal analysis of spatial or temporal patterns of this data set has been reported to date.

**Fig. 2.** Geographic distribution and individual river time-series coverage of rivers with annual return assessments by size group of Atlantic Salmon in eastern North America.

**By regional groups within continental stock complexes**

Estimates of spawners, returns to regions, and pre-fishery abundance (PFA) have been developed using the concept of run-reconstruction (Rago et al. 1993). Returns to rivers or regions are derived based on catch data, estimates of exploitation rates, and or river specific estimates of returns raised to regions using habitat areas or other raising factors. The specific methods vary among regions and in some cases have changed over the time series which extends from 1970 to present. Details are available in the ICES Annex (2017) which details the methods used by ICES to derive stock status and provide advice for management of high seas fisheries. Data in ICES (2017) contains estimates of small or 1SW salmon, 2SW salmon (for NAC) and multi-sea-winter (MSW) salmon by regional groups and combined for the continental stock complexes. The data sets include fields for life stage, year, abundance type (returns, spawners, pre-fishery abundance), continental stock complex (NAC, SNEAC, NNEAC), region within continental stock complex, and summaries of estimates of number of fish (median, 5th percentile, 95th percentile). Summary plots by age groups and continental stock complex for returns and pre-fishery abundance are shown in Fig. 3.

**Recruitment (pre-fishery abundance) and population dynamics (life cycle model)**

A life cycle model has been developed to provide a framework to improve understanding of the drivers and mechanisms of changes in Atlantic salmon population dynamics and productivity in the North Atlantic (Massiott-Granier et al. 2014; ICES 2018; Olmos et al. 2019). The model is structured into a single hierarchical model that incorporates covariation in the dynamics of the different populations that share migration routes and feeding areas at sea, and which are harvested in mixed-stock fisheries. The life history parameters of interest are the trends in
the marine productivity (expressed as post-smolt survival rate to January 1 of the first winter at sea) and the proportion maturing as one-sea-winter salmon for all stock units in the North Atlantic.

**Fig. 3.** Estimates of regional returns and pre-fishery abundance for NAC (left panel) and for returns in NEAC (middle panel) and for NEAC pre-fishery abundance (right panel) by size / sea-age groups based on data compiled in ICES (2018).

**Life history dynamics**

There is limited river/population specific information on life history population dynamics of Atlantic salmon. Freshwater population dynamics data are available from 14 rivers in eastern Canada and eight rivers in the Northeast Atlantic with time series of variable lengths. Information on egg depositions and total smolt production by year class are available from these rivers and the stock and recruitment dynamics of the rivers in eastern Canada have been analyzed for the purpose of deriving reference points (Chaput et al. 2015). Detailed information on other aspects of these monitoring programs are available in some jurisdictional reports (for example Cauchon and April 2018).

Spawner to adult stock and recruitment relationships have been presented for twelve rivers in the Quebec region of eastern Canada (Dionne et al. 2018) and for the subset of rivers with adult to adult data for the Northeast Atlantic (Prévost et al. 2003). Other data sets exist for these types of analyses, but they have not been reported on.

Smolt to adult returns of monitored salmon populations in the North Atlantic are tabulated in ICES (2018). The data of varying time series length and time period coverage includes 31 populations from eastern North America, including 12 hatchery smolt and 19 wild smolt return rate series, and 30 populations from the Northeast Atlantic area, including 16 hatchery stocks and 14 wild populations. For these monitored populations, more detailed biological data is available, but these are infrequently reported (exception for example Cauchon and April 2018). These time series illustrate the general decline in marine return rates of Atlantic salmon populations in the North Atlantic (Fig. 4).

**Biological characteristics**

Biological characteristics data including lengths, weights (generally or at age), sex ratios, freshwater ages, sea ages are available from specific monitored rivers, and from sampling programs in fisheries.
Fig. 4. Trends in marine return rates of exemplary stocks in the North Atlantic (data from ICES 2018).

One of the longest and summarized time series is from samples of the mixed-stock salmon fisheries at West Greenland. The annual summaries of biological characteristics are available in the reports of the ICES Working Group of North Atlantic Salmon (ICES 2018). Data summaries include the annual estimates of the continent of origin of the sampled catches, and in recent years, origin to one of 12 regions of eastern North America, mean fork length and weight by sea age group, sea age proportions, river age proportions, of salmon by continent. In 2015, ICES also presented the trend in weight of salmon by continent, adjusted for a common sampling date and fork length size, which showed the large and synchronous variations in weight of salmon from the two continent complexes (Fig. 5).

Biological information is available from monitored rivers, some of which has been published, available in jurisdictional reports and considered in ICES study groups (ICES 2009). Trends in characteristics such as fork length or weight at age show contrasted patterns among the continents. Bal et al. (2015) report on declines in length and weight at age of salmon over three decades from samples in fisheries of France. This contrasts with increases in size at age of salmon sampled from the Miramichi River (Canada) over the period 1971 to 2015 (Chaput et al. 2016). General increases in size at age have reported from populations of salmon in eastern Canada. Increases in the proportion of repeat spawners in annual returns have been reported from a number of populations in eastern Canada (O’Connell et al. 2006) as well as northern populations of Europe (Niemelä et al 2006).

Biological characteristics of smolts, river age distributions, sex ratios, size and weight at age, condition, run-timing) are also available from monitored rivers. Some of these are reported in jurisdictional reports (Cauchon and April 2018) and in various other studies (ICES 2009).

There is diverse other information on salmon available from specific studies related to growth based on scale analyses, trophic state based on stable isotope ratios, which have not been collated.
Fig. 5. Biological characteristics of Atlantic salmon sampled from the West Greenland fishery (left panel, mean fork length at sea age for Europe and North America; right panel, predicted whole weight of a 1SW salmon of a standard fork length of 65 cm as of August 20) (ICES 2018).

References


O’Connell, M.F., Dempson, J.B., and Chaput, G. 2006. Aspects of the life history, biology, and population
2006/014.

Evidence for spatial coherence in time trends of marine life history traits of Atlantic salmon in the North
Atlantic. Fish and Fisheries. DOI: 10.1111/faf.12345.

Prévost, E., Parent, E., Crozier, W., Davidson, I., Dumas, J., Gudbergsson, G., Hindar, K., McGinnity, P.,
of information from data-rich to sparse-data situations by Bayesian hierarchical modelling. ICES J. Mar. Sci.
60: 1177–1193.

run reconstruction model for the non-maturing component of North American Atlantic salmon: analysis of
3 PLENARY DISCUSSION 1: DATA

During the Day 1 facilitated plenary session, participants discussed categories of data appropriate for assessing state changes and trends in salmon populations at different scales. Specifically, the usefulness, of three salmon data categories:

1. catch and pre-fishery abundance (i.e., catch plus escapement),
2. survival, distribution, and productivity (including stock and recruitment, recruits/spawner, freshwater and marine survival), and
3. biological trait information (e.g., size at age, age at maturity, age and sex composition),

were discussed in relation to these three spatial scales:

1. ocean basin (i.e., Atlantic vs. Pacific (all species); trends among species within Pacific),
2. regional (broad regions within Atlantic and Pacific), and
3. population (or Conservation Unit) specific.

Participants also identified limitations associated with different categories of data, and issues around data standards. In addition, participants worked pre and post-workshop to assemble an inventory of types and sources of available data.

3.1 Data Inventory

An inventory of the legacy datasets identified by participants is provided in Appendix E. Legacy datasets are intended to be indicative of trends for a particular population or species for which there is a high probability that the dataset will be maintained. Some of these were used in presentations at the workshop. Future work is needed to augment these datasets and decide which are best suited for further assess state changes and trends (e.g., Table 5-2).

3.2 Data for Assessing State Changes and Trends

The information gathered during this plenary session was fine-tuned using a post-workshop questionnaire\(^1\) that built on the plenary results (see Appendix F). Recipients were advised that results would be compiled and presented in the workshop report anonymously, and that by completing the questionnaire, they were agreeing to the use of their input in subsequent workshop publications.

The questionnaire (Appendix F) consisted of a series of statements organized into four sections, the first three relating to usefulness of different data categories for assessing trends at different spatial scales (Section A. Abundance data, Section B. Survival, distribution and productivity data, and Section C. Biological trait information), and the fourth relating to data standards (Section D).

Participants were asked to indicate their level of agreement/disagreement (strongly agree, agree, disagree, strongly disagree) with each statement for each spatial scale by checking the appropriate box for each scale (one box per scale). If one neither agreed nor disagreed with a statement due to lack of knowledge, etc., they were asked to not respond to that statement. Respondents were also encouraged to provide comments, concerns or ideas pertaining to each statement (in the final column). For reference, a separate attachment was provided to participants that itemized comments received during the workshop.

---

\(^1\) The questionnaire was completed by 15 out of 26 workshop participants.
3.2.1 Summary of Questionnaire Results

All workshop participants received the questionnaire shortly after the workshop. Since most attendees were experts on salmon in the Pacific, there were more responses for statements pertaining to the Pacific than the Atlantic or Arctic although some individuals responded to statements pertaining to more than one ocean. One response was provided on behalf of four Atlantic Salmon experts, so this response was equated as four separate equivalent responses. The raw compiled questionnaire results are provided in Appendix F.

As an illustration of how the results were compiled, responses to the first statement in Section A of Appendix F (Pre-fishery abundance is a useful indicator of adult salmon abundance in the Pacific) were as follows: at the ocean scale four people strongly agreed and seven agreed with the statement; at the regional scale two people strongly agreed, nine agreed and one disagreed; while at the population scale four strongly agreed, five agreed and two disagreed. Table 3-1 aggregates the overall ratings of the different types of data for assessing state changes and trends in salmon populations, by scale and by ocean.

The following is a summary of the questionnaire results; detailed analysis has not been undertaken at this point.

A. Abundance (including catch and pre-fishery abundance)

There was general consensus that pre-fishery abundance estimates are useful indicators of adult abundance in both the Pacific and the Atlantic, especially at the ocean and regional scales (Table 3-1, Appendix F). Few disagreed with its usefulness at these scales. Among these, concerns were raised about data accuracy and bias associated with spawner estimates, mixed stock fisheries, non-terminal catches, etc. It was also noted that this metric’s usefulness depends on species as well as scale, and the influence of regional variations in hatchery vs. wild fish. The respondent who disagreed with the metric’s usefulness in the Atlantic stated there are few remaining fisheries on Atlantic salmon and that many spawner populations are not accurately monitored.

The majority of respondents indicated that total aggregate catch and commercial catch were useful proxies of adult abundance in the Pacific at the ocean and regional scales only (except in Japan where they were identified as useful proxies at all scales because of very high commercial fishery pressure), although there were also several who disagreed. Concerns were raised around the reliability of catch data, and the potential masking influence of changes in fisheries management and regulations. One respondent registered their disbelief that all survival variation is in the first months at sea, stating that marine survival doesn’t account for all the salmon in the ocean that do not survive to be caught. In the Atlantic, there are virtually no commercial fisheries remaining so catch data are not useful proxies for adult abundance.

