Water Temperature, River Discharge, and Adult Sockeye Salmon Migration Observations in the Babine Watershed, 1946-2014

H.W. Stiff, K.D. Hyatt, P. Hall, B. Finnegan, and D. Macintyre

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

2015

Canadian Manuscript Report of Fisheries and Aquatic Sciences 3053

Fisheries and Oceans Canada
Pêches et Océans Canada
Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques ques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits a l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 3053

2015

WATER TEMPERATURE, RIVER DISCHARGE, AND ADULT SOCKEYE SALMON MIGRATION OBSERVATIONS IN THE BABINE WATERSHED, 1946-2014

by

H.W. Stiff, K.D. Hyatt[1], P. Hall, B. Finnegan[2]
and D. Macintyre[3]

[1] Fisheries and Oceans Canada, Science Branch, Pacific Biological Station, Nanaimo, B.C.

[2] Fisheries and Oceans Canada, North Coast Stock Assessment Division, Prince Rupert, B.C.

[3] Lake Babine Nation Fisheries, Burns Lake, B.C.

Cat. No. Fs 97-4/3053 ISSN 1488-5387

Correct citation for this publication:

Stiff, H.W., Hyatt, K.D., Hall, P., Finnegan, B., and Macintyre, D. 2015. Water temperature, river discharge, and adult Sockeye salmon migration observations in the Babine watershed, 1946-2014. Can. Manuscr. Rep. Fish. Aquat. Sci. 3053: vi + 169 p.

TABLE OF CONTENTS

ABSTRACT

Stiff, H.W., Hyatt, K.D., Hall, P., Finnegan, B., and Macintyre, D. 2015. Water temperature, river discharge, and adult Sockeye salmon migration observations in the Babine watershed, 1946-2014. Can. Manuscr. Rep. Fish. Aquat. Sci. 3053: vi + 169 p.

Historical meteorological and hydrological data were assembled to review the influence of changes in these environmental factors on patterns of adult Sockeye migration in the Babine River, British Columbia. Regional air temperature data collected from Environment Canada meteorological stations were statistically related to intermittent water temperature time-series (2003-2014) recorded at the Babine fish fence to hind-cast daily water temperature in Babine River for 1910-2014. Flow data from two hydrometric stations in the Babine watershed were statistically-related to construct a continuous daily discharge time-series for 1945-2014. A stratified categorical frequency analysis of daily migration rates versus water temperature and flow conditions, lagged 0-7 days earlier, was used to discern the most likely combination of threshold values for temperature, discharge and associated time lags contributing to daily fence count variation. Exceedance analyses were applied to reconstructed environmental time-series to review trends in events beyond these thresholds for water temperature and flow co-variates.

Though trending upward (0.2°C per decade) since 1908, summer air temperatures remain cool in this northern watershed. Estimated daily mean water temperatures during Sockeye migration are approximately 15°C. The frequency and duration of extreme flows in the Babine River rose over the past 2-3 decades, indicating increasing variability in seasonal discharge levels. Though elevated water temperatures are still infrequent and do not appear to be limiting Sockeye migration, the frequency and duration of periods of warmer air temperatures increased since the 1970s relative to previous decades, and consequently average summer water temperatures appear to be exceeding thresholds conducive to salmon migration more frequently and for longer periods of time since the 1990s. However, there are inherent uncertainties in estimated water temperatures due to insufficient high-quality water temperature observations. The most consistent environmental impact on Sockeye migration was a delay in the start of significant migration past the fence due to initial high Babine River discharge levels: when high flows persisted into the migratory period, high migration rates were generally inhibited until daily mean discharge dropped below ~100-120 cms. A non-parametric statistical method was used to explore the possibility that a limiting factor for high migration rates existed downstream in the Babine River. Preliminary results suggest that water temperature and discharge conditions 5-6 days earlier are most highly associated with large changes in migration rates at the fence.

RÉSUMÉ

Stiff, H.W., Hyatt, K.D., Hall, P., Finnegan, B., et Macintyre, D. 2015. Observations sur la température de l'eau, le débit de la rivière et la migration des saumons rouges adultes dans le bassin versant de la rivière Babine, de 1946 à 2014. Rapp. manus. can. sci. halieut. aquat. 3053: vi + 169 p.

On a colligé des données météorologiques et hydrologiques historiques afin d'examiner l'influence des changements de ces facteurs environnementaux sur les tendances de la migration du saumon rouge adulte dans la rivière Babine, en Colombie-Britannique. On a rapproché statistiquement des données régionales sur la température de l'air recueillies à des stations météorologiques d'Environnement Canada, et une série chronologique intermittente relative à la température de l'eau (2003-2014) provenant de la barrière de dénombrement de la rivière Babine afin de prévoir *a posteriori* les températures de l'eau quotidienne dans la rivière Babine entre 1910 et 2014. Les données sur le débit recueillies à deux stations hydrométriques dans le bassin versant de la rivière Babine ont été rapprochées statistiquement à une série chronologique continue sur le débit d'eau quotidien de 1945 à 2014. Une analyse par fréquence des catégories de la migration quotidienne par rapport au débit et à la température de l'eau (décalage de 0-7 jours plus tôt) a servi à déterminer la combinaison la plus probable des valeurs de seuil de la température, de l'écoulement et des décalages connexes (ces derniers peuvent révéler l'emplacement probable de l'influence environnementale correspondante) contribuant à la variation observée lors du dénombrement quotidien à la barrière. Des analyses de l'excédence ont été appliquées aux séries chronologiques environnementales reconstituées pour examiner les tendances dans les événements au-delà de ces seuils en regard des covariables de la température de l'eau et du débit.

Même si elle affiche une hausse (0,2 °C par décennie) depuis 1908, la température de l'air en été demeure froide dans ce bassin versant nordique. La température moyenne de l'eau durant la migration du saumon rouge est estimée à 15 °C. La fréquence et la durée des périodes de débit extrême dans la rivière Babine ont augmenté au cours des deux ou trois dernières décennies, ce qui laisse supposer une variabilité accrue des niveaux d'écoulement saisonniers. Bien que les températures élevées de l'eau demeurent rarement observées et ne semblent pas restreindre la migration du saumon rouge, la fréquence et la durée des périodes de température de l'air plus chaude ont augmenté depuis les années 1970 par rapport aux décennies précédentes; par conséquent, la température moyenne de l'eau en été semblé, depuis les années 1990, plus souvent et plus longtemps dépasser les seuils déclenchant la migration des saumons. Cependant, il existe des incertitudes inhérentes aux estimations de la température de l'eau en raison du nombre insuffisant d'observations de qualité sur la température de l'eau. L'impact environnemental le plus récurrent sur la migration du saumon rouge est un retard dans le début de la migration pour la majorité des poissons après la barrière de dénombrement à cause des niveaux d'écoulement de base élevés dans la rivière Babine : lorsque le débit demeure élevé durant la période migratoire, on n'observe généralement pas un taux élevé de migration jusqu'à ce que le taux moyen d'écoulement diminue pour atteindre environ 100-120 cm^3/s. Une méthode statistique non paramétrique a été utilisée pour étudier la possibilité qu'un facteur limitatif du taux élevé de migration soit présent en aval de la rivière Babine. Les résultats préliminaires laissent entendre que la température de l'eau et les conditions d'écoulement 5-6 jours plus tôt sont principalement associées à d'importants changements dans le taux de migration à la barrière.

INTRODUCTION

Maintaining healthy and diverse populations of salmon that will support sustainable fisheries in the present and for future generations is the key goal of the Department of Fisheries and Oceans' *Wild Salmon Policy* (Fisheries and Oceans Canada 2005). This goal is advanced by safeguarding the genetic diversity of wild salmon populations, maintaining habitat and ecosystem integrity, and managing fisheries for sustainable benefits.

However, management methods to meet sustainable fisheries and biodiversity objectives are likely to be affected by climate change impacts on the distribution, abundance, and productivity of wild salmon populations (Finney et al. 2002). Therefore, conservation, restoration, and harvest management of many wild salmon populations will require improvements in knowledge of the extent to which human disturbance versus natural disturbance events control variations in salmon growth, survival, and production.

Within the general category of natural disturbance regimes or events, annual and seasonal variations in freshwater temperature and flow represent the most common factors exerting a major influence over salmon life history outcomes. Analyses of historical data indicate that significant changes in regional meteorological factors (such as air temperature and precipitation) that directly affect freshwater quantity and quality have already occurred in response to climate change in Canada's Pacific region (e.g., Whitfield and Cannon 2000; Whitfield 2001; Whitfield, Bodtker, and Cannon 2002), and regional climate model projections point to increased changes in these factors through the 21st century (Abdul-Aziz, Mantua, and Myers 2011; Littell et al. 2011).

Recent investigations in the Pacific Northwest and British Columbia have demonstrated regional temperature shifts of about 0.8°C over the past century, with projected temperature increases of 1.5-3.2°C in near-future decades (Mote et al. 2003). Seasonal precipitation has also changed markedly in the recent past (Walker and Sydneysmith 2008), and future projections point to wetter winters and drier summers, with a high likelihood that extreme events involving regional temperature and precipitation will become more frequent (Mantua, Tohver, and Hamlet 2010; IPCC 2007). These analyses also indicate that the magnitude and direction of historical and projected climate variability exhibit sub-regional specificity due to the large and topographically complex areas involved (Walker and Sydneysmith 2008).

Temperature effects on migrating adult Sockeye (*Oncorhynchus nerka*) have been well documented in many river systems in the Pacific Northwest (Hyatt, Stockwell, and Rankin 2003; Nelitz et al. 2007; Salinger and Anderson 2006). Lethal temperatures are reported in the range 21-24°C, and water temperatures in excess of 18°C may affect migration speed, cause timing delays, and alter spatial distribution of Sockeye salmon (Hyatt et al. 2015; Pellett et al. 2015). Increased water temperature also may result in secondary effects such as increased disease, resulting in pre-spawn mortality (Cooke et al. 2004; Hinch and Martins 2011). Thermal stress has also been found to reduce salmon gamete viability, fertilization rates and decrease egg to fry survival rates (Jensen et al. 2004). Since Sockeye populations may also differ in their thermal tolerances, reflecting local adaptation to conditions over their historic evolution (Farrell 2009; Martins et al. 2012), stock-specific responses to climate variation and change impacts are also possible (Martins et al. 2010).

Stream discharge levels may also be associated with variations in migration timing, causing delays, affecting swimming speed, and inducing biological stress during upstream migration of adult salmonids (Hinch and Bratty 2000). The quantitative effects may differ between waterbodies due to unique physical stream attributes (rapids and falls, canyons, etc., but also man-made fishways and weirs) which influence water velocity in key locations along the migratory route. In some cases, low flows may result in physical limits to fish passage; in other cases, high flows may generate velocity barriers that reduce or prohibit upstream migration.

This report documents the data assembled for derivation of historic water temperature and flow in the Babine watershed, the primary source of Sockeye production (80-93%) in the Skeena system in northern British Columbia and the largest single Sockeye salmon population in Canada (Wood et al. 1998; Cox-Rogers et al. 2010). This report is one of a series intended to consolidate and document historic observations on key life history events and associated environmental variables for relatively data-rich Sockeye and Chinook salmon populations distributed throughout their range in Canada's Pacific region (Hyatt et al. 2015; Stiff et al. 2013, 2015a, 2015b; Damborg et al. 2015). Although there are many potential uses for these data, the focus of our current work is to develop lifestage-specific models that identify potential associations between salmon production variations and climate variation effects in freshwater and marine ecosystems throughout the eastern rim of the north Pacific.

STUDY AREA

The Babine watershed lies within the Sub-Boreal Interior eco-province and is divided into two eco-sections: the Babine Upland eco-section and the Southern Skeena Mountains eco-section (Demarchi et al. 1990 in: Bartemucci and Williston 2012). The Babine watershed contains parts of the Babine Uplands, Southern Skeena Mountains and the Manson plateau. The watershed exhibits the continental climate of the SUB-BOREAL SPRUCE biogeoclimatic zone, and the coastal temperate climate of the INTERIOR CEDAR HEMLOCK zone (Bartemucci and Williston 2012).[1] Average annual rainfall is 538 mm, with mean annual temperature of 3.4°C (Table 1)[2]. Summer air temperatures during peak Sockeye migration periods averaged 14-15°C, with typical maximums of 20-21°C, and total monthly precipitation of 40-45 mm.

Babine Lake, situated in the rolling Nechako Plateau region, is the largest natural lake in the province of British Columbia and is generally characterized as dystrophic (stained by terrestrial organic matter), and oligotrophic (low in nutrients, particularly

[1] Trewartha climate classification: Dc; Köppen-Geiger climate classification: Dfc
[2] Environment Canada meteorological station 1078209 TOPLEY LANDING (Babine Lake) Climate Normals 1981-2010.

phosphorus, with low phytoplankton productivity) (Stockner and Shortreed 1976; Levy and Hall 1985). The lake is a long (150 km), narrow body of water located at an elevation of 711 m, draining an area of approximately 6,500 km^2. It has a surface area of 461 km^2, mean depth of 61 m, and a maximum depth of 186 m (Shortreed and Morton 2000). The lake is divided into the north arm (45 km), main basin (65 km), south basin (45 km), and Morrison Arm (13.4 km).

Four main tributaries, the Fulton, Morrison, Pinkut, and Sutherland Rivers drain 53 percent of the watershed. Peak discharge from the tributaries occurs in May or June with the Fulton River contributing approximately half of the annual discharge to the lake. Babine Lake is usually ice-covered from late October to early May.

The 2-km upper Babine River joins the outlet on the north arm of Babine Lake with Nilkitkwa Lake, a narrow lake about 10 km in length. The 96-km lower Babine River drains northward from the Nilkitkwa Lake outlet (Figure 3; drainage area: 6,732 km^2) before angling westward through the Skeena Mountains to join the Skeena River. Major tributaries to the Babine River are the Nilkitkwa River, Nichyeskwa Creek, Shelagyote River and the Shedin River. The Babine River contributes approximately 15% of the mean annual flow to the Skeena (1,760 cms) at their junction (Levy and Hall 1985).

The Skeena River system originates in the Spatsizi Plateau in northwestern British Columbia, and flows 570 km to the Pacific Ocean (Figure 1). The Skeena drains an area of 54,400 km^2 with a mean annual discharge of 1,760 cms. The drainage area of the upper Skeena, above the confluence with the Babine, is approximately 12,400 km^2. Maximum freshet discharges occur in mid-June during high elevation snowmelt. A secondary Skeena River discharge peak can occur in October in some years due to heavy autumn rainfall (Figure 4).

A natural rock slide in the Babine River near Gisgagaas[3], about 12 km from the confluence with the Skeena, severely delayed and obstructed Sockeye salmon migration in 1951 and 1952. In this area – the Babine Canyon – the river has incised a corridor sometimes up to 100 m deep, with slopes from 50 degrees to near vertical. The gradient of the 30 m wide Babine River at this site is at its steepest, averaging 9.5% between Gisgagaas and a point 14 km upstream (Godfrey et al. 1954).

The obstruction was cleared by 1953, but the event led to the formation of the SKEENA RIVER MANAGEMENT COMMITTEE in 1954 to investigate potential improvements in Babine stock condition, management, and yield (West 1978). Construction of spawning channels at Fulton and Pinkut creeks in the late 1960's during the BABINE LAKE DEVELOPMENT PROGRAM (BLDP) resulted in increased Sockeye escapements and fry densities in most years since the early 1970's (Shortreed and Morton 2000; Wood 2001; Cox-Rogers and Spilsted 2012).

[3] Also known as *Kisgegas* (Godfrey et al. 1954).

METHODS

DATA SOURCES AND ANALYSIS

Sockeye Migration

Sockeye salmon bound for the Babine watershed pass through the commercial fishery Area 4 from early June to late August. Sockeye take, on average, 3-5 weeks to travel the 360 km from the Tyee commercial fishing boundary at the mouth of the Skeena (Takagi and Smith 1973).

The Babine River salmon counting fence, situated at the lower boundary of the Sockeye spawning grounds, is located one kilometre downstream of Nilkitkwa Lake, 96 km upstream of the confluence with the Skeena River (Takagi and Smith 1973). A wooden counting fence was established in 1946 and used to provide an accurate escapement count of sockeye and other species of salmon entering Babine Lake.

All species of salmonids are present in the Babine River, with Sockeye being the most numerous. Three distinct Sockeye run timings were originally identified by tagging studies (Smith and Jordan 1973), corresponding to early-run Babine Lake tributaries spawners, mid-run Pinkut/Fulton/Morrison lake outlet spawners (largely enhanced), and late-run Babine River/Nilkitkwa river spawners.

Neither migration timing nor hydrometrics for the six years of available data between 1946-1952 were used for statistical analyses in this study, based on likelihood that the hydrology at this location was altered after the slide event in 1951 and restoration activities in 1952.

The counting fence was upgraded to the contemporary design in 1992. The fence is normally installed in early July, depending on water levels in the Babine River (Table 2). Installing the fence entails positioning sixty-six 1.5 x 2 m aluminum panels along the 110 meter frame that spans the width of the Babine River. Seven holding traps, approximately 2x3 m in size are spaced across the river on the upstream side of the frame. After all panels are in place, each of the seven traps is operated by positioning sliding doors and counting chutes.

The fence is opened to allow fish through from 6:00 to 22:00 daily and counting between these times is performed in a series of two-hour shifts by two to four persons, depending on the numbers of fish migrating. Fish are tallied by species and summed across observers for a daily total. Large numbers of pink salmon are also present and spawn directly above the counting fence. When post spawning mortalities occur, the fence may be littered with their carcasses, which are subsequently pitched over the fence. At the end of the salmon migration, the aluminum panels are removed and fence operations are terminated.

Daily Babine Lake Sockeye fence counts (1946, 1947, 1949-1963, 1965-2014) were provided by FISHERIES AND OCEANS CANADA (DFO).[4] These data are finalized post-season as daily totals of large (fish > 44 cm fork length and older than age-3) and small (“jack”) Sockeye (“jacks” which are age-3 fish < 40 cm fork length) by DFO

---

[4] Babine fence counts published online by DFO NORTH COAST STOCK ASSESSMENT DIVISION: http://www.pac.dfo-mpo.gc.ca/fm-gp/northcoast-cotenord/babine-eng.html; downloaded July 2014.

personnel. DFO and the Lake Babine Nation (LBN) have co-managed the Babine fence facility since 1993 (see notes: Table 2). LBN Fisheries have fully staffed and managed the facility since 2008. The fence counts and spawning ground counts are maintained in an Excel "Escapement Table Database" maintained by DFO in Prince Rupert (Spilsted and Spencer 2009). The data are verified each fall and subsequently transferred to the regional DFO NuSEDS escapement database each year (Cox-Rogers and Spilsted 2012).

Over the years, the Lake Babine Nation has conducted ESSR[5] or in-river commercial fisheries[6] from the fence (Table 2). Though daily tallies of the fisheries are included in the finalized fence counts, during commercial fisheries a 'fishery effect' is occasionally evident in the resulting daily migration pattern, exhibiting low total counts on fishery dates relative to days immediately prior or subsequent (e.g., 2001-2012). During fishery dates, fewer chutes were designated for fish passage for half a day, and actual fish passage through those chutes was reduced, possibly due to harvest activities at other chutes. Due to fish handling time, tallies in the harvest chutes were also reduced relative to when they were used for counting only. Combined, these activities may have contributed to brief delays (1-2 days) of fish below the fence during peak migration periods, resulting in artificially low fish passage counts during harvest dates followed by a surge in migrant counts through the fence the next day. To ameliorate the effects of this oscillating pattern, a three-day centered moving average of daily counts was used to smooth the count data in all years for use in subsequent co-variate analyses.

To standardize the annual adult migration time-series for inter-year and inter-stock comparisons, daily percentages of the three-day moving average of total adult + jack Sockeye[7] were calculated relative to the annual total stock escapement. Annual plots of daily and cumulative migration rate (percentage relative to the annual total escapement) were overlaid with historical mean and maximum daily migration rate by Julian day-of-year, for inter-annual migration pattern comparisons. Daily migration rate (percentage) data were further transformed using the arcsin function to normalize the percentage data where appropriate for parametric analyses (Sokal and Rohlf 1969).

Univariate statistical analyses were used to characterize the historical stock migration data (number of observations, central tendency (mean, median, mode, etc.), scale (range, variance, extreme values and outliers), and shape (skewness, kurtosis)). Median (50^{th} percentile) and 75^{th} quartile values of the historical datasets were calculated to establish categories of "insignificant" or "negligible" daily

---

[5] ESSR fisheries (ESCAPEMENT SURPLUS TO SPAWNING REQUIREMENTS) are currently restricted to Babine Lake near the spawning channels to target enhanced surplus Sockeye. In the past, ESSR fisheries for large Sockeye occurred at the Babine fence. ESSR dipnet fisheries for jack Sockeye continue at the Babine fence but have little or no discernible effect on daily migration patterns.

[6] In-river, demonstration commercial fisheries of large sockeye, are based on allocations from gillnet and seine licenses.

[7] Though smaller-bodied fish (jacks) exhibit 1-2 weeks later run timing than large adults at the Babine fence, jacks demonstrate similar late timing at the mouth of the Skeena (North Coast Tyee test fishery). Thus, Sockeye age classes were summed by date as in other similar analyses (Hyatt et al. 2015; Stiff et al. 2013; 2015a; 2015b).

migration rates (0-50th percentile) versus "significant-but-moderate" (50-75th percentile) and "significant-and-high" (75-100th percentile) migration activity.

The "TYEE INDEX" of daily Skeena Sockeye migration obtained from gillnet test fishery operations[8] conducted in the lower Skeena River at Tyee since 1956 enabled a subjective comparative analysis of daily migratory patterns with observations at the fence 360 km upstream, since 75-90% of Skeena Sockeye are destined for the Babine system (Cox-Rogers and Spilsted 2012). Sockeye migration time between the Tyee site and the Babine River Fence is estimated to be 3-5 weeks, depending on flow conditions and time of season (early versus middle versus late run Sockeye) – eight tag experiments between 1947 and 1958 indicated a mean range of 20-38 days ± 2-7 days (Godfrey et al. 1954; Takagi and Smith 1973; Table 3).

A simple multi-year correlation analysis was used to statistically identify the time lag between the two sites that 'explained' the most variation in daily migrant indices. Although a high degree of correspondence between Tyee and Babine fence migration patterns would not be expected at the daily resolution level given the distance, significant discrepancies in the annual patterns could be indicative of a barrier or restriction between those locations. The daily TYEE INDEX was standardized on an annual basis as above and the daily percentages were correlated with Babine daily fence count percentages (after each index was normalized using the arcsin transform) at various time lags from 15-40 days to identify the 'expected' time lag (in days) based on maximum positive correlation. The 'expected' time lag was applied to the TYEE INDEX to overlay that time-series with the fence counts. Annual coefficients (R) were ranked by the correlation level to identify years of low correspondence (i.e., where $R_{Year} << R_{AllYears}$), which might be indicative of migration pattern deviations related to environmental conditions.

Environmental Data

Meteorological, hydrographic, and water temperature data necessary for derivation of long-term (30+ years) time-series of water temperature and flow conditions were assembled from online databases, published documents, unpublished reports, and personal records from government agencies (e.g., ENVIRONMENT CANADA, WATER SURVEY OF CANADA (WSC), LAKE BABINE NATION FISHERIES[9], FISHERIES AND OCEANS CANADA (DFO).

Basic statistical analyses were used to document and describe the available data, establish relationships between regional air and site-specific water temperature datasets, and define inter-site relations for both water temperature and discharge to infill missing observations. STATISTICAL ANALYSIS SOFTWARE (SAS® Version 9.3; SAS 2011) was used to assemble data from MICROSOFT EXCEL® spreadsheets and analyze the data. The resulting datasets were stored in a relational FRESHWATER ENVIRONMENTAL VARIABLES DATABASE (Hyatt and Stiff, DFO; unpublished data) and

[8] TYEE INDEX published online by DFO NORTH COAST STOCK ASSESSMENT DIVISION: http://www.pac.dfo-mpo.gc.ca/fm-gp/northcoast-cotenord/skeenatyee-eng.html (July 2014).

[9] 225 Sus Avenue, Burns Lake, BC V0J 1E0

are available from DFO upon request.[10]

Hydrology

Mean daily discharge data (m^3/s or cms) and water level data were obtained from the web archives of the WATER SURVEY OF CANADA (WSC)[11] for relevant stations in the Babine and Skeena watersheds (Figure 1)[12], including:

- BABINE RIVER AT NILKITKWA (station 08EC013) - an active station in the lower Babine River in the vicinity of the Babine counting fence at the outlet of Nilkitkwa Lake (55°25'30"N x 126°42'10"W; gross drainage area 6,760 km^2), with mean annual discharge of 47 cms. Archived quality-assured data were available for 1972-2012, and supplemented with real-time data (provisional) for 2013-2014. Water levels, available for 2011-present, were not used in this analysis.
- BABINE RIVER AT BABINE LAKE (station 08EC001) - an active water level station located upstream of spawning grounds in the upper Babine River at the outlet of Babine Lake (55°19'25"N x 126°37'40"W; drainage area 6,350 km^2), with mean annual discharge of 46 cms. Continuous quality-assured discharge data were available since 1945, but discontinued in 1985. Water levels at this station are available since 1986.

Though water level records at both Babine sites are presently maintained, the brief 3-year time-series at Nilkitkwa, and the lack of overlap between flow and depth data at Babine Lake to calibrate and extend the upper Babine water level time-series prior to 1986, precluded the use of water level observations for co-variation analysis with the Sockeye time-series.

However, the years of overlap for discharge data between Babine River stations (1972-1985) enabled statistical reconstruction of missing flow estimates in the lower Babine at Nilkitkwa (1945-1971) and in the upper Babine (1986-2013) to encompass the period of record for adult Sockeye migration observations. Simple least-squares regression models (linear: $y = a + bX$; loglinear: $y = aX^b$; and polynomial curvilinear: $y = a + bX + cX^2$) were derived for estimating historical daily BABINE RIVER AT NILKITKWA discharge as a function of the more extensive time-series for BABINE RIVER AT BABINE LAKE. Model calibration was based on a data subset of every 10th observation, to reduce the influence of autocorrelation effects. Model selection was based on highest correlation and lowest adjusted Akaike Information Criterion (AICc), and goodness-of-fit was assessed using correlation of observed versus predicted BABINE RIVER AT NILKITKWA data and subjective examination of time-series plots.

Univariate statistical analyses were used to characterize Babine River station

[10] Contact Howard.Stiff@dfo-mpo.gc.ca or Kim.Hyatt@dfo-mpo.gc.ca.for the MICROSOFT ACCESS® database.
[11] ENVIRONMENT CANADA – WATER SURVEY OF CANADA website: http://www.ec.gc.ca/rhc-wsc/default.asp?lang=En&n=894E91BE-1.
[12] Babine fence technicians generally record water levels at a staff gauge twice daily during the Sockeye migration season (July-October); however, these data are often influenced by fish carcass buildup and were therefore, omitted from analyses.

discharge data (number of observations, central tendency (mean, median, mode, etc.), scale (range, variance, extreme values and outliers), and shape (skewness, kurtosis)). Deciles and quartiles were derived for the migration months (July-September) to identify low (< 10^{th} percentile), moderate (10-90^{th} percentile) and high (90-100^{th} percentile) categories. Plots of the historic mean and variance of daily discharge were used to characterize the flow patterns during the adult Sockeye migration period (July-September).

Water Temperature

Babine River water temperature readings were supplied courtesy of DFO and Lake Babine Nation Fisheries for the years 2003-2014. Observations were limited to the seasonal period of fence operations (July-September) in all years except 2003-2004, when an automated data logger was installed at the fence and captured almost a full year of hourly temperature data beginning in the fall of 2003.

Manual temperature data in other years were also collected at the Babine fence during the Sockeye migration period, twice a day around 9:00 am and 1:00 pm using a standard thermometer, and averaged by date where morning and afternoon readings were both obtained. Dates for which only one manual temperature reading was obtained (early 2003, 2005, 2006) were omitted from analyses as not representative of mean daily water temperature.

Water temperature data cleanup consisted of examining descriptive statistics and graphic output to identify anomalous data and outliers, in conjunction with a review of field notes regarding data logger installation and removal dates and times. Anomalous data were corrected, or retained in the database but flagged for omission (i.e., Omit field = Yes) from data analyses. Unresolved data issues included:

1. Anomalous situations where afternoon temperatures greatly exceeded morning temperatures (e.g., early and mid-August 2008; late September 2008; August 2010), or the morning and evening temperatures appeared consistently reversed (August 1-14, 2009)
2. Unusually high variability between dates (e.g., August 16, 2009 to end; 2010 up to July 21; all of 2011; late August and mid-September 2012)
3. Unusually low variability between dates (e.g., mid-August 2012)

These anomalies were not clearly related to changes in other environmental variables such as water level or precipitation, and thus were excluded from analyses.

Univariate statistical analyses were used to characterize the daily mean water temperature (MWT) time-series for the period of record (i.e., number of observations, central tendency (mean, median, mode, etc.), scale (range, variance, extreme values and outliers), and shape (skewness, kurtosis)).

Overlapping manual and data logger data in 2004 were used to examine potential bias in daily mean estimates derived from manual and data logger sources. To test the utility of deriving a daily mean water temperature estimate from temperature readings obtained solely from ‘morning’ and ‘afternoon’ samples, the daily average of two automated readings subsampled from the hourly data logger time-series (at 9:00 and 13:00) were compared to the daily mean derived from all 24 hourly data logger readings to calculate bias for adjustment of manual temperature means.

Precipitation

Precipitation data may be correlated with discharge levels and water temperature. They may also be useful for downscaling projected changes in regional precipitation from global or regional climate models to specific sites at the local level.

Daily precipitation records for the Babine watershed were obtained for Topley Landing station (1966-2013) from Environment Canada.[13] Due to the highly localized and non-normal distribution of precipitation data, missing values were not interpolated, nor were time-series extended based on parametric statistical relations with other stations.[14]

Air Temperature

The relatively short time span and frequent discontinuities in the timeline of the Babine River water temperature dataset render it inadequate for accurately assessing baseline conditions for climatological studies. Reconstruction of a long-term freshwater temperature dataset suitable for climate analyses is contingent on a set of daily mean air temperature records spanning at least 30 years, or more for historic trend analyses.

Studies have demonstrated that variations in regional air temperature (which often span the 19th century) are generally sufficient to explain as much as 80% of the variation in local daily mean water temperature (Mohseni and Stefan 1999; Hyatt and Stockwell 2003; Pilgrim, Fang and Stefan 1998; Stefan and Preud'homme 1993; Webb and Nobilis 1997). Linear and nonlinear regression models are known to be accurate at moderate air temperatures typical of adult Sockeye migration periods (i.e. 10-20°C), while water temperature "extremes" (<5°C or >20°C) are more appropriately modeled nonlinearly (Mohseni, Stefan, and Erickson 1998). The resulting time-series spanning the period of record of meteorological observations can be used as a consistent index of local water temperature conditions at the daily time-scale, and summarized to examine trends and shifts in water temperature regimes at longer time-scales (e.g., decadal).

Environment Canada's Meteorological Services group maintains an archive of climate, hydrographic and water quality data gathered from both active and inactive stations distributed throughout British Columbia and the Yukon.[15] The EC web site was accessed to identify potential sites of air temperature data within the area of interest for statistical relationships with water temperature data (Figure 1).

For the majority of Canadian climate stations, air temperature measurements are

---

[13] Adjusted and Homogenized Canadian Climate Data (AHCCD) – Daily AHCCD precipitation data are not currently freely distributable or available online but may be obtained by request to AHCCD@ec.gc.ca. See the Environment Canada website for monthly AHCCD values.

[14] An alternative approach, not attempted here, may be to obtain daily precipitation data for multiple regional meteorological stations to derive an appropriate area average. Source: National Climate Data and Information Archive (March 2013).

[15] Environment Canada Climate Data: http://climate.weatheroffice.gc.ca/climateData/canada_e.html

taken from self-registering, maximum and minimum thermometers that record parameter extremes over a 24-hour period. Daily mean temperature is defined as the average of the maximum and the minimum temperatures attained during the 24-hour period. These datasets undergo detailed quality-control analysis before posting to the web site.

EC climate station TOPLEY LANDING (1078209; 54.48”57°N x 126.09’47°W; elev. 722 m) was selected for climate data retrieval on the basis of: (i) the quantity and quality of data available (1962-2012); (ii) location in the Babine watershed and proximity to Babine River (<70 km) (Figure 1); and (iii) the potential to routinely update the time-series from an “active” climate station.

Gaps in the meteorological record for TOPLEY LANDING daily air temperature (e.g., 1910-1962; 1963-1965; early July 1966; Jul-Oct 2008; Jul-Aug 2009; Jun-Jul 2010, Aug-Oct 2012; Oct 2013-2014) were in-filled with estimated data based on statistical relations with neighbouring AHCCD[16,17,18] meteorological stations. Spearman correlation coefficients (r_s) were derived to indicate the most correlated time-series for TOPLEY data for the May-October period at daily mean air temperatures greater than or equal to zero. Regression relations were generally linear at moderate temperatures (5-25°C) for TOPLEY and SMITHERS AHCCD (1077500; 54.82°N x 127.18°W; elev. 522 m) stations, and, to a lesser degree, STEWART AHCCD (1067740; 55.93°N x 129.98°W; elev. 7 m) (Figure 16). Where AHCC Data were not available, data from the nearest EC climate station were substituted (SMITHERS AIRPORT AUTO STATION 1077501; 55.49°N x 129.11°W; elev. 518 m, and STEWART 1067742; 55.56°N x 129.59°W; elev. 7 m). Associated linear regression coefficients were then used to construct a continuous daily air temperature dataset (the TOPLEY STANDARD index, 1910-2014) that included the original non-missing TOPLEY LANDING daily air temperature values, with missing TOPLEY LANDING values estimated from: (i) the primary correlated station, SMITHERS (where data exist); or (ii) the secondary correlated station, STEWART (where data exist).

TOPLEY MULTI-DAY MEAN AIR TEMPERATURE INDEX

The best predictive air-to-water relationships exist for associations between daily mean water and multi-day mean air temperature (Hyatt and Stockwell 2003; Webb and Nobilis 1997). Centered moving averages (i.e., mean temperatures from *Date – (n-1)/2* to *Date + (n-1)/2*, where *n* is the number of days) center the multi-day means

---

[16] ENVIRONMENT CANADA has refined the air temperature and precipitation time-series for certain stations as part of the ADJUSTED AND HOMOGENIZED CANADIAN CLIMATE DATA (AHCCD) group of climatological stations across Canada. These data incorporate adjustments applied to the original station data to address non-climatological shifts related to changes in instrumentation and observation conditions or procedures, thus optimizing their use for climate research (Vincent et al. 2012).

[17] ADJUSTED AND HOMOGENIZED CANADIAN CLIMATE DATA (AHCCD) – Daily AHCCD surface air temperature data are not currently freely distributable or available online but may be obtained by request to AHCCD@ec.gc.ca. See http://www.ec.gc.ca/dccha-ahccd/default.asp?lang=En&n=B1F8423A-1 for monthly AHCCD data.

[18] AHCCD Licence Agreement: *This work contains data licensed "as is" under the Government of Canada Open Data Licence Agreement. Such licensing does not constitute an endorsement by the Government of Canada of this product*.

such that peaks and troughs more accurately align with the flux in the original daily MAT time-series (Hyatt et al. 2015).

Correlation analysis was used to identify the multi-day moving average air temperature index with the lowest *n*-value (for $n = 1, 3, 5, 7, 10$ days)[19] while retaining a high Pearson correlation coefficient with a representative subset of the site daily mean water temperature. The multi-day TOPLEY CMAT index with the lowest adjusted AKAIKE INFORMATION CRITERION (AICc) and the highest Pearson correlation coefficient for the calibration data was used for subsequent air/water temperature regression relations.[20]

Air/Water Temperature Relationships

Hyatt et al. (2015) describe the basic methodology used to estimate missing or historical daily MWTs based on statistical relations with the regional 7-day CMAT index. The authors calibrated linear (Equation 1) and logistic (Equation 2) air-to-water temperature relations using a subset of the site daily MWTs as a function of the regional multi-day air temperature index:

Equation 1: $T_w = \alpha + \beta * T_a$; where

T_w is the *estimated mean water temperature in Babine River*;

T_a is the *TOPLEY STANDARD 7-day mean air temperature index*; and

α is the y-intercept and β is the regression coefficient.

