ANNOTED BIBLIOGRAPHY

Resources Relating to Sockeye Salmon Habitat of the Skeena Watershed
Prepared by Ecotrust Canada
November, 2010

Contents

Introduction

The goal of the project was to compile and share existing data that identify habitat of sockeye salmon in the Skeena watershed. This in turn supports implementation of the Wild Salmon Policy. Ecotrust Canada carried out this work for the Habitat Subcommittee of the Skeena Watershed Initiative.

Our final products include an informational poster about high-value sockeye habitat, a set of large scale maps comprising an atlas of sockeye lake conservation units, and a large format map of the whole watershed at 1:450,000. Downloadable electronic versions of the poster and maps, and this annotated bibliography are also part of the final product.

ecotrust canada

Skeena WATERSHED INITIATIVE

Web Sites

The following web sites provide access to downloadable data, maps or reports that are relevant to sockeye habitat mapping of the Skeena watershed.

For a list of individual data layers and their sources, see the separate document entitled Data Layers.

British Columbia Marine Conservation Analysis (BCMCA)
http://www.bcmca.net/ecological-data/
Information about marine biodiversity and human activity in BC's marine waters.

Community Mapping Network
http://cmnbc.ca/category/regions/skeena
Several online atlases.

Department of Fisheries and Oceans – Community Mapping
http://www-heb.pac.dfo-mpo.gc.ca/community/tools/toolsH_e.htm#Community%20Mapping
This resource may have moved between June and November of 2010

Department of Fisheries and Oceans Libraries Catalogue (WAVES)
http://inter01.dfo-mpo.gc.ca/waves2/index2.html
Access to the library catalogue, and many of the documents are downloadable.

Department of Fisheries and Oceans GIS Maps & Data
http://www.pac.dfo-mpo.gc.ca/gis-sig/maps-cartes-eng.htm
Links to interactive mapping applications including MAPSTER, Wild Salmon Policy, Coastal Resources Information Management System (CRIMS) and Habitat Wizard, as well as to Habitat Inventory Reports and the GIS Unit Spatial Data Holdings (which include the Fisheries Information Summary System [FISS] data).

Geobase
www.geobase.ca
Access to a common, up-to-date and maintained base of quality geospatial data for all of Canada.

Lakelse Lake Watershed Society
http://www.lakelsewatershedsociety.com/report.htm
List of Research studies and Government Documents from this non-profit organization working on issues affecting the Lake and its surrounding watershed.

Land and Resource Data Warehouse (LRDW)
www.lrdw.ca
Maintained by the BC Government, LRDW is the corporate repository for integrated land, resource and geographic data that supports a variety of business requirements for the natural resource sector, other government agencies, industry and the public. There is a discovery service and downloadable data.

MapChat

http://mapchat.ca/downloads/SkeenaPosterFinal.pdf

A poster describing a software tool used to share local knowledge of salmonid habitat in the Bulkley River Valley

Pacific Fisheries Resource Conservation Council

http://www.fish.bc.ca/

The Pacific Fisheries Resource Conservation Council (PFRCC or 'the Council'), provides independent advice on conservation and environmental sustainability of Pacific salmon stocks and their freshwater and ocean habitats.

Riverscape Analysis Project

http://rap.ntsg.umt.edu/

The Project aims to produce a decision support system that will assist salmon conservation across the North Pacific Rim (NPR), based upon a robust classification (typology) of rivers and river habitats

Skeena Fisheries Commission

http://www.skeenafisheries.ca/links.htm

Links to Aboriginal, Government, Other and Data links relating to Skeena fisheries.

SkeenaWild Conservation Trust

http://skeenawild.org/resources/

Reports, maps, documents and links relating to Skeena River watershed conservation

State of the Salmon

http://www.stateofthesalmon.org/resources/

Data, Maps, Web Tools, Publications providing quantitative and qualitative information about salmon and their habitat across the North Pacific

Papers and Documents

The majority of the references are provided in PDF format in the accompanying electronic catalogue. Those that are not are typically books or older references which may be available from either the Vancouver Public Library (www.vpl.ca), interlibrary loans from your local public library, or the Libraries of Fisheries and Oceans Canada (see web sites, above).

Adkison, Milo D., and Zhenming Su. 2001. A comparison of salmon escapement estimates using a hierarchical Bayesian approach versus separate maximum likelihood estimation of each year's return. *Canadian Journal of Fisheries and Aquatic Sciences* 58, no. 8: 1663–1671.
Catalogue File: Adkison and Su 2001 A comparison of salmon escapement estimates using a HBA versus SML.pdf
Abstract
In this simulation study, we compared the performance of a hierarchical Bayesian approach for estimating salmon escapement from count data with that of separate maximum likelihood estimation of each year's escapement. We simulated several contrasting counting schedules resulting in data sets that differed in information content. In particular, we were interested in the ability of the Bayesian approach to estimate escapement and timing in years where few or no counts are made after the peak of escapement. We found that the Bayesian hierarchical approach was much better able to estimate escapement and escapement timing in these situations. Separate estimates for such years could be wildly inaccurate. However, even a single postpeak count could dramatically improve the estimability of escapement parameters.

Anon. n.d. "Catalogue of Sockeye Spawning Grounds in the Skeena System" Edited from MS report #882, Smith and Lucop 1966- additions made from Aerial Surveys (H. Smith), Ann Rpts Biol. Station, B/C 16's.
Catalogue File: Anon nd (Observations for Sustut, Johanson, Asitka, Johnson, Sicintine, Onerka lakes 1944-1967).pdf
Notes
Observations for Sustut, Johanson, Asitka, Johnson, Sicintine, Onerka lakes 1944-1967. From S Cox-Rogers at DFO October 19 2010

Anon. 1965. Adult Salmon Enumerations - Flight Records.
Catalogue File: Anon 1965 Adult Salmon Enumerations Flight Records.pdf
Notes
from DFO Library via S. Cox-Rogers Oct 2010.