In the Arctic, subsistence harvest is the primary means by which salmon abundance is monitored; salmon are a bycatch. Subsistence data are the best salmon abundance data available, but their utility is limited. This reality is reflected in the wide range of respondent views and comments on the utility of subsistence harvest as a proxy for adult salmon abundance.

Slightly more than half the respondents felt that spawner escapement estimates were useful population indicators of adult abundance in the Pacific but fewer than half felt they were useful indicators at the ocean or regional scale (limitations with using this metric for larger geographic scales were noted, and spawner escapement data are rarely recorded/available in Japan). Escapement estimates were never considered to be useful proxies for adult Atlantic Salmon abundance. One respondent argued that Atlantic experience showed escapement estimates (as fish that have survived fisheries) are not useful proxies of adult salmon abundance (as total production from the ocean) in either the Pacific or Atlantic.

In both the Pacific and the Atlantic, juvenile abundance indices were considered by most respondents to be useful
abundance proxies for individual populations, recognizing the post-smolt mortality events have not yet occurred. The majority disagreed with their usefulness for assessing abundance at ocean and regional scales (all disagreed in the case of the Atlantic), citing problems associated with rolling the data up to broader scales. One respondent strongly disagreed with the use of this metric at all scales, suggesting it was only useful in steady state populations with unchanging habitats. Another suggested correlation between smolt outmigration and adult returns are not great because most juvenile salmon die before they go offshore.

There was general agreement with the statement that catch estimates help inform salmon fisheries and habitat management, with some disagreement for the Pacific at the ocean and local scales, and one disagreement for the Atlantic at the local scale. Catch data help inform management but the situation differs among oceans. In the Pacific, despite some problems assigning catch to populations (one participant noted that apportioning fish to stocks or populations from mixed catches can be seriously misleading), catch data inform fisheries management but much less so habitat management. In the Atlantic, the situation is simpler with only one species and since the limited catch can be monitored, it can be a useful abundance proxy. In the Arctic, catch data are primarily useful for documenting occurrence and distribution.

Incorporating Indigenous and local knowledge on salmon abundance was recognized as important in all three oceans, although in the Pacific, this was primarily at the local (population) and regional spatial scales. A paucity of aboriginal knowledge in the Atlantic other than northern Labrador, and limited western science in the Arctic were commented upon (Table 3-1, Appendix F).

B. Survival, distribution, and productivity (including stock and recruitment, recruits/spawner, freshwater and marine survival)

Survival, distribution, and productivity metrics were considered by all to be essential to assessing state changes and trends at all three spatial scales, in both the Atlantic and Pacific (Table 3-1). These types of data were identified by most as being useful for informing fishery and habitat management at population and regional scales, and to a lesser extent at the ocean scale. Concerns were noted about these metrics being unavailable for many populations in the Pacific, being subject to inappropriate application of models such as the Ricker Stock-Recruit model, and currently having weak linkages to habitat management.

Where possible, the importance of incorporating local and aboriginal knowledge on survival, distribution, and productivity was recognized. In the Pacific and Atlantic, this was primarily at the local, and to a lesser extent, regional scale. It was rated by most respondents as important for all three scales in the Arctic. One respondent commented that local and aboriginal observations tend to be related to presence, abundance (and seasonality in some cases), but by themselves are not metrics of productivity or survival. Thus, they need to be paired with other data/observations (Appendix F).

C. Biological trait information (e.g., size at age, age at maturity, age and sex composition)

There was consensus that biological trait information is useful in assessing state changes and trends at all scales in both the Pacific and the Atlantic (Table 3-1). In both oceans the importance of these data in understanding mechanisms was identified although the limitations of relying on phenotypic data should be recognized.

Most people thought that biological trait information was useful in the Pacific for management, especially at the local and regional scales (it was noted that there is no marine habitat management). One person who strongly disagreed stated this was because such information either has not been collected or managed in a way to be useful. This type of information was highly valued in the Atlantic although it may not be used to its full potential.

Where possible, incorporating local and traditional information on biological traits in the Pacific was generally
valued at the local and regional scales. A lack of consensus in the Atlantic and Arctic was probably related to the fact this type of information is rarely available (Appendix F).

D. Data Standards

The final section of the questionnaire dealt with data standards. There was agreement in both the Pacific and Atlantic of the importance of standardizing datasets, defining data standards, documenting uncertainty and assumptions, highlighting differences between self-reporting and catch monitoring, providing transparency about whether and how uncertainty is included in models, and providing and describing metadata (statements 1, 2, 3, 5, 7, and 8). The value of trying to incorporate Indigenous and local knowledge on uncertainty was not clear (statement 4). Most agreed that categorical descriptions of data and model uncertainty were adequate (statement 6) although some felt this was only a first cut and better descriptions of uncertainty were needed.

One respondent indicated that the questionnaire failed to address the need for modernizing data processing and models, and the value of using habitat data in models, observing multiple life history stages, and knowing life history strategies (Appendix F).
Table 3-1. Rated usefulness of data types for assessing state changes and trends in salmon populations at different scales. Check marks indicate mainly favourable ratings from workshop participants, ‘x’ indicates mainly unfavourable ratings, and ‘VR’ indicates variable ratings. See Appendix F for details.

<table>
<thead>
<tr>
<th>Data Types</th>
<th>OCEAN</th>
<th>SCALE</th>
<th>POPULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proxies of Abundance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-fishery (catch plus spawners)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>a) in the Pacific</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>b) in the Atlantic</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Total aggregate salmon catch (all fisheries)</td>
<td>✓¹</td>
<td>✓¹</td>
<td>✗²</td>
</tr>
<tr>
<td>a) in the Pacific</td>
<td>✓¹</td>
<td>✓¹</td>
<td>✗²</td>
</tr>
<tr>
<td>b) in the Atlantic</td>
<td>✗³</td>
<td>✗³</td>
<td>✗</td>
</tr>
<tr>
<td>Commercial catch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) in the Pacific</td>
<td>✓¹</td>
<td>✓¹</td>
<td>✓²</td>
</tr>
<tr>
<td>b) in the Atlantic</td>
<td>✗³</td>
<td>✗³</td>
<td>✗</td>
</tr>
<tr>
<td>Subsistence harvest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) in the Arctic</td>
<td>VR⁴</td>
<td>VR⁴</td>
<td>VR⁴</td>
</tr>
<tr>
<td>Spawner escapement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) in the Pacific</td>
<td>VR</td>
<td>VR</td>
<td>✓</td>
</tr>
<tr>
<td>b) in the Atlantic</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Juvenile salmon abundance indices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) in the Pacific</td>
<td>✗</td>
<td>✗</td>
<td>✓⁵</td>
</tr>
<tr>
<td>b) in the Atlantic</td>
<td>✗</td>
<td>✗</td>
<td>✓⁵</td>
</tr>
<tr>
<td><strong>Survivorship, productivity &amp; distribution</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) in the Pacific</td>
<td>✓⁶</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>b) in the Atlantic</td>
<td>✓⁶</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Biological trait information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) in the Pacific</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>b) in the Atlantic</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

¹ However, some participants did not favour total aggregate and commercial catch as proxies for abundance, citing concerns associated with data reliability and the masking influence of management actions/regulations.
² Except in Japan, where catch data are useful proxies at all three scales because of very high commercial fishery pressure.
³ In the Atlantic, there are virtually no commercial fisheries remaining so catch data are not useful proxies for adult abundance.
⁴ In the Arctic, subsistence harvest is the primary means by which salmon abundance is monitored; salmon are a bycatch. Subsistence data are the best salmon abundance data available but their utility is limited.
⁵ Recognizing the post-smolt mortality events have not yet occurred.
⁶ Less useful at ocean scale than at regional and population scales.
4 PLENARY DISCUSSION 2: DRIVERS and MECHANISMS

During the Day 2 facilitated plenary session, participants identified potential drivers behind salmon trends at different scales, and possible mechanisms and hypotheses associated with these trends. A summary of the identified trends, drivers and mechanisms is provided below. This summary should be augmented by a detailed literature review and input by additional experts but is provided here for completeness.

4.1 Sockeye Salmon

4.1.1 Trends

During the last 25 years:
- salmon in the north have generally been doing better than salmon in the south
- survivals are most highly correlated with populations nearby
- marine survival has been decreasing since ~1990
- freshwater survival has been decreasing
- size at age has been decreasing
- age at return has been increasing
- freshwater distributions have expanded inland, or marine distribution have expanded northward
- there has been increasing variability with productivity and bio traits
- shifts in return timing and/or migration routes

During the last 3–5 years:
- there have been anomalous conditions in freshwater driving production down
- there have been extreme declines in salmon productivity

4.1.2 Possible Drivers and Mechanisms

- influx of warm waters from south into California current in ~1990 and associated warm water plankton correlated with reduced growth and survival. Similar response to N. Atlantic but mechanism differs.
- the frequency and magnitude of warm years affecting salmon productivity has been increasing including the blob in eastern N. Pacific
- density dependent competition including by hatchery salmon
- food quality declines
- increases in predators
- freshwater habitat impacts
- density dependent (intra and/or interspecific) competition in the marine environment
Summary of Sockeye Salmon trends.

<table>
<thead>
<tr>
<th>SOCKEYE</th>
<th>Abundance</th>
<th>Survival/ Productivity</th>
<th>Biological Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 yrs</td>
<td>3-5 yrs</td>
<td>25 yrs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3-5 Yrs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Size @ age</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time of return</td>
</tr>
<tr>
<td>Ocean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West N. Pac</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East N. Pac</td>
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<td></td>
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</tr>
<tr>
<td>NE. Pac. Regions</td>
<td></td>
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</tr>
<tr>
<td>E. Bering Sea**</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>SE Alaska, N. BC</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>S. BC, Wash</td>
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<td></td>
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<tr>
<td>Oreg/Calif</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Columbia</td>
<td>⬇️</td>
<td>⬇️</td>
<td>⬆️</td>
</tr>
<tr>
<td>Other</td>
<td>⬇️</td>
<td>⬇️</td>
<td>⬆️</td>
</tr>
</tbody>
</table>

* with some variability
** includes Yukon River

4.2 Pink Salmon

4.2.1 Trends

During the last 25 years:

- salmon in the north have generally been doing better than salmon in the south
- odd-year returning populations tend to do better in the south than even-year populations and vice versa
- even-year populations most common in Canadian arctic
- odd-year returning populations are generally doing better in recent years than even-year populations in the south east Pacific
- In BC, odd-year populations stable or increasing while even-year populations stable or decreasing
- survivals are most highly correlated with same-cycle year populations nearby
- flips in dominance of even and odd year populations in Kamchatka and Hokkaido
- no productive populations of pink salmon on outer coast of Vancouver Island, Washington, Oregon or Kamchatka
- on westerly Russian coast (i.e., western Sakhalin, western Kamchatka, and Sea of Okhotsk coast of the Iturup Island) significant production mostly in even years?
- evidence of expanded distributions northward
- In Japan, pink salmon catch is linked with autumn rainfall. Rainfall increases discharge that allows salmon to move further upstream, less density dependent effects, resulting in higher brood survival.