Equation 2 : $T_w = \mu + (\alpha - \mu) / (1 + e^{\gamma(\beta - T_a)})$; where

T_w is the estimated mean water temperature in the Babine River;

T_a is the TOPLEY STANDARD 7-day mean air temperature index;

α is the estimated maximum water temperature;

μ is the estimated minimum water temperature;

γ is a measure of the steepest slope of the function; and

β represents the air temperature at the inflection point.

The existence of hysteresis[21] in a water body, and the resulting need to use separate warming and cooling season regression models to describe air/water temperature relations at a particular site, was evaluated for both linear and logistic models. In the linear approach, an additional categorical "season" predictor was a significant effect (signifying different seasonal model intercepts), and/or whether

---

[19] $n = 1$ corresponds to the "observed" TOPLEY STANDARD mean daily air temperature time-series.

[20] Although the 10-d CMAT index was included in this assessment, and (usually) generated the maximum correlation, this index was ultimately discarded due to the undesired trade-off between high correlation versus the damping effect on daily air temperature variation (Hyatt et al. 2015).

[21] Hysteresis: the heat storage properties of water. Hysteresis is a measure of the seasonal effect of the differential rates of heat exchange between air and water as the spring-to-summer period warms up and the fall-to-winter period cools down (Wetzel 1975). The observed pattern of hysteresis is related to the complex physics of air-water heat exchange processes. These involve evaporative cooling of the lake in the late summer-to-fall, thermal de-stratification in the fall-to-winter; rapid, wind-induced, mixing of surface and deep waters through the winter, and initiation of thermal stratification and evaporative cooling once again in the spring-to-summer season.

there was a significant interaction effect with air temperature, indicating significant differences in seasonal model slopes (i.e., $P < 0.05$ for the Type III model sum of squares (SAS 2011). For the logistic analysis, hysteresis was assessed by comparison of the *Nash-Sutcliffe Coefficient* (NSC) value for the all-season model versus the averaged NSC values for the separate warming and cooling season models (Mohseni et al. 1998):

Equation 3*:* $Hysteresis = [(NSC_w + NSC_c) / 2 - NSC_{all}] \geq 0.01$; where

NSC_w = NSC for warming season;

NSC_c = NSC for cooling season;

NSC_{all} = NSC for all seasons combined.

Water Temperature Time-Series Reconstruction

MODEL CALIBRATION

Linear and logistic regression relations described above were developed using site-specific daily mean water temperatures (MWTs) from the sub-daily dataset for Babine River as a function of the regional air temperature index (7-day centered TOPLEY MAT variate).

Selection of data for the calibration dataset was not randomly determined, but based on subjective and statistical examinations of individual annual air and water temperature time-series plots and correlations. A minimum of 5 years of temperature data across multiple decades and including sufficient observations at the upper end of the range for both warming and cooling seasons is generally necessary to define a truly representative air/water temperature relationship.

Years with consistent and apparently unbiased data logger readings (e.g., 2004) associated with a maximum range of temperature values for both warming and cooling periods[22] were preferred for characterizing the all-year air/water temperature relationship. Years of evident bias in the readings (e.g., 2003, 2005, 2006) or excessive anomalies (e.g., 2011) were excluded from the calibration dataset. This resulted in the calibration dataset being composed of the single year of automated data logger data, while the manual readings were used for model validation. The remaining data were used for validation of statistical relations.

Calibration Data	Validation Data	Omitted Data
2004, 2007, 2008, 2010, 2012-2014	2003, 2005, 2006, 2009	2011

Due to a lack of late spring observations, the range of temperature observations available was limited, hampering parameter estimation for logistic models, especially for the warming season. The logistic intercept (μ parameter) was constrained to 0°C or more, and the α parameter was constrained to 21°C or less, to enable model convergence.

To determine whether seasonally distinct regression relations were required, the

[22] Derivation of the seasonal flux point between warming and cooling "seasons" is described below.

air/water temperature data for each water body were checked for hysteresis. To detect hysteresis, separate functions were fitted to the air and water temperature data in each of the warming and cooling seasons.

The warming and cooling seasons were first distinguished from each other by determining the seasonal temperature "turn-around point" (the timing of the winter season turn-around point was not required for the purpose of this analysis).[23] The seasonal transition dates were obtained by plotting weekly mean daily water temperatures as a function of weekly mean daily air temperatures, and connecting the points chronologically. The week associated with the maximum mean air temperature, indicating the ending of the warming season (and the starting point of the cooling season) was converted to day-of-year to pinpoint the seasonal turn-around date.

Site-specific hysteresis effects were then assessed as described above using all-year all-season data for both linear and logistic models. If hysteresis was detected in either case, linear and logistic models were then fitted to the all-year data for each of the warming and cooling seasons separately.

MODEL VALIDATION

Site-specific linear and nonlinear air/water regression parameter estimates were tested for statistical significance, and applied to the TOPLEY STANDARD air temperature index to estimate reference site daily MWT for the period of record of air temperature data. Modeled MWTs for the validation dataset were correlated with observed reference site water temperature data graphically and statistically as a measure of goodness-of-fit. The all-year Pearson and Spearman correlations for the validation years were compared between model types to determine whether linear or logistic outputs best simulated observed MWTs at the Babine River reference site.

Trend and Exceedance Analyses

AIR TEMPERATURE

Historic regional air temperature data (based on TOPLEY STANDARD daily MAT, 1908-2012) were summarized by year to obtain the mean value during the summer months (July-September), and plotted to review the long-term time trend in regional air temperature conditions during the migratory period.

Monthly mean air temperatures of 20°C are considered an upper threshold for salmonid life history stages (Mote et al. 2003). Historic mean daily air temperature data (based on TOPLEY STANDARD climate data; 1908-2012) were analyzed for the frequency of dates in each year and month (July-September) for which mean daily air temperature exceeded this threshold value, and summarized by decade as a trend indicator. In addition, the frequency of annual periods in which water temperature continuously exceeded this value, and the mean duration (days) of these periods, was derived for each year, and summarized by decade to review trends in the frequency and duration of continuous periods of potentially stressful

---

[23] For linear models, an additional "winter" season was defined (November 25th to March 10th), encompassing the cold-weather months when changes in air temperature are not reflected in changes in water temperature due to hysteresis effects at low temperature extremes. These data were omitted from this analysis.

temperature conditions.

WATER TEMPERATURE

Reconstructed daily mean temperature data were summarized by site and year to determine mean values during the summer months (July-September), and plotted to review the long-term time trend in site-specific water temperature conditions during the migratory period.

A similar threshold exceedance analysis, tallying the decadal mean monthly frequency of dates for which the reconstructed MWT temperature index exceeded 18°C ($POT_{18°C}$; i.e., peak-over-threshold > 18°C), was used to examine site-specific trends in water temperature conditions during the adult migration period (July-September).

In addition, the frequency of annual periods in which water temperature continuously exceeded this value, and the mean duration (days) of these periods, was derived for each year. These data were summarized by decade to review trends in the frequency and duration of continuous periods of potentially stressful water temperature conditions.

RIVER LEVEL / DISCHARGE

For discharge, exceedance analyses for both “low flow” and “high flow” dates are of potential interest, since, conceivably, either flow extreme may influence upstream migration. The frequency of dates for which estimated water levels in the lower Babine River at Nilkitkwa were either less than the lower 10^{th} percentile (~30 cms), or greater than the upper 90^{th} percentile (~120 cms) of summer readings, was calculated by year and month (July-September), and summarized by decade. From these data, the frequency of annual periods in which flow levels continuously remained below/above the lower/upper thresholds, and the mean duration (days) of these periods was derived for each year, and summarized by decade to review trends in the frequency and duration of continuous periods of potential flow barriers to upstream migration.

Migration, Temperature and Discharge

Daily mean Babine River water temperature and discharge estimates were combined with daily Sockeye migration rate data to test the null hypothesis that daily migration rates were not influenced by changes in Babine water temperature and discharge. For categorical analyses, the continuous variates were classified according to thresholds based on percentiles (i.e., for migration and discharge) or assumed upper limits (water temperature). For this northern Sockeye stock, a threshold temperature of 18°C was used to classify daily mean temperature data as negative (“low”) or positive (“high”). The 25^{th}, 50^{th}, and 75^{th} percentiles of the discharge distribution during the sockeye migratory period were used to classify low, median and high flow thresholds, and extreme thresholds were based on the 10^{th} (“drought”) and 90^{th} (“flood”) percentiles.

The 50^{th} percentile (median) migration rate was used as the threshold to define whether a daily migration rate was “low” or “negligible” (i.e., negative anomaly) or positive, and the 75^{th} percentile of migration rates was used to define whether a positive migration rate was “moderate” (between 50^{th} and 75^{th} percentiles) or “high”

(>= 75th percentile).

The environmental variates and categorical classifications were date-lagged and merged with the migration data to test the null hypothesis that downstream conditions in the previous week, either at the Babine Canyon[24], or at the Babine/Skeena confluence, were not associated with variations in adult migration patterns at the fence. Non-parametric test statistics of association derived from frequency analyses of the categorical contingency tables were used to indicate to what degree differences in daily migration rate (high versus low level) were associated with variable water temperature and discharge categories, based on the Cochran-Mantel-Haenszel (CMH) statistic of General Association, which provides a stratified statistical analysis of the relationship between migration and temperature variables after controlling for the strata variable (discharge level) in the multi-way table (SAS 2011).[25]

This analysis was repeated at each integer temperature threshold (15-20°C) and flow decile (30-130 cms), for data merged with eight different, time lags[26]. A heat map of the resulting CMH General Association statistics was used to identify the date lags and threshold levels for each environmental variable that generated the most significant associations with large changes in migration rate[27]. This was used to determine the most likely combination of temperature and discharge time lags (and, by extension, the potential location of the corresponding environmental influence) contributing to fence count variation during historic stock migration.

To then characterize the temperature and discharge conditions, the frequency distribution of observed active migration dates (i.e., filtered for non-zero migration rates) at varying levels of temperature, discharge, and both temperature and discharge were then generated for the selected date lags. This basic frequency distribution, tallying the number of dates in the historical dataset of non-zero migratory activity, indicated the general distribution of temperature and flow conditions that were available during the migratory period.

A similar frequency distribution of active migration dates, weighted by the daily migration rate, was then used to quantify *how much* migration occurred at a given temperature, discharge level, or temperature-discharge combination. In contrast to the simple distribution of dates of migration (leaving numbers of fish out of the equation), these plots indicated which water temperature and flow conditions were associated with highest migration rates (i.e., presumably most favourable to salmon migration), and, by extension, possible thermal and hydrological limits (if any) that

[24] Godfrey et al (1954) found that Babine Sockeye travel time from above the Babine slide location (20 miles upstream of the Skeena confluence) to the fence (40 miles upstream) was approximately 5 days, indicating a swim speed of 8 miles/day, or 13 km/day.
[25] The stratified analysis provides a way to adjust for the possible confounding effects of water temperature and discharge without being forced to estimate parameters for them (SAS 2011).
[26] Date lags ranged from 0 days, corresponding to environmental effects occurring at the fence site; up to 7 days, corresponding to environmental effects occurring downstream.
[27] It should be noted that the CMH-GA statistic does not indicate the *direction* of changes in association, just that differences exist. Frequency distributions and other statistics may be used to determine whether the differences across a given threshold are 'positive' or 'negative'.

differentiate high versus low rates of migration.

Environmental thresholds derived from the above analyses were used to revise values for calculation of daily deviations in the modeled water temperature and discharge time-series. These were combined with deviations in daily migration rate (from the median of the historical daily migration rate) on annual anomaly plots to examine the pattern of daily variation in each time-series in relation to each other.

RESULTS

SOCKEYE MIGRATION DATA

An annual average of ~968,000 Sockeye returned to the Babine watershed over the past 63 years of complete data (1946-1947, 1949-1950, 1953-1963, 1965-2014), ranging from <100,000 to over 2 million fish in annual escapement (Table 3).

Counts of fish at the Babine Sockeye fence counts typically commenced in early-to-mid July and terminated by mid-to-late September, with time-to-50% (TT50%) occurring approximately August 18th (Table 2; Figure 5). Non-zero migrant counts averaged almost 14,000 fish per day; maximum daily counts surpassed 160,000 fish in 1996.[28] The median daily fish passage over the years was approximately 9,000 fish per day. Summarized across all years, a broad, primarily unimodal pattern emerged centered in mid-August, with a hint of a secondary mode occurring in early August that may be attributed to the early run (Figure 5).

The corresponding all-year mean daily migration rate was ~1.2% of total annual escapement. Annual peak daily rates were typically in the range of 2 - 4%, though 6 - 7% of the annual escapement occurred on one day in 1954, and again in 1996 and 2009 (Table 3). Based on daily migration statistics from 1953-2014, the daily median (50th percentile) characterizing “negligible” versus “significant” migration was 0.9% of annual migration, and the 75th percentile characterizing the threshold between “moderate” and “high” migration was 2.0%.

Annual time-series of Babine Sockeye daily migration rates (%) were plotted in Appendix B, along with mean and maximum daily migration rates across all complete years 1953-2014, displaying, in many years, late onset of migration (e.g., 1960, 1972, 1976, 1996, 2011)[29] and/or multi-modal migration pulses separated by periods of relatively low migration (e.g., 1954, 1965, 1973, 1982, 1999, 2004) which might be evidence of environmental factors influencing migration patterns.

A consequence of multi-day averaging of migration data (which was implemented to “smooth” the apparent effects on migrant counts of commercial fishing activity on alternating days at the Babine fence) is the unavoidable dampening of peak counts not associated with fishing activity. This resulted in a reduction of the daily migration rate roughly proportional to the peak migration rate and inversely proportional to the

[28] Note: Migration statistics in Table 3 are based on 3-day averages, and thus underestimate peak counts.
[29] Which, in some years, also delayed fence operations, though, with the possible exception of 2011, significant migration rates were not evident for 4-7 days after fence counts commenced (Appendix C).

number of days of counts associated with the peak. Largest reductions therefore occurred where the migration rate peak was large (>5%) and based on less than three days of counts: e.g., early August 2009, where the peak daily migration rate of ~10% was reduced to ~6% after 3-day averaging (Appendix B) – in which case, the reduced migration rate would still be classified as “high”. For the most part, however, Babine migration peaks were more moderate and gradual (e.g., 1963, 1973, 1983, 1993, 2003, 2013), with a net result in a negligible reduction of daily migration rate of 0.0 - 0.5%.

The multi-year correlation analysis between daily TYEE INDEX values and Babine Fence counts (1956-2014) indicated high significance at lag values of 20-27 days, with maximum Spearman correlation coefficient based on a 24-day lag (r_s = 0.69, n = 4,419, P < .0001). The TYEE INDEX, converted to daily percent of the total annual index and lagged by the multi-year optimum of 24 days, was overlaid on the daily migration plots for comparison (Appendix B).

Annual Spearman correlations between daily TYEE INDEX values and Babine Fence counts (1956-2014; Table 4) based on the 24-day lag of the TYEE INDEX ranged from a high of 0.91 in 2011 (n = 60, P < .0001) to a low of 0.12 in 1997 (n = 54, P > .05). Years of low significance are of interest since they may indicate large deviations in migration timing between the Tyee test fishery and the Babine fence, potentially due to environmental factors.

HYDROLOGY

Babine River

Observed mean seasonal discharge during the migratory period for the lower Babine (at Nilkitkwa) since the early 1970s appeared stable, though a sustained period of sub-average summer discharge characterized the years 1977 to 1995 (Figure 6). Higher variability in summer flows before and after that period was evident in the discharge and water level time-series for the upper Babine at the outlet of Babine Lake (Figure 7, Figure 8).

Unsurprisingly, given the stations’ proximity to each other, daily mean discharge levels recorded in the upper Babine at the outlet of Babine Lake showed a high degree of correspondence with the lower BABINE RIVER BELOW NILKITKWA Lake for the period of overlap (1972-1985). Annual hydrographs indicated, typically, a steady drop in mean daily flow levels throughout the Sockeye migration period (Jul-Sep; Figure 9), indicating little day-to-day variation or sudden changes in flow, as is characteristic of watersheds with large headwater lakes.

Daily mean discharge at Babine River hydrometric stations indicated a highly linear relationship (r^2 = 0.989; P < .0001; n = 126; Figure 10), but linear regression statistics for discharge at BABINE RIVER AT NILKITKWA as a function of BABINE RIVER AT BABINE LAKE was characterized by a significant Lack of Fit term (P = 0.04), often associated with heteroscedasticity or nonlinearity. The log-linear power model ($Nilkitkwa = a \bullet Babine^{b}$) provided the best fit based on lowest AICc and insignificance of the Lack of Fit statistic (Figure 11). This relation enabled extending the BABINE AT NILKITKWA time-series back to 1945, fully encompassing the Sockeye migration time-series.

Subsequent correlation between observed and estimated BABINE AT NILKITKWA discharge was high ($r^2 = 0.985$), but time-series plots showed increased estimation error at the higher discharge levels (e.g., July 1972, 1976; Figure 12) relative to low discharge conditions (e.g., 1981, 1983, 1985; Figure 13), likely due to larger variation earlier in the season (Figure 9).

Average daily flow levels in the lower Babine, near the Babine fence, ranged from 230 cms (corresponding to about ~1.6 m depth at the NILKITKWA hydrometric station) down to a minimum of 19 cms (~0.2 m), though 90% of flows ranged between 30-144 cms (median 60 cms), with a seasonal mean of 69 ± 36 cms (Table 5).

Notable high water years during which recorded discharge exceeded the 90th percentile of daily flows (~120 cms) during the peak Sockeye migration period (August) occurred in 1972, 1976, 1997, 2002, 2007, and 2011 (Figure 14; Appendix A). Additional high flow years at NILKITKWA (based on statistically reconstructed estimates derived from upper Babine data) were evident in 1954, late 1957, 1959, and 1964 (Figure 15; Appendix B).

At the other extreme, low water years, characterized by flows persistently below the 25th percentile (i.e., < 40 cms) during peak migration, were evident in observed and estimated Nilkitkwa time-series for 1961, 1969, 1978, 1980, 1989, 1995, 1998, 2004, 2006, and 2010 (Figure 14, Figure 15). Minimum daily discharges of 18-20 cms near the Babine fence were common during these years (Table 5), and also during 2014[30] (Appendix B).

WATER TEMPERATURE DATA

Babine River

After removal of anomalous temperature records, the remaining annual time-series for water temperature data obtained at the Babine Fence (2003-2010, 2012-2014) were plotted by year in Appendix B, condensed in Figure 17, and summarized for the months of Sockeye migration (July-September) by year in Table 6 and Figure 18.

Based on the limited observed data, mean daily temperatures during migration were 14.5 ± 2.6°C, surpassing 20°C on occasion. Water temperatures were above average in 2004, 2009, 2013 and 2014, though not significantly (Table 6). Maximum observed water temperatures at the fence peaked over 20°C (but did not exceed 22°C) for extended periods in 2004 (July 15-25 and August 13-20), and brief periods in 2009 (July 31 – August 2) and 2014 (July 14-15).

Comparison of mean daily water temperature estimates based solely on a ‘morning’ and ‘afternoon’ two-sample procedure versus a full 24-hour time-series indicated negligible differences ($r = 0.99$, $P < .0001$; Figure 19), suggesting that manual temperatures, as are typically obtained twice a day at the Babine fence, did provide a reasonable estimate of daily mean water temperature, assuming no other source of observation error.

[30] 2014 discharge data were incomplete at the time of publication.

WATER TEMPERATURE TIME-SERIES RECONSTRUCTION

Seasonal Turn-Around Point

The mid-year seasonal turn-around point was set to week 32 – approximately day 224, or August 16th – based on maximum mean weekly air and water temperatures occurring between week 31 and week 33 for the calibration data years (Figure 20). Selecting week 32, instead of weak 33, as the turn-around-point allocated a few more high water temperature observations to the cooling season for logistic model calibration. The "warming season" therefore extended from April 1 to August 16th, followed by the "cooling season" from day 225-329, i.e., August 17th – Nov. 25th.

Multi-Day Air Temperature Index

The multi-day TOPLEY STANDARD air temperature index that best correlated with all-year daily mean water temperature was identified as the 7-day centered moving average air temperature index (7d-CMAT; Figure 21). Daily MWTs from the calibration dataset were highly correlated with the 7d-MAT index for the warming season (r_P = 0.92; P < .0001; n = 221) and cooling season (r_P = 0.82; P < .0001; n = 191). The 7D-MAT index provided the best trade-off between maximizing correlation and minimizing the effects of multi-day averaging on predictive power at longer period lengths. Thus, the TOPLEY STANDARD 7d-MAT was used for subsequent air/water temperature analyses.

Like other multi-day moving air temperature means, this indicator tends to bias extreme air temperatures towards the mean, thus under-estimating the amplitude and frequency of peak thermal events that may affect fish behaviour. Therefore, this index, and, by extension, any water temperatures estimated as a function of this index, should be treated as a conservative indicator of extreme events.

Model Calibration and Validation

Logistic and linear air/water temperature models were parameterized using a subset of the available data for calibration, and tested for goodness-of-fit against the remaining years for model validation. Due to insufficient data, the split between calibration and validation years was not randomly determined, but drawn from a subjective review of annual correlation analyses highlighting strong air/water relations across the broadest range of temperature conditions for a representative subset of years.

Water temperature data from automated data logger readings in 2004 represented the most comprehensive annual dataset, representing all months of the year, and appeared un-biased in relation to manual water temperature data during that period. However, air-water temperature relations calibrated solely on 2004 data yielded estimated mean water temperature time-series biased in the positive direction, suggesting warmer water conditions, especially in the warming season, than empirically observed during Babine Sockeye migration.

Thus, water temperature observations from manual readings were included in the calibration dataset. The final calibration dataset series included mean daily water temperature estimates from 2004 data logger data, plus the mean of morning and afternoon manual temperature readings during Babine fence operations for 2008, 2009, and 2013-2014 (Table 7).

Hysteresis was detected for logistic relations based on the difference between seasonal and all-season goodness-of-fit (NSC) coefficients (Table 8), as well as for linear relations based on significance tests for equal intercepts and equal slopes (Table 9), indicating that air/water temperature relationships were best modeled using separate seasonal models (logistic models: Figure 22; linear models: Figure 23). Due to insufficient data in the warming season, the logistic model intercept (μ parameter) was constrained to 0°C or more, and the α parameter was constrained to 21°C or less, to reasonably reflect likely minimum and maximum water temperatures, and enable model convergence. Logistic model parameters, 95% confidence limits, and NSC goodness-of-fit coefficients are listed in Table 8. Linear regression model output for seasonal air/water temperature relationships and calibration data are provided in Table 9.

Season-specific Pearson (least squares) and Spearman (rank) correlation coefficients between modeled estimates and validation data are contrasted in Table 10. Poor correlations with 'warming season' data were due to insufficient data and the poor quality of the remaindered data available for validation. Both correlation coefficients indicated that the two model types were essentially equivalent in their skill at predicting Babine River water temperatures. However, linear estimates were more 'responsive' to the 7d-CMAT predictor, resulting in over-estimating water temperatures at the high end of temperature range (i.e., ~20°C) by 3-4°C, specifically in the warming season (Figure 23).

Logistic estimates also tended to over-estimate water temperatures (in the 10-15°C range) in the warming season (e.g., 2003, 2012), but approximated observed temperatures more accurately at higher air temperatures (~20°C; e.g., 2004, 2009, 2014) due to the asymptotic nature of the logistic curve.

Thus, the seasonal logistic model parameters were selected as the best estimators of daily mean water temperature at each site, and were used to reconstruct historical daily water temperature estimates for the period of available air temperature data. A subset of the validation data years with observed and modeled MWT output, along with daily MAT and the 7-d MAT index, are plotted in Figure 24. The modeled estimates tended to predict average conditions reasonably well (e.g., 2007, 2013), but underestimated water temperatures in warm years (e.g., 2004), especially in the warming season, yielding conservative estimates of the frequency and duration of warm water periods.

TEMPERATURE, FLOW, AND MIGRATION

Trends in Environmental Variables

Since a weak long-term warming trend in the regional air temperature index for the summer months (July-September) is evident over the period of record (1908-2012) (Figure 25), the analogous estimated Babine River mean water temperature indicated a corresponding warming trend of ~0.015 degrees per year (or 0.15ºC per decade) ($r = 0.16$, $P < .0001$; Table 11, Figure 26). Mean summer water temperature remains below 15ºC, however.

The extended time-series of observed and reconstructed discharge in the lower Babine at Nilkitkwa suggested a weak long-term decline in summer mean flows since the 1940s (slope = -0.195, r = 0.012, P <.001), amounting to an average of about 2 cms per decade (Figure 27).

Migration in Relation to Temperature and Discharge

A heat map of the distribution of 7,488 CMH-GA[31] statistics was used to help identify, for each environmental variable, the time lags and threshold levels most associated with large changes in migration rate at the Babine fence (Figure 28).

The distribution indicated maximum statistical association between the environmental variates and migration at 17-18°C water temperatures[32], across a range of daily mean flow levels of 60-140 cms. The 17°C temperature threshold appeared to be most influential at a date lag of 5-7 days – suggesting that migration rates at the fence were affected by or associated with Babine River water temperatures approximately six days earlier (Figure 29). A secondary maximum at 18°C was evident at a similar date lag of 4-6 days, which also indicated a variable influence of discharge conditions over the previous 7 days. The data suggest that (modelled) water temperatures of ~18°C[33], six days in advance of the fish reaching the fence, present an environmental threshold defining high versus low Babine Sockeye migration rates, especially at flow levels above 60 cms. Significant, but lower associations were also evident at very low flows (30 cms), but least of all at moderate flow levels (40-60 cms), supporting the possibility that Babine Sockeye migration rates may be negatively influenced at both ends of the discharge spectrum.

While the maximum influence of discharge levels on migration was distributed across a wide range of flow levels and date lags, evidence for a 6-7 day lag in discharge as the locus of maximum influence was apparent in the spread in peak CMH-GA statistics at higher temperatures of 18-19°C (Figure 29), where discharge displayed expanding influence on migration rates with increased date lag at flow strata above 70 cms.

These results support the idea that Babine River conditions 5-7 days prior were most significantly associated with variation in daily migration rates at the fence, placing the location of the corresponding environmental influence within one week's travel time downstream, i.e., in association with the Babine Canyon and/or the confluence with the Skeena (Figure 2). An average 6-day lag was subsequently used to match environmental conditions to daily migration rates.

An un-weighted tally of non-zero migration dates indicated that approximately 70%

---

[31] The Cochran-Mantel-Haenszel General Association statistic provides a stratified analysis of the level of association between response and environmental variables to adjust for confounding effects of water temperature and discharge.

[32] Temperatures less than 17°C or greater than 19°C were not displayed as they did not indicate strong evidence of influence on migration changes.

[33] It should be noted, however, that the apparent lack of influence at higher temperature thresholds (>=19°C) is most likely an artifact of the lack of observations in the contingency tables due to limitations in the air/water temperature model to hind-cast water temperatures above 19°C.

of the historic migration dates occurred when Babine flows six days earlier were ~40-80 cms (Figure 30). Weighting the frequency distribution by the daily migration rate indicated that moderate daily migration rates (1-2%) occurred at a wide range of discharge levels (30-140 cms), while high daily migration rates (>2% per day) occurred at Babine River flows of ~100-120 cms (Figure 31).

Dates of migration activity were approximately normally distributed around 15°C, with the majority of dates (~80%) characterized by water temperatures of 13-17°C (Figure 32). Perhaps surprisingly, the highest average migration rates (>2% per day) occurred at (estimated) temperatures of 18-20°C (Figure 33), though <10% of migration dates occurred at these temperatures (Figure 33). The weighted frequency distribution supports the CMH-GA statistical finding that modelled water temperatures of ~18°C present a threshold defining low versus high migration – albeit in this case, higher migration rates occurred above the thermal threshold.

A weighted two-way frequency distribution based on combined flow and temperature ranges showed that high migration rates were found at a range of discharge and temperature levels, with maxima in the 40-80 cms range at 17-20°C. Another local maximum, at 15°C and 120 cms, likely represented early run migrants, when flows are typically high and temperatures are cool (Figure 34).

Anomaly plots of migration versus water temperature and discharge deviations based on environmental thresholds of 18°C and low (40 cms) or high (100 cms) discharge levels six days earlier demonstrated an erratic relation between flow and temperature levels and Babine Sockeye migration rates (Appendix C).

The most consistent environmental impact in the historical data was the delay in the onset of early migration due to high discharge levels: when high Babine flows persisted into the migratory period, high migration rates (> 2% per day) were generally inhibited until daily mean discharge dropped below ~120 cms.[34] This effect appeared evident in 1953; 1959-1960; 1965-1966; 1971-1973; 1976; 1981; 1988; 1990; 1997; 1999; and 2009. In a few years (e.g., 1972; 1976; 2002; 2007; 2011), persistent high discharge levels into late summer were associated with major migratory delays of 2-3 weeks.

Evidence of high flow delays in migratory events at the fence relative to Sockeye timing in the TYEE INDEX (assuming a 24-day lag between the two sites) can be ascertained for some of these years, notably: 1968; 1974; 1976; 1996; 1997; 2002; 2007; 2011; 2012 (Appendix B). Most of these years were characterized by above normal flows in both the Skeena and the Babine. Only 1997 did not demonstrate

[34] Indeed, initial fence counts were not apparently feasible until flow levels fell to the point where fence operations could safely occur: ~140 cms or less (e.g., 1972, 1974, 1996, 1997, 1999, 2002, 2007, 2011). In some instances, it was unclear at what discharge level Sockeye had begun migrating in significant numbers, since initial fence operations were roughly coincident with significant counts (e.g., 2002, 2007, 2011), but in most cases, several days to a week of low counts were obtained after fence operations commenced, potentially indicating an upper critical flow level (~120 cms) below which significant migration levels were possible (e.g., 1972, 1981, 1988, 1997, 1999, 2012).

flow levels above the 75th percentile for the Skeena as well[35] – notably, perhaps, significant migration counts at the fence commenced in 1997 when Babine discharge fell to 100 cms six days earlier (*cf*. Appendix B; Appendix C).

A number of exceptions to this Babine "high-flow rule" were also evident, in which high migration rates occurred despite flow levels above 100-120 cms (e.g., 1954; 1968; 1974; 1976; 1996; 2011; 2012). In most of these cases, however, water levels were progressively falling. By contrast, in 1954, 1976, and 2011, persistent high flows of 120 cms or more late into the migratory period were ultimately met with high Sockeye migration, presumably as a function of the biological imperative to complete the migration stage. An evaluation of the biological condition and reproductive viability of such migrants in the future might be important to obtain.

Little or no effects on migration rate due to flow levels below the 25th percentile (40 cms) were evident in the data. Moderate to high migration rates were apparent at mean discharges as low as 30-40 cms in most low flow years (e.g., 1969; 1980; 1987; 1989; 1995; 1998; 2004; 2006; 2014).

Negative effects of high temperature resulting in low migration rates were not widely apparent in the anomaly plots, though reductions in migration from high to moderate levels as temperatures approached 18ºC or more were evident for some years (e.g., 1962; 1965; 1970; 1973; 1974; 1990; 1991; 1999; 2004; 2005). In 2009, daily migration rates of 5% and higher fell to 2% as water temperatures reached 20ºC in early August.

In other cases, increases in temperature to 18ºC or more were positively associated with high migration (1956; 1966; 1968; 1996; 1998; 2000; 2009). Years in which Sockeye apparently migrated in significant numbers at estimated temperatures of 20ºC or more included: 1977; 1982; 1998; 2004; 2009; 2013; and 2014.

Temperature Exceedance Analyses

A frequency analysis of regional daily mean air temperature in the Babine watershed indicates that the cumulative total number of $POT_{>20°C}$ dates per year has averaged less than 3 days per year in the past century (Table 12, Figure 38). Though the duration of continuous $POT_{>20°C}$ periods was less than three days on average, warmer temperature conditions in the 1970s, 1990s, and 2000s resulted in a doubling in the frequency of such periods since the 1970s (Figure 39).

A similar frequency analysis based on estimated daily mean water temperature exceeding 18ºC across all migration months (July-September) indicated that the cumulative total number of $POT_{>18°C}$ dates per year fluctuated from 2-3 days per year on average, averaging closer to 4 days during the warmest decades: 1970s, 1990s, and 2000s (Figure 40; Table 13).

The average length of $POT_{>18°C}$ periods was < 5-6 days for most decades, with no apparent trend (Figure 41, Table 13). The frequency of periods of this average length, however, was highest in the warmer decades since the 1970s. Maximum

[35] 1952, the second year of obstruction after the 1951 slide, was another year of high Babine flows but moderate Skeena flows – Sockeye were delayed at the obstruction, where water velocity was at one unspecified point in time estimated at 10 m/s (Godfrey et al. 1954).

period length has, on occasion, extended longer than a week, indicating the potential for direct or indirect thermal impacts. Years with extended periods of elevated water temperature were 1977 (14 days), 1990 and1997 (11 days), and 2004 (10 d) (Table 14).

In the 1977 case, the 14-day $POT_{>18°C}$ event occurred in mid-August; Sockeye migration dropped from high to moderate (see Appendix A and Appendix C). A similar event occurred in 1990 and 2004, during which active high migration dipped to moderate levels and rebounded to significant levels (>2% per day) as water temperatures receded (Appendix C).

Discharge Exceedance Analyses

The frequency and duration of extreme flows in the Babine River rose over the past 2-3 decades, indicating increasing variability in daily discharge levels.

Low flows (< 10^{th} percentile of ~30 cms) occurred on average 2-3x more frequently in the 1980s – 2000s relative to the 1940-1970s (Figure 42; Table 15), principally in September. This coincided with the period 1977-1995, when Babine discharge was generally lower than the long-term average (Figure 6). Though the frequency of extreme low flow dates diminished somewhat in the 2000s, the duration of continuous low flow periods doubled from a long-term average of 10-15 days up to the end of the 1990s, to over 30 days in the 2000s (Figure 43). Low flow periods commencing in August were increasingly common in the late 1990s (1995, 1998) and 2000s (2004, 2006, 2010, 2014) (Figure 42; Table 16). However, migrant Sockeye appeared largely undeterred, maintaining high daily migration rates during the low flow periods for these years (Appendix B; Appendix C).

On the other hand, the frequency and duration of extreme high flows (> 90^{th} percentile of ~120 cms) which have been shown to delay the onset of migration (e.g., 1972, 1976, 2002, 2007, 2011), may be returning to pre-1980s levels (Figure 44; Figure 45). Average POT_{120} durations between the 1950s and 1970s were 20-30 days (the record of 60 days was during 1964, when no adult migration counts were obtained). Peak flow period lengths averaged 21 and 25 days in the 1990s and 2000s, respectively (Table 17). Strong evidence of the delay in Sockeye migration counts at the fence due to high water were observed in relation to lagged TYEE INDEX timing for 1996, 1997, 2002, 2007, 2011 and 2012. The 47-day high flow period in 2011, for example, delayed salmon migrants to the middle of August.

DISCUSSION

Babine Sockeye Migration

Much can happen along the 360-km journey from the mouth of the Skeena River to the Babine fence, so it is almost surprising that the daily timing pattern at the Babine fence bears any resemblance to the pattern at the Tyee test-fishery site. However, in over half of the years since 1956, annual correlation between the two indices[36] ranged from 0.70 – 0.91 (Table 4), suggesting that run timing at the Skeena outlet

[36] Using the “optimum” lag of 24 days based on the maximized “all-year” correlation r = 0.69.

accounted for 50-80% of variation in timing at the fence in those years (e.g., 1989, 1998, 2011, 2013).