Anon. 2006. Improved Salmon Escapement Enumeration using Remote Video and Time-lapse Recording Technology. Exxon Valdex Oil Spill Trustee Council, March 5.
Catalogue File: Anon 2006 Improved Salmon Escapement Enumeration using Remote Video and Time-lapse Recording Technology.pdf.
URL: http://www.evostc.state.ak.us/Files.cfm?doc=/Store/Proposal_Documents/432.pdf
Abstract
Salmon resources and services within the spill area, and particularly within Prince William Sound, were injured by the 1989 Exxon Valdez oil spill and have not yet fully recovered. To monitor the recovery of salmon stocks in the spill area and improve escapement information used to set spawning escapement goals, we propose to develop remote video and time-lapse recording technology for enumerating salmon escapement. Remote video has the potential to provide accurate, archivable documentation of salmon escapements well beyond the capacity of aerial survey indices, and well below the cost of weir and sonar projects. Videotapes can be retrieved and reviewed weekly to facilitate in-season management of commercial fisheries.
Notes
Has some general info about salmon escapement methods.

Augerot, Xanthippe. 2005. *Atlas of Pacific salmon: the first map-based status assessment of salmon in the North Pacific*. Berkeley; Portland, Or.: University of California Press; State of the Salmon.

BC Fisheries Information Services Branch. 2001. Standards for Fish and Fish Habitat Maps. B.C. Fisheries Information Services Branch, April.
Catalogue File: FISB 2001 Standards for Fish and Fish Habitat Maps.pdf
Abstract
This document presents guidelines to standardize the map format, content and presentation of the Fish and Fish Habitat information on aquatic inventory maps. Although designed for 1:20,000 or 1:50,000 scale of map presentation (common scales of representation for aquatic information in reconnaissance and overview inventories), many of these guidelines are also applicable to maps at other scales.

Beamish, R.J., B.E. Riddell, K.L. Lange, E Farley Jr., S. Kang, T. Nagasawa, V. Radchenko, O. Temnykh, and S. Urawa. 2009. The effects of climate on Pacific salmon - A Summary of published literature. June.
Catalogue File: Beamish et al 2009 The Effects of Climate on Pacific Salmon.pdf
Abstract
This is a summary of the published studies of the effects of climate and climate change on Pacific salmon. The current abundances of Pacific salmon are at historic high levels of abundance. This indicates that, in general, the recent climate is favourable for Pacific salmon production. However, not all species and not all stocks are prospering. The reasons for the high abundance of Pacific salmon and the low abundance of some species and stocks are not well understood.

Beamish, Richard J., Chrys-Ellen M. Neville, and Alan J. Cass. 1997. Production of Fraser River sockeye salmon (Oncorhynchus nerka) in relation to decadal-scale changes in the climate and the ocean. *Canadian Journal of Fisheries and Aquatic Sciences* 54: 543-554.
Catalogue File: Beamish et al 1997 Production of Fraser R Sockeye Salmon in relation to Decadal-Scale Changes in Climate and Ocean.pdf.
URL: http://article.pubs.nrc-cnrc.gc.ca/ppv/RPViewDoc?issn=1205-7533&volume=54&issue=3&startPage=543

Beamish, Richard J., Isobell A. Pearsall, and Mike C. Healey. 2003. A history of the research on the early marine life of Pacific salmon off Canada's Pacific coast. *North Pacific Anadromous Fish Commission Bulletin* 3: 1-40.
Catalogue File: Beamish et al 2003 A history of the research on the early marine life of Pacific salmon off Canada's Pacific coast.pdf
Abstract
We review studies of the early ocean period of salmon life history conducted in the coastal areas off Canada's West Coast. The role of the ocean in the dynamics of salmon populations has received considerably less study than their life cycle in fresh water, even though Pacific salmon in general spend more time in the ocean than in fresh water and the survivals in the ocean are extremely low and variable. Feeding, growth and distribution studies from the late 1950s until the present have contributed to an improved appreciation of biology of salmon during the marine phase of their life history. However, conclusions about the processes that cause the high and variable mortality in the ocean remain speculative. How fishing impacts interact with natural processes also remain to be clarified. Recent studies have demonstrated that ocean and climate conditions are important contributors to the total marine mortality of a number of species, and to the stock and recruitment relationship. We suggest that it is time to conduct the definitive studies that will identify the processes that regulate the survival of Pacific salmon throughout their entire life cycle. We propose that an international effort to study the early marine period is the way to change the current beliefs and speculations into explanations.
Notes
Good summary of the research, but little on Skeena specifically.

Boehlert, George W., ed. 1997. Application of Acoustic and Archival Tags to assess Estuarine, Nearshore, and Offshore Habitat Utilization and Movement by Salmonids. In *Proceedings of a workshop held 10-11 September, 1996*. NOAA Technical Memorandum NMFS. Seattle, Washington: National Oceanic and Atmospheric Administration (NOAA), March.

Catalogue File: Boehlert 1997 Application of Acoustic and Archival Tags to assess Estuarine, Nearshore, and Offshore Habitat Utilization and Movement by Salmonids.pdf.

Brett, J.R. 1952. Skeena River Sockeye Escapement and Distribution. *Journal of the Fisheries Research Board of Canada* 8, no. 7: 453-468.

Catalogue File: Brett 1952 Skeena R Sockeye Escapement and Distribution.pdf

Abstract

Population estimates made from observations on the number of sockeye salmon in the spawning streams of the Skeena River, B.C., during the period 1944-48 are presented. The methods used include a fence count at Babine Lake, the most important spawning area, supplemented by stream counting in the other areas and sample tagging at Lakelse. Estimates made at Babine by the latter methods were compared with the fence counts; the stream count estimates were about one-third of the actual number present, whereas estimates from tagging about twice the actual.

A brief description of the spawning streams of the Skeena is accompanied by a map showing their location. Best estimates of 1946-47 escapements to major spawning areas are: Babine, 480,000; Morice, 70,000; Bear, 42,000; Lakelse, 29,000. These comprise 92 per cent of the total for the river system. The area of the spawning beds used by sockeye in the system is about 100 acres, or of the order of 1.5 square yards per spawning pair. The division of the whole run is approximately 45 per cent to the commercial fishery, 6 per cent to the Indian fishery, and 49 per cent escapement.

Notes

Photocopied, from VPL collection.

Brett, J.R. n.d. Draft Manuscript (Skeena River Sockeye Escapement and Distribution).

Catalogue File: Brett nd Draft Manuscript Skeena Sockeye Escapement and Distribution.pdf

Notes

Starts at manuscript Page 9 as Provided by S Cox-Rogers, DFO, Oct 14, 2010.