During the last 3–5 years:

- 2017 anomaly of westward extended distribution of Russian origin salmon from Norway to Labrador
- increased variability in Fraser odd-year pink salmon returns

4.2.2 Possible Drivers and Mechanisms

- hatcheries
- interactions between even and odd year populations in coastal marine environment
- freshwater habitat impacts, especially logging
- prey quality

### Summary of odd year Pink Salmon trends.

<table>
<thead>
<tr>
<th>PINK (odd year)</th>
<th>Abundance</th>
<th>Survival/Productivity</th>
<th>Biological Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 yrs</td>
<td>3-5 yrs</td>
<td>Size @ age</td>
</tr>
<tr>
<td><strong>Ocean</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>West N. Pac</td>
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<tr>
<td>East N. Pac</td>
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<tr>
<td><strong>NE Pac. Regions</strong></td>
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<tr>
<td>E. Bering Sea**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Alaska, N. BC</td>
<td></td>
<td></td>
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<tr>
<td>S. BC, Wash Oreg/Calif</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Population</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fraser</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** includes Yukon River

### Summary of even year Pink Salmon trends.

<table>
<thead>
<tr>
<th>PINK (even year)</th>
<th>Abundance</th>
<th>Survival/Productivity</th>
<th>Biological Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 yrs</td>
<td>3-5 yrs</td>
<td>Size @ age</td>
</tr>
<tr>
<td><strong>Ocean</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West N. Pac</td>
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<td></td>
<td></td>
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<tr>
<td>East N. Pac</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NE Pac. Regions</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>E. Bering Sea**</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SE Alaska, N. BC</td>
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<tr>
<td>S. BC, Wash Oreg/Calif</td>
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</tr>
<tr>
<td><strong>Population</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fraser</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td></td>
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<td></td>
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</tbody>
</table>

** includes Yukon River

### 4.3 Chum Salmon

#### 4.3.1 Trends

During the last 25 years:
- Generally increasing numbers
• In Hokkaido, survivals increased mid-80's to 90's, then variable until ~2006, declining since then
• Chum salmon in Asia doing worse in south than north
• Chum in Nass and Skeena are doing worse than populations to the south;
• Some declines in body size for chum and pink
• Chum tend to get older as we get further north

During the last 3–5 years:
• reduced survivals in Hokkaido and Amur River (Russia)
• increases in Canadian arctic
• reduced survivals in eastern N. Pacific

4.3.2 Possible Drivers and Mechanisms

• hatcheries, not only release numbers but also quality of fish released
• fishing

Summary of Chum Salmon trends.

<table>
<thead>
<tr>
<th>CHUM</th>
<th>Abundance</th>
<th>Survival/Productivity</th>
<th>Biological Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 yrs</td>
<td>3-5 yrs</td>
<td>Size @ age</td>
</tr>
<tr>
<td>Ocean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West N. Pac</td>
<td>↑</td>
<td>?</td>
<td>↓</td>
</tr>
<tr>
<td>East N. Pac</td>
<td>↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE Pac. Regions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arctic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Bering Sea**</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>SE Alaska, N. BC</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>S. BC, Wash Oreg/Calif</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Population</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* with some variability
** includes Yukon River

4.4 Chinook Salmon

4.4.1 Trends

During the last 25 years:
• declining abundances, especially recently, most noticeable in NE Pacific
• in BC, ocean type populations doing better than stream type
• size at age has been decreasing
• trend towards increasing relative abundance of younger age classes N to S
• freshwater survival has been decreasing
• For Chinook, a lot of covariation among regions within ocean basins depending on life history type, lots of synchrony among ocean basins with an overall downward trend

During the last 3–5 years:
• continuing declines in survival and growth

4.4.2 Possible Drivers and Mechanisms

• hatcheries and straying
• fishing—especially on larger sized fish
• warming including permafrost melt and erosion
• forest cover removal
• timing of spring bloom (match mismatch)
• early marine predation affecting larger stream type more than ocean type
• freshwater warming impacting early migrating spring type more than later returning ocean type

Summary of Chinook Salmon trends

<table>
<thead>
<tr>
<th>CHINOOK</th>
<th>Abundance</th>
<th>Survival/ Productivity</th>
<th>Biological Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 yrs</td>
<td>3-5 yrs 25 yrs 3-5 yrs</td>
<td>Size @ age Time of return</td>
</tr>
<tr>
<td>Ocean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West N. Pac</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East N. Pac</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE Pac. Regions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Bering Sea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Alaska, N. BC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. BC, Wash, Oreg/Calif</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* some variability

** includes Yukon River

4.5 Atlantic Salmon

4.5.1 Trends

During the last 25 years:
• marine survivals declining since ~1990 throughout their range including Baltic where salmon do not go to Atlantic Ocean (i.e., remain in Baltic)
• Survival for Atlantic generally down everywhere
• declines in growth (size at age) in some areas including France but not North America
• proportion of fish that mature after 1 sea winter increasing
• increases in maturation at age 0 in some rivers??

During the last 3–5 years:
• continuing declines in survival and growth

4.5.2 Possible Drivers and Mechanisms

• major changes in ecosystem—bottom up processes. Decreases in quantity and energy content of food in W Greenland area. Less capelin and herring—more squid
- aquaculture (fish farm) impacts in E and SW North Atlantic
- influx of cold arctic waters and associated species in ~1990 in NW Atlantic. Plankton community has not reverted back to pre-1990 state and growth and survival continues to be depressed. Similar to NE Pacific but mechanism differs (reduced growth but cold water in NW Atlantic, warm water in NE Pacific)
- in NW Atlantic some increases in returns to river not seen in S. part of range in W. Atlantic
- teleconnections?
- interspecific competition effects not important (salmon uncommon in ocean) but intraspecific effects may be occurring that are not understood
- size at ocean entry may be driving survival trends
- tradeoffs between returning early to spawn to avoid predation and staying at sea longer to be bigger

*Summary of Atlantic Salmon trends*

<table>
<thead>
<tr>
<th>ATLANIC</th>
<th>Abundance</th>
<th>Survival/ Productivity</th>
<th>Biological Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 yrs</td>
<td>3-5 yrs</td>
<td>Size @ age</td>
</tr>
<tr>
<td>Ocean</td>
<td></td>
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<tr>
<td>East</td>
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<td></td>
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<tr>
<td>West</td>
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<td></td>
</tr>
<tr>
<td>Region</td>
<td></td>
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<td></td>
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<tr>
<td>N. NA</td>
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<td></td>
<td></td>
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<tr>
<td>S. NA</td>
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<tr>
<td>N. EUR</td>
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<td></td>
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<tr>
<td>S. EUR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

### 4.6 Steelhead

#### 4.6.1 Trends

- Decline in Steelhead from Mid BC southward and stability from mid BC north
- Lack of steelhead indicator stocks in Alaska, trends stable in Skeena and Nass; evidence of decline in Puget Sound, complicated in WA-OR; N. Cal populations doing very poorly

### 4.7 All Species

- Southern populations for all salmon are doing worse than northern counterparts (generally), except for some populations of chum and Chinook
- Survivorship not down for odd year pink and western Alaskan sockeye; down for the remainder
- Increase prevalence of Pacific species in Arctic
- More populations extirpated in southern range than northern range in both oceans; More habitat problems the further south
- Similar declines in steelhead marine survival from north to south (Welch et al., 2018)

Table 4-1. summarizes 25-year trends identified during the workshop with a focus on North American populations. These patterns have not been reviewed by others or compared with results reported in the literature.
Table 4-1. 25-year trends across salmon species.

<table>
<thead>
<tr>
<th>25-year Trends</th>
<th>SOCKEYE</th>
<th>PINK (ODD)</th>
<th>PINK (EVEN)</th>
<th>CHUM</th>
<th>CHINOOK</th>
<th>ATLANTIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Survival Decreasing</td>
<td>✓ 1</td>
<td>×</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Freshwater Survival Decreasing</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓ 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern populations doing better than southern</td>
<td>✓ 3</td>
<td>×</td>
<td>✓</td>
<td>✓ 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution Expanding north and/or inland</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size at Age Decreasing</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>Later Seasonal Return Timing</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Some exceptions in Alaska.
2 In BC, ocean type Chinook populations are generally doing better than stream type populations.
3 In the southern part of their range in the Eastern N. Pacific, odd year Pinks generally doing better than even years; flips in dominance of even and odd year populations in Kamchatka and Hokkaido; no productive populations of pink salmon on outer coast of Vancouver Island, Washington, Oregon or Kamchatka.
4 East West differences seem more important than North South. In Hokkaido, survivals increased mid-80's to 90's, then variable until ~2006, declining since then; increases in Canadian Arctic over last 25 yrs.
5  PLENARY DISCUSSION 3: NEXT STEPS

During the afternoon of the Day 2 facilitated plenary session, participants identified a number of next steps for building on the workshop results and achieving IYS outcomes.

5.1  Objectives

The following overarching objectives for next steps were identified:

1. Identify and assemble legacy datasets, and develop data standards.

2. Describe state changes and trends for salmon species at ocean basin, regional, and local scales, with a focus on answering the research questions proposed in Table 5-1.

3. Link state changes and trends to potential drivers and mechanisms, with a focus on answering the research questions proposed in Table 5-1.

4. Develop advice on possible futures, e.g., which species/populations are likely to be winners and losers in the face of continuing environmental change?

5.2  Action Items

Participants also recommended a number of strategies and supporting actions for achieving the above objectives. These are detailed in Table 5-2.
Table 5-1. Proposed research questions for Objectives 2 and 3.