The corollary is that for the other years, the TYEE INDEX accounts for less than 50% of the Babine fence variation; in some years as low as 15-25% (e.g., 1969, 1974, 1978, 1997, 2006, and 2014; Table 4). These years may be the more informative years in the sense that they indicate strong deviations in the migration pattern between sites that may be related to environmental conditions along the route, for different components of the run, and may include compounding influences in the Skeena and Babine sections. Although outside of the scope of this analysis, a logical analytical extension might be to incorporate discharge and temperature conditions for the Skeena River into a subsequent study. For example, a comparison of annual hydrographs indicated general similarities in relative discharge (in relation to each watershed's median discharge) between Babine and Skeena systems for highly correlated timing years (e.g., both watersheds were at the lower quartile during fish passage in 1989 and 1998, and both were at or beyond the upper quartile in 2011), whereas there appeared to be more variation between the two waterways in years of low timing correlation, such as 1978, 1997.[37] Cases for which the site daily migration patterns are significantly different without explicit differences in flow or temperature conditions might shed light on the influence of other factors such as fish condition, in-river fisheries, or Babine River velocity barriers at certain flow levels.

Tagging studies have indicated that the order of arrival of fish at the Skeena River outlet was mirrored at the fence (Smith and Jordan 1973; Takagi and Smith 1973). However, early run fish (entering the Skeena in June and destined for Babine Lake streams) and late run fish (entering in late August destined for Upper and Lower Babine River) were also found in most years to take 4-5 more days to travel the distance than middle run fish (Pinkut, Fulton, and Morrison fish entering the Skeena in July and early August) (Takagi and Smith 1973). Travel days from the Skeena River boundary to the fence varied from 14-40 days (i.e., 9-25 km/day). Most significant differences in travel time appeared to be related to month (or "run") or location of tagging (fish tagged in coastal inlets had fewer "days out" than fish tagged at the river boundary, presumably because they were less disoriented by the time they reached the river). Though it is within the range of travel speeds, the 13 km/day estimated by Godfrey et al. (1954) for the travel rate from the slide area to the Babine fence (i.e., 64 km / 5 days = 12.8 km/day) is much less than the average speed of 18-20 km/day calculated by Takagi and Smith (1973) based on mean days out traversing the Skeena and Babine rivers. This may suggest a more arduous ascent for at least part of the Babine system, perhaps related to the 9.5% grade above Gisgagaas through the Babine Canyon (Godfrey et al. 1954).

Takagi and Smith (1973) did not find any differences in travel time due to fish age or body size[38], and only a weak positive relationship between travel days and Skeena

---

[37] Plots available at EC WSD site: http://wateroffice.ec.gc.ca/search/search_e.html?sType=h2oArc.

[38] Age 3-, 4- and 5-year old fish travelled about the same rate in the pre-slide year of 1947 (Takagi and Smith (1973) p.6, Table 4); in other years, where data were restricted to 4- and 5-year olds, it was the Age 4's that travelled faster, not the 5's – seemingly contradicting the idea that larger fish travel faster.

discharge (Appendix II in Takagi and Smith 1973). The latter might be due to only accounting for Skeena flows; they noted high Skeena flows in 1955 were associated with more days out, but low Skeena flows in 1958 were not accompanied by reduced travel time. The difference might be related to Babine flows, which remained high through June and July in 1958 (Appendix C). Fish in 1946 (experiencing average Skeena and elevated Babine flows) and especially 1947 (below average Skeena and below average Babine flows) travelled somewhat faster than in subsequent years – however, Takagi and Smith noted that these pre-slide years might not be directly comparable to post-slide years due to changes in the stream hydraulics, the same reason why this study excluded 1946-1952 years from migration statistics.

These elements point to a potential velocity barrier associated with the canyon and/or the 1951 slide site, approximately 4-7 days travel time below the fence, depending on conditions.

Sockeye Migration and Water Temperature Conditions

A strong negative influence of high water temperatures in the daily pattern Babine Sockeye adult migration was not particularly evident in the reconstructed temperature data and anomaly plots, though reductions in migration from high to moderate levels as temperatures approached or exceeded 18ºC were evident in some years (e.g., 1990, 1999, 2004). However, there is some evidence that the air-to-water temperature models were inadequate, i.e., could not be parameterized with the existing data effectively, due to limitations in the observational time-series, especially in the ‘warming season’ which extends to early August, and for which data records are sparse.

This is most apparent where observed elevated water temperature data exist for comparison to modelled water temperatures, such as 2004. In this case, the model for the ‘cooling season’ (mid-August and on) reasonably estimated the maximum water temperatures around mid-to-late August, but underestimated an apparent heat wave in mid-to-late July 2004. In both periods, observed water temperatures reached or exceeded 20°C (and were associated with diminishing migration rates), but only the August event was ‘captured’ by the modelled water temperature.

Similarly, in 2009, a rapid reduction in migration rate in early August (warming season) was associated with an observed peak-over-20°C MWT event, which was underestimated by the modelled water temperatures.

Basing model calibration solely on the one complete year of high-resolution data logger data in 2004 yielded seasonal models more responsive to air temperatures above 20°C in both warming and cooling seasons, but over-estimated warming season temperatures for all other years, indicating that, climatologically, 2004 was a likely a unique year. In fact, 2004 was an exceptionally warm year in the Babine, with mean summer air temperatures about 1°C higher than other “warm/warm” PDO-ENSO years such as 2003 and 2005 (Appendix C). Thus, the issue of effective model calibration may not be simply a lack of sufficient observed water temperature;

there may be other climatological[39] and hydrological factors[40] in the Babine system that need to be taken into account to parameterize water temperature models (Littell et al. 2011; Stefan and Preud'homme 1993).

Linear estimation was rejected for similar reasons – too sensitive at the upper end of air temperatures in the warming season (e.g., 2004, 2006, 2009; Figure 23) – and likely to result in false positives in peak-over-20°C exceedance analyses.

Thus, by selecting the logistic output of water temperature estimates, the results of analyses regarding average and peak temperatures, including exceedance analyses of frequency and duration over temperature thresholds (Figure 40; Figure 41), must be considered conservative, though inter-annual and decadal trends should be consistent.

Given these qualifications, it appears that estimated mean water temperatures in the Babine River during the Sockeye migratory period are estimated to be approximately 15 ± 2°C currently, but have been rising at a rate of about 0.16°C per decade, based simply on the fact that regional air temperatures have been rising at that rate over the past century (Figure 25; Figure 26).

On average, the frequency and duration of periods in which conditions might be thermally-stressful to Sockeye migrants (18°C or more) appears to be negligible, with perhaps one or two periods per year in which water temperatures rise above that threshold, typically for 2-3 days. However, the maximum length of such periods may be a better indicator of the potential cumulative stress on migrants. In 1977, for example, a 14-day POT>18°C event occurred in mid-August (Appendix C); Sockeye migration fell to moderate levels (2% per day) during this period. Similar extended periods of 10 or 11 days occurred in 1990, 1991, 1999, and 2004 that were associated with reduced migration levels (Appendix C).

Events such as these, though currently intermittent, may provide some insight into the potential impacts if regional climate conditions were to become warmer or drier in the future. However, it is not possible from the data to conclude that migration was actually affected in these cases, since migration remained at low to moderate levels.

Sockeye Migration and Flow Conditions

As mentioned earlier, the most consistent apparent environmental impact on Sockeye migration was the delay in the start of significant migration past the fence due to initial high Babine discharge levels: when high spring flows persisted into the migratory period, high migration rates were generally inhibited until daily mean discharge dropped below ~100-120 cms.[41] High discharge levels persisting into mid-August resulted in significant migratory delays of 2-3 weeks in some years (e.g.,

[39] The north-central region of B.C. responds more strongly to ENSO phase than elsewhere in B.C., with winter temperatures 2.5°C to 3.5°C warmer during El Niño years than normal, and 10% to 30% more precipitation (Picketts, Werner and Murdock 2009).

[40] E.g., changes in precipitation, snowpack, lake ice, vegetation, run-off, groundwater, climate regimes, basin geography, etc.

[41] Indeed, initial fence counts were generally not feasible until flow levels fell to the point where fence operations could safely occur: ~140 cms or less. High flows were likely responsible for the lack of daily counts in 1964.

1972; 1976; 1997; 2002; 2007; 2011; Appendix B, Appendix C).

Exceptions to this “high-flow rule”, in which high migration rates occurred despite flow levels well above 100 cms, seemed to be the result of two situations:

1. Early summer high flows, usually dropping progressively, met by an early pulse of migrants, possibly the ‘early run’ (e.g., 1974, 1998). Takagi and Smith (1973) documented ‘early run’ fish as ‘slower’ travelers in early tag studies, perhaps due to the likelihood of this sub-population encountering higher flows more often by virtue of their early timing.
2. Persistent high flows of 120 cms or more late into the migratory period, ultimately met with high Sockeye migration in one long agglomerated migratory pulse, presumably as a function of the biological imperative to complete the migration stage (e.g., 1954, 1976, 2007, 2011).

Little or no effects on migration rate due to flow levels below the 25th percentile (40 cms) were evident in the data from a subjective examination. Moderate to high migration rates were apparent at mean discharges as low as the 10th percentile (30 cms) in low flow years which predominated in 1977-1998 (during the warm PDO regime), and again in 2003-2006, 2010, and 2014 (Figure 35; Figure 36; Appendix C).

<u>Testing for Location of Environmental Impacts</u>

Most of the high Babine flow years were also characterized by high Skeena flows, thus it was not feasible to distinguish directly whether Sockeye were being delayed in the Skeena, the Babine, or both. Only 1997 did not demonstrate flow levels above the 75th percentile for the Skeena as well as the Babine[42] – notably in 1997, significant migration counts at the fence did not commence until mid-August, as Babine discharge fell to 100 cms over the previous week (Appendix C). This provided at least one hint that conditions in the Babine alone might be sufficient to delay Sockeye migrants.

Coincidentally or not, air temperatures peaked near 20°C at about that point in time (~August 16-17th), followed by (estimated) mean daily water temperatures of 18-19°C. Elevated water temperatures might act as a thermal barrier if there was a large temperature differential between the Babine, with its large sun-soaked headwater lake, versus the Skeena with its origins at high altitudes in the Spatsizi Plateau[43]. In any case, it was not clear where either potential barrier might act, or if there might be an interaction effect between flow and temperature at:

- the Babine fence, in the congestion below the fence;
- a velocity barrier in the Babine Canyon;
- the confluence with the Skeena, below which fish might hold until conditions

[42] 1952, the second year of obstruction after the 1951 slide, was another year of high Babine flows but moderate Skeena flows – Sockeye were delayed at the obstruction, where water velocity was at one unspecified point in time estimated at 10 m/s (Godfrey et al. 1954).

[43] Water temperature data for the Skeena River above Babine River were not available for comparison.

in the Babine were conducive to upstream migration.

The stratified CMH-GA test provided a preliminary means of detecting, in a relatively unknown watershed, what environmental variate threshold levels were most associated with changes in Babine Sockeye migration rate classification[44] at the fence. No prior assumptions about critical thresholds for temperature or flow levels need be made, though thresholds may be arrived at by repeating the statistical test at various combinations of time lags and environmental variate threshold levels[45,46], and examining the CMH-GA test statistics for maximum significance. The corresponding environmental threshold levels would have the most “influence” or association with categorical changes in the migration rate, response variate.

A specific environmental impact point along the migration route might be indicated by a high association with a particular date lag. Conversely, the environmental impacts might be more drawn out over time, essentially affecting the fish continuously as they moved upstream over the course of 5-7 days, as might occur if Babine water temperature remained elevated and/or flows were high and continuous. In the latter case, the degree of association would likely be similar across the range of time lags.

When no date lags are applied (i.e., lag = 0 for both temperature and flow), the test generated a same-day analysis representative of environmental conditions at the fence as the fish were being tallied. Merging fence counts with the previous day’s environmental conditions (lag = 1 day) and repeating the test across all temperature and flow thresholds examined the association (if any) of conditions one day earlier – i.e., when the fish were still one day away from the fence – on the current day’s migration rates[47]. This was repeated for lag = 0 to 7 (assuming fish could, on average, enter and traverse the entire lower Babine River within one week[48]) for each environmental variate independently (i.e., generating all combinations of flow and MWT over the past week in association with a day of fence counts).

Figure 28 and Figure 29 portray the resulting CMH-GA test statistics (not their probabilities) for the range of water temperature[49] and flow thresholds at each date lag. Maximum CMH-GA statistics, indicating the most significant associations with large changes in migration rate, were located at: 17°C lagged 6 days and 18°C lagged 5 days, at a wide range of discharge date lags and threshold levels ranging from 60-120 cms.

This result appears to be somewhat unexpected, at first. A definitive signal regarding the influence of water temperatures in the 17-18°C range on migration rates seems

---

[44] Migration rate class: high (or “significant”) vs low (or “negligible”), based on the 50th percentile of daily migration rates from the historical data.
[45] Water temperature thresholds tested: integer increments 13-20°C (only 17-19°C shown).
[46] Discharge thresholds tested: 30-150 cms by increments of 10 cms.
[47] Under the assumption that discharge and water temperature estimates are applicable “instantaneously” throughout the lower Babine River.
[48] Godfrey et al (1954) found that Babine Sockeye travel time from above the Babine slide location (20 miles upstream of the Skeena confluence) to the fence (40 miles upstream) was approximately 5 days, indicating a swim speed of 8 miles/day, or 13 km/day.
[49] Water temperature thresholds tested: integer increments 13-20°C (only 17-19°C shown).

unlikely, given (a) the poor quality of the water temperature data; (b) difficulty in calibration of the air-to-water temperature conversions; and (c) the resulting biased temperature estimates. It should be remembered, however, that estimated peak water temperatures were biased downward by a few degrees relative to observed peaks (Figure 24), thus the resulting CMH-GA statistics might simply reflect actual upper limits in the water temperature dataset of 18-20°C (Figure 32), and may not reveal much beyond the fact that the data are limited at that temperature range.

Conversely, there appears to be no evidence from this and similar analyses (Stiff et al. 2013; 2014a; 2014b) of a decrease in critical thermal thresholds (e.g., to 15-17°C) for Sockeye salmon from the Central Coast to northern populations. Along with other analyses for more southerly populations (e.g. Somass (Hyatt et al. 2015); Okanagan (Hyatt and Stockwell 2003)), the findings suggest that Sockeye readily migrate at temperatures up to 18-20°C, although above 18 degrees, migration may shift from high to lower rates depending on interactions with flow.

The date lags for the water temperature classes most associated with migration rate changes ranged from 4-7 days, with peaks at 5-6 days. It is revealing that, within a MWT class, date lags of 0-3 days were relatively unimportant,, and rules out strong temperature effects on migration at or just below the fence site (see also: Withler 1949[50]). That the two MWT thresholds appeared most strongly associated with a particular but different date lag (6 days at 17°C and 5 days at 18°C) at a wide range of discharge levels, may also be unexpected, but this may be an indirect indication that travel time may be reduced at lower flow levels. As a rule, cooler water temperatures are associated with higher flow levels earlier in the season, and flows decline and temperatures rise as the migration period progresses. Higher flow levels are likely to result in increased travel time (Takagi and Smith 1973). Thus, it may be reasonable to expect reduced travel time at 18°C, which generally occurred later in the season, compared to 17°C conditions.

The CMH-GA output revealed interesting elements regarding discharge as well, which were best examined on the two-dimensional version of the distribution (Figure 29). Whereas a subjective review of the multi-panel (Appendix B) and anomaly plots (Appendix C) suggested that high discharge levels (>100-120 cms) have a negative effect on migration rate, at least early in the season, the CMH-GA heat map seems to indicate significant influences at a wider range of flow thresholds, from 60-150 cms at 17°C, and 60-100 cms at 18°C. Flow thresholds of 40-50 cms have reduced significance at both temperature levels – evidently flows at that level could not differentiate migration rates – while thresholds of 30 cms do exert some influence (though perhaps principally as a lower bound in the data).

An interaction effect between discharge and MWT thresholds may be apparent in this plot. For the 17°C threshold, it appears that all discharge thresholds at 70+ cms had some influence on migration across the entire set of date lags, perhaps exerting

[50] Based on tagging experiments over three years between July and September (at various fish densities), Withler (1949) detected no effects on Sockeye migration rate past the Babine fence due to water levels or 'population pressure' below the fence. Although the author did not examine for temperature effects directly, it is likely that the replicate experiments throughout the season would highlight any influence of temperature on fish passage if present.

a consistent influence for the entire 7 days of upstream travel in the Babine River. A slight widening at the 6-7 day lag at higher flow thresholds (e.g., 100-110 cms) might indicate that those flow levels are more arduous and have a stronger influence on migration rate since a migrant must work harder to reach the fence at high flows.

This is most apparent at the 18°C threshold – flows of 70 cms seven days earlier (i.e., somewhere near the Skeena / Babine confluence) tend to have a significant influence on 'migration success' in concert with water temperature conditions ranging from 4-7 days earlier. In other words, fish experiencing 70 cms and 18°C seven days downstream from the fence share similar migration rate outcomes as fish experiencing 18°C just four days before – the flow rate appears to be an important factor across a range of thermal environments. At 18°C, the pattern is similar at higher flow thresholds but diminished, likely as a function of fewer observations at both high flows and high temperatures.

At 60 cms, a reduction in the significance of the CMH-GA statistic at lag 7 seems to suggest the possibility of an effect further downstream, at the Babine outlet. Perhaps entering the Babine estuary at 60 cms flows has less consequence on migration success than entering at higher flow rates. Generally-speaking, though, flow conditions in the canyon seem to be most likely associated with changes in migration counts at the fence, given that the additional 20 km to the Babine-Skeena confluence should have produced a best-fit to a lag-time closer to 7-9 days, as opposed to 5-7 days.

Though strong conclusions based on this method would be ill advised without further examination, it does point to some areas of field research for monitoring, specifically in the Babine Canyon region, where velocity barriers associated with its 9.5% gradient are likely playing a part in defining early season migration scenarios.

For example, if 'early run' Babine Sockeye are of concern due to diminishing returns (Wood 2001; Cox-Rogers and Spilsted 2012), it may be useful to understand what impact prolonged high flows during their upstream passage may have had (or will have, under future climate change scenarios) on these fish. The data indicate significant migration rates occurring up to 120 cms (Figure 30, Figure 31) for a particular segment of the population migrating at low temperatures (15°C) (Figure 34[51]), and a number of instances of early migration events occurring at flows in excess of 120 cms (e.g., 1954, 1958, 1968, 1974, 1982, 1998; Appendix C) – what is the condition of those fish upon arrival? In high flow years where there is no evidence of a distinct 'early run' (e.g., 1972, 1976, 1997), does that indicate these fish perished? Alternatively, were they amalgamated into the 'middle run'? If this sub-population is simply delaying upstream migration until flows abate, in what reproductive condition are they upon arrival on the spawning grounds? What remedial measures, such as fishways, might be advised to support or enhance this remnant 'wild' sub-population?

[51] A weighted frequency distribution of historical Babine Sockeye migration rates (daily %), at varying levels of Babine River water temperature and discharge six days earlier indicated that high migration rates (>2% per day) were found at a wide range of discharge and temperature levels, with maxima at 15°C and 120 cms earlier in the season and 18-20°C and 30-100 cms later in the season (see contour plot Figure 34).

Ascertaining the presence and degree of physiological impacts on Babine Sockeye reproductive condition and success is complex and outside the scope of this paper, but would be a logical extension. Sockeye salmon, enduring temperature- and flow-related stresses during upstream migration, would be highly susceptible to freshwater parasitic infections, such as *Ichthyophthirius multifiliis*, to which the anadromous fish had not yet been exposed (Traxler, Richard and McDonald 1998).

Of the years of notable pre-spawn mortality (PSM >10%) recorded for Pinkut and Fulton stocks since 1979 (Table 18), 1997 and 2007 were associated with high flow conditions in the Babine, and 1995, 1998, 2000, and 2006 were associated with low flow conditions. Moderate flows but elevated temperature conditions during portions of the peak migratory period likely characterized 1990, 1994, 2001, 2009 and 2013. The remaining years of significant PSM (1986, 1993) were not apparently associated with extremes in Babine River discharge or water temperature, nor were high pre-spawn mortality events associated with either the extreme high discharge of 2002, 2011, or the extreme low discharge in 1980, 1995, 2014.

While environmental stressors must be an important element in the susceptibility of a fish to an infectious agent, pre-spawn mortality events from the Babine spawning ground facilities (Table 18) do not appear to associate infection outbreaks to any one particular stressor during upstream migration. The effects of parasites on pre-spawn mortality appears rather to be a function of crowding and holding in areas near the terminal spawning grounds, as opposed to migration conditions (pers. comm. Mark Higgins, Fish Health Biologist, DFO, 2014).

Trends in Extremes

The frequency and duration of periods of warmer air temperatures have increased in recent decades (since about the 1970s) relative to previous decades (Figure 38; Figure 39), and consequently average summer water temperatures appear to be exceeding thresholds conducive to salmon migration more frequently since the 1990s (Figure 40), and for longer periods of time (Figure 41). This is in keeping with the general warming trend in north-central British Columbia of 1.3°C over the past century (Picketts, Werner and Murdoch 2009).

Projected changes in climate over the next 50 years include warming of 1.4-2.1°C, generating “complex adjustments to stream flow” as expected changes exceed the historical range in variability for the area (Picketts, Werner and Murdoch 2009). Anticipated impacts are increased instances of melt-water flooding in spring and drier periods in summer due to decreased precipitation. This trend has already been apparent in the Babine system, for which the frequency and duration of extreme flows in the Babine River rose over the past 2-3 decades, indicating increasing variability in seasonal discharge levels (Figure 42 - Figure 45).

RECOMMENDATIONS

The Babine River system is one of the most important Sockeye watersheds in British Columbia. Babine Sockeye stocks comprise up to 80-93% of the Sockeye production in the Skeena (Cox-Rogers and Spilsted 2012), representing over $7 million in current landed value (LBN 2012). Given the significance of these stocks, monitoring of the physical environment appears to be under-resourced, at least for watershed temperature regimes. Continuous monitoring of environmental variables in this watershed via automated data logger installations, combined with advances in the analysis of how environmental factors co-vary with Babine Sockeye behaviour and migration patterns, might be considered a wise investment in this valuable resource.

Specific recommendations that arise out of this analysis are organized by topic.

Water Temperature Data

Annual and seasonal variations in freshwater temperatures exert significant influence on productivity for multiple life stages of salmon (Hyatt and Stockwell 2003). In the Babine, outside of enhancement facilities, the network of temperature stations is currently sparse, hampering the ability to relate historical and anticipated future changes in the watershed's temperature regime to Sockeye production. Monitoring water temperatures at a strategically developed network of locations in the Skeena watershed would assist in understanding these changes over time (Knox 2012).

Issue: For one key site, the Babine River, air/water temperature relationships currently rely on less than 10 years of instantaneous "spot" temperature measurements taken during summer daylight hours only. There is some evidence that observed water temperatures at this site are not sufficiently explained by air temperature alone, that other factors may have some influence, however the water temperature data are of insufficient length or quality to resolve the issue, yielding questionable estimates of water temperature for co-variation analyses. The inability to reliably hind-cast or forecast Babine River water temperature may also limit climate analyses that depend on suitable baseline reference data for downscaling of climate model outputs to local conditions.

- **Recommendation**: Continuous high-resolution water temperature data at the fence, collected 24 hours a day by automated data loggers, including dates outside the Sockeye migration season, would help to address this data need, and improve the confidence in site air/water temperature relationships. Besides higher temporal resolution in the data, data loggers would improve data accuracy and reliably minimize data gaps through daily over-sampling.
- **Recommendation**: An automated data logger maintained at the Babine fence, and (for comparison) another in the Skeena River near the confluence with the Babine, would improve the area's environmental network density, and document temperature differentials between the waterways that might influence salmonid migratory behaviour and movement up the Skeena and into the Babine system.

Hydrometric Data

The density of the network of hydrometric stations in the Babine and Skeena watersheds is probably above average for northern British Columbia (but see Knox 2012), with multiple sites around Babine Lake and at its outlet, in Babine River near the Babine fence, in the Skeena above the confluence, and multiple stations downstream. Continuous daily averages of water level and flow factors are documented in some cases since the early 1900s. Real-time data are available at many of the key locations in the principle waterbodies. Terminated time-series (e.g., Babine discharge at the outlet of Babine Lake) may be reasonably reconstructed from nearby active stations.

This level of spatial and temporal resolution may provide further useful inputs into the understanding of Babine Sockeye upstream migration timing and success (perhaps in conjunction with application of archival button tags to track individual fish progress). Analyses based on conversion of discharge to velocity may provide insight on the energetic requirements at velocity barriers along the route.

Issue: One apparent data gap in the hydrometric network arises from this study: the Gisgagaas Canyon in the lower Babine, site of historic landslides. This steep-sided 15-km channel carved through intrusive igneous rock, which is "especially susceptible to weathering and in its exposed areas is very soft and crumbly" (Godfrey et al. 1954) may continue to present a temporary barrier to upstream migration at certain water levels, both low and high, but the site is unmonitored due to its remote location[52].

- **Recommendation**: A comprehensive stream survey throughout the canyon area to document the longitudinal channel profile, bank-full channel widths, wetted widths and water velocity at various stage heights could be done to determine the locations of potential velocity barriers at various water levels. Rating curves could be developed for each location, and statistically related to discharge levels at BABINE RIVER AT NILKITKWA for reconstruction of the historic, current, and potential future time-series under various climate change scenarios.
- **Recommendation**: A solar-powered automated data logger, measuring water depth and velocity (and, optionally, water temperature and turbidity) would be a superior method of obtaining further useful and complementary data, if the site was conducive to installation and ongoing operation.

Migrant Data

While the productivity for all Sockeye stocks has declined over recent decades from previous highs, unenhanced Babine stocks have declined the most (Cox-Rogers and Spilsted 2012). These stocks make up the bulk of the smaller 'early' and 'late' runs, while the enhanced stocks largely compose the 'middle' run.

Issue: The 'early' run appears to be most susceptible to impacts due to high spring flows in the Babine River persisting into the peak migration period in July and August.

[52] Gisgagaas Canyon has road access (from the 1950's work that was subsequently used for forestry) and there is usually a small First Nation's food fishery there each year. In the 2000s there were a few commercial Sockeye fisheries at the site using dipnets and fishwheels. The Gitksan commercial fishery is currently done on the Skeena mainstem with beach seines. There are currently no year-round residents in Gisgagaas Canyon.

- **Recommendation**: Utilize biological sampling to identify the ‘early’ run component of the return to determine the extent of the impact of variable discharge rates on migration success. Utilize biotelemetry and biosampling methods to understand how Skeena/Babine environmental factors affect fish condition (reproductive) upon arrival, i.e., non-lethal biopsy samples for blood, gill tissue for quantification of energetic status (e.g., Cooke et al. 2009). Project environmental conditions into future decades based on climate model applications to identify probable futures. Develop science-based adaptation or mitigation responses to conserve the stock as appropriate.

Adult Sockeye migration speeds through the Babine system are highly variable, ranging from ~10 to 17 km/d (mean 13 km/d; Takagi and Smith 1973). Since temperature and discharge impacts might be more pronounced on jacks than on larger adults, age or size class may be a factor influencing migration speed, potentially confounding the analysis of lag effects of Babine water temperature or flow on fence count variation.

Issue: Combined large and jack Sockeye indices may obscure differences in age-specific responses to water temperature and discharge thresholds.

- **Recommendation**: Partition data by age-class and re-run non-parametric weighted frequency analyses for detection of environmental co-variate thresholds by age group. Rerun CMH-GA statistical analyses to explore date lags most associated with age-specific migration rate changes.

Issue: Adult Sockeye migration speed data have not been updated since 1973, and have largely ignored jack Sockeye that can contribute ~25% of spawners in some years (51% in 2013).

- **Recommendation**: Implement tagging studies to update age-specific travel speeds through the Skeena/Babine system for age 3’s, 4’s and 5’s.
- **Recommendation**: Incorporate thermal button tags and/or PIT tags into the study to evaluate temperatures encountered and travel rates.

ACKNOWLEDGEMENTS

The material data for this report was made available from a variety of organizations, through the generous provision of time and effort of a number of individuals. This study would not be possible without the dedicated efforts of FISHERIES AND OCEANS CANADA field crew and personnel in the DFO NORTH COAST STOCK ASSESSMENT GROUP, as well as the following contributors:

- Donna Macintyre, LAKE BABINE NATION Fisheries Manager and technicians (including Mark Tiley, Jason Balczer, Tony Michell, Jonathon William and Ken Aslin) were involved in data collection and management. Marilyn Helin assisted in reviewing the data. Ken Rabnett (SUSKWA RESEARCH, Suskwa, B.C.) provided useful insights into the Skeena watershed monitoring network.
- Steven Cox-Rogers and David Peacock (DFO NORTH COAST STOCK ASSESSMENT) provided information related to the Babine Sockeye stock and environmental monitoring. Natalie Newman (A/Comm. Advisor) provided temperature data from Fort Babine operations.
- DFO personnel, including George Chandler, Dennis Graf, Mitchell Harborne, and Doug Lofthouse (OHEB) provided information concerning spawning ground datasets. Mark Higgins (Fish Health Biologist, SCI) assisted with interpretation of spawning ground mortality data. Margot Stockwell assisted with editing and formatting of the final document.
- Lucie Vincent (CLIMATE RESEARCH DIVISION), Eva Merkis and Giselle M. Bramwell (CLIENT SERVICES OUTREACH SECTION METEOROLOGICAL SERVICES) of ENVIRONMENT CANADA provided regional AHCCD meteorological datasets with daily temporal resolution.
- Lynn Campo and Lauren Wick of ENVIRONMENT CANADA WATER Survey DIVISION provided WSC station water temperature data.

Funding for this analysis and report was provided to Dr. K. Hyatt by FISHERIES AND OCEANS CANADA as part of DFO's 2012-2016 AQUATIC CLIMATE CHANGE AND ADAPTATION SERVICES PROGRAM.

LITERATURE CITED

Abdul-Aziz, O.I., Mantua, N.J., and Myers, K.W. 2011. Potential climate change impacts on thermal habitats of Pacific salmon (*Oncorhynchus* spp.) in the North Pacific Ocean and adjacent seas. Can. J. Fish. Aquat. Sci. 68(9): 1660-1680.

Bartemucci, P., and Williston, P. 2012. Rare Ecosystems of the Babine River Watershed. Project 2009-1 Report prepared for the Babine Watershed Monitoring Trust, Smithers BC. Available at: http://www.babinetrust.ca/DocumentsBWMT/BWMTReports/2009-1BabineRareEcosystemsAugust2012.pdf

Cooke, S.J., Donaldson, M.R., Hinch, S.G., Crossin, G.T., Patterson, D.A., Hanson, K.C., English, K.K., Shrimpton, J.M., and Farrell. A.P. 2009. Is fishing selective for physiological and energetic characteristics in migratory adult sockeye salmon? Evol. Appl. 2(3): 299-311.

Cooke, S.J., Hinch, S.G., Farrell, A.P., Lapointe, M.F., Jones, S.R.M., MacDonald, J.S., Patterson, D.A., and Healey, M.C. 2004. Abnormal migration timing and high en route mortality of Sockeye salmon in the Fraser River, British Columbia. Fisheries 29: 22-33.

Cox-Rogers, S., and Spilsted, B. 2012. Update assessment of sockeye salmon production from Babine Lake, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2956: ix + 65 p.

Cox-Rogers, S., Hume, J.M.B., Shortreed, K.S., and Spilsted, B. 2010. A risk assessment model for Skeena River sockeye salmon. Can. Manuscr. Rep. Fish. Aquatic. Sci. 2920: 60 p.

Damborg, J.G., Stiff, H.W., Hyatt, K.D., Brown, G., and Baillie, S. 2015. Observations of water temperature, river discharge, and adult Chinook salmon migration observations in the Cowichan watershed, 1986-2012. Can. Manuscr. Rep. Fish. Aquat. Sci. 3028: vii + 92 p.

Farrell, A.P. 2009. Environment, antecedents and climate change: lessons from the study of temperature physiology and river migration of salmonids. J. Exp. Biol. 212(23): 3771-3780.

Finney, B., Gregory-Eaves, I., Douglas, M.S.V., and Smol, J.P. 2002. Fisheries productivity in the northeastern Pacific Ocean over the past 2,200 years. Nature 416: 729–733.

Fisheries and Oceans Canada (DFO). 2005. Canada's Policy for the Conservation of Wild Pacific Salmon. ISBN 0-662-40538-2 Cat No. Fs23-476/2005E. 57 p.

Godfrey, H., Hourston, W., Stokes, J., and Withler, F. 1954. Effects of a rock slide on Babine River salmon. Fish. Res. Board. Can. Bulletin 101: 100 p.

Hinch, S.G., and Bratty, J. 2000. Effects of swim speed and activity pattern on success of adult Sockeye salmon migration through an area of difficult passage. Trans. Am. Fish. Soc. 129: 598-606.

Hinch, S G., and Martins, E.G. 2011. A review of potential climate change effects on survival of Fraser River Sockeye salmon and an analysis of inter-annual trends in en route loss and pre-spawn mortality. Cohen Commission Tech. Rept. 9, 134 p. Vancouver, B.C.

Hyatt, K.D., and Stockwell, M.M. 2003. Analysis of seasonal thermal regimes of selected aquatic habitats for salmonid populations of interest to the Okanagan Fish and Water Management Tools (FWMT) Project. Can. Manuscr. Rep. Fish. Aquat. Sci. 2618: 26 p.

Hyatt, K.D., Stockwell, M.M., and Rankin, D.P. 2003. Impact and Adaptation Responses of Okanagan River Sockeye Salmon (*Oncorhynchus nerka*) to Climate Variation and Change Effects During Freshwater Migration: Stock Restoration and Fisheries Management Implications. Can. Water. Resour. J.28 (4): 689-713.

Hyatt, K.D., Stiff, H.W., Stockwell, M.M., Luedke, W., Rankin, D.P., Dobson, D., and Till, J. 2015. A synthesis of adult sockeye salmon migration and environmental observations for the Somass watershed, 1974-2012. Can. Tech. Rep. Fish. Aquat. Sci. 3115: vii + 199 p.

International Panel on Climate Change (IPCC). 2007. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson. Cambridge University Press, Cambridge, UK, 976 p. [Electronic version Feb 2007] http://www.ipcc.ch/ipccreports/assessments-reports.htm.

Jensen, J.O.T., McClean, W.E., Damon, W., and Sweeten, T. 2004. Puntledge River high temperature study: Influence of high water temperature on adult pink salmon mortality, maturation and gamete viability. Can. Tech. Rep. Fish. Aquat. Sci. 2523: 50 p.

Knox, G.J. 2012. Implementing a freshwater salmon habitat monitoring program in the Skeena watershed. MSc Thesis, Royal Roads University, Victoria, B. C. Available at: http://skeenawild.org/images/uploads/docs/Knox,_Greg_Thesis,_Final_Version.pdf

Levy, D.A., and Hall, K.J. 1985. A review of the limnology and sockeye salmon ecology of Babine Lake. Westwater Research Centre Tech. Rept. 27: 78 p.

Littell, J.S., Elsner, M.M., Mauger, G.S., Lutz, E., Hamlet, A.F., and Salathé, E. 2011. Regional Climate and Hydrologic Change in the Northern US Rockies and Pacific Northwest: Internally Consistent Projections of Future Climate for Resource Management. Project report: April 17, 2011. Latest version online at: http://cses.washington.edu/picea/USFS/pub/Littell_etal_2010/

Mantua, N., Tohver, I., and Hamlet, A. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. Climatic Change 102: 187-223.

Martins, E.G., Hinch, S.G., Cooke, S.J., and Patterson, D.A. 2012. Climate effects on growth, phenology, and survival of sockeye salmon (*Oncorhynchus nerka*): a synthesis of the current state of knowledge and future research directions. Rev. Fish. Biol. Fisher. 22 (4): 887-914.

Martins, E.G., Hinch, S.G., Patterson, D.A., Hague, M.J., Cooke, S.J., Miller. K.M., Lapointe, M.F., English, K.K., and Farrell, A.P. 2010. Effects of river temperature and climate warming on stock-specific survival of adult migrating Fraser River Sockeye salmon (*Oncorhynchus nerka*). Global Change Biol. 17(1): 99-114.

Mohseni, O., and Stefan, H.G. 1999. Stream temperature/air temperature relationship: a physical interpretation. J. Hydrol. 218: 128-141.

Mohseni, O., Stefan, H.G., and Erickson, T.R. 1998. A nonlinear regression model for weekly stream temperatures. Water Resource Res. 34 (10): 2685-2692.