Burgner, Robert L. 1991. --Life History of Sockeye Salmon (Oncorhynchus nerka). In *Pacific salmon life histories*, ed. C. Groot and L. Margolis, 3-117. UBC Press

Abstract

Contents: Introduction; Distribution of Spawning Stocks; Comparison of Sockeye Salmon Spawning Systems; Age Composition; Sexual Dimorphism; Upstream Migration; Spawning - including Spawning Habitat; Fecundity and Egg Size; Incubation; Emergence; Fry Movemement and Dispersal; Freshwater Life; Seaward Migration; Early Sea Life; Distribution, Migrations, and Origins of Sockeye in Offshore Waters, Feeding and Growth, Survival in the Ocean, Utilization and Abundance, Cycles and Regulating Mechanisms, Concluding Remarks, Acknowledgeents, References.

Canada. 2005. *Canada's policy for conservation of wild Pacific salmon.* Vancouver: Fisheries and Oceans Canada, June.

Catalogue File: DFO 2005 WSP.pdf

Notes

This is the Wild Salmon Policy.

Carr-Harris, Charmaine. 2009. Skeena and Nass Hydroacoustic Surveys 2008. Report to the Pacific Salmon Commission. Skeena Fisheries Commission, June.
Catalogue File: Carr-Harris 2009 Skeena and Nass Hydroacoustic Surveys 2008.pdf
URL: http://www.skeenafisheries.ca/pub_hydroacoustic_2008.pdf
Abstract
Skeena Fisheries Commission conducted hydroacoustic surveys of 4 juvenile sockeye rearing lakes in the Skeena and Nass Watersheds in 2008. Surveys were completed at Lakelse, Damdochax, Wiiminosik, and Bear Lakes. The results of these surveys are contained in this report.

Cloud, Joseph, Gary H. Thorgaard, and North Atlantic Treaty Organization. 1993. --*Genetic conservation of salmonid fishes*. New York: Plenum Press.
URL: http://books.google.ca/books?id=1GiMOOZZZkwC&lpg=PA241&ots=W0lZ3u3Sst&dq=genetic%20conservation%20of%20salmonid%20fishes&pg=PP1#v=onepage&q&f=true.

Cox-Rogers, S. 2005. A Risk Assessment Model for Skeena River Sockeye Salmon. Fisheries and Oceans Canada, January.
Catalogue File: Cox-Rogers 2005 A Risk Assessment Model for Skeena Sockeye Salmon.pdf
Abstract
This paper presents a risk assessment simulation model for Skeena River sockeye salmon harvested in marine and in-river fisheries in northern British Columbia. The model generates probabilistic statements about stock-specific catch, escapement, harvest rates, and fishery values under different fishing regimes. The model utilizes stock and recruitment production relationships derived from photosynthetic rate (PR) assessments of lake rearing capacity for 29 sockeye lakes (stockes) in the Skeena River drainage (Shortreed et al. 2001, Cox-Rogers et al 2004).

Cox-Rogers, S., J.M.B. Hume, and K.S. Shortreed. 2004. Stock Status and Lake-Based Production Relationships for Wild Skeena River Sockeye Salmon. CSAS.
Catalogue File: Cox-Rogers et al 2004 Stock Status and Lake-Based Production Relationships for Wild Skeena River Sockeye Salmon.pdf
URL: http://www.dfo-mpo.gc.ca/csas/Csas/publications/ResDocs-DocRech/2004/2004_010_e.htm
Abstract
This paper outlines stock status for wild Skeena River sockeye salmon based on updated assessments of freshwater production in nursery lakes, available catch and escapement data, and modelled exploitation rates. The aggregate stock is dominated by sockeye returning to the Babine Lake spawning channels at Pinkut and Fulton Creeks. In addition to Babine Lake, wild sockeye spawn in at least 28 other nursery lakes throughout the Skeena River drainage. Skeena River sockeye are harvested in mixed-stock marine commercial fisheries in south-southeast Alaska and northern British Columbia, in Skeena River First Nations food, social, and ceremonial fisheries, and in recreational fisheries within the Skeena River drainage. The fisheries primarily target the enhanced Babine Lake component which can withstand higher exploitation rates compared to the un-enhanced wild stocks.

Recent analyses of limnological, acoustical fall fry, and spawning ground survey data indicate that, in most cases, wild stock escapements are much too low to fully utilize lake rearing habitat and maximize smolt production. Although many lakes still require evaluation and production parameter estimates are still under review, our findings re-enforce previous assessments (Shortreed et al. 1998, 2001) concluding that the majority of Skeena nursery lakes that have been surveyed are oligotrophic, appear to be largely fry-recruitment limited (not enough spawners) and producing sockeye below potential production. In addition to recruitment limitation, some lakes are also being limited by factors such as low spawning ground capacity or quality, low in-lake growth and/or survival, nutrient limitation, glacial turbidity, and species competition. All of these factors act to reduce sockeye productivity and limit sustainable exploitation rates. Increased fry recruitment through increased escapements, combined with lake-specific restorative and/or enhancement techniques, has been suggested for improving sockeye production from non-Babine nursery lakes (Shortreed et al. 1998, 2001).

Cox-Rogers, S., J.M.B. Hume, K.S. Shortreed, and B. Spilsted. 2010. A risk assessment model for Skeena River Sockeye Salmon. *Canadian Manuscript Report of Fisheries and Aquatic Sciences*, no. 2920 (March): xii + 60p.

Catalogue File: Cox-Rogers et al 2010 A risk assessment model for Skeena River Sockeye Salmon.pdf

Abstract

This paper presents a risk assessment simulation model for Skeena River sockeye salmon harvested in marine and in-river fisheries in northern British Columbia. This paper also provides production and stock status background for Skeena River sockeye lakes. The model can be used to generate probabilistic statements about stock-specific catch, escapement, harvest rates, and fishery values under different or optional fishing scenarios. The model can also be used to evaluate re-building and recovery options. The model utilizes a stock and recruitment "engine" for predicting future production from specific escapements. The stock and recruitment parameters (productivity and capacity) used in the model are inferred from photosynthetic rate (PR) assessments of lake rearing capacity for 29 sockeye lakes (stocks) in the Skeena River drainage. User-supplied harvest rates are applied to estimated run-timing proportions (by stock) to calculate catch and escapement in each fishery. The model is spreadsheet-based and is run stochastically as a Monte Carlo simulation. We consider the simulation approach outlined in this paper to be a starting point for further work and development.