<table>
<thead>
<tr>
<th>Proposed Research Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective 2: Describe state changes and trends for salmon species at ocean basin, regional, and local scales</strong></td>
</tr>
<tr>
<td>1. What is the trend/state/status of salmon species: what are the common trends and what are the anomalies?</td>
</tr>
<tr>
<td>2. What are hemispheric wide trends linking Atlantic and Pacific salmon populations</td>
</tr>
<tr>
<td>3. What are the differences in trends between hatchery and wild salmon in Japan and elsewhere?</td>
</tr>
<tr>
<td><strong>Objective 3: Link state changes and trends to potential drivers and mechanisms</strong></td>
</tr>
<tr>
<td>1. What is the North Pacific carrying capacity for all six salmon species?</td>
</tr>
<tr>
<td>2. What are possible drivers of big events: long term vs extreme drivers?</td>
</tr>
<tr>
<td>3. What are possible drivers behind recent declines in abundance across species?</td>
</tr>
<tr>
<td>4. What are drivers of common South to North patterns?</td>
</tr>
<tr>
<td>5. What are possible drivers of common patterns across hemispheres?</td>
</tr>
<tr>
<td>6. What controls salmon productivity on east and west sides of north Pacific and Atlantic?</td>
</tr>
<tr>
<td>7. How can trophic dynamics be conceptualized at basin scales?</td>
</tr>
<tr>
<td>8. What are the commonalities in trophic drivers among ocean basins?</td>
</tr>
<tr>
<td>9. What are drivers responsible for changes in size and age at maturity?</td>
</tr>
<tr>
<td>10. What limits early marine survival of Japanese hatchery chum salmon fry in Okhotsk Sea?</td>
</tr>
<tr>
<td>11. What effects do hatchery fish have on wild salmon in terms of carrying capacity and introgression of genes?</td>
</tr>
<tr>
<td>12. Can we link hatcheries to environments that optimize returns?</td>
</tr>
</tbody>
</table>
Table 5-2. Strategies and action items for achieving overarching objectives.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Strategy</th>
<th>Actions</th>
</tr>
</thead>
</table>
| 1. Assemble legacy datasets, and develop associated data standards       | 1.1. Develop data inventory                                               | • Continue to identify available data and data holders  
  • Contact lower 48 reps to ask about data in their jurisdiction  
  • Identify data gaps  
  |
|                                                                           | 1.2. Obtain available data and fill data gaps                            | • Form a data working group to:  
  o Secure potential $ support from NCEAS  
  o Coordinate with ISDL to explore modern technologies that can be used to deal with all this data  
  o Collaborate with Salmon Explorer and others to obtain available data  
  o Identify opportunities for filling data gaps  
  o Engage and expand interactions between data suppliers and data users  
  o Identify ways of sharing and reproducing data  
  |
|                                                                           | 1.3. Develop data standards                                              | • Form data standards working group to collaborate with other relevant groups and individuals to:  
  o Develop standards for data and meta-data, to optimize data quality and interoperability  
  o Determine appropriate metrics for assessing state changes/status/trends and different scales  
  |
| 2. Describe state changes and trends for salmon species at ocean basin, regional, and local scales | 2.1. Report on key trends from workshop findings                        | • Assemble as a NPAFC Technical Report (publicly available but not peer reviewed)  
  o Link to workshop presentations  
  o Refer to Santa Barbara workshop report findings  
  o Include a 500-word extended abstract from each presenter  
  o Compile plenary results as part of the report.  
  o Synthesize workshop results to identify key trends that appear to be emerging from data.  
  o Assemble a list of priority follow-up research questions for inclusion in report  
  o Identify relevant publications and data availability for each priority research question.  
  o Draft report to be sent out for steering committee review in a month  
  |
|                                                                           | 2.2. Clarify/confirm/build on key trends identified during workshop      | • Assemble research teams to follow-up on research questions outlined for Objective 2 in Table 8  
  |
|                                                                           | 2.3. Host annual IYS salmon research workshop to report                  | • Present team progress and research results at workshop  
<p>|</p>
<table>
<thead>
<tr>
<th>Objective</th>
<th>Strategy</th>
<th>Actions</th>
</tr>
</thead>
</table>
| 3. Link state changes and trends to potential drivers and mechanisms | 3.1. Carry out research to determine drivers and mechanisms behind key trends | • Steering committee to triage which of the research questions outlined for Objective 3 in Table 8 can be addressed with existing data  
• Assemble research teams to follow-up on research questions |
| | 3.2. Integrate traditional knowledge and archaeological findings into data | • Invite FNFC to be involved in next steps; contact Indigenous groups throughout North America |
| | 3.3. Host annual IYS salmon research workshop | • Present team progress/results at workshop and identify next steps  
• Invite Indigenous Peoples to participate in yearly workshop |
| 4. Develop advice on possible futures | | |
APPENDIX A: WORKSHOP AGENDA
International Year of Salmon (IYS) Workshop on Salmon Status and Trends

23–24 January 2019

Room 320 at the Morris J Wosk Centre for Dialogue 580 W Hastings St., Vancouver, BC, Canada

PRIMARY OBJECTIVE:

1. identify a series of legacy datasets and where possible, associated standards (e.g., accuracy and reliability)

Secondary objectives:

1. Day 1—look at broad temporal patterns:
   a. for three salmon data categories:
      i. catch and pre-fishery abundance (i.e., catch plus escapement),
      ii. survival, distribution, and productivity (including stock and recruitment, recruits/spawner, freshwater and marine survival), and
      iii. biological trait information (e.g., size at age, age at maturity, age and sex composition)
   b. and three scales:
      i. Ocean Basin (i.e., Atlantic vs. Pacific (all species); trends among species within Pacific)
      ii. Regional (broad regions within Atlantic and Pacific)
      iii. Population specific

2. Day 2—link state changes and trends from Day 1 to potential drivers and mechanisms (hypotheses) and identify data requirements for more thorough evaluation

3. Identify additional datasets, data providers, and other information necessary to better understand how natural environmental variability and human factors affect salmon status and trends, and

4. To achieve IYS outcomes, identify next steps including a) improved documentation of data standards (accuracy, precision, metadata), and b) coordinated data assembly, integration, storage, processing, analysis and communication of findings.

AGENDA

23 January

• 0830—morning coffee
• 0900–0930—Introductions, review agenda (Day 1 focused on salmon data, Day 2 focused on hypotheses/mechanisms), overview IYS presentation (JRI or MS)
• 0930–1030 Overview Presentations
  o Sockeye Salmon—Kim Hyatt
  o Pink Salmon—Sue Grant
  o Chum Salmon—Eric Hertz
• 1030–1045 coffee
• 1030–1200 Overview Presentations Continue
  o Chinook Salmon—Mary Thiess
  o Atlantic Salmon—Gérald Chaput
  o Review common patterns among species, regions etc.
Facilitated brainstorming session to determine categories of data appropriate for determining trends at different scales, and to identify limitations, and available and missing data.

<table>
<thead>
<tr>
<th>Ocean Basin Trends (Pacific/Atlantic/Arctic)</th>
<th>Regional Trends (broad regions within Pacific and Atlantic)</th>
<th>Population Trends (Population/Conservation Unit/Watershed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>i. Catch and pre-fishery Abundance data</strong></td>
<td>Are these useful metrics for assessing state changes and trends among oceans and among species at the Pacific basin scale?</td>
<td>Are these useful metrics for assessing state changes and trends at population scales?</td>
</tr>
<tr>
<td></td>
<td>Data standards?</td>
<td>Data standards?</td>
</tr>
<tr>
<td></td>
<td>What has been learned?</td>
<td>What has been learned?</td>
</tr>
<tr>
<td></td>
<td>What questions can be asked with this data?</td>
<td>What questions can be asked with this data?</td>
</tr>
<tr>
<td></td>
<td>Limitations?</td>
<td>Limitations?</td>
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<tr>
<td></td>
<td>Available data?</td>
<td>Available data?</td>
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<tr>
<td></td>
<td>Missing data?</td>
<td>Missing data?</td>
</tr>
<tr>
<td></td>
<td>What data providers need to be contacted?</td>
<td>What data providers need to be contacted?</td>
</tr>
<tr>
<td><strong>ii. Survival, distribution, and productivity (including stock and recruitment, spawner, freshwater and marine survival)</strong></td>
<td>Are these useful metrics assessing state changes and trends among oceans and among species at the Pacific basin scale?</td>
<td>Are these useful metrics for assessing state changes and trends at the population scale?</td>
</tr>
<tr>
<td></td>
<td>Data standards?</td>
<td>Data standards?</td>
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<tr>
<td></td>
<td>What has been learned?</td>
<td>What has been learned?</td>
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<td>What questions can be asked with this data?</td>
<td>What questions can be asked with this data?</td>
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<td>Available data?</td>
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<td>Missing data?</td>
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<td></td>
<td>What data providers need to be contacted?</td>
<td>What data providers need to be contacted?</td>
</tr>
<tr>
<td><strong>iii. Biological trait information (e.g., size at age, age at maturity, age and sex composition)</strong></td>
<td>Are these useful metrics for assessing state changes and trends among oceans and among species at the Pacific basin scale?</td>
<td>Are these useful metrics for assessing state changes and trends at the population scale?</td>
</tr>
<tr>
<td></td>
<td>Data standards?</td>
<td>Data standards?</td>
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<tr>
<td></td>
<td>What has been learned?</td>
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<td>What questions can be asked with this data?</td>
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<td>Limitations?</td>
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<td>Available data?</td>
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<td>Missing data?</td>
<td>Missing data?</td>
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<tr>
<td></td>
<td>What data providers need to be contacted?</td>
<td>What data providers need to be contacted?</td>
</tr>
</tbody>
</table>

For 5 x Pacific spp.

- Are these useful metrics for assessing state changes and trends among species at the Pacific basin scale?  
- Data standards?  
- What has been learned?  
- What questions can be asked with this data?  
- Limitations?  
- Available data?  
- Missing data?  
- What data providers need to be contacted?
• 1630–1700—Summary, plans for next day, group photo
• 1830–2100—Reception: Steam Works 375 Water Street, Vancouver
24 January

- 0830 Morning coffee
- 0900–1200 (with coffee break 1030) PLENARY DISCUSSION—DRIVERS & MECHANISMS

Facilitated brainstorming session to examine potential drivers behind trends at different scales, and possible mechanisms/hypotheses/responses, data needed to test hypotheses, data availability, data gaps.

1. Ocean Basin Trends (Pacific vs. Atlantic, among species within oceans)
2. Regional trends (among species)
3. Population trends (within species at CU/watershed level)

<table>
<thead>
<tr>
<th>OCEAN BASIN (Pacific/Atlantic/Arctic) TRENDS</th>
<th>REGIONAL TRENDS (broad regions within Pacific and Atlantic)</th>
<th>POPULATION TRENDS (Population/Conservation Unit/Watershed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What are main trends at the basin scale and possible drivers behind them?</td>
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<td></td>
</tr>
<tr>
<td>• What are some possible mechanistic hypotheses?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What response would be consistent with hypothesis?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What data are needed to test these responses?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Possible analytical approaches?</td>
<td></td>
<td></td>
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<tr>
<td>• What data are available?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What data are missing?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What are main trends at regional scale and possible drivers behind them?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What are some possible mechanistic hypotheses?</td>
<td></td>
<td></td>
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<tr>
<td>• What response would be consistent with hypothesis?</td>
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<tr>
<td>• What data are needed to test these responses?</td>
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<tr>
<td>• Possible analytical approaches?</td>
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<tr>
<td>• What data are available?</td>
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<tr>
<td>• What data are missing?</td>
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</tr>
<tr>
<td>• What are main trends at population scale and possible drivers behind them?</td>
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<tr>
<td>• What are some possible mechanistic hypotheses?</td>
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<tr>
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<tr>
<td>• What data are needed to test these responses?</td>
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<tr>
<td>• What data are available?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• What data are missing?</td>
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</tr>
</tbody>
</table>

- 1200–1300—lunch provided
- 1300–1630h (with coffee break 1430) PLENARY DISCUSSION—NEXT STEPS

Facilitated brainstorming session to layout next steps, details not finalized but will likely include:

- Data quality and standards, metadata
- Standardization to make our data sets comparable
- Coordinated data assembly, integration, storage (common database?), processing, analysis and communication of findings
- Roles and responsibilities of NPAFC, NASCO, ICES, ISDL
- Management issues (resourcing, ownership, publication rights),
- How to fill data gaps?
- How to compile data?
- Common approaches to categorize status
- Where do we want to be in four years?
- Individual/group assignments
- Content and structure for follow up workshops
- Publication of workshop report
- Timelines
APPENDIX B: WORKSHOP PARTICIPANTS
## WORKSHOP PARTICIPANTS