Mote, P., Parson, E., Hamlet, A., Ideker, K., Keeton, W., Lettenmaier, D., Mantua, N., Miles, E., Peterson, D., Slaughter, R., and Snover, A. 2003. Preparing for climate change: The water, salmon, and forests of the Pacific Northwest. Climatic Change 61: 45-88.

Nelitz, M., Wieckowski, K., Pickard, D., Pawley, K., and Marmorek, D.R. 2007. Helping Pacific salmon survive the impact of climate change on freshwater habitats: Case Studies. Final report prepared by ESSA Technologies Ltd., Vancouver, B. C. for Pacific Fisheries Resource Conservation Council, Vancouver, BC. 67 p.

Pellett, K., Stiff, H.W., Damborg, J., and Hyatt, K.D. 2015. A PIT-tag based investigation into Somass River adult sockeye salmon migration behaviour in response to environmental conditions. Can. Tech. Rep. Fish. Aquat. Sci. 3116: vi + 154 p.

Picketts, I.M., Werner, A.T., and Murdock, T.Q. 2009. Climate change in Prince George: summary of past trends and future projections. Pacific Climate Impacts Consortium, University of Victoria, Victoria BC, 48 p.

Pilgrim, J.M., Fang, X., and Stefan, H.G. 1998. Stream temperature correlations with air temperatures in Minnesota: implications for climate change. J. Am. Water Res. Assoc. 34 (5): 1109-1121.

Salinger, D.H., and Anderson, J.J. 2006. Effects of water temperature and flow on adult salmon migration swim speed and delay. Trans. Am. Fish. Soc. 135(1): 188-199.

SAS Institute Inc. 2011. Base SAS® 9.3 Procedures Guide: Statistical Procedures. Cary, NC: SAS Institute Inc. 528 p.

Shortreed, K.S., and Morton, K.F. 2000. An assessment of the limnological status and productive capacity of Babine Lake, 25 years after the inception of the Babine Lake Development Project. Can. Tech. Rep. Fish. Aquat. Sci. 2316: 52 p.

Smith, H.D., and Jordan, F.P. 1973. Timing of Babine Lake sockeye salmon stocks in the north-coast commercial fishery as shown by several taggings at the Babine counting fence and rates of travel through the Skeena and Babine rivers. Fish. Res. Board Can. Tech. Rep. 418: 31 p.

Sokal, R.R., and Rohlf, F.J. 1969. Biometry. The Principles and Practices of Statistics in Biological Research. W.H. Freeman & Co., San Francisco. 776 p.

Spilsted, B., and Spencer, B. 2009. Documentation of North Coast (Statistical Area 1 to 6) Salmon Escapement Information. Can. Manuscr. Rep. Fish. Aquat. Sci. 2802: 66p.

Stefan, H.G., and Preud'homme, E.B. 1993. Stream temperature estimation from air temperature. Water Resour. Bull. 29 (1): 27-45.

Stiff, H.W., Hyatt, K.D., Stockwell, M.M., Cox-Rogers, S., and Levesque, W. 2015a. Temperature, and discharge conditions associated with migration of adult Sockeye salmon entering the Docee River and Long Lake watershed, B.C. from 1968-2012. Can. Manuscr. Rep. Fish. Aquat. Sci. 3052: vii + 159 p.

Stiff, H.W., Hyatt, K.D., Stockwell, M.M., Cox-Rogers, S., Hall, P., Alexander, R., Kingshott, S., Percival, N., and Stewart, B. 2015b. Water temperature, river discharge, and adult Sockeye salmon migration observations in the Meziadin watershed, 1966-2012. Can. Manuscr. Rep. Fish. Aquat. Sci. 3019: v + 147 p.

Stiff, H.W., Hyatt, K.D., Stockwell, M.M., Etherton, P.M., and Waugh, W.D. 2013. Water temperature, river discharge, and adult Sockeye salmon migration observations for the Tahltan watershed, 1959-2012. Can. Manuscr. Rep. Fish. Aquat. Sci. 3018: ix + 112 p.

Stockner, J.G., and Shortreed, K.R. 1976. Babine Lake monitor program: biological, chemical, and physical data for 1974 and 1975. Fish. Res. Bd. Can. Manuscr. Rep. Fish. Aquat. Sci. 1373: 35 p.

Takagi, K., and Smith, H.D. 1973. Timing and migration of Babine Sockeye stocks through the Skeena and Babine Rivers. Fish. Res. Boardd. Can. Tech. Rep. 419: 61 p.

Traxler, G., Richards, J., and McDonald, T.E. 1998. *Ichthyophthirius multifiliis* (Ich) epizootics in spawning Sockeye salmon in British Columbia, Canada. J. Aquat. Animal Health 10: 143-151.

Vincent, L.A., Wang, X.L., Milewska, E.J., Wan, H., Yang, F., and Swail, V. 2012. A second generation of homogenized Canadian monthly surface air temperature for climate trend analysis. J. Geophys. Res. 117: D18110 doi:10.1029/2012JD017859.

Walker, I.J., and Sydneysmith. R. 2008. British Columbia. *In* From Impacts to Adaptation: Canada in a Changing Climate 2007. Edited by D. S. Lemmen, F. J. Warren, J. Lacroix and E. Bush; Government of Canada, Ottawa, ON. p. 329-386.

Webb, B.W., and Nobilis, F. 1997. Long-term perspective on the nature of the air-water temperature relationship: a case study. Hydrol. Process. 11: 137-147.

West, C.J. 1978. A review of the Babine Lake Development Project, 1961-1977. Can. Fish. Mar. Service Tech. Rep. Series No. 812: xi + 105 p.

Wetzel, R.G. 1975. Limnology. W.B. Saunders Company, Toronto.

Whitfield, P.H. 2001. Linked hydrologic and climate variations in British Columbia and Yukon. Environ. Monit. Assess. 67: 217–238.

Whitfield, P.H., and Cannon, A.J. 2000. Recent variations in climate and hydrology in Canada. Can. Water Resour. J. 25(1): 19–65.

Whitfield, P.H., Bodtker, K., and Cannon, A.J. 2002. Recent variations in seasonality of temperature and precipitation in Canada, 1976-1995. Int. J. Climatol. 22: 1617–1644. doi: 10.1002/joc.813.

Withler, F.C. 1949. Summary of tagging experiments to determine whether Sockeye salmon runs were retarded by Babine River fence in 1946, 1947 and 1949. North Coast Stock Assessment File: XIII-2, 1949.

Wood, C. 2001. Managing Biodiversity in Pacific Salmon: The Evolution of the Skeena River Sockeye Salmon Fishery in British Columbia. *In* Blue Millennium: Managing Global Fisheries for Biodiversity. Edited by B. Harvey and D. Duthie. Victoria, B.C.

Wood, C.C., Rutherford, D.T., Bailey, D., and Jakubowski, M. 1998. Assessment of Sockeye salmon production in Babine Lake with forecast for 1998. Can. Tech. Rep. Fish. Aquat. Sci. 2241: 50 p.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

TABLES

TOPLEY LANDING * BRITISH COLUMBIA					
Latitude:	54°48'57.000" N	Longitude:	126°09'47.000" W	Elevation:	722.00 m
Climate ID:	1078209	WMO ID:		TC ID:	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-8.5	-6	-1.6	3.6	8.4	12.4	14.6	14.1	9.7	4	-2.6	-6.9	3.4
Standard Deviation	4.2	3.2	2.2	1.2	1.8	1.6	1.1	1.1	1.4	1.2	2.9	3.5	2
Daily Minimum (°C)	-12	-10.4	-6.9	-2.3	2.2	6.3	8.4	7.7	4.1	-0.2	-5.4	-9.8	-1.5
Daily Maximum (°C)	-5	-1.5	3.7	9.4	14.6	18.5	20.7	20.4	15.4	8.1	0.3	-3.9	8.4
Extreme Max (°C)	10	12.8	16	24.5	33	32.8	34.4	33.5	31	24.5	17.8	11	
Date	1976/ 16	1968/ 26	1979/ 23	2005/ 25	1983/ 29	1969/ 10	1971/ 31	1990/ 12	1988/ 04	1987/ 01	1976/ 04	2005/ 10	
Precipitation (mm)	54.4	34.5	29.6	25	42.2	58.5	46.4	42.1	43.1	54.4	57	51.1	538
Extreme Max (mm)	8.2	17	8.6	20	23	33.8	54.9	30.7	34.2	21.4	20.2	8.6	
Date	1997/ 29	2005/ 01	1979/ 05	1987/ 30	1998/ 28	2003/ 29	1970/ 25	1966/ 26	2004/ 17	1997/ 01	1987/ 07	1989/ 24	

Table 1. Babine Lake (TOPLEY LANDING) Climate Normals (1981-2010). Source: Environment Canada (http://climate.weather.gc.ca/climate_normals/index_e.html)

YEAR	INSTALLATION DATE	FIRST COUNT	LAST COUNT	REMOVAL DATE	FIELD DATA COMMENTS
1946		July 1	October 4		*No comments recorded.*
1947		June 27	October 7		*No comments recorded.*
1948					*No comments recorded.*
1949		June 30	October 3		*No comments recorded.*
1950		July 18	October 15		*No comments recorded.*
1951		July 12	October 4		Babine Slide - migration disrupted. Estimated 30% of sockeye reached fence
1952		July 22	October 13		Babine Slide - cleanup and restoration continued. Migration disrupted. High water flows. Estimated 30% of sockeye reached fence
1953		July 5	October 28		*No comments recorded.*
1954		July 23	October 3		*No comments recorded.*
1955		July 5	October 3		*No comments recorded.*
1956		July 3	September 30		*No comments recorded.*
1957		July 6	October 29		*No comments recorded.*
1958		July 8	October 1		*No comments recorded.*
1959		July 19	October 2		*No comments recorded.*
1960		July 12	September 28		*No comments recorded.*
1961		July 8	September 21		*No comments recorded.*
1962		July 12	September 22		*No comments recorded.*
1963		July 12	September 13		*No comments recorded.*
1964					Flows at historic maximum all season. No daily fence counts?
1965		July 13	September 13		*No comments recorded.*
1966		July 14	September 15		*No comments recorded.*
1967		July 16	September 23		*No comments recorded.*
1968		July 20	September 14		*No comments recorded.*
1969		July 15	September 21		*No comments recorded.*
1970		July 10	September 15		*No comments recorded.*
1971		July 12	September 24		*No comments recorded.*
1972		August 3, Lg and Jk Sockeye Estimates for August 2	September 20		*No comments recorded.*
1973		July 1	September 15		*No comments recorded.*
1974		July 1	September 19		*No comments recorded.*
1975		July 7	September 30 Coho: October 1		*No comments recorded.*
1976		July 22	October 28		*No comments recorded.*
1977		July 8	October 19 Coho: October 20		*No comments recorded.*
1978		July 11	October 9 Coho: October 10		*No comments recorded.*
1979		July 4	October 31		*No comments recorded.*
1980		July 1	September 29		*No comments recorded.*
1981		July 12	September 29		*No comments recorded.*
1982		July 11	September 27 Coho: September 28		*No comments recorded.*
1983		July 10	September 24 Coho: September 25		*No comments recorded.*

Table 2. Field notes from Babine Fence operations (1946-2014).

YEAR	INSTALLATION DATE	FIRST COUNT	LAST COUNT	REMOVAL DATE	FIELD DATA COMMENTS
1984	Unknown	July 9	October 1 Coho: October 2		*No comments recorded.*
1985	Unknown	July 7	October 24		*No comments recorded.*
1986	July 14	July 15	September 21	September 22	*No comments recorded.*
1987	Unknown	July 14	September 29 Pink: September 30 Coho: October 1	October 1	*No comments recorded.*
1988	July 18	July 18	October 4	October 4	High water installation delay. No jack sockeye harvest due to inadequate returns.
1989	July 4	July 4	October 20	October 20	A commercial harvest of jack sockeye was carried out at the fence.
1990	July 20	July 21	October 14	October 14	High water installation delay. A commercial harvest of jack sockeye was carried out at the fence.
1991	July 7	July 8	October 19	October 20	A commercial harvest of jack sockeye was carried out at the fence. Due to a PSAC strike in 1991 population estimates from a tag recovery program were not available for the Lower Babine River.
1992	Unknown	July 29	September 29	?	The fence was managed by the Babine Lake Nation this year. March 30, 1992 the Babine River fence was assessed for future repairs.
1993	July 8	July 8		October 14	A new counting fence constructed of concrete and steel was built on the river in the same location as the old wooden fence during the winter of 1992/93. Natives from Fort Babine harvested both Jack and Large Sockeye. A Peterson tag / recovery program wa
1994	July 13	July 14	November 1	November 1	Removal date extended though use of Green Plan funds to obtain accurate dipnet counts and tag recovery in conjuntion with the Skeena Radio Tagging Project. Daily and cummulative counts of sockeye harvested at the fence by Fort Babine natives.
1995	July 1	July 2	November 6	November 7	Daily and cummulative counts of sockeye harvested at the fence by Fort Babine natives.
1996	July 27	July 28	November 3, Coho November 4	November 4	High water installation delay. Using dive gear, holes were repaired making the fence fish proof on the evening of July 29. Harvested fish included in daily counts as well as tallies of sockeye harvested by Lake Babine Nation. Poor returns of jack sockeye.
1997	July 28	July 29	October 19	October 20	High water installation delay. Sockeye harvested at the fence as part of an ESSR was recorded.
1998	June 24	June 25	November 15	November 16	Low water conditions favored this early installation. No ESSR or jack sockeye harvest due to inadquate returns.
1999	July 20	July 20	November 23	November 23	High water installation delay. Harvest numbers for sockeye jacks and adults not included in the daily counts.
2000	Unknown	July 14	November 22	Unknown	*No comments recorded.*
2001	July 22	July 22	December 2	December 2	Harvest numbers included in daily sockeye and chinook counts. No jack sockeye harvest
2002	August-06-02	August-07-02	October-10-02	Unknown	Babine Adult Weir counts discontinued due to Fort Babine occupancy
2003	July-17-03	July-17-03	November-26-03	November-26-03	Electronic entry of hourly counts summing to a daily spreadsheet and email reconnected will resolve data errors and improve the flow of data in 2004. No Comments received from the fence crew yet.

Table 2, (cont'd). Field notes from Babine Fence operations (1946-2014).

YEAR	INSTALLATION DATE	FIRST COUNT	LAST COUNT	REMOVAL DATE	FIELD DATA COMMENTS
2004	July-05-04	July-05-04	December-01-04	December-01-04	Computer generated hourly records available. Email via satellite was not established. Fence counts were relayed via telephone in-season to DFO Fish Management.
2005	July-11-05	July-12-05	October-12-05	October-12-05	*No comments recorded.*
2006	July 5th	July 7th	October 4th	October 5th	Native food/commercial harvest took place over month of August; food fish daily; commercial fishing Aug2 to Sept 5/06 - 3-day schedule (2 days fishing / one day off). Extremely low water in system throughout summer.
2007	August 7th	August 7th	Sept. 30th	October 1st	Fence installation delayed due to high flows.
2008	July-14-08	July-18-08	October-01-08	October-23-08	After October 1, 2008, two chutes remained in operation and counting continued with security camera.
2009	July-08-09	July-16-09	September-21-09	September-22-09	The Daily Count field sheets during the period September 5 to 20, 2009 also reflected "Harvest Release" amounts representing fish that were dipped/captured and then released (they were not permitted to be kept). The fish were tallied as they were released and these amounts were included in the daily totals. The Babine Fence was removed on September 22, 2009 (one week earlier than planned) due to extremely high numbers of pink salmon carcasses on the fence preventing the crew from fishing the traps.
2010	July-10-10	July-12-10	Sept. 27,2010	Sept. 27,2010	*No comments recorded.*
2011	August-04-11	August-10-11	October-04-11	October-05-11	Installation of the fence panels and counting chutes was delayed in 2011 due to high water levels and large amounts of debris blocking the fence . Panels were installed on August 4th but no counting chutes, therefore no counts. Partial counts started on August 10th with only 3 of 7 chutes and the fence was in full operation on August 12, 2011. The adult fence count of 890,743 was adjusted by 1.235 to account for the fish going through prior to the late fence installation and the Jack Sockeye count of 32,163 was adjusted by 1.095% to account for the fish going through prior to the late fence installation.
2012	19-Jul-12	23-Jul-12	02-Oct-12	03-Oct-12	The Babine Fence was installed on July 29 (first count on July 23) and removed on October 3 (last count October 2). August 4th to 18th - Commercial harvest every 2 days - relatively low tallies every 2nd day during harvest.
2013	15-Jul-13	16-Jul-13	25-Sep-13	27-Sep-13	Minor commercial catch Aug 13th
2014	11-Jul	13-Jul			14-JUL: All 7 traps were closed during the fish fence assessment at 1 pm and re-opened at 6:30 PM. 18-JUL: There were a total of 18 sockeye mortalities that are included in the 2215 total. The mortalities were likely due to prolonged containment within the traps. JULY 22: food fishing begins. Aug 2: comm. fishing begins (Aug 2-7, 10-).

Table 2, (cont'd). Field notes from Babine Fence operations (1946-2014).

	Babine Fence											
	Date			Sockeye Migrants (3-d Avg)				Migration Rate (%)				
	Date Count	Min Date	Max Date	Min	Mean Daily	Max Daily	Annual Total	Mean Daily	P50	P75	P95	Max Daily
Year												
1946	91	05JUL	04OCT	1	5,228	16,876	475,725	1.10	0.75	1.84	2.98	3.55
1947	94	05JUL	07OCT	2	5,559	19,626	522,572	1.06	0.63	2.10	3.43	3.76
1949	90	03JUL	03OCT	0	5,657	22,214	509,140	1.11	0.74	1.62	3.89	4.36
1950	98	10JUL	15OCT	3	5,548	19,787	543,668	1.02	0.86	1.59	3.14	3.64
1953	114	05JUL	28OCT	1	6,268	29,899	714,606	0.88	0.17	1.25	3.94	4.18
1954	73	23JUL	03OCT	22	6,897	34,563	503,484	1.37	0.74	1.90	5.71	6.87
1955	84	06JUL	03OCT	0	1,214	4,381	101,969	1.19	0.64	2.03	3.70	4.30
1956	89	04JUL	30SEP	1	4,197	18,183	373,520	1.12	0.81	1.82	3.74	4.87
1957	113	06JUL	29OCT	1	4,277	16,012	483,311	0.88	0.37	1.59	2.72	3.31
1958	86	08JUL	01OCT	75	9,801	23,236	842,850	1.16	1.28	1.71	2.42	2.76
1959	73	19JUL	02OCT	1	11,161	36,186	814,783	1.37	0.74	2.36	4.18	4.44
1960	77	12JUL	28SEP	1	4,054	12,471	312,132	1.30	0.83	2.34	3.76	4.00
1961	76	08JUL	21SEP	4	12,759	36,354	969,696	1.32	1.34	2.11	3.58	3.75
1962	70	13JUL	22SEP	1	8,490	27,754	594,266	1.43	1.15	2.31	4.45	4.67
1963	63	12JUL	13SEP	2	12,079	43,293	760,955	1.59	1.01	2.68	4.96	5.69
1965	63	13JUL	13SEP	6	10,227	26,204	644,309	1.59	1.39	3.07	3.66	4.07
1966	63	15JUL	15SEP	14	9,063	22,295	570,974	1.59	1.71	2.49	3.70	3.90
1967	70	16JUL	23SEP	210	9,032	17,933	632,233	1.43	1.67	2.14	2.58	2.84
1968	57	20JUL	14SEP	188	10,622	26,995	605,443	1.75	1.86	2.46	4.18	4.46
1969	69	15JUL	21SEP	2E3	11,420	44,318	787,979	1.45	0.97	2.10	4.32	5.62

(Continued)

Table 3. Annual migration statistics for Babine Sockeye daily migrants, 1946-2014 (filtered for non-zero observations and smoothed with 3-day average), including migration period and length, mean and maximum daily migrant count, total annual escapement, and mean, maximum, and 50th, 75th, 95th percentiles of daily migration rate (%). All-year summary statistics based on complete post-slide years only (1953-2014).

	Babine Fence											
	Date			Sockeye Migrants (3-d Avg)				Migration Rate (%)				
	Date Count	Min Date	Max Date	Min	Mean Daily	Max Daily	Annual Total	Mean Daily	P50	P75	P95	Max Daily
Year												
1970	66	12JUL	15SEP	1	12,547	31,043	828,092	1.52	1.50	2.53	3.61	3.75
1971	75	12JUL	24SEP	3	11,609	27,491	870,676	1.33	1.18	2.34	2.76	3.16
1972	49	03AUG	20SEP	541	18,781	40,928	920,284	2.04	1.72	3.32	4.09	4.45
1973	64	11JUL	15SEP	1	15,716	56,812	1,005,814	1.56	1.74	2.38	4.38	5.65
1974	71	11JUL	19SEP	5	13,857	43,328	983,826	1.41	1.38	2.29	3.35	4.40
1975	84	07JUL	30SEP	1	11,407	41,271	958,196	1.19	0.78	2.27	3.60	4.31
1976	79	22JUL	14OCT	1	10,583	38,722	836,054	1.27	0.35	3.03	4.29	4.63
1977	104	08JUL	19OCT	2	9,478	55,990	985,691	0.96	0.17	1.44	4.59	5.68
1978	91	11JUL	09OCT	151	7,666	19,876	697,642	1.10	1.17	1.91	2.59	2.85
1979	114	04JUL	28OCT	1	10,978	59,590	1,251,473	0.88	0.10	2.11	2.74	4.76
1980	91	01JUL	29SEP	4	8,353	22,030	760,132	1.10	0.82	2.20	2.60	2.90
1981	80	12JUL	29SEP	16	19,852	52,846	1,588,151	1.25	0.70	2.47	3.00	3.33
1982	79	11JUL	27SEP	3	15,152	38,165	1,197,030	1.27	1.04	2.30	2.96	3.19
1983	76	10JUL	24SEP	1	16,311	39,458	1,239,641	1.32	1.15	2.29	3.11	3.18
1984	81	09JUL	01OCT	1	14,481	38,036	1,172,963	1.23	0.90	2.25	2.94	3.24
1985	104	07JUL	21OCT	1	21,296	91,694	2,214,752	0.96	0.37	1.77	3.47	4.14
1986	68	16JUL	21SEP	2	11,613	32,814	789,680	1.47	1.24	2.43	3.49	4.16
1987	78	14JUL	29SEP	3	24,954	61,273	1,946,450	1.28	0.91	2.70	3.05	3.15
1988	79	18JUL	04OCT	65	18,817	50,724	1,486,544	1.27	1.24	2.16	3.11	3.41

(Continued)

Table 3. Annual migration statistics for Babine Sockeye daily migrants, 1946-2014 (filtered for non-zero observations and smoothed with 3-day average), including migration period and length, mean and maximum daily migrant count, total annual escapement, and mean, maximum, and 50th, 75th, 95th percentiles of daily migration rate (%). All-year summary statistics based on complete post-slide years only (1953-2014).

	Babine Fence											
	Date			Sockeye Migrants (3-d Avg)				Migration Rate (%)				
	Date Count	Min Date	Max Date	Min	Mean Daily	Max Daily	Annual Total	Mean Daily	P50	P75	P95	Max Daily
Year												
1989	107	04JUL	20OCT	1	11,729	36,714	1,255,026	0.93	0.50	1.64	2.77	2.93
1990	86	21JUL	14OCT	44	12,422	34,992	1,068,304	1.16	0.75	2.18	3.01	3.28
1991	102	10JUL	19OCT	6	15,611	38,108	1,592,363	0.98	0.84	1.73	2.26	2.39
1992	63	29JUL	29SEP	437	22,275	40,924	1,403,302	1.59	1.84	2.18	2.76	2.92
1993	99	08JUL	14OCT	2	18,465	67,816	1,828,006	1.01	0.65	1.73	3.02	3.71
1994	110	14JUL	31OCT	2	12,488	46,084	1,373,699	0.91	0.37	1.81	2.56	3.35
1995	122	02JUL	31OCT	4	18,688	61,281	2,279,895	0.82	0.68	1.62	2.13	2.69
1996	96	28JUL	31OCT	18	20,258	118,308	1,944,744	1.04	0.39	1.88	4.24	6.09
1997	83	29JUL	19OCT	76	12,079	34,458	1,002,540	1.21	1.17	1.78	2.82	3.44
1998	123	01JUL	31OCT	8	4,543	17,099	558,833	0.81	0.41	1.58	2.46	3.06
1999	104	20JUL	31OCT	4	7,507	33,943	780,695	0.96	0.89	1.42	2.74	4.35
2000	110	14JUL	31OCT	4	16,806	92,164	1,848,653	0.91	0.23	1.31	3.79	4.99
2001	102	22JUL	31OCT	14	20,227	81,035	2,063,173	0.98	0.72	1.80	3.02	3.93
2002	65	07AUG	10OCT	58	6,917	19,777	449,614	1.54	1.02	2.85	4.09	4.42
2003	105	17JUL	29OCT	4	12,400	55,051	1,302,015	0.95	0.29	1.59	3.69	4.23
2004	119	05JUL	31OCT	16	7,876	31,048	937,281	0.84	0.38	1.74	2.57	3.31
2005	91	12JUL	12OCT	2	9,501	24,897	864,572	1.10	1.16	1.62	2.13	2.88
2006	90	07JUL	04OCT	4	15,788	42,584	1,420,921	1.11	1.14	1.63	2.84	3.00
2007	55	07AUG	30SEP	511	8,992	20,741	494,539	1.83	1.96	2.68	3.92	4.22
2008	76	18JUL	01OCT	2	14,529	44,626	1,104,182	1.32	0.99	2.30	3.51	4.04
2009	68	16JUL	21SEP	27	10,276	47,504	698,768	1.47	0.97	2.38	3.36	6.80
2010	76	12JUL	25SEP	2	9,813	25,126	745,760	1.32	1.23	2.22	3.08	3.37
2011	56	10AUG	04OCT	301	15,867	47,015	888,555	1.79	1.65	2.66	4.75	5.32
2012	71	23JUL	02OCT	46	19,213	68,546	1,364,134	1.41	0.62	2.67	4.40	5.02
2013	72	15JUL	25SEP	6	8,795	26,853	633,219	1.39	1.26	2.15	3.77	4.24
2014	81	13JUL	01OCT	17	27,374	87,133	2,217,308	1.23	1.24	1.64	2.79	3.93
1953-2014	5,478	05JUL	01OCT	0	11,978	118,308	65616802	1.19	0.87	2.04	3.39	6.87

Table 3. Annual migration statistics for Babine Sockeye daily migrants, 1946-2014 (filtered for non-zero observations and smoothed with 3-day average), including migration period and length, mean and maximum daily migrant count, total annual escapement, and mean, maximum, and 50th, 75th, 95th percentiles of daily migration rate (%). All-year summary statistics based on complete post-slide years only (1953-2014).

Ranked Year	R		Year	Ranked R
1956	0.76		2011	0.91
1957	0.59		1998	0.86
1958	0.71		1989	0.85
1959	0.70		2000	0.83
1960	0.62		1983	0.83
1961	0.75		1993	0.83
1962	0.70		2013	0.82
1963	0.65		1984	0.81
1965	0.58		1976	0.81
1966	0.57		1996	0.79
1967	0.68		1987	0.79
1968	0.54		2010	0.79
1969	0.25		2003	0.79
1970	0.71		2012	0.78
1971	0.76		1988	0.77
1972	0.75		2004	0.77
1973	0.69		1990	0.77
1974	0.36		1971	0.76
1975	0.59		1956	0.76
1976	0.81		1995	0.75
1977	0.71		1961	0.75
1978	0.38		1999	0.75
1979	0.64		1972	0.75
1980	0.57		1981	0.74
1981	0.74		2001	0.73
1982	0.72		2008	0.72
1983	0.83		1982	0.72
1984	0.81		1970	0.71
1985	0.67		1977	0.71
1986	0.60		1958	0.71
1987	0.79		2009	0.70

Ranked Year	R		Year	Ranked R
1988	0.77		1959	0.70
1989	0.85		1962	0.70
1990	0.77		1973	0.69
1991	0.66		1992	0.68
1992	0.68		2002	0.68
1993	0.83		1967	0.68
1994	0.66		1985	0.67
1995	0.75		1991	0.66
1996	0.79		1994	0.66
1997	0.12		2007	0.65
1998	0.86		1963	0.65
1999	0.75		1979	0.64
2000	0.83		1960	0.62
2001	0.73		1986	0.60
2002	0.68		1957	0.59
2003	0.79		1975	0.59
2004	0.77		1965	0.58
2005	0.57		1980	0.57
2006	0.49		2005	0.57
2007	0.65		1966	0.57
2008	0.72		1968	0.54
2009	0.70		2006	0.49
2010	0.79		2014	0.44
2011	0.91		1978	0.38
2012	0.78		1974	0.36
2013	0.82		1969	0.25
2014	0.44		1997	0.12
Total	**0.68**			**0.68**

Table 4. Spearman correlation coefficients for daily TYEE INDEX values and daily Babine Fence counts, ranked by year (1956-2014, left two columns), and ranked by descending correlation coefficient (right two columns), based on a 24-day lag of the TYEE INDEX.

	Discharge (cms)						Percentiles					
	Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year												
1972	92	52	115	212	49.0	0.4	54	56	70	109	160	203
1973	92	40	74	133	28.4	0.6	42	44	50	67	97	129
1974	92	45	90	153	32.8	0.4	46	52	62	80	120	145
1975	92	37	56	84	13.2	0.6	39	40	47	52	65	80
1976	92	67	132	229	45.8	0.4	70	75	94	128	165	217
1977	92	41	62	94	17.8	0.3	41	41	46	58	80	89
1978	92	28	49	82	15.8	0.6	29	32	37	43	60	78
1979	92	31	63	114	25.5	0.5	32	33	42	56	84	109
1980	92	28	39	58	8.9	0.6	28	29	31	36	47	55
1981	92	35	66	126	26.9	0.8	36	37	45	55	85	120
1982	92	37	74	126	27.2	0.3	40	42	51	68	103	118
1983	92	37	65	93	18.1	0.0	41	42	47	65	83	90
1984	92	33	60	101	21.0	0.6	35	38	43	53	76	99
1985	92	31	56	94	19.7	0.6	33	35	39	49	72	91
1986	92	30	59	120	24.3	0.8	32	33	38	51	76	107
1987	92	27	50	91	18.2	0.7	29	31	34	43	64	84
1988	92	34	73	131	28.6	0.5	37	40	47	66	97	125
1989	92	19	39	68	14.5	0.4	20	22	27	37	50	63
1990	92	30	69	131	29.6	0.5	33	35	43	64	93	123
1991	92	25	49	84	17.7	0.4	26	27	32	45	64	79

(Continued)

Table 5. Discharge statistics for observed data from the lower Babine River below Nilkitkwa Lake, July-September, 1972-2014.

	Discharge (cms)						Percentiles					
	Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year												
1992	92	27	56	117	26.8	0.7	28	28	32	47	76	109
1993	92	43	73	102	17.7	-0.1	46	48	58	74	88	99
1994	92	33	66	117	25.3	0.5	35	36	44	61	86	113
1995	92	20	38	63	13.1	0.4	20	21	27	35	48	60
1996	92	43	90	150	33.2	0.3	44	49	60	83	122	144
1997	92	49	101	191	43.0	0.5	50	52	64	90	135	180
1998	92	20	39	70	15.1	0.5	20	21	26	35	52	67
1999	92	48	89	144	29.0	0.5	50	57	66	80	112	142
2000	92	31	53	88	17.8	0.5	32	33	38	48	68	87
2001	92	37	65	107	21.6	0.5	39	40	46	58	82	104
2002	92	52	105	212	48.0	0.7	55	57	61	90	144	196
2003	92	34	59	97	20.0	0.5	37	38	41	55	77	93
2004	92	36	53	73	12.0	0.5	38	39	42	49	65	73
2005	92	33	59	90	18.1	0.2	34	36	43	58	73	88
2006	92	20	38	69	15.9	0.5	20	21	23	34	51	67
2007	92	67	119	191	35.0	0.4	70	75	90	111	151	183
2008	92	43	70	120	21.6	0.8	44	47	52	64	85	115
2009	92	33	67	123	27.8	0.6	36	39	43	56	91	117
2010	92	25	48	92	19.7	0.7	26	28	31	43	64	85
2011	92	61	125	206	45.5	0.1	63	66	85	123	170	199
2012	92	40	94	185	44.5	0.5	41	43	54	84	129	176
2013	92	31	60	107	22.2	0.6	32	35	41	54	77	100
2014	92	21	40	75	16.3	0.7	22	23	25	34	53	71
All	3956	19	69	229	36.0	1.4	28	33	42	59	85	143

Table 5. Discharge statistics for observed data from the lower Babine River below Nilkitkwa Lake, July-September, 1972-2014. (continued)

	Water Temperature						Percentiles			
	Dates	Min	Mean	Max	Std	Skew	P25	P50	P75	P95
Year										
2003	60	9.36	12.17	16.00	1.63	0.07	10.8	12.4	13.5	14.5
2004	92	8.55	15.60	20.66	3.53	-0.69	13.7	16.7	18.2	20.0
2005	76	10.05	14.23	17.10	1.69	-0.40	13.5	14.1	15.7	16.7
2006	83	10.80	14.20	16.80	1.37	-0.82	13.9	14.5	14.9	16.2
2007	47	11.40	13.29	14.80	0.83	-0.78	13.1	13.5	13.7	14.6
2008	63	11.25	14.18	17.65	1.76	0.51	13.1	13.8	15.9	17.2
2009	38	9.60	16.61	20.65	2.48	-1.19	15.7	17.3	18.2	20.3
2010	63	10.50	14.04	17.75	2.08	0.18	12.7	13.6	16.1	17.3
2011	0									
2012	61	9.00	13.50	17.50	2.37	-0.21	11.5	14.0	15.0	17.5
2013	53	12.00	15.68	18.00	1.54	-0.65	15.0	16.0	16.5	18.0
2014	61	11.50	15.83	19.00	1.49	-0.81	15.0	16.0	16.5	18.3
All	697	8.55	14.46	20.66	2.37	-0.05	13.0	14.5	16.2	18.3

Table 6. Statistical summary of observed daily water temperature data for Babine River at the fence during Sockeye migration (July-September) (Source: Lake Babine Nation). All statistics are derived from daily mean temperatures from *N* annual dates. For example, *Min* and *Max* are the minimum and maximum of the daily mean temperature estimates, not the observed extremes.

	Calibration		Validation	
	Warming	Cooling	Warming	Cooling
	Observations	Observations	Observations	Observations
Year				
2003			16	57
2004	135	62		
2005			32	55
2006			37	49
2007			5	42
2008	18	45		
2009	24	14		
2010			17	46
2011			0	0
2012			18	45
2013	13	40		
2014	31	30		

Table 7. Number of annual water temperature observations available for Babine River air/water temperature analyses, partitioned into warming and cooling seasons at August 16th for seasonal relationships. Air/water temperature model calibration data years were selected based on strength of association between air and water time-series and range of temperature observations.

Babine Air/Water Logistic (No-Intercept) Model - All Seasons 2003-2014 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	3	82322.9	27441.0	4804.71	<.0001
Error	409	2335.9	5.7113		
Uncorrected Total	412	84658.8			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness
alpha	18.0904	0.3725	17.3582	18.8226	0.3038
beta	7.9636	0.2069	7.5568	8.3704	0.1099
gamma	0.3071	0.0230	0.2617	0.3524	0.1547

Babine Air/Water Logistic (No-Intercept) Model - Warming Season 2003-2014 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	3	43645.5	14548.5	4709.11	<.0001
Error	218	673.5	3.0894		
Uncorrected Total	221	44319.0			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness
alpha	18.1596	0.3102	17.5482	18.7709	0.1966
beta	10.0692	0.1806	9.7132	10.4253	0.0384
gamma	0.3839	0.0228	0.3390	0.4288	0.1858

Babine Air/Water Logistic (No-Intercept) Model - Cooling Season 2003-2014 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	3	39807.2	13269.1	4683.40	<.0001
Error	188	532.6	2.8332		
Uncorrected Total	191	40339.8			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness	Label
alpha	25.0000	0	25.0000	25.0000	.	
beta	9.2651	0.2147	8.8416	9.6886	-0.1667	
gamma	0.1135	0.00609	0.1014	0.1255	0.0288	
Bound0	0.0112	0.7016	-1.3623	1.3848	.	alpha <= 25

Goodness of Fit for Season Data & Hysteresis Check against NSC for All Data

------------------------ Site=Babine Dataset=Calibration ------------------------------

Season Numerator	Season Denominator	NSC Season Data	NSC All Data	NSC Season - NSC All	Result
1206.14	8600.87	0.85977	0.73322	0.12654	Hysteresis detected

Table 8. Logistic regression output for air/water temperature relationship between the TOPLEY 7d-CMAT (air temperature index) and calibration data for lower Babine River daily mean water temperatures: seasons combined (top); warming season (middle); cooling season (bottom). The intercept (μ parameter) was constrained to 0°C or more to reasonably reflect likely water temperatures in the winter and assist in model convergence. Hysteresis was detected ($NSC_{seasonal} – NSC_{all}$ = 0.13).