Cox-Rogers, S, and Peter Hall. 2010. Pers. Com

Catalogue File: Cox-Rogers Hall 2010 Pers Com Map Annotations.pdf

Notes

Comments on draft 1:450,000 map of Skeena sockeye habitat

David Suzuki Foundation, and Karl English. 2008. *An upstream battle - Declines in 10 Pacific salmon stocks and solutions for their survival*. Vancouver, B.C. :: David Suzuki Foundation.

Catalogue File: DSF 2008 UpstreamBattle.pdf.

URL: http://www.davidsuzuki.org/publications/downloads/2008/DSF_UpstreamBattle.pdf

Department of Fisheries and Oceans - Science. 2003. Skeena River Sockeye Salmon (update). *Canadian Science Advisory Secretariat Stock Status Report*, no. 047.

Catalogue File: DFO 2005 Skeena River Sockeye Salmon.pdf.

URL: http://www.dfo-mpo.gc.ca/csas/Csas/status/2003/SSR2003_047_e.pdf

———. 2009. Pacific salmon research: facing the climate challenge. May 20.

URL: http://www.dfo-mpo.gc.ca/science/Publications/article/2005/01-04-2005-eng.htm

Eggers, Douglas M., and James R. Irvine. 2007. Trends in Abundance and Biological Characteristics for North Pacific Sockeye Salmon. *North Pacific Anadromous Fish Commission Bulletin* 4: 53-75.

Catalogue File: Eggers 2007 Trends in Abundance and Biological Characteristics for North Pacific Sockeye Salmon.pdf

Abstract

Trends in abundance, productivity, and average size were reviewed for sockeye salmon populations from Washington, British Columbia, southeast Alaska, central Alaska, western Alaska, and Russia. Aggregate catch estimates were reasonable indicators of overall stock status, but in areas toward the southern extent of their range, population-specific return and escapement estimates are also needed by fishery managers. Sockeye abundance in Russia and western and central Alaska declined coincident with a regime shift in 1949. Declines also occurred in the eastern North Pacific although they were less severe. Abundance increases were ubiquitous around the time of the regime shift in 1977. Short-term reductions in abundance in western Alaska and parts of central Alaska followed the 1989 shift but were not evident in Russia or the eastern North Pacific. The status of many North American stocks recently declined, with severest declines in southernmost areas. Trends in survival rate indices were similar to trends in catch and abundance. Average body size was inversely related to aggregate abundance, implying that growth was density-dependent. The coherence in trends in abundance, catch, and average weight among stocks suggests that large-scale environmental processes are major factors controlling sockeye salmon survival and production around the North Pacific Rim, and probably restrict the total production from particular ocean zones. However, local-scale environmental processes can result in regional differences in productivity.

Fisheries and Oceans, and BC Ministry of Environment. n.d. -*Stream Summary Catalogue Subdistrict #4D Smithers (Vol 1)*. Fish Habitat Inventory & Information Program. Fisheries and Ocean.

Flathead Lake Biological Station. n.d. Salmonid Rivers Observatory Network. Flathead Lake Biological Station.

Catalogue File: FLBS ND Salmonid Rivers Observatory Network.pdf

URL: http://www.umt.edu/flbs/Research/Whitepapers/THE%20SALMONID%20RIVERS%20OBSERVATORY%20NETWORK%20v3.pdf

Notes

White Paper.

French, R., H. Bilton, M. Osako, and A. Hartt. 1976. --Distribution and origin of sockeye salmon (Oncorhynchus nerka) in offshore waters of the North Pacific Ocean. *Bulletin (International North Pacific Fisheries Commission)* 34. Bulletin: 113p

Abstract

In this report emphasis is on the high-seas distribution, migrations and identification of major stocks of sockeye salmon together with the relationship of distribution to the environment. A brief discussion of the life history of sockeye salmon and of the spawning stocks is provided as background information. The report concludes with a section detailing the distribution and hypothetical models of migration of stocks of sockeye salmon of Asia and North America.

Notes

Not accessed. Cited by Quinn 2005.

Gottesfeld, Allen S., Charmaine Carr-Harris, Bart Proctor, and Dave Rolston. 2008. Sockeye Salmon Juveniles in Chatham Sound 2007. Pacific Salmon Forum, July.

Catalogue File: Gottesfeld 2008 Sockeye Salmon Juveniles in Chatham Sound.pdf.

URL: http://www.skeenafisheries.ca/pub_sx_juv_chtm_snd.pdf

Abstract

The 2007 field research was designed to define the distribution of sockeye salmon smolts in the Skeena and Nass estuaries.

Juvenile sockeye migration routes and habitat use were explored in this study by examining the abundance of sockeye smolts, the timing of collections, the size of smolts and their diet, and by using microsatellite DNA analysis and mixed stock assignment techniques to shown the origin of smolts using the Skeena estuary.

Gottesfeld, Allen S., and Ken A. Rabnett. 2008. *Skeena River Fish and Their Habitat*. Portland OR; Hazelton B.C.: Ecotrust; Skeena Fisheries Commission.

Gottesfeld, Allen S., Ken A. Rabnett, and Peter E. Hall. 2002. Conserving Skeena Fish Populations and their Habitat. *Skeena Fisheries Commission* (November).
Catalogue File: Gottesfeld 2002 Conserving Skeena Fish Populations and their Habitat.pdf
Abstract
Page 93: Sockeye
The Kispiox River Watershed is among the eight most important sockeye producing watersheds in the Skeena system. Kispiox River sockeye are a unique population with spawning taking place primarily in streams tributary to the Swan, Club and Stephens Lakes. From the DFO BC16 and SEDS records, the population size seems stable, although variable from year to year.
Sockeye adults typically enter Stephens Creek in August and the beginning of September (Sterritt and Gottesfeld 2002) and migrate upstream to spawn in Club Creek and other Swan Lake tributaries. A small number of sockeye also spawn in the lower reaches of Stephens Creek. Once through Stephens Creek the sockeye will hold in either Stephens Lake or Swan Lake until ready to spawn. The major spawning grounds are located on upper and lower Club Creeks (FRB 1948). The sockeye spawning in Club Creek may be unique in the Skeena in that the spawning substrate is primarily boulder size. Other spawning areas are found on four creeks tributary to Swan Lake, of which Falls Creek is the most important. Some sockeye also spawn in Swan Lake and possibly Stephens Lake. Spawning takes place in September (Sterritt and Gottesfeld 2002). Following emergence from the spawning beds, most juvenile sockeye (>95%, Rutherford et al. 1999) spend 1 year in Swan, Club or Stephens Lakes before migrating to the sea.