<table>
<thead>
<tr>
<th>Last Name</th>
<th>First Name</th>
<th>Affiliation</th>
<th>E-mail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akenhead</td>
<td>Scott</td>
<td>DFO PBS Nanaimo</td>
<td><a href="mailto:scott@s4s.com">scott@s4s.com</a></td>
</tr>
<tr>
<td>Bendriem</td>
<td>Nathan</td>
<td>NPAFC</td>
<td><a href="mailto:nbendriem@npafc.org">nbendriem@npafc.org</a></td>
</tr>
<tr>
<td>Bison</td>
<td>Rob</td>
<td>BC Fish Wildlife Kamloops</td>
<td><a href="mailto:Robert.Bison@gov.bc.ca">Robert.Bison@gov.bc.ca</a></td>
</tr>
<tr>
<td>Chapman</td>
<td>Kelly</td>
<td>VIU, Powell River</td>
<td><a href="mailto:kelly.chapman@gmail.com">kelly.chapman@gmail.com</a></td>
</tr>
<tr>
<td>Chaput</td>
<td>Gérald</td>
<td>DFO Moncton NB</td>
<td><a href="mailto:Gerald.chaput@dfo-mpo.gc.ca">Gerald.chaput@dfo-mpo.gc.ca</a></td>
</tr>
<tr>
<td>Kim</td>
<td>Suam</td>
<td>President, NPAFC</td>
<td><a href="mailto:suamkim@pknu.ac.kr">suamkim@pknu.ac.kr</a></td>
</tr>
<tr>
<td>Hertz</td>
<td>Eric</td>
<td>Pacific Salmon Foundation</td>
<td><a href="mailto:ehertz@psf.ca">ehertz@psf.ca</a></td>
</tr>
<tr>
<td>Dunmall</td>
<td>Karen</td>
<td>DFO FWI Winnipeg</td>
<td><a href="mailto:karen.dunmall@dfo-mpo.gc.ca">karen.dunmall@dfo-mpo.gc.ca</a></td>
</tr>
<tr>
<td>Grant</td>
<td>Sue</td>
<td>DFO Vancouver</td>
<td><a href="mailto:sue.grant@dfo-mpo.gc.ca">sue.grant@dfo-mpo.gc.ca</a></td>
</tr>
<tr>
<td>Harding</td>
<td>Joel</td>
<td>DFO Whitehorse</td>
<td><a href="mailto:joel.harding@dfo-mpo.gc.ca">joel.harding@dfo-mpo.gc.ca</a></td>
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<tr>
<td>Holt</td>
<td>Carrie</td>
<td>DFO PBS Nanaimo</td>
<td><a href="mailto:carrie.holt@dfo-mpo.gc.ca">carrie.holt@dfo-mpo.gc.ca</a></td>
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<tr>
<td>Hyatt</td>
<td>Kim</td>
<td>DFO PBS Nanaimo</td>
<td><a href="mailto:kim.hyatt@dfo-mpo.gc.ca">kim.hyatt@dfo-mpo.gc.ca</a></td>
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<tr>
<td>Irvine</td>
<td>Jim</td>
<td>DFO PBS Nanaimo</td>
<td><a href="mailto:james.irvine@dfo-mpo.gc.ca">james.irvine@dfo-mpo.gc.ca</a></td>
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<tr>
<td>Ladell</td>
<td>Jason</td>
<td>DFO NHQ Ottawa</td>
<td><a href="mailto:jason.ladell@dfo-mpo.gc.ca">jason.ladell@dfo-mpo.gc.ca</a></td>
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<tr>
<td>Meerburg</td>
<td>Dave</td>
<td>Science and Policy Advisor, Atlantic Salmon Federation</td>
<td><a href="mailto:dmeerburg@asf.ca">dmeerburg@asf.ca</a></td>
</tr>
<tr>
<td>Munro</td>
<td>Andrew</td>
<td>Alaska Dept Fish and Game</td>
<td><a href="mailto:andrew.munro@alaska.gov">andrew.munro@alaska.gov</a></td>
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<tr>
<td>Patten</td>
<td>Bruce</td>
<td>DFO PBS Nanaimo</td>
<td><a href="mailto:bruce.patten@dfo-mpo.gc.ca">bruce.patten@dfo-mpo.gc.ca</a></td>
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<tr>
<td>Radchenko</td>
<td>Vladimir</td>
<td>Executive Director, NPAFC</td>
<td><a href="mailto:vlrad@npafc.org">vlrad@npafc.org</a></td>
</tr>
<tr>
<td>Riddell</td>
<td>Brian</td>
<td>Pacific Salmon Foundation</td>
<td><a href="mailto:briddell@psf.ca">briddell@psf.ca</a></td>
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<tr>
<td>Rivot</td>
<td>Etienne</td>
<td>Univ Wa, Seattle USA)</td>
<td><a href="mailto:etienne.rivot@agrocampus-ouest.fr">etienne.rivot@agrocampus-ouest.fr</a></td>
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<td>Robertson</td>
<td>Martha</td>
<td>DFO NWAFC St. John's NL</td>
<td><a href="mailto:martha.robertson@dfo-mpo.gc.ca">martha.robertson@dfo-mpo.gc.ca</a></td>
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<tr>
<td>Sato</td>
<td>Shunpei</td>
<td>Hokkaido</td>
<td><a href="mailto:shuns@fra.affrc.go.jp">shuns@fra.affrc.go.jp</a></td>
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<tr>
<td>Saunders</td>
<td>Mark</td>
<td>NPAFC Vancouver</td>
<td><a href="mailto:msaunders@yearofthesalmon.org">msaunders@yearofthesalmon.org</a></td>
</tr>
<tr>
<td>Sloat</td>
<td>Matthew</td>
<td>Wild Salmon Center</td>
<td><a href="mailto:msloat@wildsalmoncenter.org">msloat@wildsalmoncenter.org</a></td>
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<tr>
<td>Suzuki</td>
<td>Kengo</td>
<td>Hokkaido</td>
<td><a href="mailto:skengo@fra.affrc.go.jp">skengo@fra.affrc.go.jp</a></td>
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<tr>
<td>Taylor</td>
<td>Stephanie</td>
<td>NPAFC Vancouver</td>
<td><a href="mailto:staylor@yearofthesalmon.org">staylor@yearofthesalmon.org</a></td>
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<tr>
<td>Thiess</td>
<td>Mary</td>
<td>DFO PBS Nanaimo</td>
<td><a href="mailto:Mary.Thiess@dfo-mpo.gc.ca">Mary.Thiess@dfo-mpo.gc.ca</a></td>
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</table>
Workshop participants: 1-Karen Dunmall, 2-Martha Robertson, 3-Kengo Suzuki, 4-Nathan Bendriem, 5-Jason Ladell, 6-Suam Kim, 7-Gérald Chaput, 8-Brian Riddell, 9-Mark Saunders, 10-Kim Hyatt, 11-Dave Meerburg, 12-Andrew Munro, 13-Rob Bison, 14-Dion Oxman, 15-Vladimir Radchenko, 16-Stephanie Taylor, 17-Mathew Sloat, 18-Eric Hertz, 19-Carrie Holt, 20-Bruce Patten, 21-Sue Grant, 22-Shunpei Sato, 23-Etienne Rivot, 24-Mary Thiess, 25-Scott Akenhead, 26-Jim Irvine, 27-Kelly Chapman. Missing from photo-Joel Harding
APPENDIX C: INTERNATIONAL YEAR OF THE SALMON OVERVIEW PRESENTATION

(Mark Saunders, NPAFC, Vancouver BC)
**International Year of the Salmon (2018-2022)**

**VISION:** TO ENSURE SALMON AND PEOPLE ARE RESILIENT IN A CHANGING WORLD

- The IYS is a 5-year hemispheric-wide partnership to respond to a rapidly changing physical and social environment.
- Through an intense burst of outreach and research IYS will fill knowledge gaps and catalyze new ways to generate and share knowledge.
- IYS will leave a legacy of a well-informed community of decision makers who can establish the conditions necessary for the resilience of salmon and people in an uncertain future.

**IYS THEMES/OUTCOMES**

- Status of salmon: The present status of salmon and their environments is understood.
- Salmon in a Changing Salinosphere: The effects of natural environmental variability and human factors affecting salmon distribution and abundance are understood and quantified.
- New Frontiers: New technologies, analytical methods, ideas and ways of thinking are advanced and applied to salmon research. Research is carried out to fill gaps in poorly studied regions of the salinosphere.

**IYS OUTCOMES (continued...)**

- Human Dimension: Communities, Indigenous Peoples, youth, harvesters, scientists and resource managers across the Northern Hemisphere share knowledge and collaborate in the development of new tools and approaches to restoring, managing and sustaining salmon.
- Information Systems: Information systems that house and mobilize historic and current data about salmon and their environments are being developed.
- Outreach and Communication: People understand the value of healthy salmon populations and engage to ensure salmon and their varied habitats are conserved and restored against an ever-increasing environments change.
APPENDIX D: INTERNATIONAL SALMON DATA LABORATORY (ISDL)  
INTRODUCTORY PRESENTATION  
(by Scott Akenhead)
Why ISDL?
Predicting salmon populations will require mobilizing extensive ecological data, applying new analyses. Effective use of that knowledge will require better decision-support products.

WHAT the ecologists need to accomplish exceeds the capabilities of the technologies presently accessible to them.

ISDL will identify HOW those needs can be met with modern technology for data processing, analysis, and presentation.

International Salmon Data Laboratory
Workshop 2019 January 25

- **Consider** salmon data examples of critical issues, historical datasets, proposed analyses, desired products, emerging practices, and future requirements.
- **Determine** what these imply for data processing.
- **Specify** the next generation of technology, tools, and practices for collecting, integrating, analyzing, and communicating salmon information.
- **Identify** means to lower barriers to implementing these new practices and striking new collaborations throughout the international salmon community.
- **Decide** on the strategy, plan, and budget required to effect this transformation.

What is a “salmon data laboratory”?

**METHOD**
- Salmon ecologists identify experiments in data processing.
- The *laboratory* is cloud-based computer technology circa 2019: graph database, workflows, tools, code.

**RESULT**
- Irresistible examples, easily reapplied.
- Wide adoption.
- Wiser, more nimble management.
- resilience for salmon.

What tools are needed?

- **Assemble Data**
  - access
  - describe
  - clean
  - conform

- **Integrate & Analyze**
  - models
  - statistics
  - workflow
  - automate

- **Decision Support**
  - data viz.
  - infographics
  - scenarios

What is a “salmon data laboratory”?

**PROBLEM**
- Improve the flow of salmon information: from field collections, through integration and analyses, to decisions.