Babine Air/Water Linear Model - Warming Season 2003-2014 - Calibration

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	5830.23760	5830.23760	1135.16	<.0001
Error	219	1124.79807	5.13606		
Corrected Total	220	6955.03566			

Root MSE	2.26629	R-Square	0.8383
Dependent Mean	13.00261	Adj R-Sq	0.8375
Coeff Var	17.42949		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	Intercept	1	-1.60790	0.45966	-3.50	0.0006	-2.51383	-0.70197
Topley_7DMAT	7d-MAT	1	1.06575	0.03163	33.69	<.0001	1.00341	1.12809

Babine Air/Water Linear Model - Cooling Season 2003-2014 - Calibration

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1109.38627	1109.38627	390.86	<.0001
Error	189	536.44909	2.83835		
Corrected Total	190	1645.83535			

Root MSE	1.68474	R-Square	0.6741
Dependent Mean	14.23328	Adj R-Sq	0.6723
Coeff Var	11.83664		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	Intercept	1	6.32965	0.41795	15.14	<.0001	5.50520	7.15410
Topley_7DMAT	7d-MAT	1	0.66773	0.03377	19.77	<.0001	0.60111	0.73435

TYPE III SS for SEASON significance - if P<.05, intercepts are different (hysteresis)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Topley_7DMAT	1	6674.134171	6674.134171	1416.76	<.0001
Season	1	870.621662	870.621662	184.81	<.0001

TYPE III SS for interaction term significance - if P<.05, slopes are different (hysteresis)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Topley_7DMAT	1	1814.000321	1814.000321	445.52	<.0001
Season	1	613.588888	613.588888	150.70	<.0001
Topley_7DMAT*Season	1	265.489692	265.489692	65.20	<.0001

Table 9. Linear regression output for air/water temperature relationship between the TOPLEY 7d-CMAT (air temperature index) and calibration data for Babine River daily mean water temperatures: warming season (top); cooling season (middle). Type III sum of squares for season effect (test for equal intercepts) and season interaction effect (test for equal slopes) were highly significant, indicating hysteresis.

------------- Site=Babine Dataset=Validation Season=Warming --------------

Pearson Correlation Coefficients, N = 125
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.18013	0.18837
Daily MWT	0.0444	0.0354

Spearman Correlation Coefficients, N = 125
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.27297	0.24804
Daily MWT	0.0021	0.0053

------------ Site=Babine Dataset=Validation Season=Cooling ------------

Pearson Correlation Coefficients, N = 294
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.81425	0.82047
Daily MWT	<.0001	<.0001

Spearman Correlation Coefficients, N = 294
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.82848	0.82996
Daily MWT	<.0001	<.0001

Table 10. Comparison of Pearson (least squares) and Spearman (rank) correlation coefficients for observed (WaterT) versus estimated (from logistic and linear models) daily mean water temperature for validation data years: warming season (top); cooling season (bottom).

		Air Temp						Est'd Water Temp				
		N	Min	P10	Med	P95	Max	Min	P10	Med	P95	Max
Decade	Year											
1940s	1946	92	2.1	7.7	11.4	14.2	18.5	7.0	7.8	13.2	14.9	15.8
	1947	92	3.4	6.4	11.4	15.2	17.9	8.0	9.0	12.9	14.9	15.6
	1948	92	1.2	6.6	12.1	16.5	18.2	7.3	9.3	13.1	16.8	17.8
	1949	92	2.9	8.0	11.6	16.3	18.8	7.6	9.6	12.8	16.5	16.9
	Total	368	1.2	6.9	11.5	15.7	18.8	7.0	9.0	13.0	15.8	17.8
1950s	Year											
	1950	92	2.6	7.5	12.3	16.3	20.6	6.1	11.3	13.8	16.7	17.8
	1951	92	-0.2	8.3	14.1	17.4	22.2	6.1	10.6	15.0	16.9	18.1
	1952	92	6.0	8.0	12.6	18.5	21.1	7.3	10.6	13.8	18.7	19.8
	1953	92	3.2	7.2	12.0	16.0	19.3	7.3	9.7	13.4	17.0	17.8
	1954	92	1.8	8.0	12.3	15.4	16.8	6.3	9.3	13.2	16.4	16.8
	1955	92	3.2	5.1	11.1	15.4	18.2	7.4	8.4	12.9	14.5	16.3
	1956	92	0.0	6.9	13.6	18.0	20.2	6.4	9.4	15.2	17.8	18.6
	1957	92	5.8	8.8	12.0	14.0	17.1	8.2	9.7	13.0	15.4	15.6
	1958	92	1.8	6.3	13.1	19.1	20.0	6.6	9.0	15.3	17.6	17.9
	1959	92	2.4	6.9	10.9	16.0	17.7	8.4	9.7	12.6	15.0	16.7
	Total	920	-0.2	7.4	12.3	17.1	22.2	6.1	9.6	13.7	17.0	19.8
1960s	Year											
	1960	92	4.3	5.8	10.9	17.4	21.6	8.7	9.1	12.3	17.5	19.2
	1961	92	0.3	6.3	13.8	17.9	20.5	7.3	9.7	15.8	17.6	18.7
	1962	92	4.7	7.2	11.9	18.1	19.8	7.0	9.5	13.4	17.5	19.2
	1963	92	5.8	8.6	13.7	17.1	18.5	9.7	10.7	15.4	17.5	18.1

(Continued)

Table 11. Statistics for regional mean air temperature (TOPLEY LANDING) and estimated water temperature in Babine River for the months of July-September, 1946-2012.

		Air Temp						Est'd Water Temp				
		N	Min	P10	Med	P95	Max	Min	P10	Med	P95	Max
Decade	Year											
1960s	1964	92	3.7	7.4	11.2	13.6	17.4	8.5	9.8	12.2	14.9	15.7
	1965	92	0.1	7.7	13.3	18.8	20.8	7.7	10.2	14.5	18.5	20.0
	1966	92	5.6	7.5	12.0	16.7	19.7	9.7	10.8	14.1	16.5	17.2
	1967	92	5.0	8.1	12.4	17.0	19.5	9.3	11.0	13.8	16.9	18.6
	1968	92	3.6	6.7	12.2	16.7	19.7	7.5	9.1	13.9	16.4	17.6
	1969	92	5.0	6.7	11.4	15.6	17.5	8.4	10.2	12.9	15.6	16.4
	Total	920	0.1	7.0	12.0	17.1	21.6	7.0	10.0	13.5	17.2	20.0
1970s	Year											
	1970	92	1.4	7.5	12.0	15.3	20.3	8.4	9.8	13.3	15.5	18.0
	1971	92	1.4	7.0	12.0	20.3	24.4	7.1	9.3	13.7	18.3	20.6
	1972	92	-0.3	3.3	12.8	17.2	19.8	4.8	7.5	14.6	16.9	18.4
	1973	92	3.6	7.5	11.4	16.4	19.4	8.2	10.0	12.6	17.1	17.7
	1974	92	3.1	8.7	12.8	17.5	21.1	7.8	10.6	14.1	17.9	18.9
	1975	92	5.9	8.9	11.7	18.1	21.7	11.3	11.7	13.3	17.5	18.0
	1976	92	6.7	9.2	11.7	15.9	19.2	10.0	11.0	12.5	16.9	18.4
	1977	92	4.8	8.1	12.3	19.2	21.7	7.6	10.6	12.9	19.2	19.7
	1978	92	4.3	8.0	13.0	18.0	20.8	8.8	10.0	15.1	17.6	19.0
	1979	92	6.0	9.5	13.9	18.0	20.8	9.8	11.8	15.5	17.9	18.9
	Total	920	-0.3	7.8	12.2	17.8	24.4	4.8	10.4	13.6	17.7	20.6
1980s	Year											
	1980	92	5.5	7.8	11.0	15.8	19.0	9.8	10.5	12.6	15.1	17.4
	1981	92	4.3	7.3	14.3	18.5	23.3	7.9	9.4	15.4	18.6	20.6

(Continued)

Table 11. Statistics for regional mean air temperature (TOPLEY LANDING) and estimated water temperature in Babine River for the months of July-September, 1946-2012.

		Air Temp						Est'd Water Temp				
		N	Min	P10	Med	P95	Max	Min	P10	Med	P95	Max
Decade	Year											
1980s	1982	92	6.8	9.5	13.3	18.0	21.8	10.0	12.2	14.7	17.1	19.9
	1983	92	2.3	6.0	12.1	15.3	17.8	7.2	9.5	13.7	15.9	16.9
	1984	92	2.5	6.5	11.3	17.5	20.0	7.1	8.9	12.5	17.3	19.0
	1985	92	4.5	7.0	12.4	16.5	19.5	8.6	10.1	14.4	16.6	18.6
	1986	92	4.0	6.8	12.8	17.3	19.5	7.9	9.9	14.2	17.1	18.4
	1987	92	5.3	8.5	13.8	17.3	21.3	9.4	11.8	15.0	17.1	17.9
	1988	92	3.3	6.5	12.3	16.5	21.0	7.8	9.0	14.2	17.1	17.8
	1989	92	6.0	11.0	14.4	17.5	19.5	11.6	12.8	15.9	18.0	18.6
	Total	920	2.3	7.3	12.8	17.3	23.3	7.1	10.1	14.3	17.2	20.6
1990s	Year											
	1990	92	6.5	9.8	13.5	19.3	23.0	8.5	13.0	14.9	18.3	20.0
	1991	92	4.5	8.8	12.8	17.3	22.0	9.8	12.1	13.7	17.4	20.3
	1992	92	2.5	6.3	12.9	17.8	20.8	7.4	9.9	15.0	17.5	19.3
	1993	92	5.3	8.8	13.0	17.3	20.3	10.1	11.3	14.9	17.3	18.8
	1994	92	3.3	9.5	14.4	18.8	22.8	8.1	12.4	15.4	18.4	18.7
	1995	92	7.0	9.5	12.8	16.3	19.3	10.9	12.5	14.5	16.8	17.5
	1996	92	2.5	7.3	11.9	16.5	19.5	8.2	9.4	13.4	16.2	17.8
	1997	92	5.5	9.0	13.5	17.3	20.5	8.8	11.5	14.8	17.9	19.0
	1998	92	5.8	8.5	13.3	18.8	22.5	10.5	11.4	15.1	17.9	19.9
	1999	92	3.3	7.8	12.7	16.5	22.5	7.1	11.4	13.6	16.7	19.6
	Total	920	2.5	8.3	13.0	17.8	23.0	7.1	11.2	14.5	17.7	20.3

(Continued)

Table 11. Statistics for regional mean air temperature (TOPLEY LANDING) and estimated water temperature in Babine River for the months of July-September, 1946-2012.

		Air Temp						Est'd Water Temp				
		N	Min	P10	Med	P95	Max	Min	P10	Med	P95	Max
Decade	Year											
2000s	2000	92	4.0	8.0	12.5	16.8	21.3	8.6	11.2	14.1	16.9	18.8
	2001	92	5.5	8.0	12.5	17.8	21.8	8.6	10.9	14.0	17.5	19.5
	2002	92	5.0	7.5	12.0	16.8	20.0	8.4	10.2	13.7	16.5	17.8
	2003	92	4.3	8.5	13.2	17.3	19.8	8.5	10.1	14.5	17.3	18.4
	2004	92	2.8	7.5	14.0	19.5	21.0	8.7	9.7	15.3	18.2	20.3
	2005	92	5.5	8.5	12.7	15.5	19.5	8.6	10.4	13.8	16.7	18.8
	2006	92	5.3	9.0	13.3	18.3	22.8	9.7	11.4	15.1	17.4	18.0
	2007	92	2.0	8.5	12.3	17.8	22.8	7.6	10.9	14.6	17.1	18.1
	2008	92	3.1	7.7	12.0	17.5	20.2	7.7	10.4	12.8	17.6	18.5
	2009	92	3.5	8.8	14.4	19.1	25.5	7.3	12.6	15.6	18.4	21.4
	2010	92	5.8	8.0	11.9	18.8	21.0	7.9	10.5	13.7	18.7	19.2
	2011	92	2.8	7.8	12.0	15.5	19.5	7.8	9.4	14.0	16.1	17.3
	2012	92	6.2	9.4	13.3	18.5	21.0	10.2	11.9	15.6	17.6	18.4
	Total	1196	2.0	8.0	12.8	18.0	25.5	7.3	10.6	14.3	17.5	21.4
Total		6164	-0.3	7.7	12.5	17.5	25.5	4.8	10.2	14.0	17.3	21.4

Table 11. Statistics for regional mean air temperature (TOPLEY LANDING) and estimated water temperature in Babine River for the months of July-September, 1946-2012.

Decadal Mean Monthly AirT Peaks > 20c

Site: Topley Standard

	Years in Decade	Mean No. Days			Mean Annual Total
		Jul	Aug	Sep	
Decade					
1900s	2				
1910s	10	2.1			2.1
1920s	10				
1930s	10		0.1		0.1
1940s	10	0.7	0.1		0.8
1950s	10	0.5	0.3		0.8
1960s	10	0.4	0.4		0.8
1970s	10	1.8	0.9		2.7
1980s	10	0.8	0.5	0.1	1.4
1990s	10	1.2	1.6		2.8
2000s	15	1.7	1.1		2.8

Annual Frequency & Mean Duration (days) for POT20c Events

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1900s	0				
1910s	9	1	2.3	5	1.5
1920s	0				
1930s	0				
1940s	4	1	2.0	5	2.0
1950s	4	1	2.0	3	1.2
1960s	5	1	1.6	3	0.9
1970s	12	1	2.2	6	1.5
1980s	7	1	2.3	5	1.9
1990s	15	1	2.0	4	1.1
2000s	19	1	2.6	8	2.1
Total	75	1	2.2	8	1.6

Table 12. Frequency analysis of decadal mean number of dates per month (July-September) in which regional daily mean air temperature at TOPLEY weather station exceeded 20°C (top); min., mean and max. length (days) and total frequency of periods in which regional daily mean air temperature continuously exceeded 20°C (July-September), by decade (bottom).

Decadal Mean Monthly MWT Peaks > 18c

Site: Babine River

	Years in Decade	Mean No. Days			Mean Annual Total
		Jul	Aug	Sep	
Decade					
1900s	2				
1910s	10		2.0		2.0
1920s	10		0.3		0.3
1930s	10		0.9		0.9
1940s	10		2.2		2.2
1950s	10		1.5		1.5
1960s	10		2.4		2.4
1970s	10		3.7		3.7
1980s	10		2.0		2.0
1990s	10		4.4		4.4
2000s	15	0.3	4.0		4.3

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1900s	0				
1910s	3	2	6.3	10	4.0
1920s	2	1	1.0	1	0.0
1930s	3	1	2.3	4	1.5
1940s	7	1	3.1	4	1.1
1950s	2	7	7.5	8	0.7
1960s	5	3	4.2	5	1.1
1970s	7	1	5.3	14	4.6
1980s	3	4	6.3	11	4.0
1990s	6	2	7.2	11	4.2
2000s	13	1	4.8	10	3.1
Total	51	1	4.9	14	3.3

Table 13. Frequency analysis of decadal mean number of dates per month (July-September) in which estimated mean water temperature in the Babine River exceeded 18°C (top); min., mean and max. length (days) and total frequency of periods in which estimated mean water temperature continuously exceeded 18°C (July-September), by decade (bottom).

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1940s	1940	0				
	1941	3	1	2.3	3	1.2
	1942	2	3	3.5	4	0.7
	1943	0				
	1944	0				
	1945	1	4	4.0	4	
	1946	0				
	1947	0				
	1948	1	4	4.0	4	
	1949	0				
	Total	7	1	3.1	4	1.1
1950s	Year					
	1950	0				
	1951	0				
	1952	1	8	8.0	8	
	1953	0				
	1954	0				
	1955	0				
	1956	1	7	7.0	7	
	1957	0				

(Continued)

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1950s	1958	0				
	1959	0				
	Total	2	7	7.5	8	0.7
1960s	Year					
	1960	1	5	5.0	5	
	1961	1	5	5.0	5	
	1962	0				
	1963	1	5	5.0	5	
	1964	0				
	1965	1	3	3.0	3	
	1966	0				
	1967	1	3	3.0	3	
	1968	0				
	1969	0				
	Total	5	3	4.2	5	1.1
1970s	Year					
	1970	0				
	1971	1	6	6.0	6	
	1972	1	1	1.0	1	
	1973	1	1	1.0	1	

(Continued)

Table 14. Min., mean and max. length (days) and number of periods in which estimated mean Babine River water temperature continuously exceeded 18°C (July-September), by year (1946-2014).

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1970s	1974	1	4	4.0	4	
	1975	0				
	1976	1	3	3.0	3	
	1977	1	14	14.0	14	
	1978	0				
	1979	1	8	8.0	8	
	Total	7	1	5.3	14	4.6
1980s	Year					
	1980	0				
	1981	1	11	11.0	11	
	1982	0				
	1983	0				
	1984	0				
	1985	0				
	1986	1	4	4.0	4	
	1987	0				
	1988	0				
	1989	1	4	4.0	4	
	Total	3	4	6.3	11	4.0
1990s	1990	1	11	11.0	11	
	1991	1	8	8.0	8	
	1992	1	2	2.0	2	
	1993	0				
	1994	1	9	9.0	9	
	1995	0				
	1996	0				
	1997	1	11	11.0	11	
	1998	0				
	1999	1	2	2.0	2	
	Total	6	2	7.2	11	4.2
2000s	Year					
	2000	1	2	2.0	2	
	2001	1	8	8.0	8	
	2002	0				
	2003	1	1	1.0	1	
	2004	1	10	10.0	10	
	2005	1	6	6.0	6	
	2006	0				
	2007	0				
	2008	2	3	3.5	4	0.7
	2009	1	4	4.0	4	
	2010	1	6	6.0	6	
	2011	0				
	2012	2	1	1.5	2	0.7
	2013	1	9	9.0	9	
	2014	1	7	7.0	7	
	Total	13	1	4.8	10	3.1
Total		51	1	4.9	14	3.3

(Continued)

Table 14. Min., mean and max. length (days) and number of periods in which estimated mean Babine River water temperature continuously exceeded 18°C (July-September), by year (1946-2014).

Decadal Mean Monthly Flow < 30 cms

Site: Babine River

	Years in Decade	Mean No. Days			Mean Annual Total
		Jul	Aug	Sep	
Decade					
1940s	10			3.7	3.7
1950s	10			1.9	1.9
1960s	10			2.2	2.2
1970s	10			0.6	0.6
1980s	10			5.6	5.6
1990s	10		0.3	8.9	9.2
2000s	15		1.0	5.3	6.3

Decadal Mean Monthly Flow > 120 cms

Site: Babine River

	Years in Decade	Mean No. Days			Mean Annual Total
		Jul	Aug	Sep	
Decade					
1940s	10	1.4			1.4
1950s	10	12.7	2.4		15.1
1960s	10	12.6	3.5		16.1
1970s	10	9.4	2.5		11.9
1980s	10	1.5			1.5
1990s	10	8.3			8.3
2000s	15	8.2	1.5		9.7

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1940s	3	6	12.3	23	9.3
1950s	2	7	9.5	12	3.5
1960s	2	2	11.0	20	12.7
1970s	1	6	6.0	6	
1980s	4	6	14.0	29	10.6
1990s	6	1	15.5	32	13.2
2000s	3	20	31.7	39	10.2
Total	21	1	15.6	39	11.8

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1940s	2	4	7.0	10	4.2
1950s	7	2	21.6	38	12.9
1960s	6	10	26.8	60	18.7
1970s	4	10	30.3	49	17.2
1980s	4	1	4.5	8	2.9
1990s	4	7	21.3	31	10.3
2000s	6	2	25.0	47	18.5
Total	33	1	21.2	60	15.7

Table 15. Decadal mean number of dates per month (July-September) in which observed or estimated discharge at BABINE RIVER AT NILKITKWA was less than 30 cms (10th percentile; left); or greater than 120 cms (90th percentile; right). Min., mean and max. duration (days) of POT periods, by year.

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1940s	1945	2	6	14.5	23	12.0
	1949	1	8	8.0	8	
	Total	3	6	12.3	23	9.3
1950s	Year					
	1950	1	7	7.0	7	
	1951	1	12	12.0	12	
	Total	2	7	9.5	12	3.5
1960s	Year					
	1961	2	2	11.0	20	12.7
	Total	2	2	11.0	20	12.7
1970s	Year					
	1978	1	6	6.0	6	
	Total	1	6	6.0	6	
1980s	Year					
	1980	2	7	10.5	14	4.9
	1987	1	6	6.0	6	
	1989	1	29	29.0	29	
	Total	4	6	14.0	29	10.6

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1990s	1991	1	13	13.0	13	
	1992	2	4	8.0	12	5.7
	1995	1	31	31.0	31	
	1998	2	1	16.5	32	21.9
	Total	6	1	15.5	32	13.2
2000s	Year					
	2006	1	39	39.0	39	
	2010	1	20	20.0	20	
	2014	1	36	36.0	36	
	Total	3	20	31.7	39	10.2
Total		21	1	15.6	39	11.8

Table 16. Min., mean and max. length (days) and number of periods in which observed or estimated discharge at BABINE RIVER AT NILKITKWA was less than 30 cms (10th percentile) July-September, by year (1945-2014).

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1940s	1946	1	4	4.0	4	
	1948	1	10	10.0	10	
	Total	2	4	7.0	10	4.2
1950s	Year					
	1952	1	29	29.0	29	
	1953	2	2	9.0	16	9.9
	1954	2	13	25.5	38	17.7
	1958	1	18	18.0	18	
	1959	1	35	35.0	35	
	Total	7	2	21.6	38	12.9
1960s	Year					
	1960	1	20	20.0	20	
	1964	1	60	60.0	60	
	1965	1	20	20.0	20	
	1966	1	10	10.0	10	
	1967	1	14	14.0	14	
	1968	1	37	37.0	37	
	Total	6	10	26.8	60	18.7
Decade	Year					
1970s	1972	1	39	39.0	39	
	1973	1	10	10.0	10	
	1974	1	23	23.0	23	
	1976	1	49	49.0	49	
	Total	4	10	30.3	49	17.2
1980s	Year					
	1981	1	5	5.0	5	
	1982	1	4	4.0	4	
	1986	1	1	1.0	1	
	1988	1	8	8.0	8	
	Total	4	1	4.5	8	2.9
1990s	Year					
	1990	1	7	7.0	7	
	1996	1	26	26.0	26	
	1997	1	31	31.0	31	
	1999	1	21	21.0	21	
	Total	4	7	21.3	31	10.3
2000s	Year					
	2002	1	33	33.0	33	
Decade	Year					
2000s	2007	1	37	37.0	37	
	2008	1	2	2.0	2	
	2009	1	3	3.0	3	
	2011	1	47	47.0	47	
	2012	1	28	28.0	28	
	Total	6	2	25.0	47	18.5
Total		33	1	21.2	60	15.7

Table 17. Min., mean and max. length (days) and number of periods in which observed or estimated discharge at BABINE RIVER AT NILKITKWA exceeded 120 cms (90th percentile) July-September, by year (1945-2014).

Brood Year	Project	River / Channel #	Total Large Sockeye Counted	Pre-Spawn Mortality %	Babine River Conditions
1986	Fulton	River	91,100	11.1%	
1990	Fulton	River	322,904	16.3%	High temps?
1993	Fulton	River	264,173	13.5%	
1994[53]	Fulton	Project		Up to 90%	High temps?
	Pinkut	Project		Up to 90%	
1995[53]	Fulton	Project		30-79%	Low flows?
	Pinkut	Project		29-90%	
1997	Fulton	Channel 2		27.0%	High flows?
	Fulton	River	275,017	24.0%	
	Pinkut	Channel		13.0%	
1998	Fulton	River	94,700	19.0%	Low flows?
2000	Fulton	Channel 1		26.0%	Low flows?
	Fulton	Channel 2		31.0%	
	Fulton	River	530,172	38.0%	
2001	Fulton	Channel 1		55.0%	High temps?
	Fulton	Channel 2		16.0%	
	Fulton	River	301,281	34.0%	
2006	Pinkut	Creek	54,400	38.0%	Low flows?
2007	Fulton	River	400,970	12.0%	High flows?
	Pinkut	Creek	79,000	14.5%	
2009	Fulton	Channel 1		43.2%	High temps?
	Fulton	Channel 2		31.5%	
	Fulton	River	188,326	16.0%	
	Pinkut	Creek	27,000	17.0%	
2013[54]	Fulton	Channel 2		40.1%	High temps?
	Fulton	River		13.5%	
	Pinkut	Channel		22.0%	
	Pinkut	Creek		17.0%	

Table 18. Years of significant pre-spawning mortality (>10%) in spawning channels and adjacent river or creek, 1964 - 2013 (source: unpub. data, Doug Lofthouse, OHEB).

[53] Pinkut and Fulton pre-spawn mortality rates in 1994 and 1995 (Traxler, Richard and McDonald 1998).
[54] Pinkut and Fulton pre-spawn mortality rates in 2013 (unpub. data: Dennis Graf, Watershed Enhancement Manager, Fulton River Project, 2014).

FIGURES

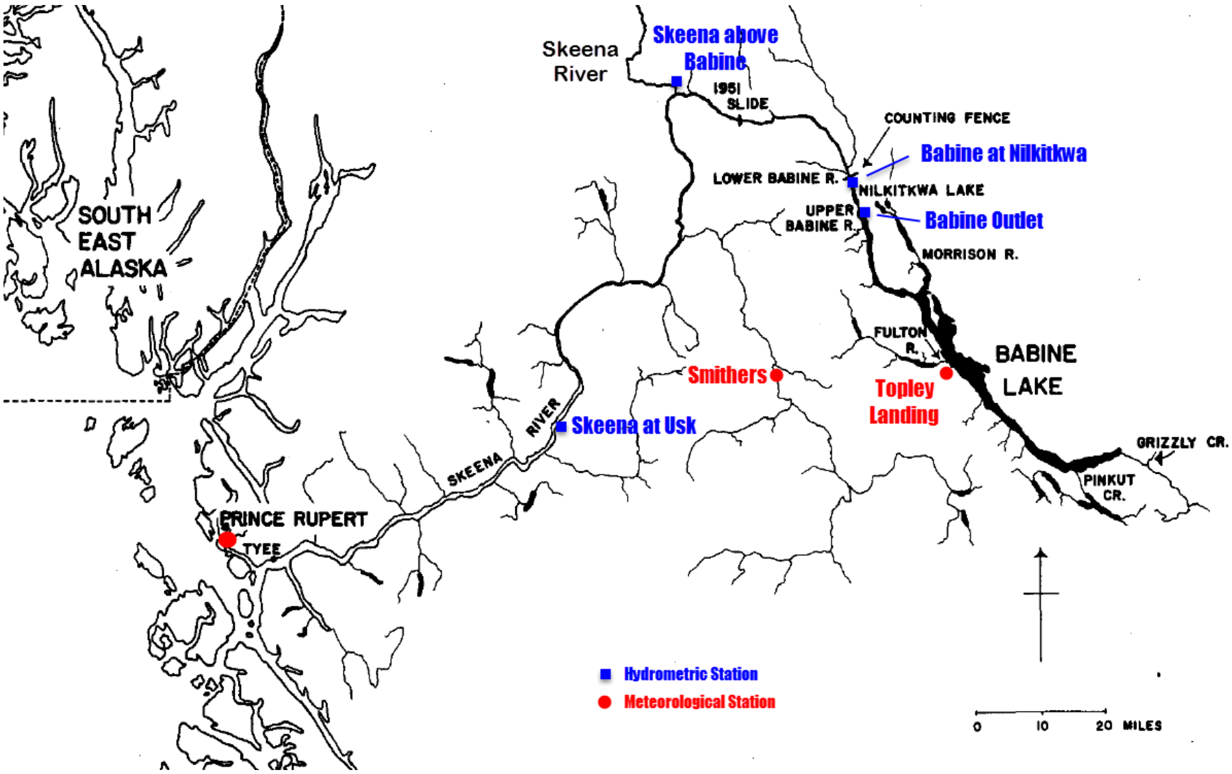
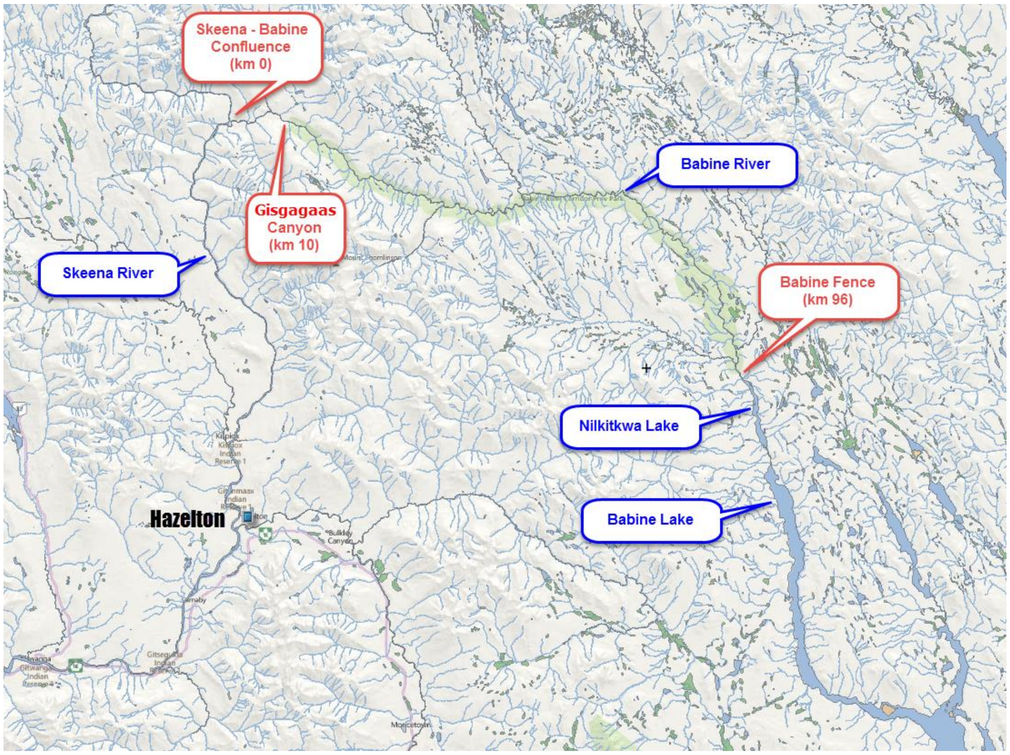


Figure 1. Babine watershed, tributary to the Skeena River, with site of Babine Fence, Environment Canada meteorological stations (Topley Landing and Smithers), and hydrological stations (Babine at Nilkitkwa and Babine at Babine Lake).



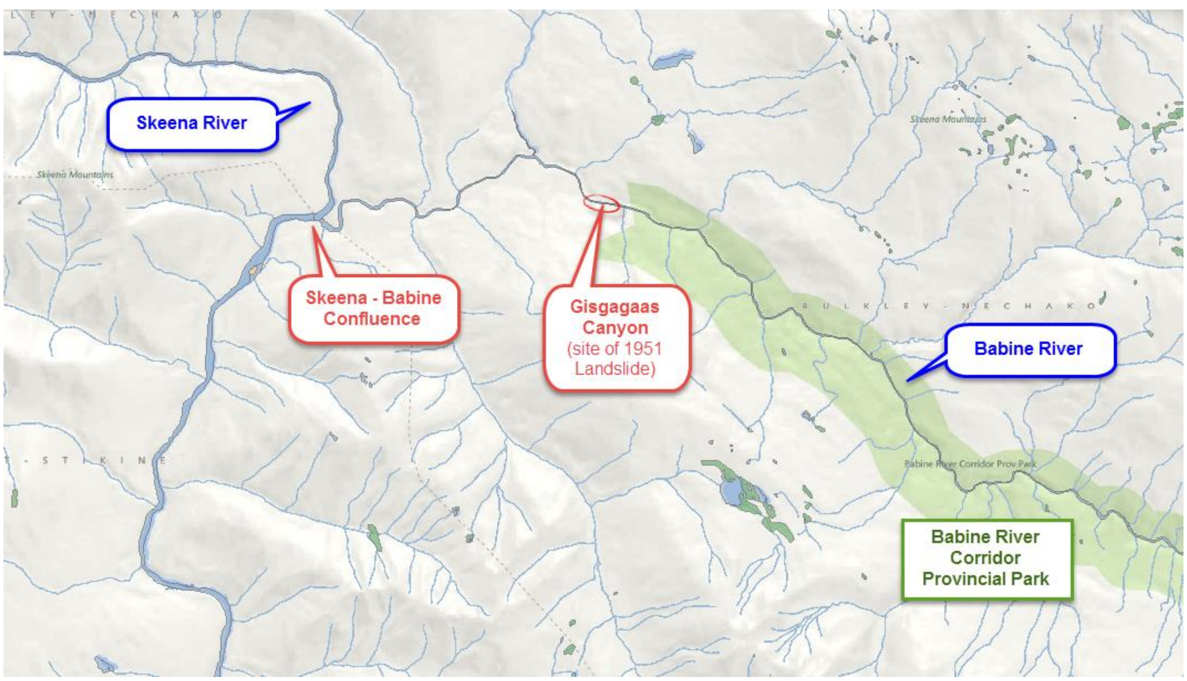


Figure 2. Lower reaches of the Babine River, near the confluence with the Skeena River. Gisgagaas (Kisgegas) Canyon is 84 km downstream of the Babine Slide area, approximately 6 days swim time to the Babine Fence depending on discharge levels, run timing, and fish condition (Godfrey et al. 1954).

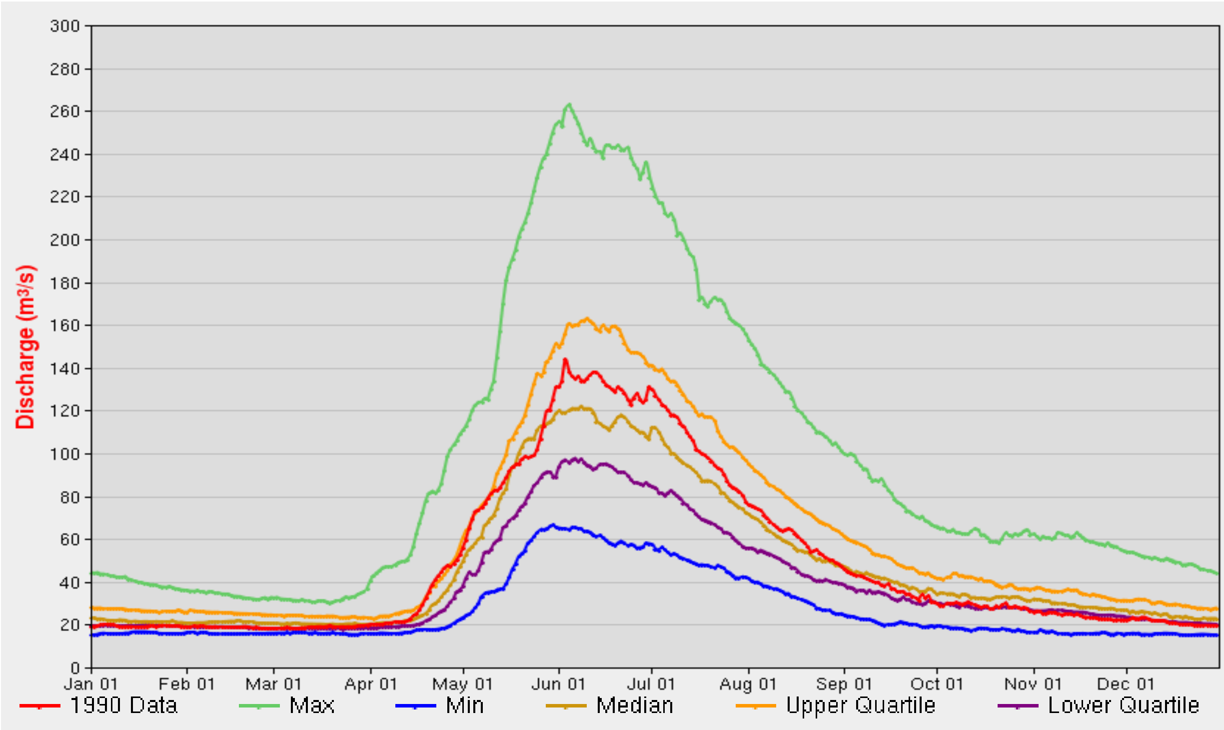


Figure 3. Lower BABINE RIVER BELOW NILKITKWA (WSC Station 08EC013) – daily discharge statistics, 1972-2014.