Hancock, M.J., A.J. Leaney, and D.E. Marshall. 1983. --*Catalogue of Salmon Streams and Spawning Escapements of Statistical Area 4 (Upper Skeena River)*. Canadian Data Report of Fisheries & Aquatic Sciences No. 394. Department of Fisheries and Oceans, April.

Hancock, M.J., A.J. Leaney-East, and D.E. Marshall. 1983. *Catalogue of Salmon Streams and Spawning Escapements of Statistical Area 4 (Lower Skeena River)*. Canadian Data Report of Fisheries & Aquatic Sciences No. 394. Department of Fisheries and Oceans, April.
Catalogue File: Hancock et al 1983 Catalogue of Salmon Streams and Spawning Escapements of Statistical Area 4 (Lower Skeena River).pdf.
URL: http://www.dfo-mpo.gc.ca/Library/23705.pdf
Abstract
Area 4 including Coastal Streams and Lower Skeena River.
Catalogue containing each stream's location, spawning distribution, barriers and points of difficult ascent, escapement records and other general dta pertaining to the stream. The catalogue also includes a topographical map of the stream's location and in some cases a sketch which further describes the surrounding area.

Holt, Carrie, Alan Cass, and Brian Riddell. 2009. Indicators of status and benchmarks for Conservation Units in Canada's Wild Salmon Policy. DFO, February 5.
Catalogue File: Holt 2009 Indicators of status and benchmarks for Conservation Units in Canada's Wild Salmon Policy.pdf

Holtby, L. Blair, and Kristine A. Ciruna. 2007. Conservation Units for Pacific Salmon under the Wild Salmon Policy. *Canadian Science Advisory Secretariat*, no. 070.
Catalogue File: Holtby and Ciruna 2007 Conservation Units for Pacific Salmon under the Wild Salmon Policy.pdf
URL: http://www.dfo-mpo.gc.ca/CSAS/Csas/Publications/ResDocs-DocRech/2007/2007_070_e.htm

Hoos, Lindsay M. 1975. The Skeena River Estuary, Status of Environmental Knowledge to 1975. Report of the Estuary Working Group, Department of the Environment, Regional Board, Pacific Region. [Ottawa] - Environment Canada

Howes, D.E., British Columbia Land Use Coordination Office, and Resources Inventory Committee (Canada). Coastal Task Force. 1999. *British Columbia estuary mapping system*. 1st ed. Victoria B.C.: Resources Inventory Committee.
Catalogue File: Howes 1999 British Columbia Estuary Mapping System.pdf
Abstract
This manual provides a mapping and database system and methodology for large scale (typically 1:5,000) mapping of estuaries. This standard provides an overview of the mapping system, and describes the methodology, database structure and mapping procedures of the system.

Hume, J.M.B., and S.G. MacLellan. 2000. *An Assessment of the Juvenile Sockeye Salmon (Oncorhynchus nerka) Populations of Babine Lake.* Canadian Technical Report of Fisheries and Aquatic Sciences 2327: 37 p.
Catalogue File: Hume and MacLellan 2008 Pelagic Fish Surveys of 23 lakes 335615.pdf
URL: http://www.dfo-mpo.gc.ca/Library/335615.pdf
Abstract
Juvenile sockeye salmon (*Oncorhynchus nerka*) rearing in Babine Lake were re-examined 22 years after the initiation of the Babine Lake Development Project (BLDP). Abundance, distribution, size, and species composition of the limnetic fish populations, including juvenile sockeye salmon, were determined by hydroacoustic and midwater trawl surveys in the autumn of 1993 and the summer and fall of 1994 and 1995 and compared to results collected before and shortly after the start of the BDLP. Our objectives were to look for: 1) changes in the abundance of juvenile sockeye relative to spawning numbers; 2) changes in the utilization of the available nursery area; and 3) the effects of increased population size and density on the size and growth of juvenile sockeye. Abundance of fall sockeye fry ranged from $52.0 \cdot 10^6$ (1,400 fry/ha) in the fall of 1993 to ~$16.5 \cdot 10^6$ (455 fry/ha) in the autumns of 1994 and 1995. While the acoustic estimates appeared to be valid estimates of abundance, they were considerably lower than the smolt estimates from the same brood years. The dispersal and subsequent distribution of juvenile sockeye fry was similar to that found in the years before and immediately after the start of the BLDP. The size and growth rate of juvenile sockeye was similar to the earlier years and did not vary with density over the ranges studied. Our study found that Babine Lake has not reached nor exceeded its rearing capacity for juvenile sockeye salmon.

Hume, J.M.B., and S.G. MacLellan. 2008. *Pelagic Fish Surveys of 23 Sockeye Rearing Lakes in the Skeena River System and in Northern British Columbia Coastal Watersheds From 1997 to 2005.* Canadian Technical Report of Fisheries and Aquatic Sciences 2812: vi + 99 p.
Catalogue File: Hume and MacLellan 2008 Pelagic Fish Surveys of 23 lakes 335615.pdf
URL: http://www.dfo-mpo.gc.ca/Library/335615.pdf
Abstract
We conducted pelagic fish surveys using hydroacoustics, midwater trawls and small mesh gillnets in 23 sockeye (Oncorhynchus nerka) rearing lakes in the Skeena River and north and central coast regions of British Columbia. We present the results in relation to lake water type and provide detailed results for each lake. Clear lakes had the most diverse pelagic fish community but age-0 O. nerka (mostly sockeye) were the most common species found. Glacially turbid lakes had far fewer species and age-0 O. nerka were the most common. Threespine stickleback (Gasterosteus aculeatus) were the dominant species in the stained lakes and age-0 O. nerka were the only other abundant taxa. Daphnia were the dominant prey item of age-0

O. nerka in clear lakes while Bosmina dominated in the diets in stained lakes. Copepods and terrestrial insects were the most common prey items in glacially turbid lakes. The potential competitor, threespine stickleback, comprised the majority of the planktivorous biomass in stained lakes but age-0 O. nerka had the largest biomass in clear and glacial lakes.