**QUESTIONS**
- What new efficiencies are possible by adopting 2019 data processing technology?
- How can barriers to implementing these new technologies be lowered?
APPENDIX E: LEGACY DATASETS
<table>
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<tr>
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<th>Species</th>
<th>Data</th>
<th>Ocean Scale</th>
<th>Reg. Scale</th>
<th>Populations Scale</th>
<th>Duration</th>
<th>Quantitative?</th>
<th>Data Availability</th>
<th>Used in Presentation?</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>NPAFC</td>
<td>All Pacific salmon</td>
<td>Catch (commercial, recreational, subsistence), numbers and metric tonnes</td>
<td>North Pacific</td>
<td>Regions within Canada, USA, Russia, Japan, Korea</td>
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<td>1925–2017</td>
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<td>Annual estimates, metadata described in separate file</td>
<td>No</td>
<td>Updated annually.</td>
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<td>NPAFC</td>
<td>All Pacific salmon</td>
<td>Hatchery releases</td>
<td>North Pacific</td>
<td>Regions within Canada, USA, Russia, Japan, Korea</td>
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<td>1952–2017</td>
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<td>Annual estimates, metadata described in separate file</td>
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<td>ICES</td>
<td>Atlantic salmon</td>
<td>Catches</td>
<td>North Atlantic</td>
<td>Country</td>
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<td>1960–2017</td>
<td>No</td>
<td>ICES working group report, Excel table available upon request to working group chair</td>
<td>Atlantic salmon</td>
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<td>Pre-fishery abundance</td>
<td>North Atlantic</td>
<td>Continent/complex/jurisdiction</td>
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<td>1971–2016</td>
<td>Yes (min-max ranges)</td>
<td>ICES working group report, Excel table available upon request to working group chair</td>
<td>Atlantic salmon</td>
<td>ICES need to identify a structure for providing access to these data.</td>
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<td>ICES</td>
<td>Atlantic salmon</td>
<td>Returns/spawners</td>
<td>North Atlantic</td>
<td>Continent/complex/jurisdiction</td>
<td></td>
<td>1971–2017</td>
<td>Yes (min-max ranges)</td>
<td>ICES working group report, Excel table available upon request to working group chair</td>
<td>Atlantic salmon</td>
<td>ICES need to identify a structure for providing access to these data.</td>
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<td>Gérald Chaput / DFO</td>
<td>Atlantic salmon</td>
<td>Returns/spawners</td>
<td>Eastern North America</td>
<td>Rivers</td>
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<td>1971–2018</td>
<td>No</td>
<td>Compilation of published values for returns to monitored rivers in eastern Canada, compiled by Gerald Chaput, DFO, Excel table</td>
<td>Atlantic salmon</td>
<td>Atlantic salmon</td>
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<tr>
<td>Etienne Rivot</td>
<td>Atlantic salmon</td>
<td>Pre-fishery abundance</td>
<td>North Atlantic</td>
<td>Continent/Complex/Country or Region</td>
<td></td>
<td>1978–2016</td>
<td>Yes (min-max ranges)</td>
<td>Model outputs of life cycle model, to 6 regions in North America, 7 regions of</td>
<td>Atlantic salmon</td>
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<td>Data</td>
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<td>Return rates</td>
<td>Eastern North America</td>
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<td>Excel table of estimated return rates to individual monitored rivers, for hatchery / wild salmon, available from ICES Working Group</td>
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<td>Julien April</td>
<td>Atlantic salmon</td>
<td>Biological characteristics</td>
<td>Quebec</td>
<td>Rivers</td>
<td>1984–2017</td>
<td>Yes</td>
<td>Cauchon and April 2018. Summary information on returns, spawners, smolt production, age structure, sex ratio, various biological characteristics for two monitored salmon populations in province of Quebec, 1984 to present</td>
<td>Atlantic salmon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gérald Chaput / DFO</td>
<td>Atlantic salmon</td>
<td>Biological characteristics</td>
<td>NAC</td>
<td>Rivers</td>
<td>1971–2005</td>
<td>Yes</td>
<td>O’Connell et al. 2006. Summaries across rivers presented as figures, data are not in tables in the report, not readily accessible</td>
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<td>Biological characteristics</td>
<td>North Atlantic Regional Populations</td>
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<td>ICES study group report on biological characteristics of salmon</td>
<td>Atlantic salmon</td>
<td>ICES. 2009. Report of the Study Group on Biological Characteristics as Predictors of Salmon</td>
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<td>Aaron Foos</td>
<td>Chinook</td>
<td>Aggregate stock abundance (terminal run, catch data, escapement), CWT data with US and CDN recoveries and smolt estimates, productivity, age-sex-length from fishery and escapement, aerial index surveys, detailed mark-recapture datasets, some years with telemetry data</td>
<td>Pacific</td>
<td>Transboundary Rivers</td>
<td>Taku River</td>
<td>1980–present</td>
<td>Yes</td>
<td>Available on DFO network drive and annual Transboundary Technical Committee Reports to the Transboundary Rivers Panel (<a href="http://www.psc.org">http://www.psc.org</a>)</td>
<td>No</td>
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<tr>
<td>Aaron Foos</td>
<td>Chinook</td>
<td>Aggregate stock abundance (terminal run, catch data, escapement), CWT data with US and CDN recoveries and smolt estimates, productivity, age-sex-length from fishery and escapement, escapement weir counts, aerial index surveys, detailed</td>
<td>Pacific</td>
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<td>Stikine River</td>
<td>1970s–present</td>
<td>Yes</td>
<td>Available on DFO network drive and annual Transboundary Technical Committee Reports to the Transboundary Rivers Panel (<a href="http://www.psc.org">http://www.psc.org</a>)</td>
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<td>Sub-stock abundance and productivity</td>
<td>Yukon Territory (from US-CAN border assessment)</td>
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<td>1982–present</td>
<td>Yes, estimates from aggregate data set combined with GSI</td>
<td>Will be publicly available upon project completion</td>
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<td>Brian Wells and Coho</td>
<td>Chinook</td>
<td>Escapement, can also supply ocean abundance for Sacramento Fall Run (CA), hatchery proportion</td>
<td>California Current</td>
<td></td>
<td>1980–present</td>
<td>Yes</td>
<td><a href="https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-indicator-status-trends">https://www.integratedecosystemassessment.noaa.gov/regions/california-current/cc-indicator-status-trends</a></td>
<td>Chinook presentation</td>
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<td>Joel Harding</td>
<td>Chum</td>
<td>Abundance, age, sex, length from Fishing Branch weir</td>
<td>Yukon Territory</td>
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<td>1972–present</td>
<td>Yes</td>
<td>Available on DFO network drive</td>
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<td>Coho</td>
<td>Aggregate stock abundance</td>
<td>Pacific Transboundary Rivers Taku River</td>
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<td>1980–present</td>
<td>Yes</td>
<td>Available on DFO network drive and annual</td>
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<td>Kim Hyatt</td>
<td>Sockeye</td>
<td>Pre-fishery abundance, recruits/spawner, pre and post smolt survivals, size at age, annual time to 50% return</td>
<td>Broad regions of NE Pacific</td>
<td>Index stocks comprised of 9 Sockeye CUs</td>
<td>1975–2015</td>
<td>Broad descriptions can be provided</td>
<td>Transboundary Technical Committee Reports to the Transboundary Rivers Panel (<a href="http://www.psc.org">http://www.psc.org</a>)</td>
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<td>Sockeye presentation</td>
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<td>Aaron Foos</td>
<td>Sockeye</td>
<td>Aggregate stock abundance (terminal run, catch data, escapement), productivity, age-sex-length from fishery and escapement, escapement weir counts, some stocks with smolt counts and fry-smolt survival data, GSI data, detailed mark-recapture datasets, some years with telemetry data</td>
<td>Pacific Transboundary Rivers</td>
<td>Taku River</td>
<td>1980–present</td>
<td>Yes</td>
<td>Available on DFO network drive and annual Transboundary Technical Committee Reports to the Transboundary Rivers Panel (<a href="http://www.psc.org">http://www.psc.org</a>)</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>Aaron Foos</td>
<td>Sockeye</td>
<td>Aggregate and 2 sub stock abundances (terminal run, catch</td>
<td>Pacific Transboundary Rivers</td>
<td>Stikine River</td>
<td>1954–present</td>
<td>Yes</td>
<td>Available on DFO network drive and annual Transboundary Technical Committee Reports to the Transboundary Rivers Panel (<a href="http://www.psc.org">http://www.psc.org</a>)</td>
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<td>Greg Ruggerone</td>
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<td>Athena Ogden</td>
<td>Sockeye, Pink, Chum</td>
<td>Recruits/Spawner</td>
<td>North Pacific</td>
<td>Canada Regions in BC, CUs</td>
<td>1950–2012</td>
<td>Yes, categorical estimates based on algorithm</td>
<td><a href="https://open.canada.ca/data/en/dataset/3d659575-4125-44b4-8d8f-c050d6624758">https://open.canada.ca/data/en/dataset/3d659575-4125-44b4-8d8f-c050d6624758</a></td>
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APPENDIX F: PLENARY DISCUSSION 1—DATA QUESTIONNAIRE RESULTS
### QUESTIONNAIRE RESULTS (number of responses for each statement at various scales indicated)

#### A. Abundance (including catch and pre-fishery abundance)

<table>
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<th>OCEAN SCALE</th>
<th>REGIONAL SCALE</th>
<th>POPULATION SCALE</th>
<th>STATEMENT SPECIFIC COMMENTS</th>
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<tr>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>1.1 Pre-fishery abundance (i.e., catch plus spawners) is a useful proxy for adult salmon abundance:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>a) In the Pacific</td>
<td>4</td>
<td>7</td>
<td>2</td>
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</table>

- It depends on scale of “Regional”
- Because catch and escapement constitute total abundance their sum is not a proxy for adult abundance but rather directly indicates abundance. Answers here would have been quite different at the various scales if the questions had been oriented to whether catch and escapement are useful indicators of state changes or trends in abundance.
- At the population scale, it depends on the population, and how reliable run reconstructions are
- Challenge is having accurate catch and spawner data – spawner estimates often biased low. At population scale, need to be aware of non-terminal catches.
- This is only useful at the population level if you have a reasonably thorough and accurate understanding of catch at this level of detail (mixed stock fisheries can be problematic).
- Usefulness depends on what questions you are trying to address.
- agree, return data are helpful to track trends, though does not remove catch information, which can be a driver of the patterns/trends we observe; but does describe overall numbers annually where we have these data; scale does not matter, same response;
- NuSEDS problems from linear apportionment of regional catch to spawners in a local watershed. Local variation in R/S is not actually observed in that case.
- Thinking about this further, it will depend on the species and the scale. At the ocean scale, the sum of catch and escapement is unambiguous as an indicator (assuming Ocean scale in Pacific includes GOA and Bering Sea). At regional scale (e.g., eastern Pacific, western Pacific) it will depend on the species and the exact definition of regional. For example, since most Sockeye Salmon are produced in the eastern Pacific catch and escapement aggregated will indicate what is going on there. However, because chum and pink vary greatly from wild and hatchery origins on both sides of the Pacific, one needs to precisely define what is meant by regions i.e. NPAFC “regions”, DFO regions etc…Without this common understanding answers to these questions are not useful.
### A.2 Total aggregate salmon catch (i.e. all fisheries) is a useful proxy for adult salmon abundance:

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</table>

- (disagree) There are few remaining fisheries on Atlantic salmon and many spawner populations not accurately monitored.
- Pre-fishery abundance is another phrase for recruitment (before fishing) – it is interpreted differently on the Atlantic and Pacific coasts. The point (time, space) at which this estimate is made is very important. For species/populations that have multiple sea ages at return, finding a common point in time at which recruitment is estimated is a challenge that necessitates accounting for natural mortality from the PFA (recruitment) point to the time when escapement and catches are quantified. Marine mixed stock fisheries on multiple ages complicate the calculation, stock origin is frequently not well known, and fisheries can prosecute fish at different time periods in the salmon life cycle at sea, necessitating assumptions on timing from fisheries to escapement.