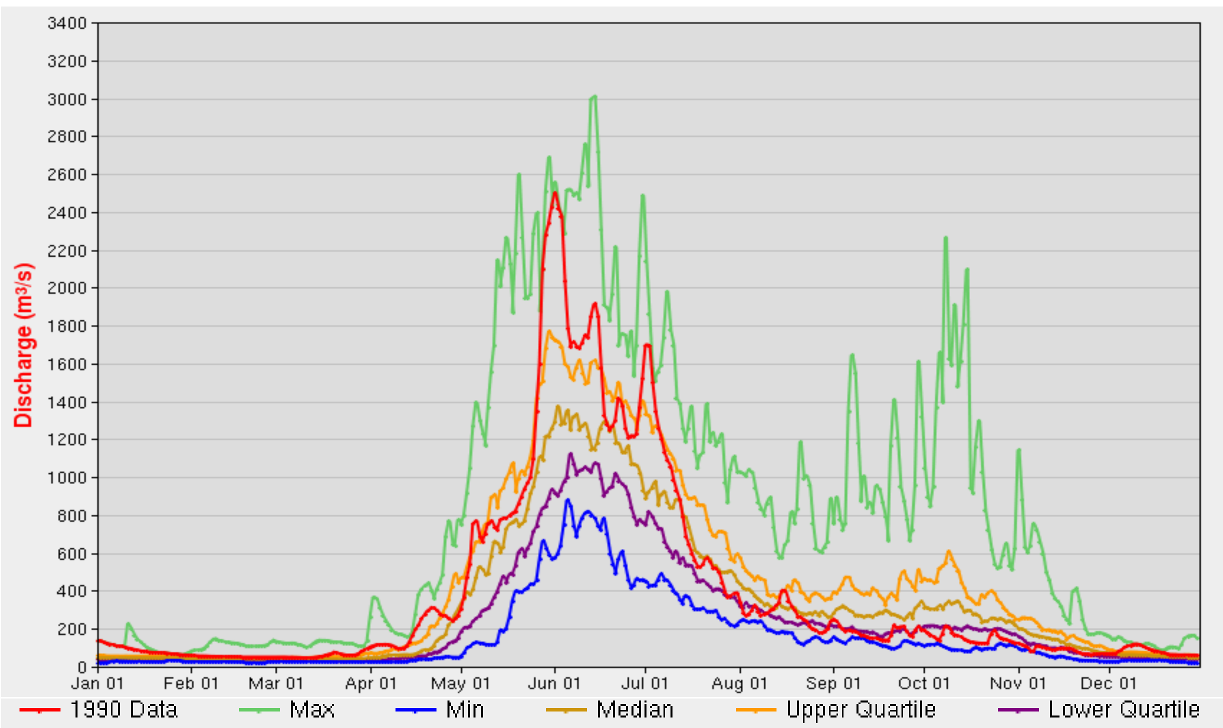


Figure 4. SKEENA RIVER ABOVE BABINE (WSC Station 08EB005) – daily discharge statistics, 1970-1996, 2009-2011.

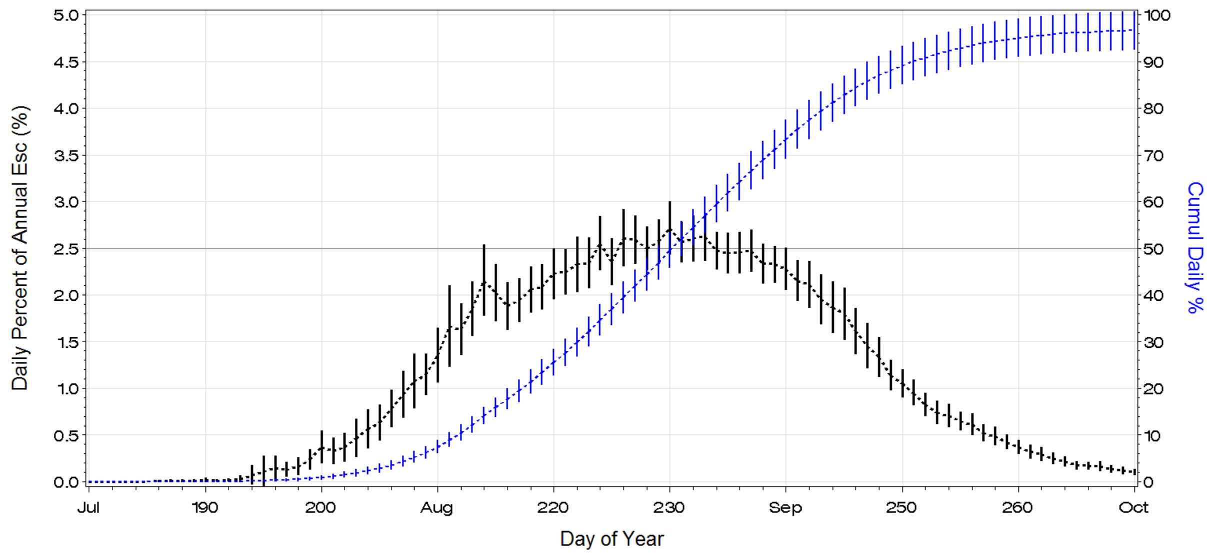


Figure 5. Historical mean daily migration timing (1953-2013). Mean and variance (95% CI) of daily Babine Sockeye migrants (top) and mean daily % and cumulative % of total annual escapement (bottom). Time-to-50% ~ day 230 ~ August 18th (Source: DFO North Coast, unpub. data).

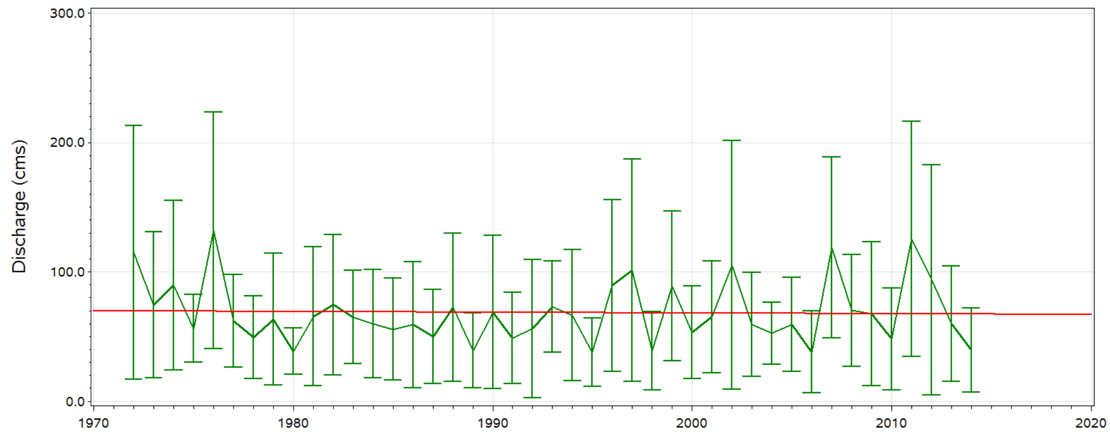


Figure 6. Lower BABINE RIVER BELOW NILKITKWA - mean discharge ± 2 standard deviations, July-September 1972-2014.

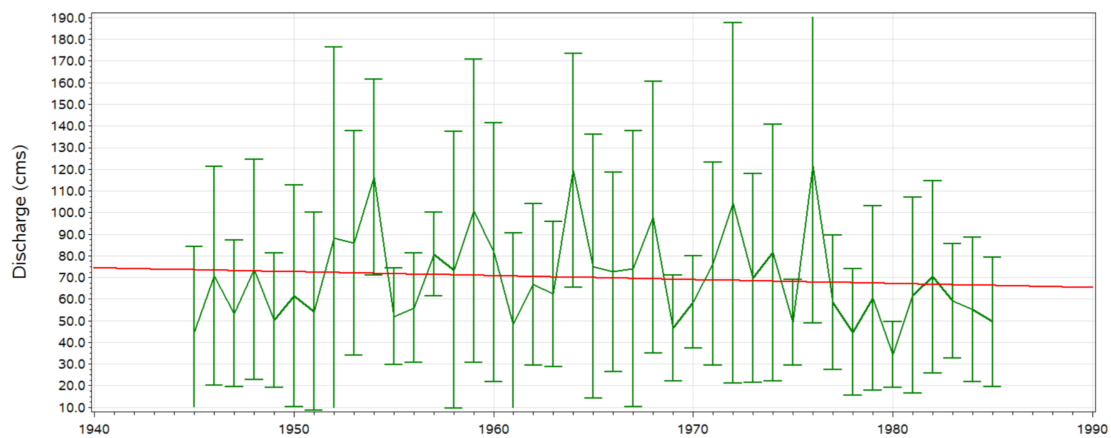


Figure 7. Upper BABINE RIVER BELOW BABINE LAKE - mean discharge ± 2 standard deviations, July-September 1945-1985.

Figure 8. Upper BABINE RIVER BELOW BABINE LAKE - water level ± 2 standard deviations, July-September 1986-2013.

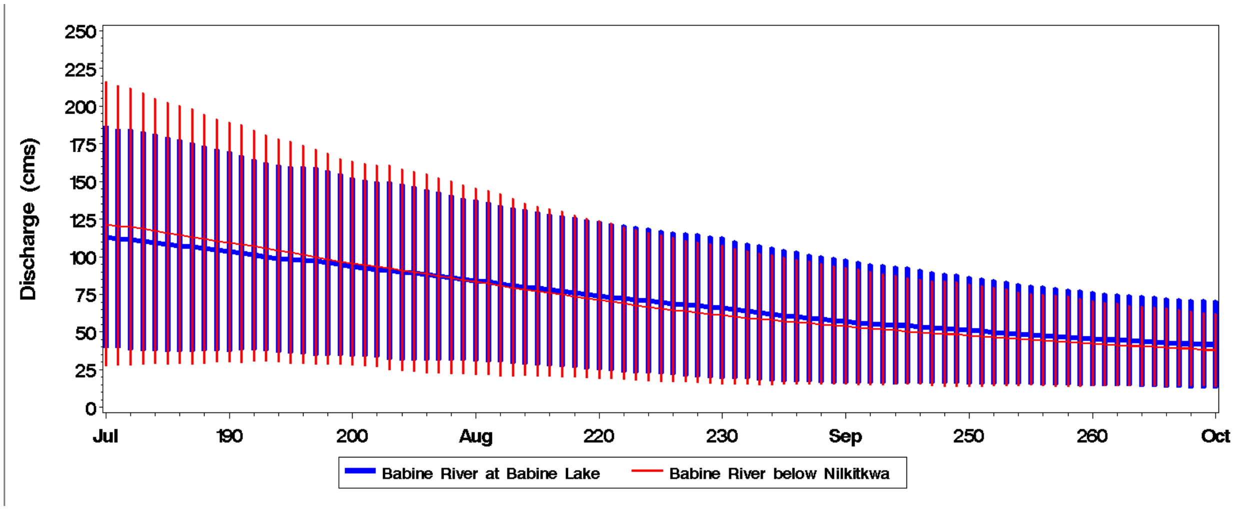
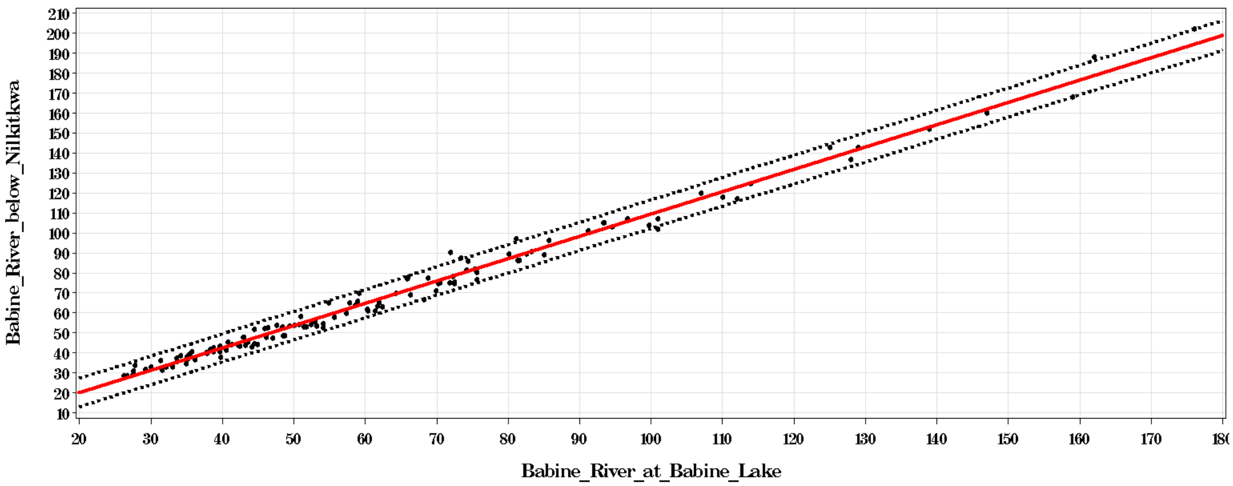


Figure 9. Observed daily mean discharge (cms) ± two standard deviations during the Sockeye migration period for upper BABINE RIVER AT BABINE LAKE (08EC001; 1945-2013; blue) and lower BABINE RIVER AT NILKITKWA (08EC013; 1972-2013; red).



Analysis of Variance

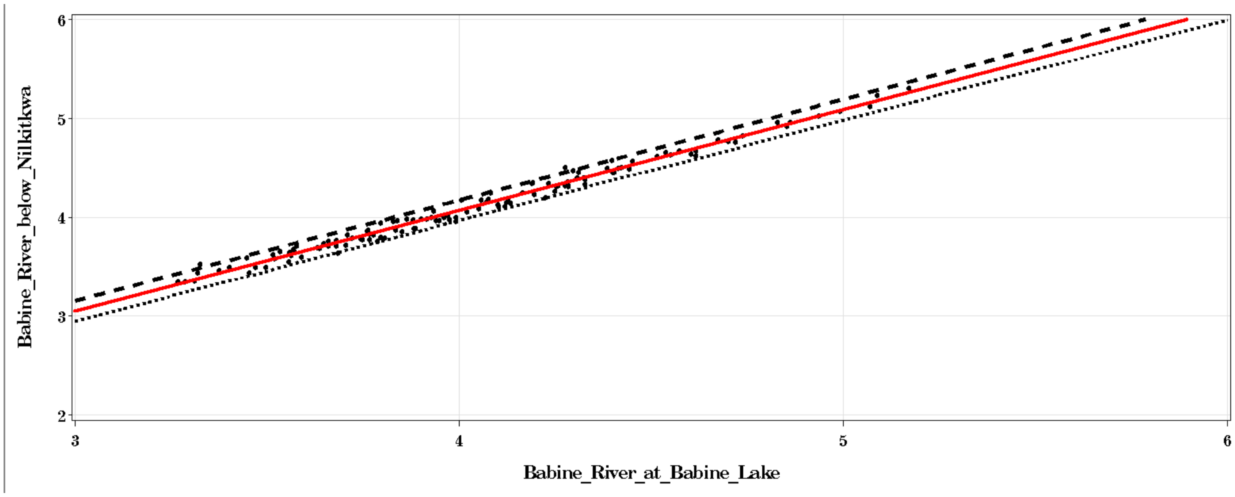
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	143987	143987	11302.7	<.0001
Error	124	1579.66076	12.73920		
Lack of Fit	113	1522.51076	13.47355	2.59	0.0407
Pure Error	11	57.15000	5.19545		
Corrected Total	125	145567			

Root MSE	3.56920	R-Square	0.9891
Dependent Mean	67.63095	Adj R-Sq	0.9891
Coeff Var	5.27747		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-2.29351	0.73054	-3.14	0.0021
Babine_River_at_Babine_Lake	1	1.11675	0.01050	106.31	<.0001

Figure 10. Mean daily discharge (cms) in the lower BABINE RIVER AT NILKITKWA (Babine fence area) as a linear function of mean daily discharge in the BABINE RIVER AT BABINE LAKE during the adult Sockeye migration period (July-September, 1972-1985).



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	24.43212	24.43212	8962.69	<.0001
Error	124	0.33802	0.00273		
Lack of Fit	113	0.31883	0.00282	1.62	0.1900
Pure Error	11	0.01919	0.00174		
Corrected Total	125	24.77014			

Root MSE	0.05221	R-Square	0.9864
Dependent Mean	4.10930	Adj R-Sq	0.9862
Coeff Var	1.27056		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-0.00610	0.04372	-0.14	0.8892
Babine_River_at_Babine_Lake	1	1.01909	0.01076	94.67	<.0001

Figure 11. Mean daily discharge (cms) in the lower BABINE RIVER AT NILKITKWA (Babine fence area) as a log-linear function of mean daily discharge in the BABINE RIVER AT BABINE LAKE during the adult Sockeye migration period (July-September, 1972-1985).

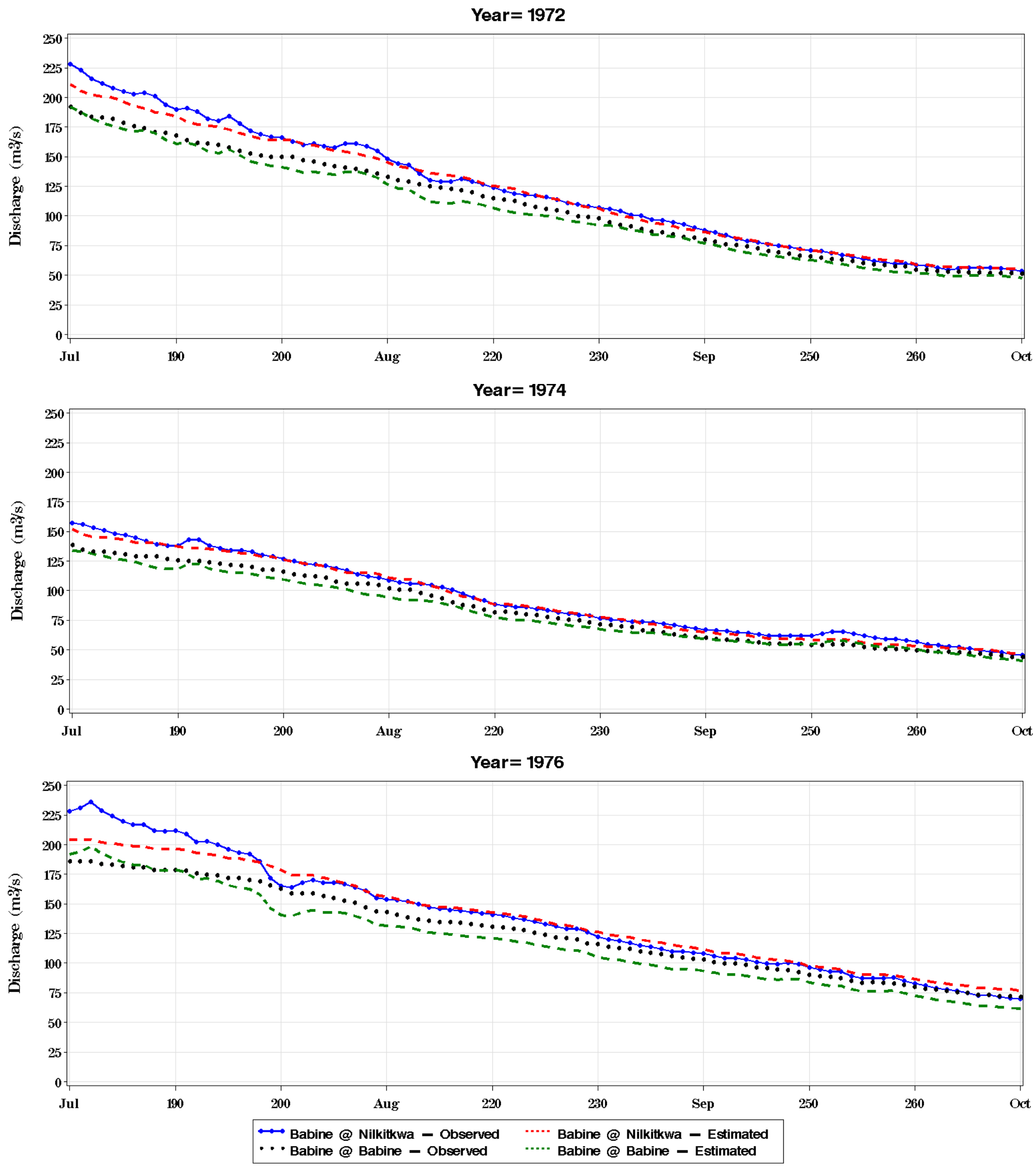


Figure 12. Sample plots of observed and estimated daily mean discharge at Babine hydrometric stations based on log-linear ($Y=aX^b$) relations for overlapping years.

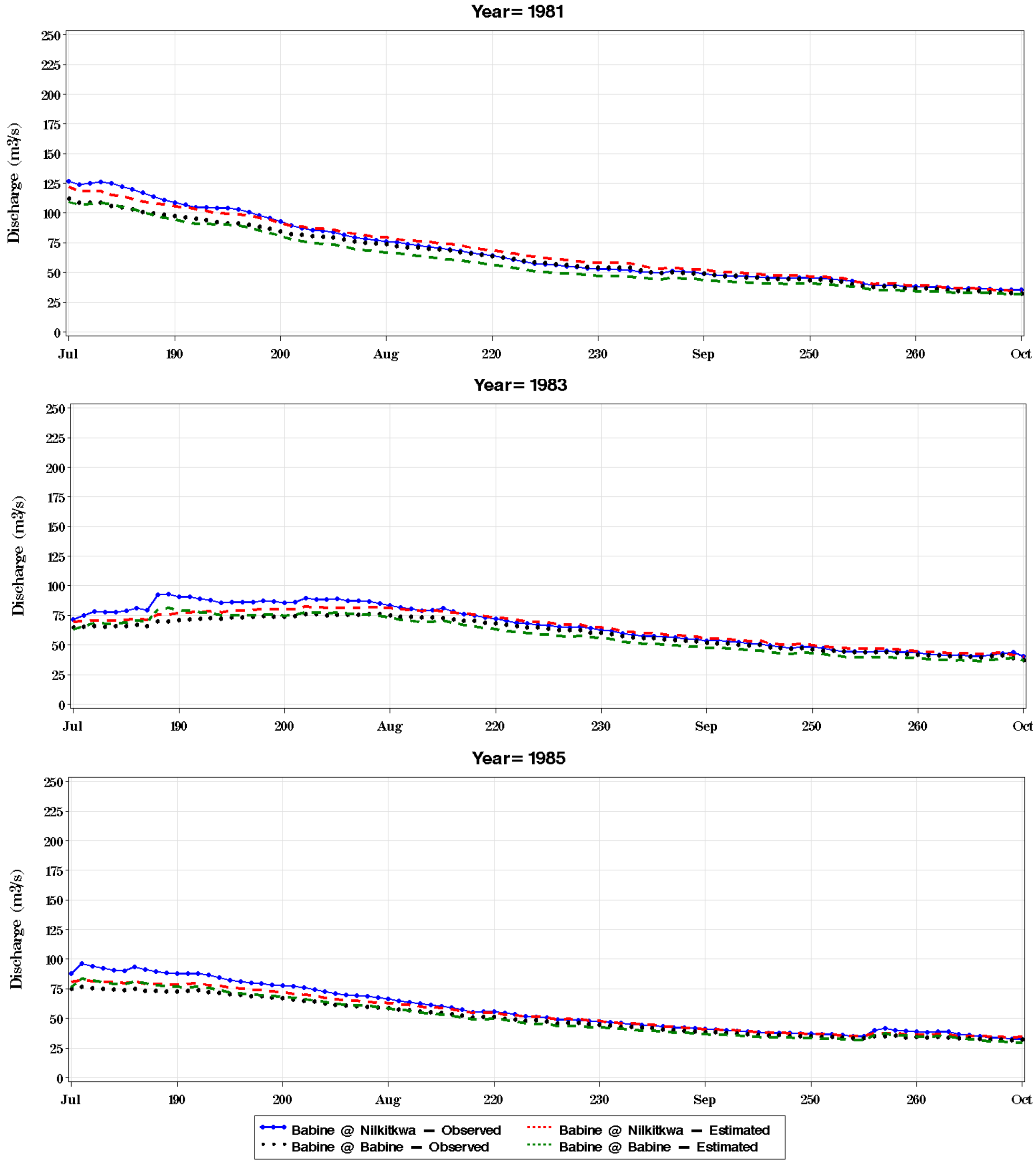


Figure 13. Sample plots of observed and estimated daily mean discharge at Babine hydrometric stations based on log-linear ($Y=aX^b$) relations for overlapping years.

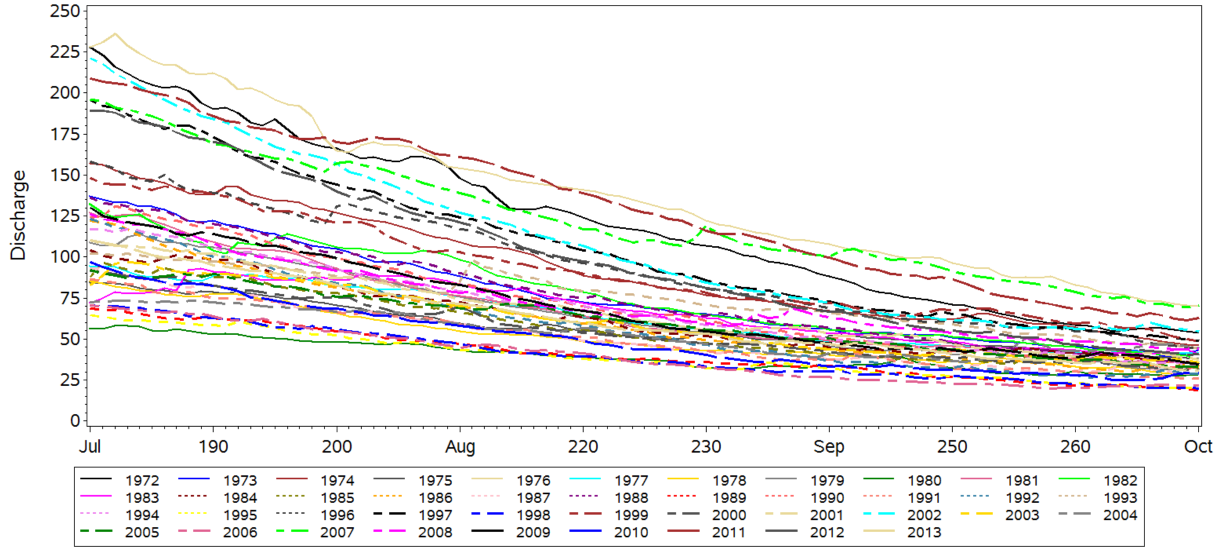


Figure 14. Observed daily mean discharge (cms) in the lower Babine River, below Nilkitkwa Lake, by year (1972-2013). Extreme high summer flows are evident in 1972, 1976, 1997, 2002, 2007, and 2011. Persistently low seasonal flows are evident in 1978, 1980, 1989, 1995, 1998, 2004, 2006, and 2010.

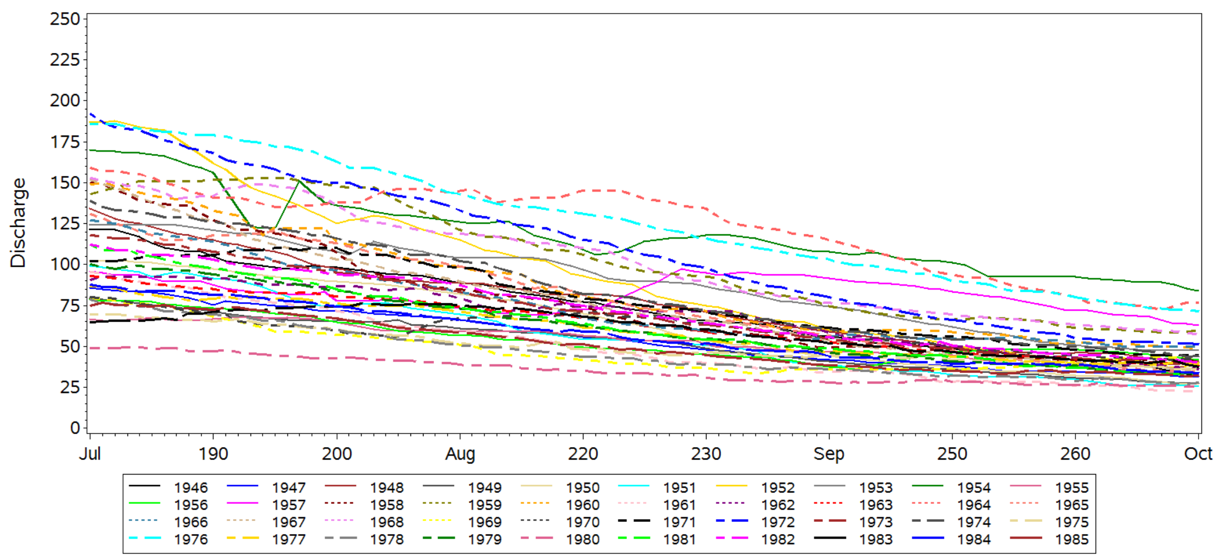
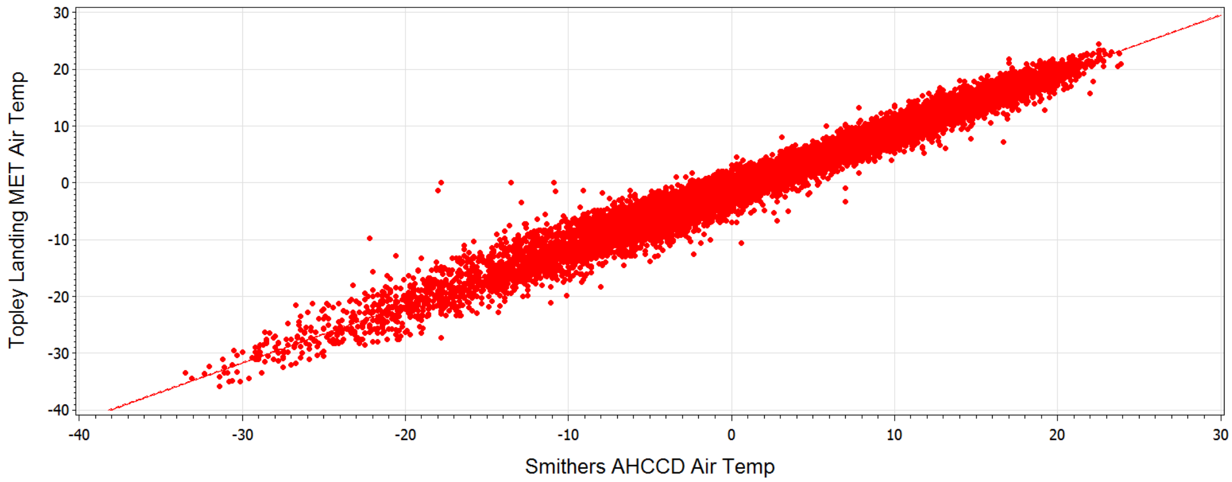


Figure 15. Observed daily mean discharge (cms) in the upper Babine River, below Babine Lake, by year (1946-1985). Extreme high summer flows were evident in 1954, late 1957, 1959, 1964, 1972, 1976. Persistently low seasonal flows are evident in 1955 (?), 1956 (?), 1961, 1969, 1975, 1978, 1980, 1985 (?).



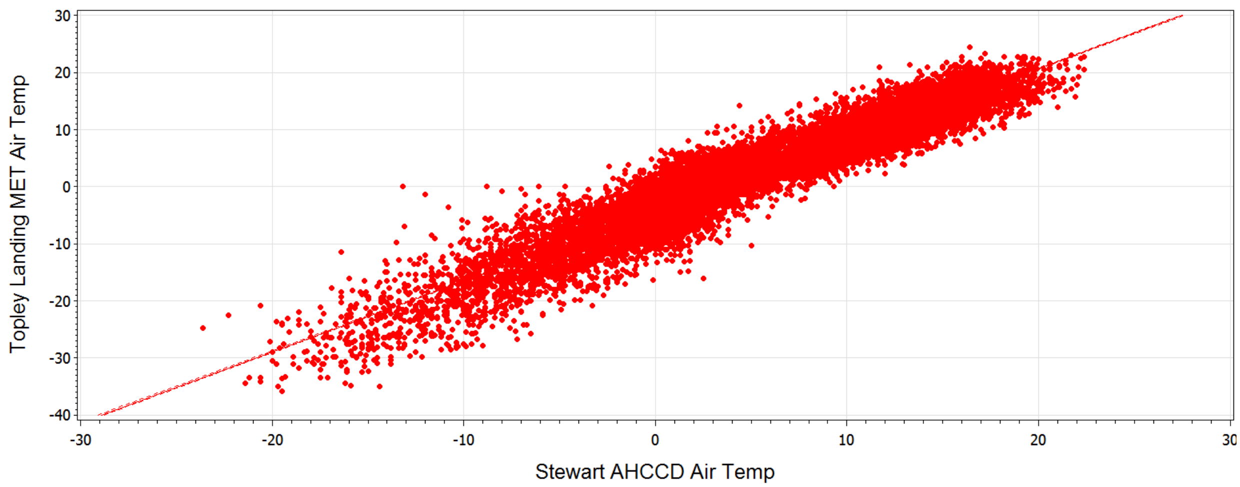


Figure 16. TOPLEY LANDING daily air temperature as a function of regional AHCCD station air temperature (1966-2013; SMITHERS (top; r_s = 0.988), STEWART (bottom, r_s = 0.908)). Restricting regression data to temperatures >= 0°C provided coefficients more appropriate for adult migration periods.

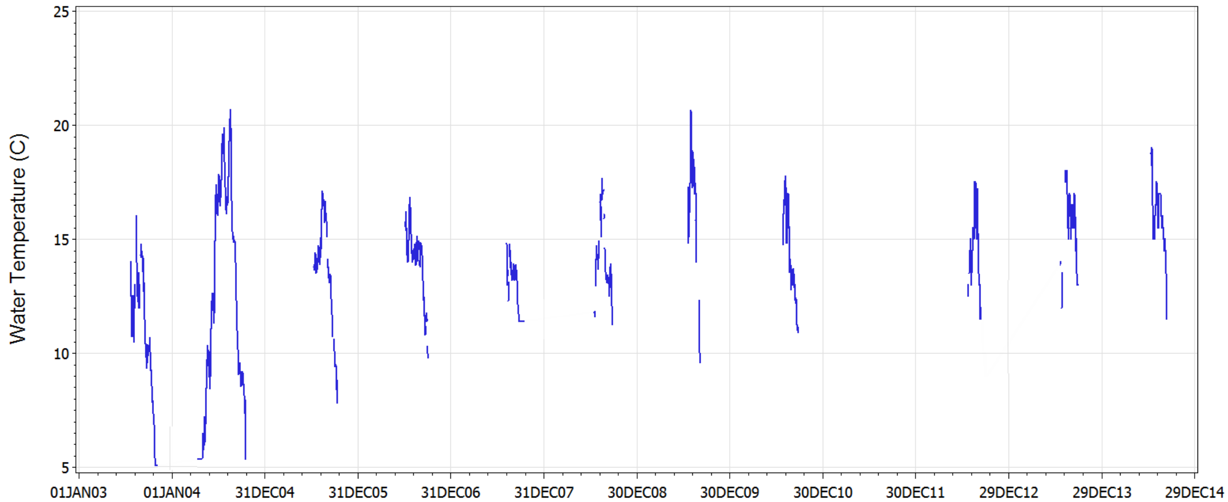


Figure 17. Water temperature data for Babine River at the fence (Source: DFO NORTH COAST STOCK ASSESSMENT DIVISION and Lake Babine Nation Fisheries).