IBM Business Consulting. 2006. *Valuation of the Wild Salmon Economy of the Skeena River Watershed*. March 13.

Catalogue File: IBM 2006 Valuation of the Wild Salmon Economy.pdf

Abstract

The Skeena watershed is Canada's second largest salmon producing river.

Although the Skeena and Nass Rivers do not have salmon farms, there have been proposals to expand the fish farm industry into this region. These proposals have been met with staunch opposition from commercial and sport fishing businesses, lodge owners and the vast majority of First Nations and local residents.

The report, Valuation of the Wild Salmon Economy of the Skeena River Watershed commissioned by these concerned citizens from IBM Business Consulting in 2006 concluded the healthy wild salmon of the Skeena River watershed are worth $110 million annually. Wild salmon support recreational tourism, sport and commercial fishing, value-added processing and provide value to BC First Nations and Alaskan citizens.

http://www.farmedanddangerous.org/page/skeenasalmon.

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Comments on maps of spawning observations for selected Conservation Units

Larkin, P.A., and J.G. McDonald. 1968. --Factors in the Population Biology of the Sockeye Salmon of the Skeena River. *Journal of Animal Ecology* 37, no. 1 (February): 229-258. URL: http://www.jstor.org/stable/2721

Abstract

1. A commercial fishery at the mouth of the Skeena River, British Columbia, has yielded an average of 881 000 sockeye salmon per year since 1908. The catch is largely 4- and 5-year-old fish that went to sea in their second year. The individual stocks of the Skeena River run are produced in twenty-one lakes and tributary streams, the largest being the Babine Lake watershed which currently provides 90% of the total yield. 2. The purpose of this study was to examine features of population biology, to indicate factors that may have contributed to them, and to assess with a computer simulation, whether a synthesis of the contributing factors explains the observed history of population changes. 3. The main features of the population biology have been the following. (i) A decline in the total size of the run. This occurred gradually between 1910 and 1948, and was associated with a decline in catch of about 50%. More recently the catch has been about 500 000 sockeye per year. In the short term, abundance has fluctuated over a four- or five-fold range, with major peaks in abundance at 3-5 year intervals. (ii) Since 1948 there has been a decline in the non-Babine stocks from 30 to 7% of the total. (iii) The relation between spawning stock size and resultant production for Skeena sockeye is a composite curve reflecting the component stocks. The variability of these makes statistical separation of the component curves difficult. Compensation coefficients of 1.75 and 1.25 for Babine and non-Babine stocks respectively, seem reasonable values in the Ricker type formulation of the stock-recruit relationship. (iv) There is a weak correlation (r = 0.36) between the proportion of 4-year-old fish in the present spawning stock and the proportion of 4-year-old fish in the progeny. Ignorance of the mechanisms which determine age of return makes the weakness of the correlation not surprising. (v) Cyclic recurrence of high brood-success occurred at 5-year intervals up to 1919, irregularly between 1919 and 1932 and at 4-year intervals between 1932 and 1948. The age composition of the spawning populations that produced peaks, varied substantially. Although 4-year-old fish predominated in the brood successes at 4-year intervals, simple notions that 4-year-old parents produce 4-year-old progeny and that a large brood always produces a large brood are inadequate as explanation. 4. Possible contributing factors to population changes are the following. (i) The commercial fishery was regulated to remove about 60% of the annual run between 1920 and 1939, and 50% from 1940 to 1950. The relation between spawning stock size and production suggests a maximum sustained yield at a rate of

exploitation of 57%, and the decline in abundance thus reflects a history of slight over-exploitation. The fishery does not harvest precocious 3-year-old males, and selectively removes 5-year-olds at a rate 1.5 times that of 4-year-olds. Dates of passage suggest that some of the non-Babine fish may have been relatively unexploited; in general there is no pronounced seasonal differential effect that would account for decline of the non-Babine stocks. (ii) Sparse information on the rearing capacity of the various lake systems suggests that the non-Babine stock may have less productive environments than the Babine. (iii) The observed variations in brood success may reflect the effect of big spawning populations on those of following years. Of many possible mechanisms predation in fresh water seems most likely as a mediating factor in the dominating effect of large runs. This depensatory effect, or some similar effect, may maintain 4-year-cycles, each of a very large run followed by three small runs, provided the population is predominantly 4-year-old fish. With the large proportion of 5-year-old fish on the Skeena, dominance effects would be more complex, producing 20-year cycles as multiples of superimposed 4- and 5-year cycles. 5. A model for the simulation of Skeena sockeye stocks was developed as follows. (i) If these are the major factors responsible for the population fluctuations of Skeena River sockeye salmon, their synthesis in a single model should provide the basis for a simulation of the history of population changes. The general model of Larkin & Hourston (1964) was adapted for this purpose. (ii) The simulation showed decline in total abundance of an appropriate order of magnitude and decrease in the relative abundance of non-Babine stocks. However, the simulation involved rapid elimination of 5-year-old fish, reflecting the selective action of the fishery in conjunction with inheritance of age of return, whereas in the real history 5-year-olds have persisted as a major age group in the run. Additionally, the short-term pattern of fluctuation was different in the simulation from that in nature, showing recurring 4-year lows, related to the predominance of 4-year-olds and the simulated dominance effect. (iii) The simulation was kept virtually free from manipulation based on hindsight and may therefore be a fair reflection of present understanding of the population biology of Skeena sockeye salmon. It underlines a lack of understanding of mechanisms determining age of return; and a lack of field studies on the possible existence of depensatory mortality from predation or other causes.

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Abstract

The Aquatic Information Partnership (AIP) is a province wide initiative focused on creating practical user-friendly tools to improve access to aquatic information in British Columbia. In order to improve scientific information and tools, previous survey results were reviewed and a user needs assessment was conducted – to build a shared understanding of user needs.

A ‘user needs assessment’ was developed by the AIP to gather further information specific to internet mapping tools, internet information catalogues and opportunities for data sharing and collaboration. One hundred respondents, from 11 major watersheds, represented Not-For-Profit organizations, consultants, federal, provincial and local governments and a smaller proportion represented aboriginal governments and academia. Watersheds (freshwater ecosystems), salmon, and ‘rivers and streams’ were the top three selected topic areas considered most significant by respondents.