### A.3 Commercial catch is a useful proxy for adult salmon abundance:

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</table>
- Not as useful as pre-fishery abundance, but in the absence of pre-fishery abundance, may be useful
- (agree) In the sense that you require this to have 1.1 (above).
- Total catch is a reasonable indicator for chum and pink and sockeye salmon at ocean scale, so so at regional scale but not at population scale. Catch is rarely a decent indicator for non-commercial species although can work for chinook in some areas.
- (disagree) Changes in fisheries regulations could mask changes in salmon abundance (particularly if fisheries are reduced to conserve specific stocks while others are abundant). Plus, not easy to get reliable catch estimates from all fisheries.
- Less useful than pre-fishery abundance estimates.
- really need to carefully interpret since catch is influenced by management actions; we do not use these to track trends; this might be all we have at ocean scales so might be useful at these broader scales since might be the only type of data we have between countries, largely I would try to avoid this; not as useful at regional scales and definitely not at population scale
- the whole problem of marine survival is all the salmon in the ocean that do not survive to be caught. I do not believe all of the survival variation is in the first months at sea.

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</table>
- Only ok for large ocean regions.
- In the absence of accounting for fisheries management changes which have a direct effect on exploitation rates, catch is not a useful proxy of abundance.

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</table>
- (agree) Because coastal commercial fishery pressure is very high in Japan.
- (agree) In the sense you need this data to provide for 1.2 and 1.1.
- Commercial catch is a reasonable indicator for chum and pink and sockeye salmon at ocean scale, so so at regional scale but not at population scale.
• Fishing Pressure in the coast of Japan is so high that commercial catch can be a useful proxy for abundance
• (strongly disagree) Changes in fisheries regulations could mask changes in salmon abundance (particularly if fisheries are reduced to conserve specific stocks while others are abundant).
• Less useful than total aggregate catch, and dependent upon the fishery/fisheries and changes over time in prosecution of fishery (management actions, gear type, etc.). Even at regional and population scales, there can be economic, environmental, or logistic reasons (poor price, no processor, fuel spills) for a lack of commercial fishery. Thus, these sometimes do not reflect adult salmon abundance.
• really need to carefully interpret since catch is influenced by management actions; we do not use these to track trends at pop scale; this might be all we have at ocean scales and regional scales;
• Catch is allocated quotas from fisheries management models and processes. Escapement can be 100%.

b) In the Atlantic

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• Almost zero commercial fisheries for Atlantic salmon.
• So, when commercial fisheries are closed, as is the case for Atlantic salmon in eastern Canada beginning in 1984 and culminating in 2000, if commercial catch is zero, does this mean abundance is zero? Not at all.

A.4 Subsistence harvest is a useful proxy for adult salmon abundance in the Arctic

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• Subsistence harvest is not conducted in Japan.
• Subsistence catch is the only abundance indicator in the Arctic.
• Subsistence harvest is not allowed in Japan.
• Community-based monitoring of subsistence harvests is effective for monitoring the occurrences and geographical distribution of vagrant salmon (and also other fishes outside known distributions) in the Canadian Arctic. While there are limits and biases with this approach, this information provides a useful proxy for abundance trends across a vast and remote area. Some basic assumptions underlying this approach include that Indigenous food fisheries (subsistence harvests) are stable across years (i.e., same locations, same effort, same gear), that reporting is constant in areas where regular reports originate, and that novel occurrences in new areas are noted and reported.
• We do not have sufficient information to support population scale assessments for salmon in the Arctic. Regional scale for salmon harvests is organized by land claims. Ocean scale is the combination of regional harvests.
• Conditions in the Arctic may be changing so fast that subsistence users are not accustomed to harvesting species that have only recently arrived or have recently increased in abundance.
• Yes, because the salmon catches are not constrained by harvest management. This will not always be true. And when salmon are abundant beyond subsistence catch requirements, that index fails (changes).
• Subsistence fisheries are a source of observations, as are all fisheries. If subsistence fisheries are relatively consistent over time, within season, in terms of effort, location fished, etc. the observations
can be informative of changes in the local ecosystem and relative abundance of salmon in the area, but the catches are difficult to relate to abundance of species overall. I know of few arctic datasets for which exploitation rates are quantified and abundance of species are known, beyond catch data.

<table>
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<th>A.5</th>
<th>Spawner escapement estimates are a useful proxy for adult salmon abundance:</th>
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- Spawner escapement has not been recorded in Japan
- Absolute spawning numbers are only available for a small portion of populations. For those cases, it can represent a robust estimates of population state. However, combining absolute and relative spawning abundances across populations (across regions & at ocean scale) would be misleading
- Utility of escapement estimates depends on accuracy and precision of data time series. Sometimes good but often mediocre or worse.
- Escapement estimates is not yet available in Japan.
- Can be difficult to get standardized escapement estimates at broader geographic scales.
- this is what we largely rely on at local and regional scales, along with return information to track trends; this is what is used by DFO's Wild Salmon Policy and Canada’s Committee on the Endangered Wildlife in Canada to track actual trends; works on population and regional scales, but on ocean scales more challenging given lack of common methods over time across countries/agencies
- Only in the absence of catch, by-catch, and pre-spawning mortality.
- (disagree) Escapement estimates, which means estimates of spawners (fish that have survived fisheries), are not useful proxies of adult salmon abundance, provided we mean abundance at the recruitment stage, i.e. total production from the ocean. We know from Atlantic salmon time series of spawners, that in some regions such as Newfoundland and Maritimes, the spawner abundance has actually increased over time, because fisheries were closed, however total abundance before fishing has actually declined.
### Abundance indices of juvenile salmon are useful proxies for salmon abundance:

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<td>(disagree) So there was no question for Atlantic salmon, but I would provide a similar response. Escapement estimates, which means estimates of spawners (fish that have survived fisheries), are not useful proxies of adult salmon abundance, provided we mean abundance at the recruitment stage, i.e. total production from the ocean. We know from Atlantic salmon time series of spawners, that in some regions such as Newfoundland and Maritimes, the spawner abundance has actually increased over time, because fisheries were closed, however total abundance before fishing has actually declined.</td>
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<td>Depends on where the juvenile estimates are from. If these are sampled in the marine environment, then there is some evidence that they may be useful. If sampled in lake or river, not useful due to large differences in marine survival</td>
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<td>For some populations, juvenile abundances may be more robust than spawners (though this is rare)</td>
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<td>Yes, as this provides inference from the brood year cohort rather than their parents.</td>
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<td>Juvenile estimates can be useful abundance indicators for individual populations, recognizing that post-smolt mortality events have not yet occurred.</td>
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<td>Generally, correlations between smolt outmigration and adult returns are not great because most juvenile salmon die before they go offshore.</td>
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<td>Agree/Disagree- In rare cases these are used to track trends; Fraser Pink salmon the only consistently assessed time series are juvenile time series and these may be used to track trends loosely; in most cases juveniles are not used as proxies for salmon abundance since we generally rely on escapement data, and if we have juvenile data, we usually have escapement data; rolling up at broader scales not possible since data are limited and not comparable</td>
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<td>In steady-state populations with unchanging habitats, sure. But this planet is called Earth, OK?</td>
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<td>Catch estimates help inform salmon fisheries and habitat management:</td>
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<td>Catch estimates on their own? If own its own, it may be useful for limited situations where single stocks are harvested independently (at the pop level)</td>
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<td>In the Atlantic</td>
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<td>Incorporating local and traditional knowledge on salmon abundance is important:</td>
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- Harder at smaller (population) scales, no management body as basin scale.
- Catch estimate is important for hatchery program to draw an egg collection plan.
- Agree for fisheries component, less so for habitat management
- Agree-Catch informs salmon fisheries management in-season, and also post-season to review fisheries implementation with management objectives (reference points, total allowable catch); on all scales catch can inform fisheries management at all these scales through CDN domestic, PST-US-Can, and NPAFC agreements
- Yes, but mixture analysis to apportion fish to stocks or populations, from mixed catches, can be seriously misleading, in that tiny components can be hugely overestimated due to small error rate for stock ID. See Appendix 2 of Ricker 1992 where he shows off-peak years of cyclic stocks have garbage estimates of returns.

- No real terminal fisheries so not of use at population scale for A salmon.
- Life is easier with just one species in the catch data.
- Sure, at least catch is the metric that management can at least monitor

- Catch estimates do not inform salmon fisheries in the Arctic (there are no fisheries in the Arctic that specifically target salmon). Bycatch of salmon in subsistence fisheries targeting other species provides occurrence and distribution information. Monitoring bycatch and reports of unusual fish captures over time provides trends which can inform re-shifting habitats (and geographical distributions), species, and potential interactions with native species and opportunities for emerging fisheries

- Local and traditional knowledge, as much of other data, is observational. The compilation of a large number of observations often provides a truer although variable description of abundance, albeit not necessarily without bias. All observations and in particular their interpretations, regardless of their source, must be confronted to other data

- More important at local scales
- TK most applicable at population or sub-stock level.
- Traditional knowledge tends to be focused on local populations close to where First Nations communities
- Most Important at population scale. Yes, this is embedded in all our escapement work; local and TEK helped design our projects and know where fish distribution is; partnerships exists b/w FN and DFO on abundance and catch monitoring; not sure it can be rolled up at broader scales, though TEK is embedded within many data sets so possibly there in any case;
- Not “abundance”… habitats and ecology, maybe. Not counts.

- Traditional knowledge tends to be focused on local populations close to where First Nations communities
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<td>c) In the Arctic</td>
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- In the Atlantic, European centered observations date several centuries (early 1600s) and even these records are not without bias, being localized and absent of temporal perspective. The same case can be made for Indigenous Knowledge in most of the Atlantic area (exclusive of northern areas like Labrador).
- Traditional knowledge on salmon abundance in the Arctic very limited but provides some historical context in lower Mackenzie where multiple populations were migrating so of some utility at ocean or regional scale. 
- Local and traditional knowledge is essential to documenting and understanding salmon abundance and changes in the Arctic.
- In the Arctic where “western” science has a much shorter history of observation, Indigenous Knowledge is an important component for challenging and understanding contemporary observations. But even Indigenous peoples’ observations are relatively recent in evolutionary timescales of the species to fully comprehend the response of salmon species to changing ecosystems.
B. Survival, distribution, and productivity (including stock and recruitment, recruits/spawner, freshwater and marine survival)

<table>
<thead>
<tr>
<th>B. Survival, distribution, and productivity (including stock and recruitment, recruits/spawner, freshwater and marine survival)</th>
<th>OCEAN SCALE</th>
<th>REGIONAL SCALE</th>
<th>POPULATION SCALE</th>
<th>STATEMENT SPECIFIC COMMENTS</th>
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<tbody>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Agree</td>
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<tr>
<td>B.1 These are useful for assessing salmon state changes and trends:</td>
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<td>a) In the Pacific</td>
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<td>b) In the Atlantic</td>
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<td>B.2 These help inform salmon fisheries and habitat management:</td>
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Yes, but subject to inappropriate (ideological) application of models such as Ricker Stock-Recruit model. Density independent events at high stock abundance are used to justify the conclusion of density-dependent survival at that abundance. In fact, nearly all salmon at stock levels that are a tiny fraction of “what might be possible.” Salmon populations are thereby trapped near the origin of the true stock recruit curve as identified by Walters and Staley (year?).