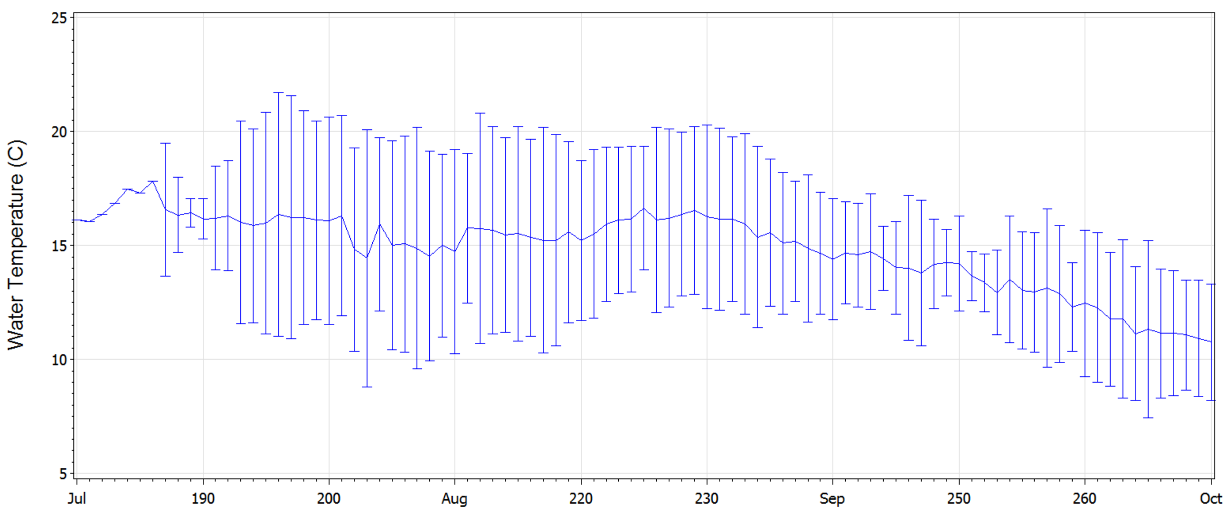


Figure 18. Annual thermograph of water temperature data ± two standard deviations for Babine River at the fence, 2003-2014 (Source: DFO NORTH COAST STOCK ASSESSMENT DIVISION and Lake Babine Nation Fisheries).

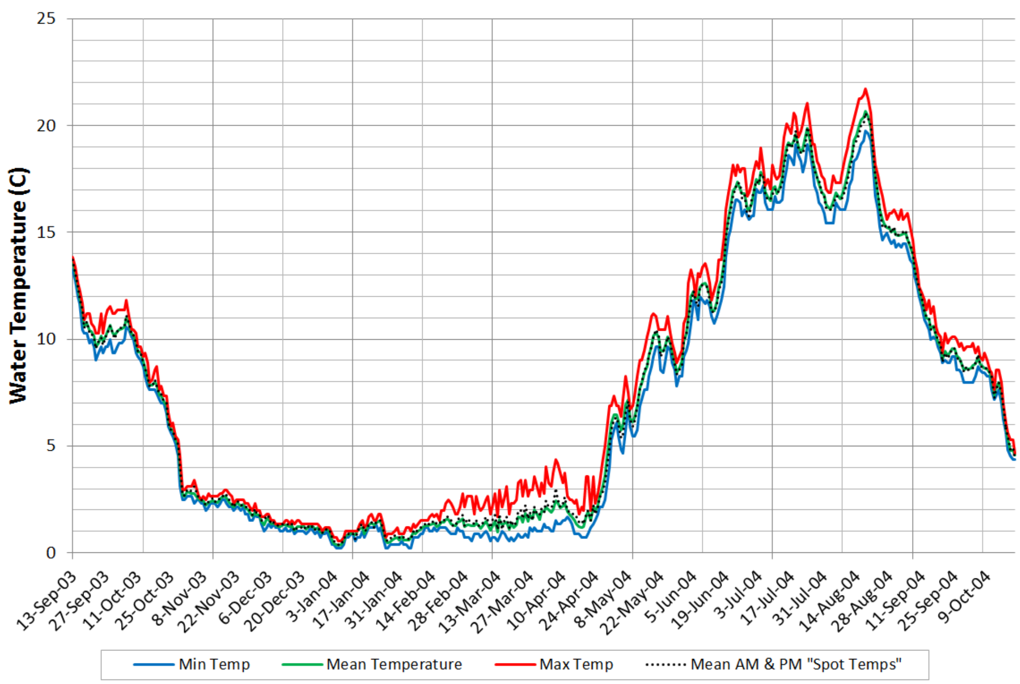


Figure 19. Daily minimum (blue), mean (green) and maximum (red) water temperature from automated data logger, Babine River 2004. Black dashed line is mean of two hourly automated datlogger readings, at 09:00 and 13:00 hours each day (Source: DFO North Coast Stock Assessment Division).

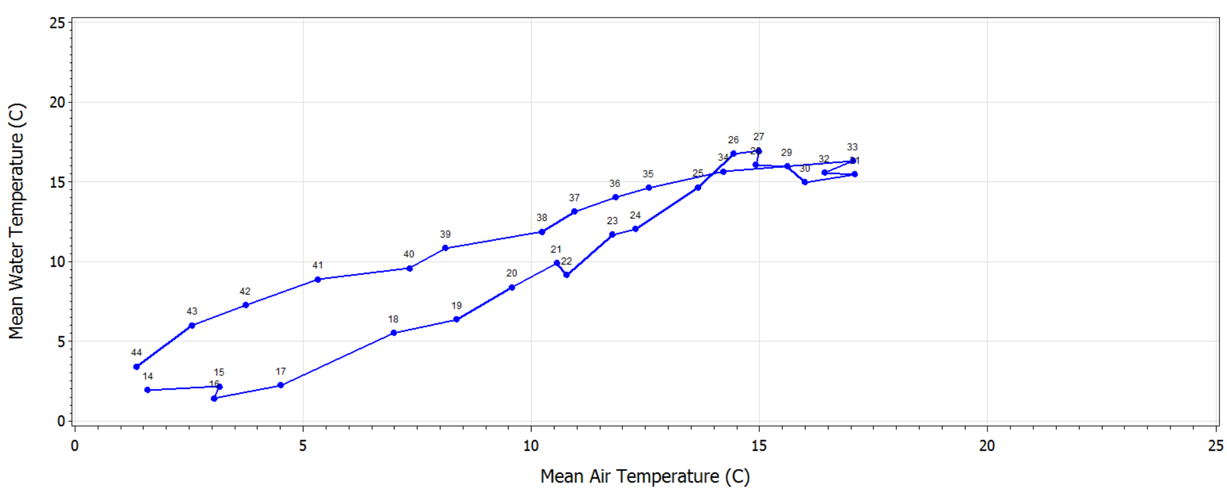


Figure 20. Derivation of seasonal turn-around point for Babine River based on maximum weekly mean air and water temperature data. The seasonal turn-around point was set to week 32 (day 224), approximately August 16th. The "warming season" therefore extends from April 1st to August 16th, followed by the "cooling season" from day 225-329, i.e., August 17th - November 25th.

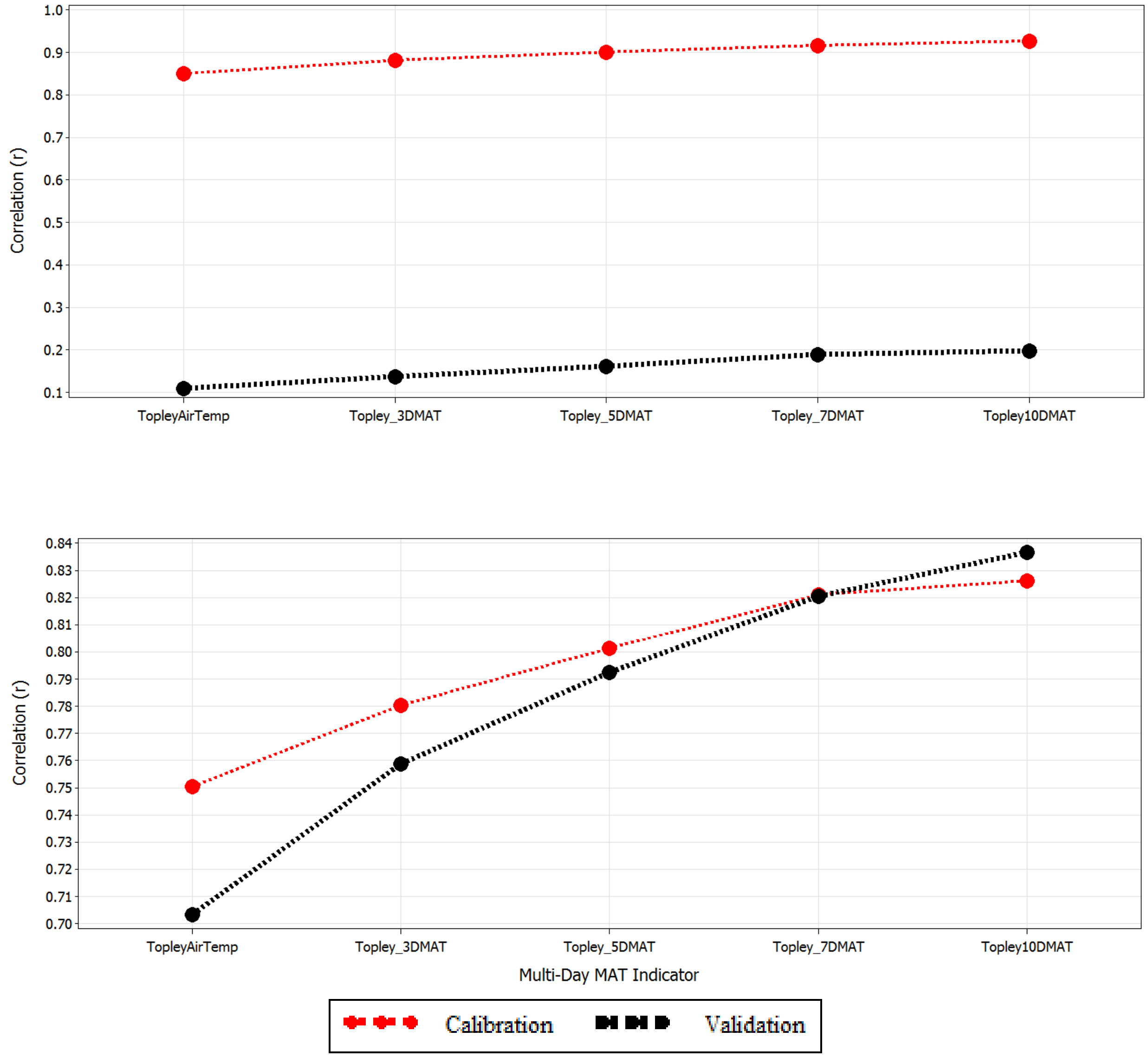


Figure 21. Derivation of optimum regional air temperature index for air/water temperature analyses, based on maximum all-year correlation between various Topley Landing multi-day mean air temperature indicators (MATs) with Babine River daily mean water temperature (MWT) for calibration (red) and validation data; warming season (top), cooling season (bottom). Topley air temperature indicators include (l-r): ToplеyAirTemp (same day mean); Topley 3-day centered moving average air temperature (3d-CMAT), 5d-CMAT, 7d-CMAT, and 10d-CMAT.

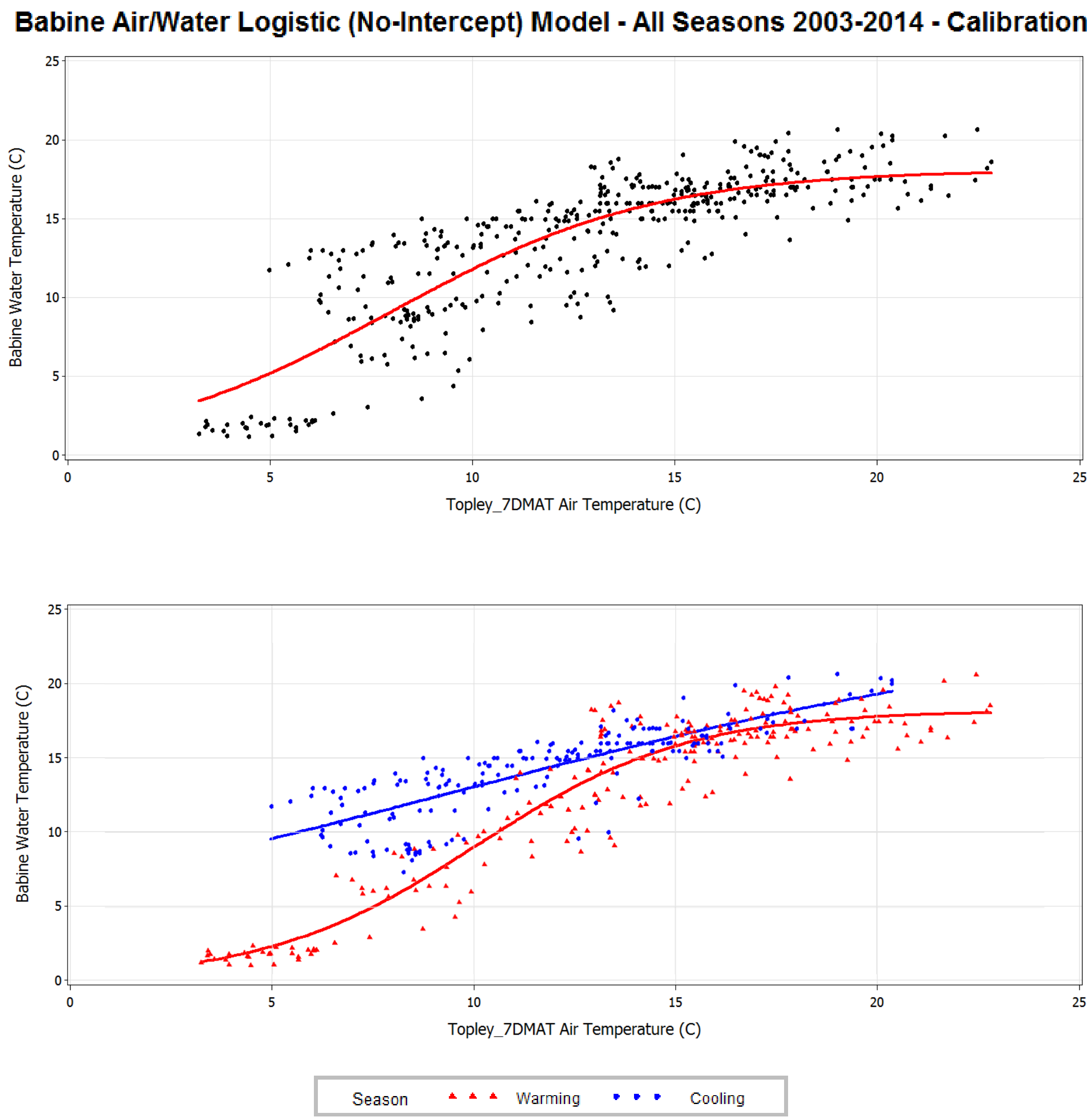


Figure 22. Logistic regression fits for air/water temperature relationship for Babine River daily mean water temperatures as a function of the TOPLEY 7d-CMAT (air temperature index) for calibration data years (see Table 7): seasons combined (top); by season (warming season: red; cooling season: blue).

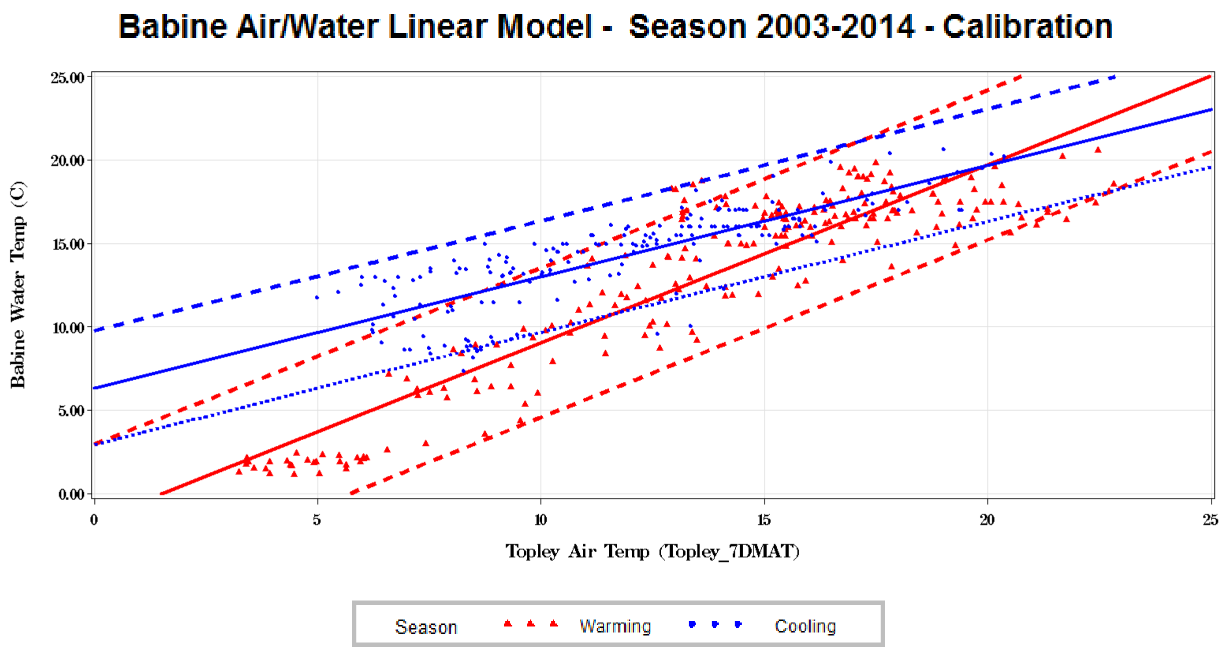
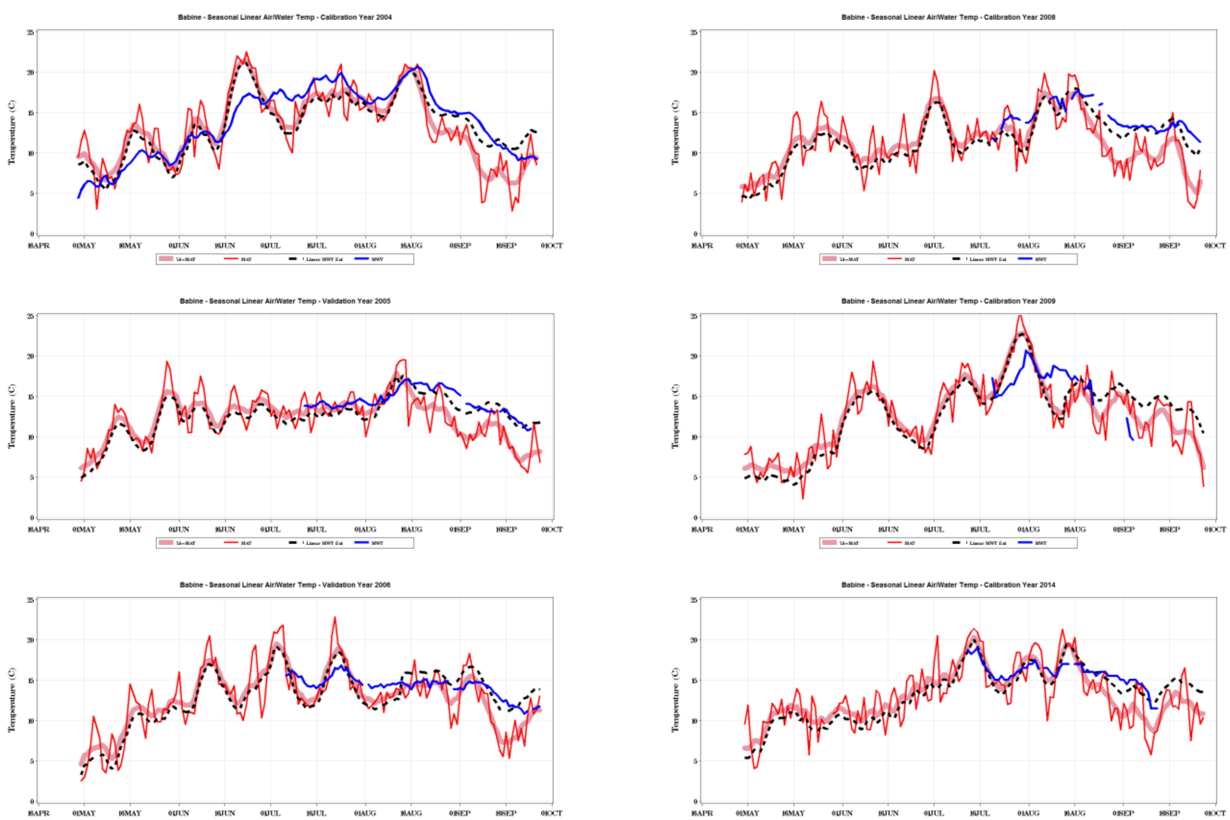


Figure 23. Linear regression fits for air/water temperature relationship for Babine River daily mean water temperatures as a function of the TOPLEY 7d-CMAT (air temperature index) for calibration data years (see Table 7), by season (warming season: red; cooling season: blue). Sample plots, below: daily mean air temperature (red line), 7-day MAT index (broad pink), observed daily mean water temperature (blue solid) and estimated MWT (dashed; based on seasonal linear regression models).



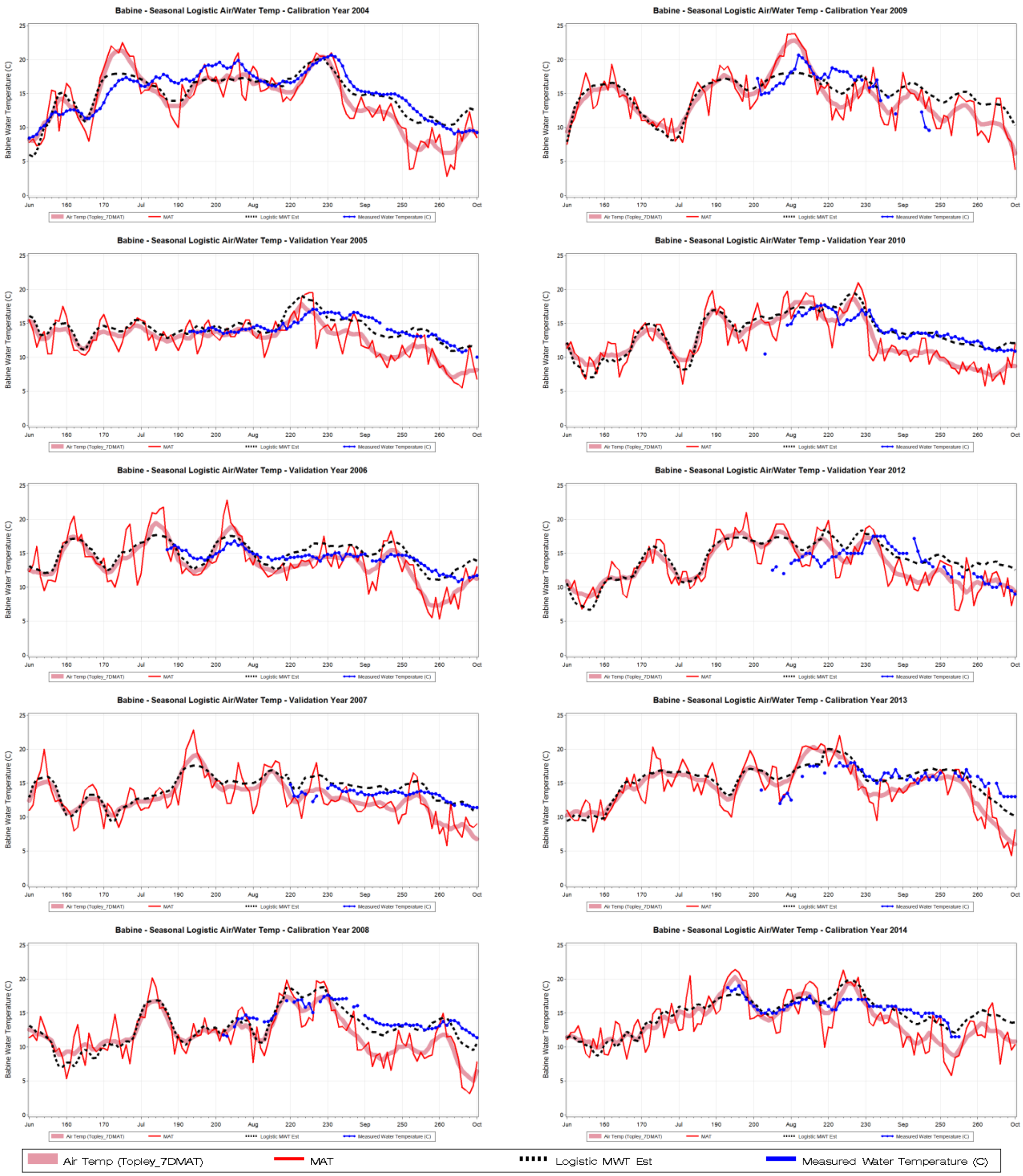


Figure 24. Sample plots of daily mean air temperature (red line), 7-day MAT index (broad pink line), observed daily mean water temperature (blue solid line) and estimated MWT (black dashed line; based on seasonal logistic regression models) for Babine River, July-October 2004-2010, 2012-2014.

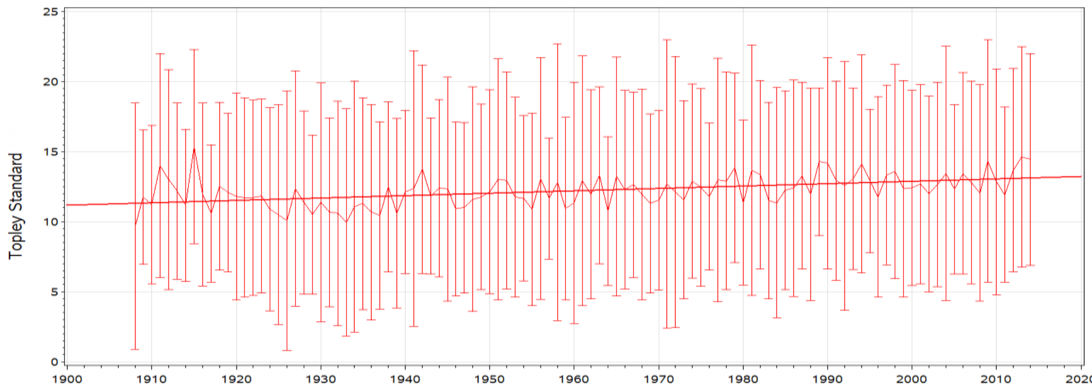


Figure 25. Observed and estimated TOPLEY LANDING mean air temperature ± 2 standard deviations, July-September 1908-2012. Long-term warming trend is evident (Y = -21.5 + 0.017 * Year; r = 0.14; P < .0001).

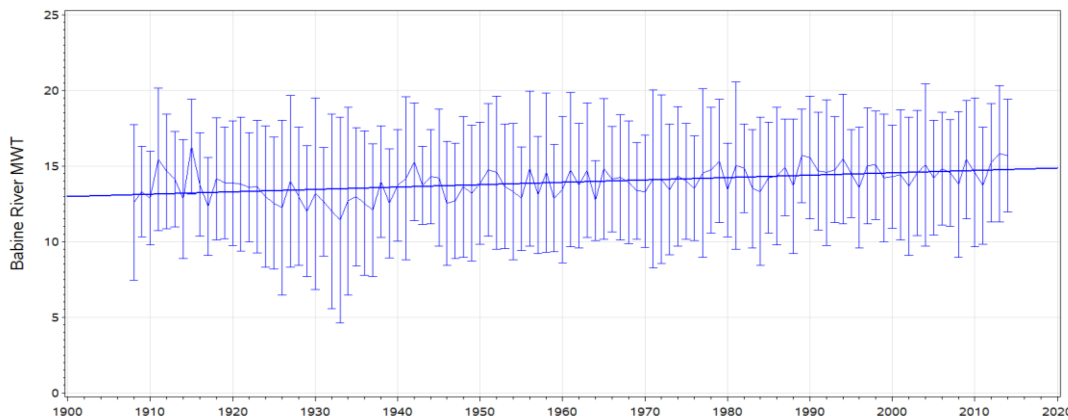


Figure 26. Estimated Babine River mean water temperature ± 2 standard deviations, July-September 1908-2012, based on seasonal logistic air/water temperature regression models. Significant long-term trend is evident (Y = -16.7 + 0.016 * Year; r = 0.20; P < .0001).

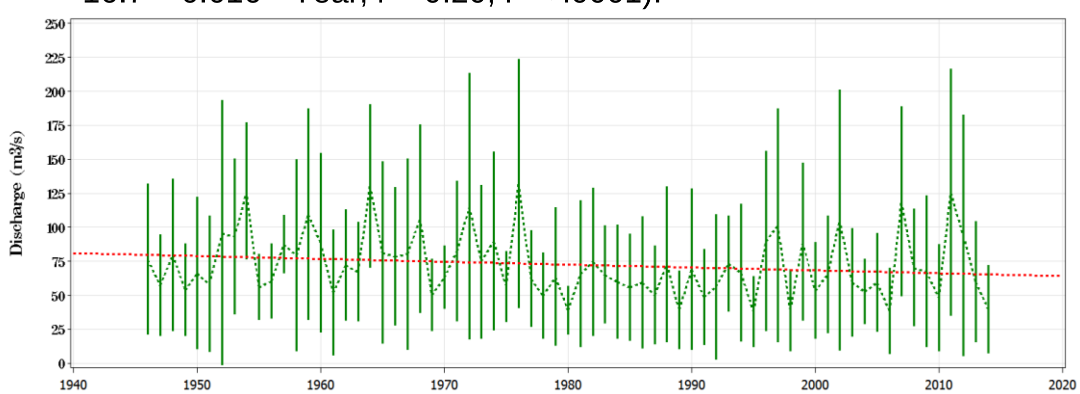


Figure 27. Reconstructed lower Babine River (at Nilkitkwa) mean summer discharge ± 2 standard deviations, July-September 1946-2014, based on log-linear regression with upper Babine discharge. Significant long-term decline in summer flows is evident (Y = 489 - 0.210 * Year; r = -0.10; P < .0001).

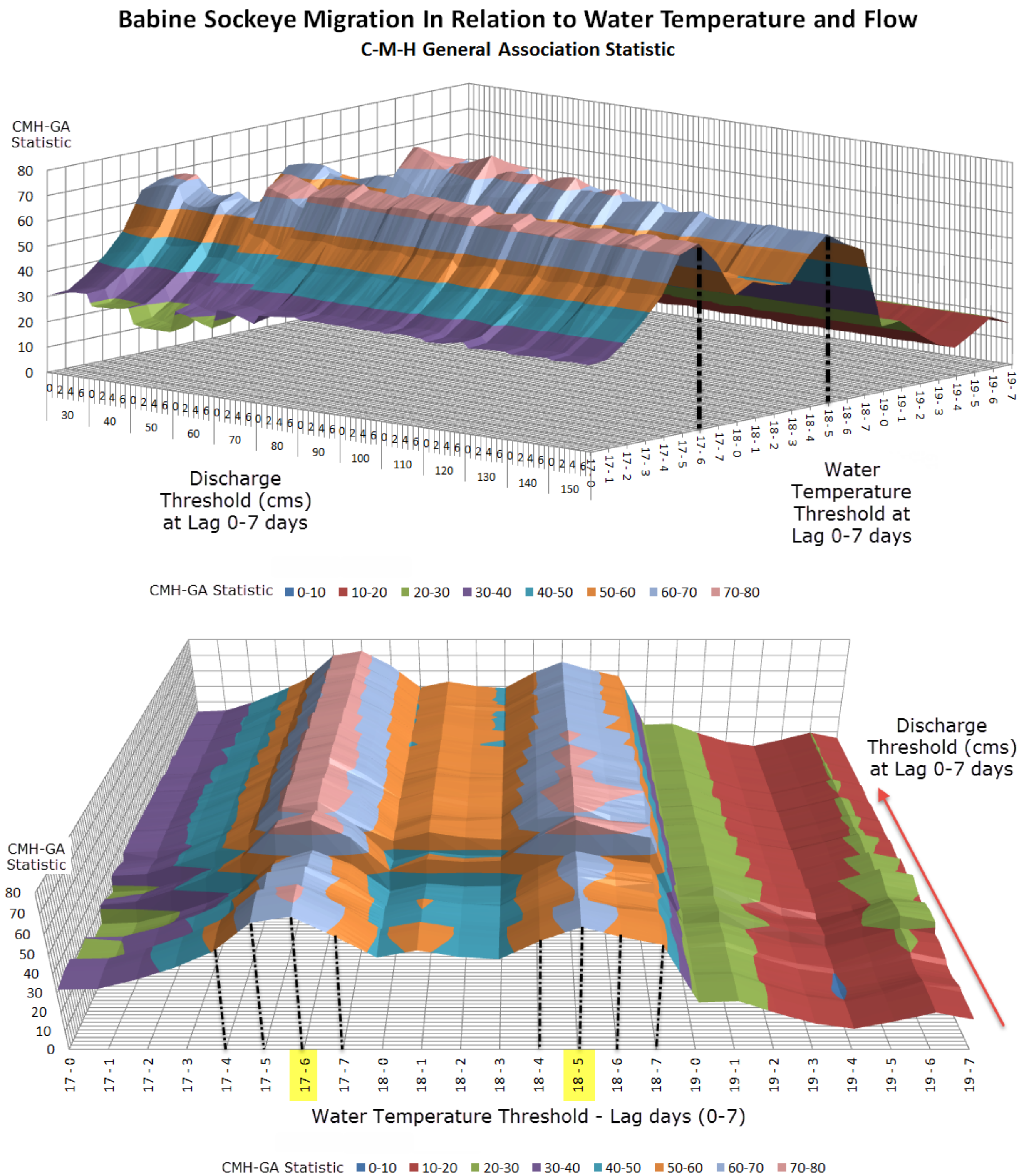


Figure 28. Distribution of the *Cochran-Mantel-Haenszel (CMH) General Association* between high/low migration rate categories as a function of water temperature and discharge categories. Peak CMH-GA statistics signify the date lags and threshold levels for each environmental variable that generated the most significant associations with large changes in migration rate: 17-18°C lagged 5-6 days at a wide range of discharge date lags and threshold levels ranging from 60-120 cms.