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Abstract
Mean summer water temperatures in the Fraser River (British Columbia, Canada) have increased by ~1.5 °C since the 1950s. In recent years, record high river temperatures during spawning migrations of Fraser River sockeye salmon (Oncorhynchus nerka) have been associated with high mortality events, raising concerns about long-term viability of the numerous natal stocks faced with climate warming. In this study, the effect of freshwater thermal experience on spawning migration survival was estimated by fitting capture–recapture models to telemetry data collected for 1474 adults (captured in either the ocean or river between 2002 and 2007) from four Fraser River sockeye salmon stock-aggregates (Chilko, Quesnel, Stellako-Late Stuart and Adams). Survival of Adams sockeye salmon was the most impacted by warm temperatures encountered in the lower river, followed by that of Stellako-Late Stuart and Quesnel. In contrast, survival of Chilko fish was insensitive to the encountered river temperature. In all stocks, in-river survival of ocean-captured sockeye salmon was higher than that of river-captured fish and, generally, the difference was more pronounced under warm temperatures. The survival–temperature relationships for ocean-captured fish were used to predict historic (1961–1990) and future (2010–2099) survival under simulated lower river thermal experiences for the Quesnel, Stellako-Late Stuart and Adams stocks. A decrease of 9–16% in survival of all these stocks was predicted by the end of the century if the Fraser River continues to warm as expected. However, the decrease in future survival of Adams sockeye salmon would occur only if fish continue to enter the river abnormally early, towards warmer periods of the summer, as they have done since 1995. The survival estimates and predictions presented here are likely optimistic and emphasize the need to consider stock-specific responses to temperature and climate warming into fisheries management and conservation strategies.

Mathisen, Ole A., Lowell Fair, Richard J. Beamish, and Victor F. Bugaev. 2007. Density-Dependent Growth of Sockeye Salmon in the North Pacific Ocean. *North Pacific Anadromous Fish Commission Bulletin* 4: 299-310.
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Abstract
Length measurements were obtained for sockeye salmon from several major rivers around the perimeter of the North Pacific Ocean. The salmon from the Kvichak River in Bristol Bay, Alaska exhibit strong cyclic changes in abundance, usually with a period of 5 years. The lengths of salmon show the same cyclic changes but are inversely related to the magnitude of salmon abundance. The same relationship was found for all streams in Bristol Bay. The strength of this association was measured by the correlation coefficients between the same age-classes in other districts. High values were interpreted as occupation of overlapping feeding areas by each age-class during the last year in the ocean before salmon reach full maturity. There was some overlap in feeding areas of salmon from neighboring districts such as the Copper River and the Karluk/Chignik watersheds in Alaska. No association was found between Bristol Bay sockeye salmon and their counterparts in either Russia or the Fraser River, British Columbia, Canada.

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Abstract

A review of background information relevant to the selection of habitat indicators for wild Pacific salmon, in support of implementing "Canada's Policy for Conservation of Wild Pacific Salmon". Results from the review were used to plan and support an expert technical workshop held on November 17, 2005. The purpose of the expert technical workshop was to: receive feedback on the information compiled; build concensus on selection of candidate indicators, information availability and requirements for additional information; and identify feasible next steps to develop indicators further. Following the expert technical workshop, a workshop report was prepared and conclusions and recommendations were developed based on the concensus outcomes from the workshop.

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Abstract
Limnological surveys of 37 lakes. Enabled us to make preliminary estimates of the lakes' trophic status and productive capacity for juvenile sockeye.

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Abstract
Working with colleagues at the University of Washington, we used down-scaled predictions of climate warming from 15-20 GCMs to drive a new model of flow and temperature changes for rivers of the North Pacific Rim. The flow-temperature predictions were generated using forcings from the variable infiltration capacity (VIC) macroscale hydrologic simulator linked to a novel routing and coupled stream temperature model we developed. We used the SCE-UA global optimization algorithm to calibrate the model runs. Validation was done by comparison of hind casts to measured stream flows in the study area. In this presentation we will show initial results for the Columbia (1/16th degree downscale) and the Skeena (1/8th degree) Rivers. In both basins we predict a spatially predominant drying trend and both rivers get warmer in the coming decades. The mean annual flow rate of all river segments in the Skeena system are predicted to decrease by 4-170m3/s in the next 100 years. The change in mean annual water temperature will range from -0.02˚C to 0.48 ˚C per decade over all river segments with drainage area >300km2. The mean summer water temperature over all river segments will warm 0.22 ˚C per decade, associated with a 7.2% decadal decrease of mean summer stream flow. This could mean summer temperatures will approach or exceed physiological thresholds for salmonids in some segments. Ground-surface water exchanges in floodplain segments were not modeled and certainly will provide some buffering of flow and temperature. In any case, climate warming effects will be significant and additive to other pressures on Skeena salmonid fisheries.

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Abstract

Ocean surveys show that extremely sharp thermal boundaries have limited the distribution of sockeye salmon (Oncorhynchus nerka) in the Pacific Ocean and adjacent seas over the past 40 years. These limits are expressed as a step function, with the temperature defining the position of the thermal limit varying between months in an annual cycle. The sharpness of the edge, the different temperatures that define the position of the edge in different months of the year, and the subtle variations in temperature with area or decade for a given month probably all occur because temperature-dependent metabolic rates exceed energy intake from feeding over large regions of otherwise acceptable habitat in the North Pacific. At current rates of greenhouse gas emissions, predicted temperature increases under a doubled CO2 climate are large enough to shift the position of the thermal limits into the Bering Sea by the middle of the next century. Such an increase would potentially exclude sockeye salmon from the entire Pacific Ocean and severely restrict the overall area of the marine environment that would support growth.

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Abstract

Mixed-stock harvest of wild and enhanced salmon stocks greatly complicates the conservation of salmon diversity, and nowhere is this more evident than in the fisheries for sockeye salmon in the Skeena River, British Columbia, Canada. The total catch and production of sockeye salmon from the Skeena River has set record high levels over the last decade after 100 years of intensive commercial fishing. However, both species and stock diversity decreased significantly over the course of the fishery. Species diversity has largely been restored through conservation action, but many individual populations remain at very low abundance. Fishery managers have struggled to find an acceptable trade-off between extracting economic benefits from enhanced stocks while protecting less productive wild stocks from extirpation. Recent policies promise to provide explicit limits to these trade-offs based on stewardship ethics and conservation principles.