These data, assuming they are collected properly, are most useful at population scale.

As a basis for understanding stock and recruitment dynamics, an accounting of known losses, particularly in fisheries, is essential.

Indigenous and local knowledge are observations that tend to be related to presence, abundance (such as number of fish per net hauled), and seasonality in some cases. By themselves, they are not metrics of productivity or survival. They have large potential in the context of distribution, both spatially and temporally, but in all cases, they are observations that need to be confronted to other data (for example, that salmon spawn in estuaries based on observations of ripe and running fish in catches from estuaries in the fall).

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Indigenous and TEK most useful at population scale in Pacific and Atlantic

Agree-Fish distribution was based on local TEK as stock assessment programs were developed originally, so essential to this; local TEK contributes still to fish distribution information and habitat information;

Again, “survival” is specified, and TEK has nothing to say about that.

Indigenous and TEK most useful at population scale in Pacific and Atlantic

There is Indigenous Knowledge related to distribution of salmon in rivers prior to industrial developments, as well as distribution of salmon at sea prior to industrial fishing at Greenland. In some cases, however, it is not clear if it relates to one species (Atlantic salmon) or a mix of species (Arctic charr, Atlantic salmon). The literature tends to be unclear on these in some cases.

Indigenous and TEK most useful at regional scale in Arctic

Local and traditional knowledge provides essential information that adult salmon are present (can survive) in the Arctic marine and freshwater environments at harvest locations during harvest periods. Local and traditional knowledge also provides essential information regarding salmon distribution and distribution change in the Arctic, including information regarding those changes over time.

There is Indigenous related to distribution of salmon in rivers prior to industrial developments, as well as distribution of salmon at sea prior to industrial fishing at Greenland. In some cases, however, it is not clear if it relates to one species (Atlantic salmon) or a mix of species (Arctic charr, Atlantic salmon). The literature tends to be unclear on these in some cases.
## C. Biological trait information (e.g., size at age, age at maturity, age and sex composition)

<table>
<thead>
<tr>
<th>Biological trait information</th>
<th>OCEAN SCALE</th>
<th>REGIONAL SCALE</th>
<th>POPULATION SCALE</th>
<th>STATEMENT SPECIFIC COMMENTS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>C.1</td>
<td></td>
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<tr>
<td>These are useful for assessing salmon state changes and trends:</td>
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<tr>
<td>a) In the Pacific</td>
<td>3</td>
<td>8</td>
<td></td>
<td>3</td>
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<tr>
<td>b) In the Atlantic</td>
<td>1</td>
<td>4</td>
<td></td>
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<tr>
<td>C.2</td>
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<td>These help inform salmon fisheries and habitat management:</td>
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<tr>
<td>a) In the Pacific</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
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</table>

- Reference here is to phenotype observations, which can be plastic and respond to genetics, environment and combinations of these. In the context of characteristics of interest to people, size of fish in the fisheries, these are useful things to monitor, however the response is not always consistent with the inferred mechanism.
- We haven’t aggregated this information at the ocean scale, or even at the regional scale (with the exception of a few primary publications), so it’s hard to say how useful it is. There is potential for it to be useful at those scales, though evidence focus on population scales.
- Very important for helping discern mechanisms behind changes.
- Agree kind of - We don’t use this to assess status in the Pacific of our salmon directly; however, this information provides qualitative information on status of salmon since if size, age, fecundity is changing, that influences the productivity of salmon stocks and is important to understand. (strongly agree) Because they provide clues to causation. E.g. changes in fecundity at length imply changes in energetics in the last few months at sea. Changes in length at age imply changes over the entire life at sea, certainly longer than F-at-L.
- These data may be also useful for improvement of salmon hatchery program
- We haven’t aggregated this information at the ocean scale, or even at the regional scale (with the exception of a few primary publications), so it’s hard to say how useful it is. There is potential for it to be useful at those scales, though evidence focus on population scales.
• No management at ocean scale.

• Potential utility of this information is high but currently not used to their potential.

• (strongly disagree) Still relatively new considerations; have largely not been incorporated into management assessments to date; data on these metrics are either not collected or data has not been managed in a way that facilitates its use.

• Agree—Yes age and age-at-maturity is included in Stock-recruitment relationships used to assess maximum sustainable yield and escapement goals and management reference points;

• There is no marine habitat management. Changes to smolt and fry in FW habitats are valuable observations for fisheries management (subsequent survival) and habitat management (suitability, quality, quantity of habitat)

| b) In the Atlantic | 4 | 1 | 5 | 5 |

| C.3 Incorporating local and traditional knowledge on these is important |

| a) In the Pacific | 4 | 3 | 2 | 1 | 6 | 1 | 1 | 3 | 6 | 1 |

• This is where TK really contributes at the local scale.

• Indigenous Knowledge and TEK on biological traits probably only available for some local populations.

• Local and traditional knowledge regarding timing of harvest, salmon size, morphology, spawning condition, stomach contents, marks or scars, presence of parasites provides essential contextual information to inform biological sampling.

• NA…not exactly sure here what this means? We don't use TEK to collect this information, but do this through science assessments;

• (strongly disagree) These estimates are not TEK. You need to ask about habitats, behavior, predictors.

| b) In the Atlantic | 1 | 1 | 1 | 1 | 4 | 5 |

• (disagree) Indigenous Knowledge and TEK on biological traits rarely available.

• Indigenous Knowledge can be useful but is it necessarily important? In the absence of other observations, it is essential. When confronted to other data, it may be additional, similar, even redundant. Much depends upon the extent of other observations available.

| c) In the Arctic | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

• (disagree) Indigenous and TEK on biological traits rarely available.
<p>| |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>• Local and traditional knowledge regarding timing of harvest, salmon size, morphology, spawning condition, stomach contents, marks or scars, presence of parasites provides essential contextual information to inform biological sampling.</td>
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</table>
# D. Data Standards

<table>
<thead>
<tr>
<th>Data Standards</th>
<th>PACIFIC</th>
<th>ATLANTIC</th>
<th>STATEMENT SPECIFIC COMMENTS</th>
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<tbody>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
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<tr>
<td>General comments</td>
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<tr>
<td>• Data processing and models need to be modernized.</td>
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<tr>
<td>• This questionnaire reflects old-fashioned approaches.</td>
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<tr>
<td>• Did not ask about using habitat data in models. Did not ask about value of observing multiple life history stages. Did not ask about value of knowing life history strategies.</td>
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<tr>
<td>D. 1 Standardizing datasets is a concern</td>
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<td>4</td>
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<td>D. 2 Developing a uniform system of defining data standards is important</td>
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<tr>
<td>D. 3 Documenting uncertainty and assumptions associated with data and models is important</td>
<td>8</td>
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<td>2</td>
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</tbody>
</table>
| D. 4 | Incorporating local and traditional knowledge on uncertainty is important | 1 | 8 | 3 | 1 | • I assume all of my “strongly” agree statements would apply to Atlantic salmon but really don’t know these data and systems they use intimately enough to answer with confidence.  
• Essential, which leads to confrontations with non-science participants that bring their local observations and interpretations that do not conform to population or species level understanding.  
• (disagree) May be difficult.  
• Agree-in cases where we have effective partnership projects then TEK included from experts in particular systems on the data collecting.  
• It is to laugh. Biologists apply subjective ideas about data quality all the time. Guides, naturalists, and First Nations do not comment on precision of estimates. Not yet, anyway.  
• So this may be an appropriately phrased question. I am not sure that uncertainty is consistent with how Indigenous Knowledge is presented. An observation is for the most part correct, although there could be uncertainty in the detail (species specific id, sex, maturity stage, size, etc.) but this is generally not discussed or even admitted. |
| D. 5 | Highlighting differences between self-reporting and catch monitoring is important | 2 | 10 | 1 | 5 | • Agree-Necessary for data quality categorization.  
• Yes, data validation and verification is important.  
• This the human dimension, there is no reason why self-reporting should be questioned although inadequate training or unwillingness to share information tend to be the main issues with self-reporting data. In some cases, independent catch monitoring is simply not feasible, for example in broadly dispersed recreational or Indigenous fisheries. Self-reporting should be encouraged with targeted validation initiatives. |
| D. 6 | Categorical descriptions of data and model uncertainty (e.g. high, medium, low) are adequate (assume standard approach is used) | 2 | 6 | 4 | 1 | 4 | • (strongly agree) As a first cut, yet. More rigorous uncertainties can be included when available.  
• (disagree) Descriptions of uncertainty require more context than this. Uncertainty can apply to specific components of a dataset or model or be derived/propagated from different sources. One thing that could be included is if the uncertainty is explicit, or in other words, can it be accounted for in models. Conversely is the uncertainty known but it cannot be accounted for. This would be valuable for those considering the use these data.  
• Depending on the context of data collection/model being used (more intensive data/models should have more quantitative assessment of uncertainty).  
• Provide more useful products by describing distributions of possible outcomes as formal probability distributions, as confidence intervals, or as descriptions of alternative scenarios.  
• Agree-This would be better than nothing or even what we have now, ideally, we could do better than this and bound uncertainty quantitatively with modeling approaches including Bayesian approaches.  
• Hidden assumptions. Categories probably based on some measures, so information discarded. Better to relate relative precision to some predictor. See Akenhead et al 2016 for use of a proxy for relative precision, not absolute, in regression.  
• It would be a start, but we need to go beyond such descriptors. How do we ensure that these categories mean the same thing across studies? You may well have other metrics to use to describe uncertainty based on the data collected, which suggests that the emphasis should be on development of quantitative measures of uncertainty as the default. |
| D. 7 | Transparency about whether and how | 6 | 4 | 1 | 4 | • Unclear what this statement says? How uncertainty associated with data inputs “transfers” to model uncertainties?  
• Don’t understand this question. |
## 3.7.4.2.2.4

<table>
<thead>
<tr>
<th>D. 8</th>
<th>Providing and describing metadata associated with datasets is important</th>
<th>10</th>
<th>2</th>
<th>1</th>
<th>4</th>
</tr>
</thead>
</table>

- Yes, else risk GIGO.
- I assume all of my “strongly” agree statements would apply to Atlantic salmon but really don’t know these data and systems they use intimately enough to answer with confidence.
- In models, data inputs and in observations.

- Strongly Agree—Yes absolutely, this should be documented and published, so that these are retained with data sets for all users.
- Metadata is data. Do not supply some of the data when you can supply all the data. What the hell kind of scientist would do that?
- I assume all of my “strongly” agree statements would apply to Atlantic salmon but really don’t know these data and systems they use intimately enough to answer with confidence.
- We should find a more easily understood phrase than metadata, one that can be understood by the public. I am not convinced that we all have the same understanding of what is meant by metadata and this information can be captured – I am a fan of data reports that are done frequently that describes what our staff did during the year, great way to describe what was different, what was new, I guess that would be metadata?