Contacts

The following people are suggested resources for research relating to sockeye salmon habitat of the Skeena watershed. Most were contacted and helped in some way in this project. We thank all of them for their contribution to the body of knowledge concerning sockeye habitat.

Contact Name	Title	Organization / Affiliation
Bruce Baxter		DFO PBS Stock Assessment
Terry Beacham	Research Scientist	DFO - Salmon Genetics (Nanaimo)
Dave Bustard		formerly DFO
†Mark Cleveland	Head Biologist	Gitanyow Fisheries Authority
†Steve Cox-Rogers	Biologist	DFO (stock assessment div, Prince Rupert)
Robbie Dams	Community Advisor	DFO (Terrace)
Waleed Elmarimi	GIS Technologist	DFO (OHEB)
Barry Finnegan	Biologist	DFO - Salmon Section (Smithers)
Matthew Goslin	GIS Analyst	State of the Salmon
***†Allen Gottesfeld**	Head Scientist	Skeena Fisheries Commission
†Peter Hall	Biologist	DFO
***Bruce Hill**		Headwaters Initiative
***Joy Hillier**	Assessment Biologist	DFO OHEB Prince Rupert
Scott Hinch	Professor	UBC
Jeremy Hume	Research Biologist (surveyed Babine Lake, etc.)	DFO, Cultus Lake Salmon Research Lab
Mike Jakubowski		DFO
Sukhbir Johal	GIS Technician	Metlakatla Treaty Office
***Greg Knox**	Executive Director	Skeena Wild
Cheryl Lynch		DFO
Donna Macintyre	Fisheries Director	Lake Babine Nation (Burns Lake)
Dwight McCullough	contact for all spatial files. GIS Coordinator	DFO
†Lana Miller	Resource Restoration Biologist	DFO (restoration unit) - Smithers
Mike Morrell		
Pat Moss	Executive Director	Northwest Institute
Dave Nicolson	Project Manager	BCMCA
Craig Outhet		North Coast-Skeena First Nations Stewardship Society (NCSFNSS)
Daniel M. Pauly	Professor	UBC Fisheries Centre
Dave Peacock	Area Chief	DFO (stock assessment div, Prince Rupert)
***Dean Peard**		MOE (Fish and Wildlife Science and Allocation Section)
†Ken Rabnett		
Brian Riddell	Executive Director	Pacific Salmon Foundation
Carrie Robb	GIS Specialist	Living Oceans Society
Ken Shortreed	Scientist, Freshwater Ecosystems Section	DFO, Cultus Lake
***Cristina Soto**	Marine planner/biologist	North Coast-Skeena First Nations

Contact Name	Title	Organization / Affiliation
		Stewardship Society (NCSFNSS)
Jack Stanford	Professor	University of Montana, Director of Flathead Biological Station
Charles Steinback	Director, Marine Planning	Ecotrust
Art Tautz		MOE (Retired)
Marc Trudel	Research Scientist	DFO - High Seas Salmon
Dan Wagner	Resource Manager	DFO (Bella Coola)
Lance Williams	GIS Technician	Formerly Gitxsan Watershed Authorities, Hazelton, B.C.
Gordon Wilson		Gitxsan Watershed Authorities, Hazelton, B.C.
Chris Wood	Research Scientist	DFO - Nanaimo

* Habitat Subcommittee Members

† Provided feedback on mapped freshwater habitat during Expert Review phase

Methodology and Data Gaps

Defining Habitat

Sockeye habitat includes spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly. Fish habitat is not confined to the water in which they are found; upstream waters and upslope lands – in other words, the watersheds – are an integral part of their habitat.

Data Gathering and Expert Review

Starting in April 2010, we researched and gathered information from a number of sources listed in the preceding sections.

For this project, the largest emphasis in data gathering was on identifying known spawning locations. These areas, and the watershed upstream of them, are shown on the maps produced. For sockeye, unlike other species of salmon, spawning occurs in lakes as well as rivers.

The Fisheries Information Summary System (FISS) dataset and Hancock *et al.*'s 1983 *Catalogue of Salmon Streams and Spawning Escapements of Statistical Area 4* proved to be the most useful for identifying known spawning locations.

To supplement and update the available, published data, we met with local experts to review the sockeye spawning and rearing locations. These people are marked with a † in the table in the previous section. In some cases, the feedback received could not be readily incorporated into our map products – for example some areas were identified as needing more research which was beyond our capacity to pursue in this project. This valuable information was scanned and is provided along with the references (Jakubowski 2010, Cox-Rogers and Hall 2010).

Some spawning locations are not used every year, depending on local conditions. In general, we included on our maps all spawning locations with recent historical observations. However we did remove historical locations where local experts told us that no spawning has been observed in a given location despite thorough exploration over a number of years.

Data Gaps and Limitations

This project was focused on identifying the best available information about sockeye in the Skeena. Specifically, the project did *not* include:

- New or original research or fieldwork
- Modelling of potential habitat

The most common life history for sockeye is to rear in lakes (known as nursery lakes), and there is general consensus about which lakes in the Skeena are used as nursery lakes. However some sockeye rear in the rivers before migrating to the ocean, and the rearing locations for these "river-type" sockeye is not well known, and was therefore not included in our maps.

Utilization of the estuary and ocean by Skeena sockeye is less studied than the freshwater, despite the importance of these habitats to the survival of the species. In the poster, this information is thus presented at a coarser scale and represents approximations to the areas used by Skeena sockeye.

Data gaps exist in published research, as some lakes and sections of the river are studied much more thoroughly than others. Further, some collected data exist in a format that is not easily accessible. The DFO has begun a library project to make information accessible, but there is a wealth of information stored only on paper regarding sockeye presence and habitat. Some reports that were pulled out for this project (including data for Onerka Lake, which may be considered as a Conservation Unit in the future) are included in the references (*Anon.*, nd; *Anon.*, 1965, Brett, nd).

Many of the data sets were collected for different purposes, and at different scales, and thus it can be problematic to display and compare some information.

Any compilation of this nature is necessarily incomplete: conditions change in the environment; areas marked are approximations; and some sockeye spawning areas or sockeye-bearing locations are unknown.

If you have information to add to future maps, please contact: Pacific Salmon Foundation at skeena@psf.ca .