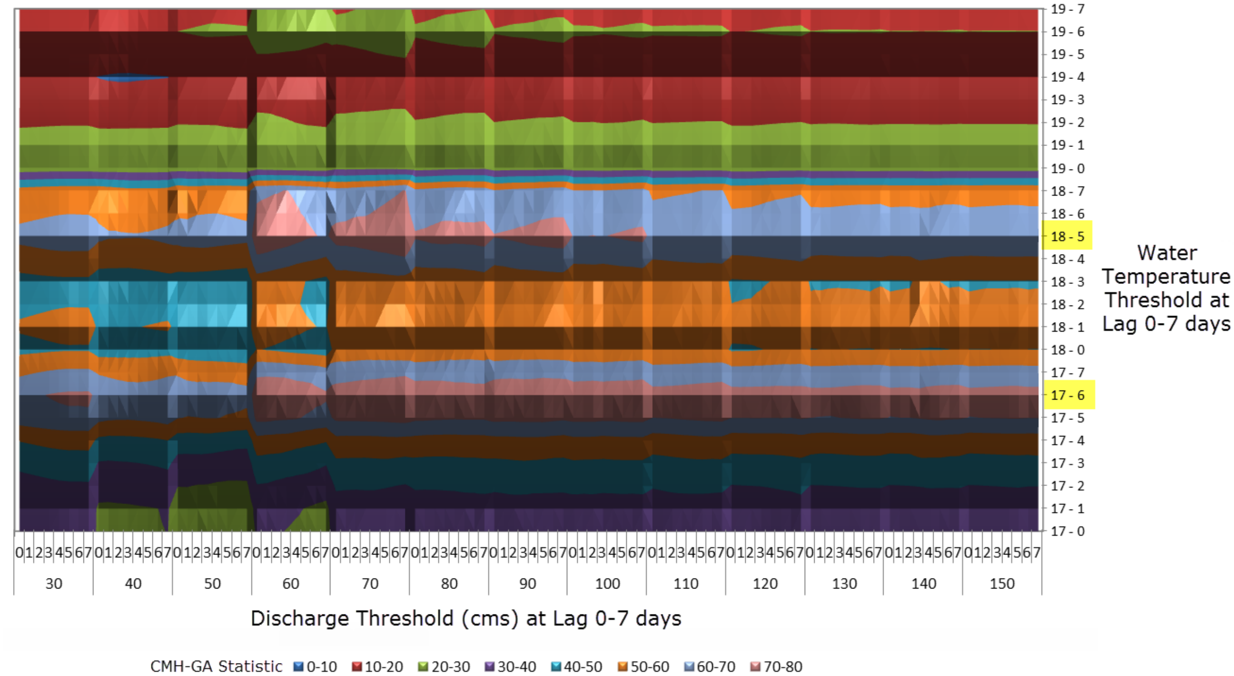
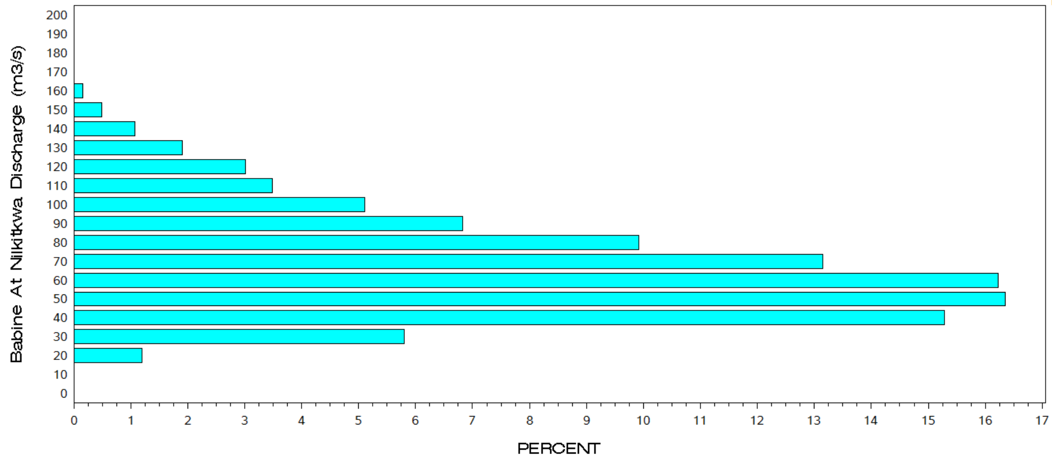
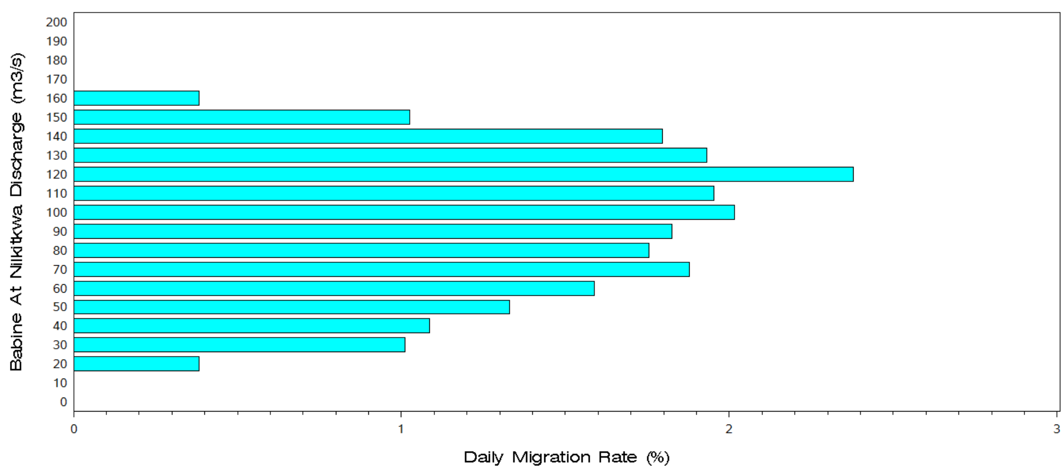


Figure 29. Distribution of the *Cochran-Mantel-Haenszel (CMH) General Association* statistic between high/low migration rate categories as a function of water temperature and discharge categories. Peak CMH-GA statistics signify the date lags and threshold levels for each environmental variable that generated the most significant association with large changes in migration rate. Environmental conditions 5-6 days earlier showed a strong influence at estimated water temperatures of 17-18°C across a wide range of discharge thresholds above 60 cms.



Babine At Nilkitkwa Discharge (m3/s)	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
200	0	3840	0.00	100.00
190	0	3840	0.00	100.00
180	0	3840	0.00	100.00
170	0	3840	0.00	100.00
160	6	3840	0.16	100.00
150	19	3834	0.49	99.84
140	41	3815	1.07	99.35
130	73	3774	1.90	98.28
120	116	3701	3.02	96.38
110	134	3585	3.49	93.36
100	196	3451	5.10	89.87
90	262	3255	6.82	84.77
80	381	2993	9.92	77.94
70	505	2612	13.15	68.02
60	623	2107	16.22	54.87
50	628	1484	16.35	38.65
40	587	856	15.29	22.29
30	223	269	5.81	7.01
20	46	46	1.20	1.20
10	0	0	0.00	0.00
0	0	0	0.00	0.00

Figure 30. Frequency plot of historical Babine Sockeye non-zero migration (un-weighted tally of non-zero migration dates), at varying levels of lower Babine River discharge six days earlier. Most dates (70%) of migration occurred when flows in the Babine six days earlier were ~40-80 cms.



Babine At Nilkitkwa Discharge (m3/s)	FREQ.	Daily Migration Rate (%)
200	0	0.00
190	0	0.00
180	0	0.00
170	0	0.00
160	6	0.38
150	19	1.03
140	41	1.80
130	73	1.93
120	116	2.38
110	134	1.95
100	196	2.02
90	262	1.83
80	381	1.76
70	505	1.88
60	623	1.59
50	628	1.33
40	587	1.09
30	223	1.01
20	46	0.38
10	0	0.00
0	0	0.00

Figure 31. Frequency plot of historical Babine Sockeye non-zero migration dates, weighted by daily migration rate, at varying levels of lower Babine River discharge six days earlier. Moderate daily migration rates (1.2 - 2%) occurred at a wide range of discharge levels (50-140 cms), while high daily migration rates (>2% per day) occurred at Babine River flows of ~100-120 cms.

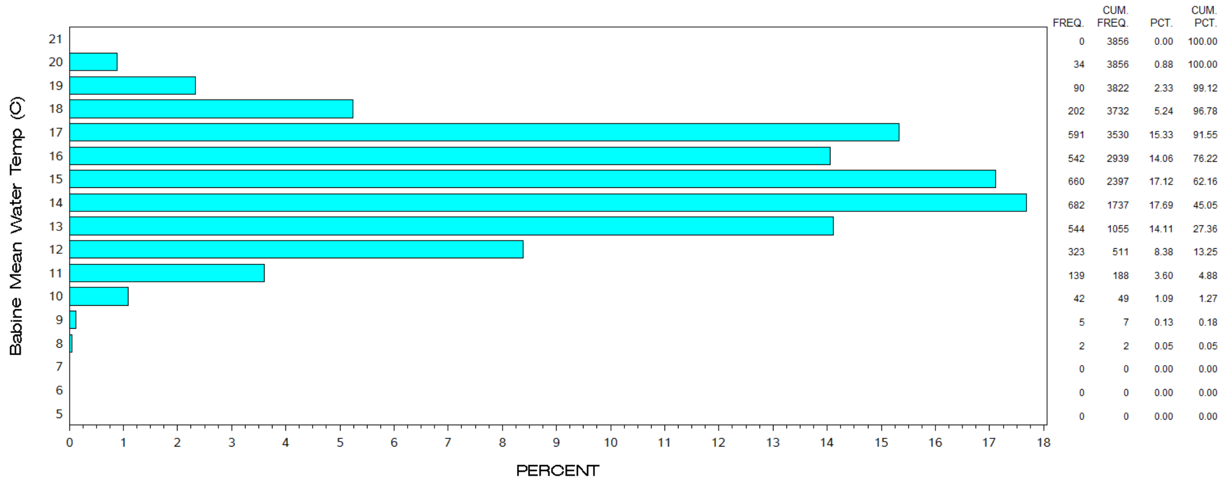


Figure 32. Frequency plot of historical Babine Sockeye non-zero migration (un-weighted tally of non-zero migration dates), at varying levels of Babine River water temperature six days earlier. ~75% of migration activity occurred at estimated temperatures of 13-17°C.

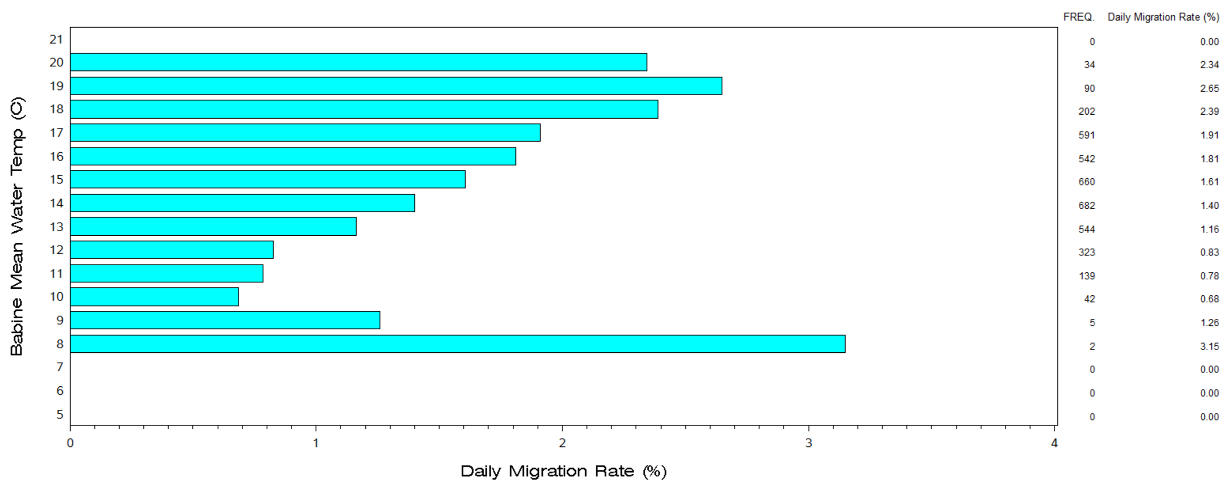


Figure 33. Frequency plot of historical Babine Sockeye non-zero migration dates, weighted by daily migration rate, at varying levels of Babine River water temperature. Ignoring infrequent occurrences below 10°C, high migration rates (i.e., > 75th percentile, ~2% per day) were associated with estimated water temperatures of 14-20°C.

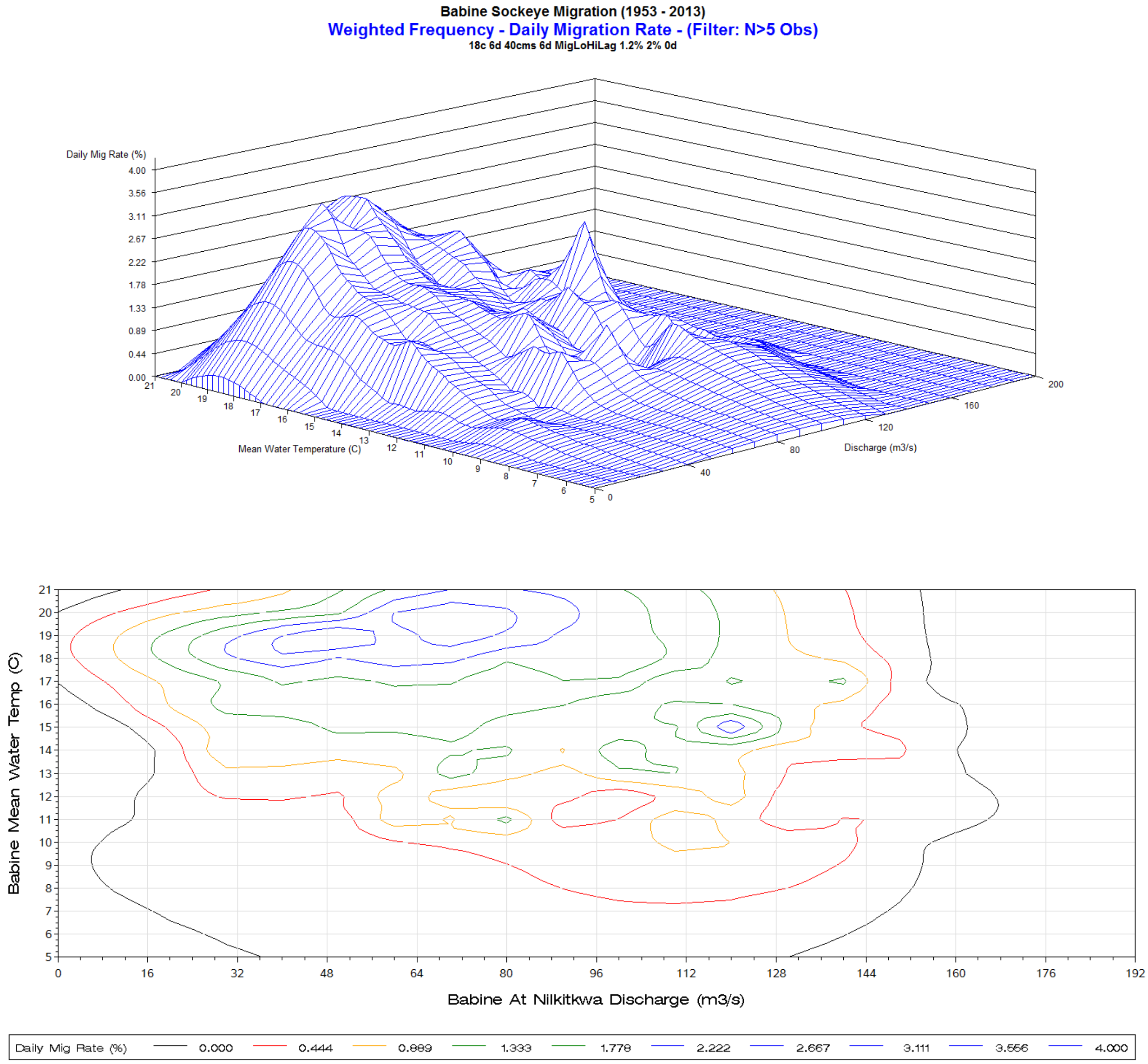
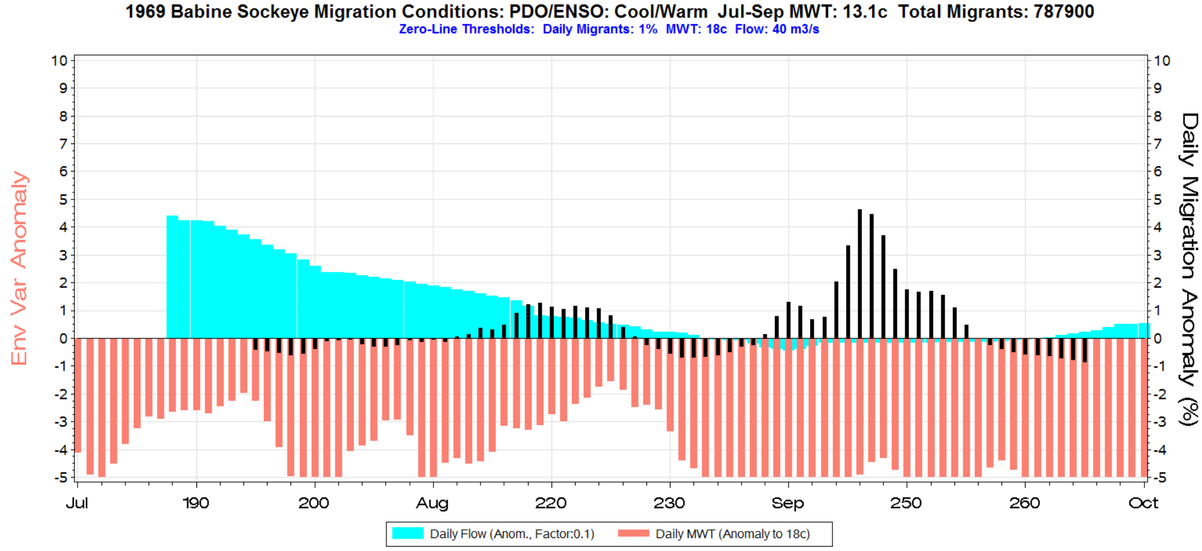


Figure 34. Weighted frequency distribution (top) and smoothed contour (bottom) of historical Babine Sockeye migration rates (daily %), at varying levels of Babine River water temperature and discharge (filtered for a minimum of 5 observations at each MWT x flow point) six days earlier. High migration rates were found at a wide range of discharge and temperature levels, with maxima at 15°C and 120 cms earlier in the season and 18-20°C and 30-100 cms later in the season.



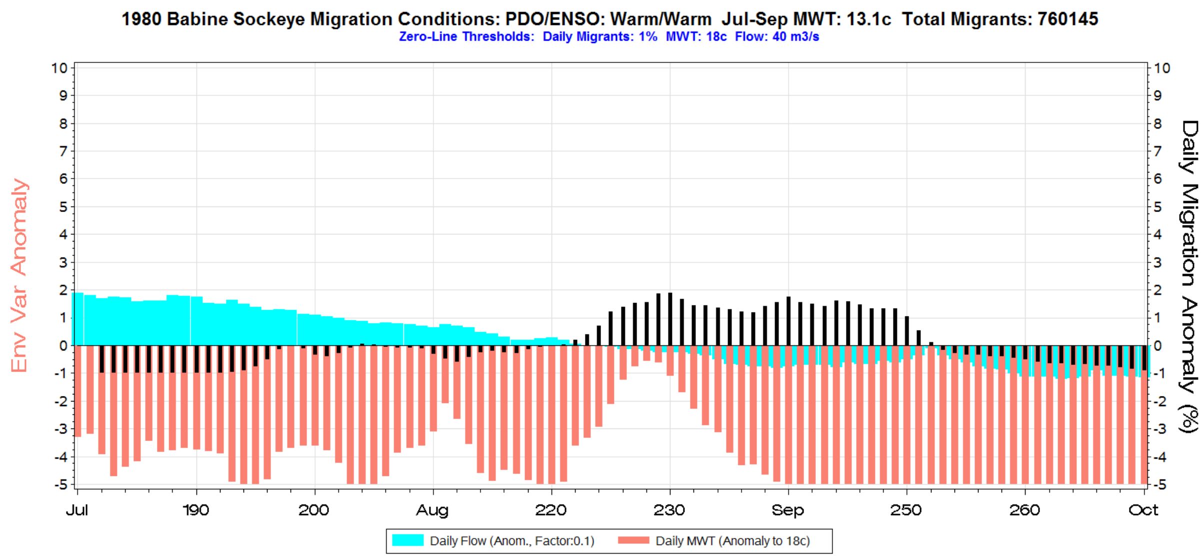
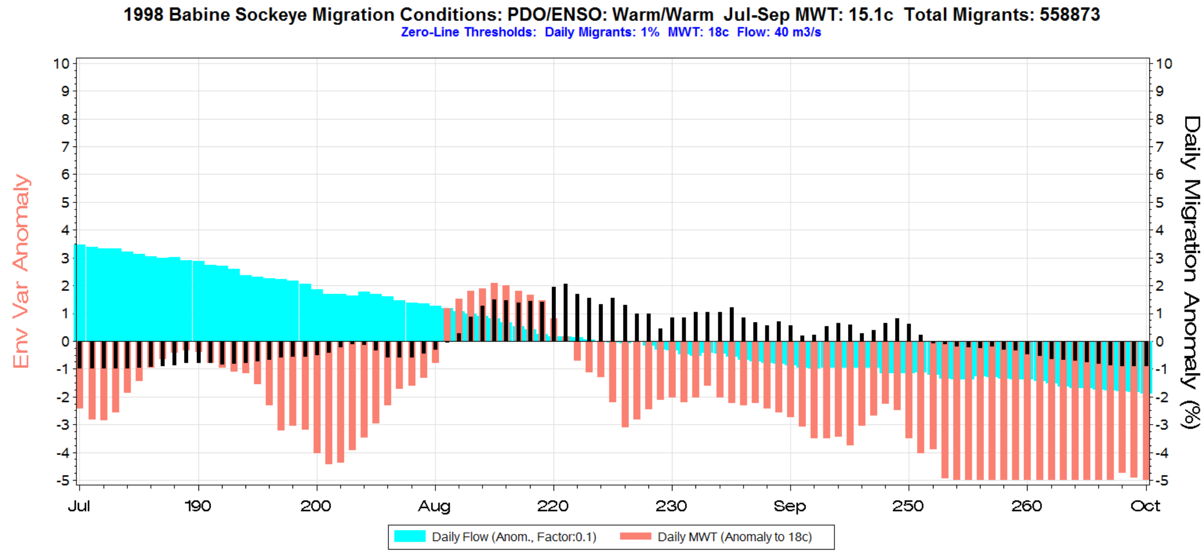


Figure 35. Annual anomaly plot for Babine Sockeye migration rate (threshold of 1% based on ~50th percentile of non-zero daily migration rates (1953-2012); estimated daily mean water temperature (threshold 18°C); and flow (threshold 40 cms; factored by 0.1 to fit on y-axis), for typical 'dry' years: 1969 (top); 1980 (bottom).



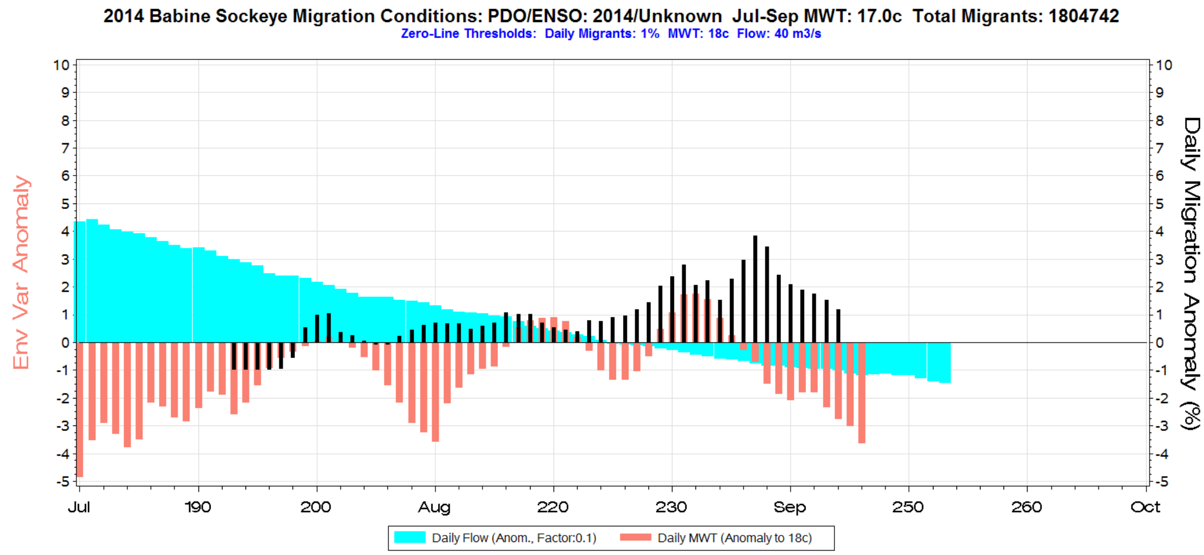
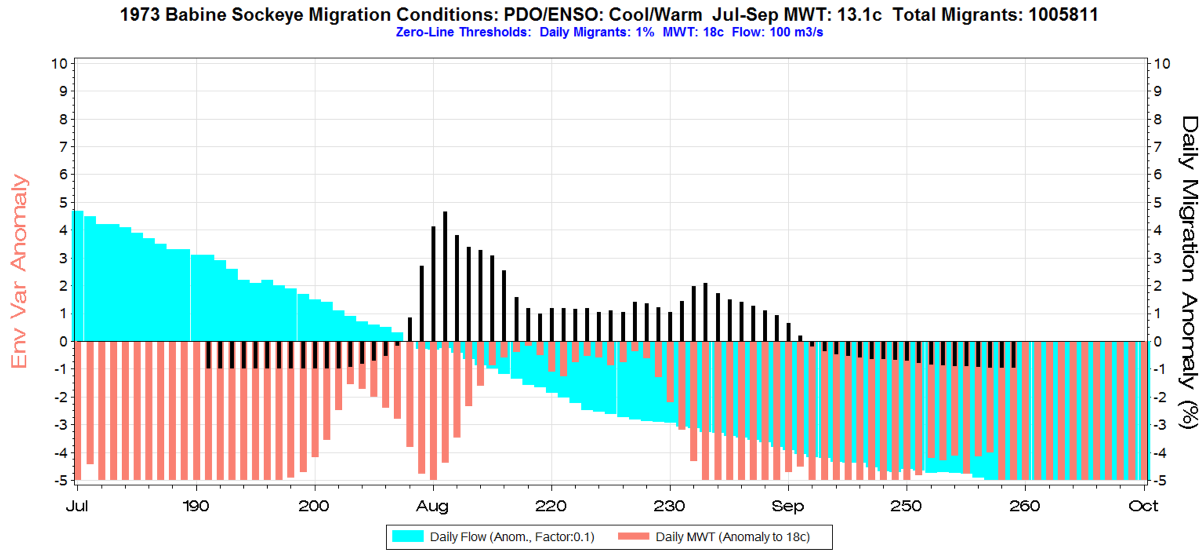


Figure 36. Annual anomaly plot for Babine Sockeye migration rate (threshold of 1% based on ~50th percentile of non-zero daily migration rates (1953-2012); estimated daily mean water temperature (threshold 18°C); and flow (threshold 40 cms; factored by 0.1 to fit on y-axis), for typical 'dry' years: 1998 (top); 2014 (bottom).



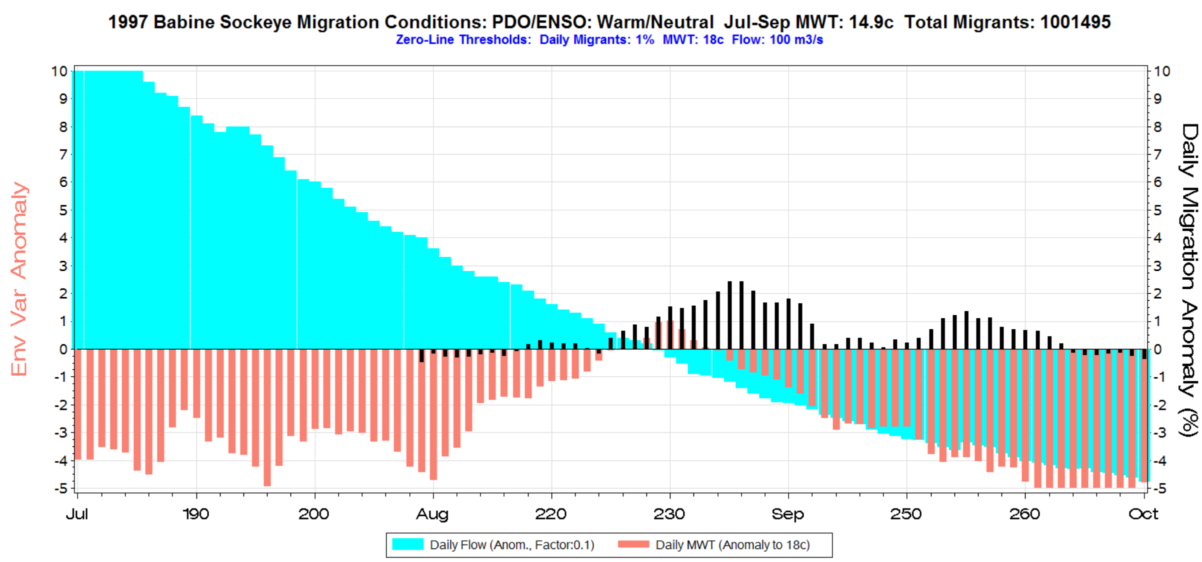


Figure 37. Annual anomaly plot for Babine migration rate versus Babine River water temperature (estimated) and discharge (factored by 0.1 to fit on y-axis) six days earlier: 1973 (top); 1980 (bottom). Zero-line thresholds: (a) Daily migration rate = 1% (~50th percentile of non-zero daily migration rates (1953-2012); (b) water temperature = 18°C; discharge = 100 cms.

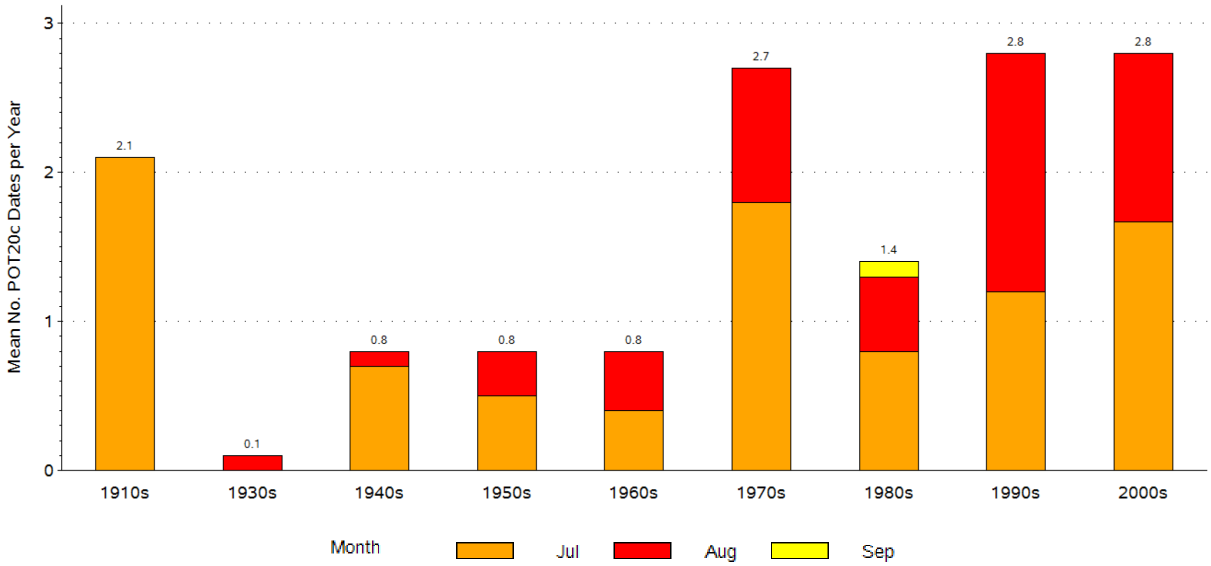


Figure 38. Frequency analysis of decadal mean number of dates per month in which regional daily mean air temperature (at TOPLEY) exceeded 20°C (Jul-Sep).

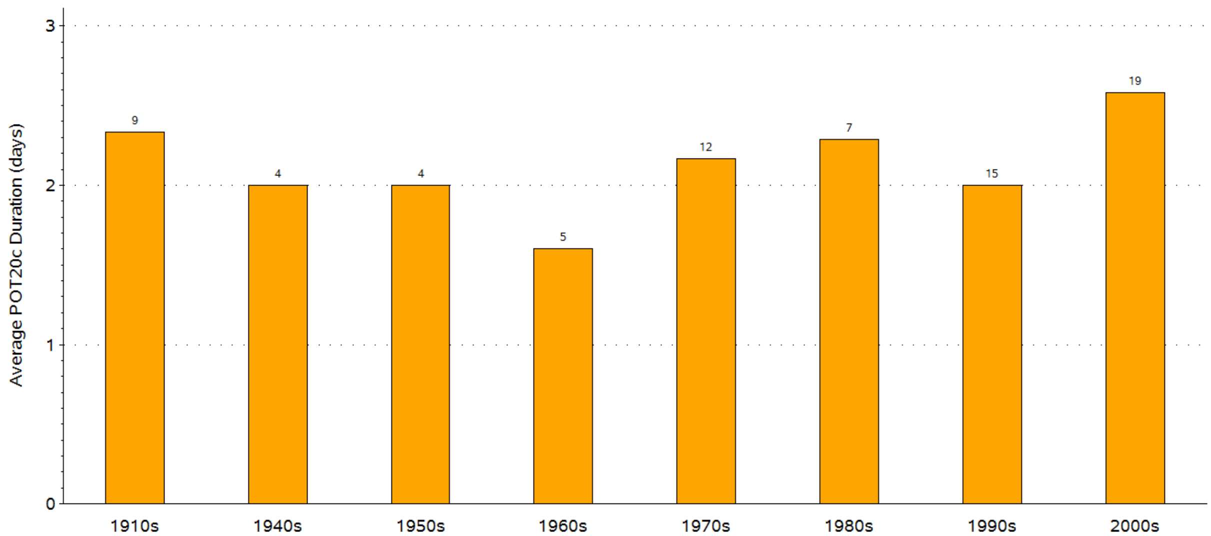


Figure 39. Mean length (days) and total decadal frequency of periods in which regional daily mean air temperature (at TOPLEY) exceeded 20°C during Jul-Sep.

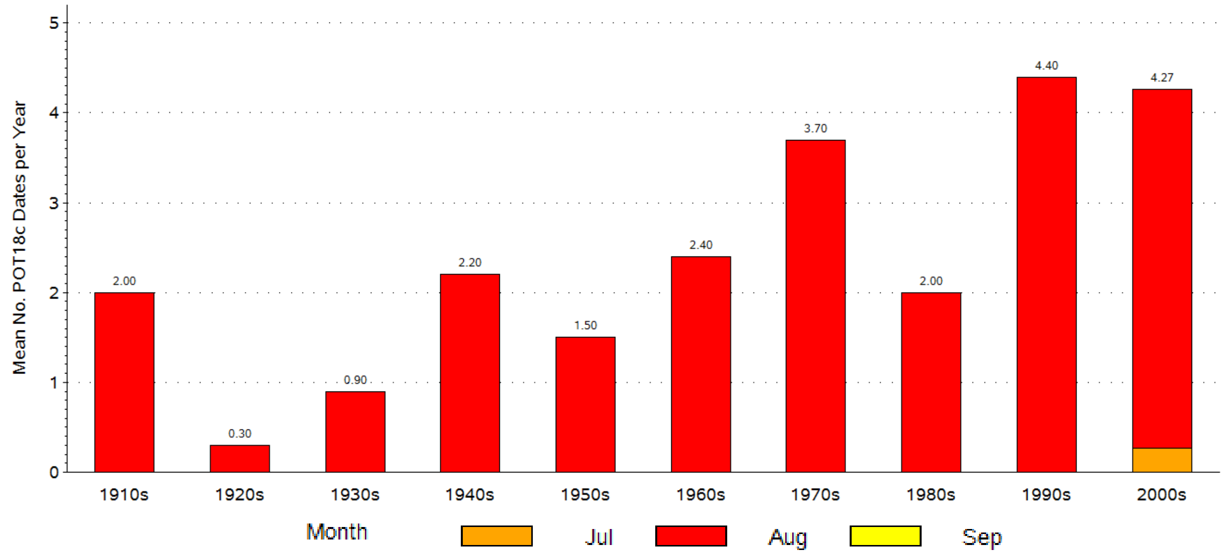


Figure 40. Frequency analysis of decadal mean number of dates per month (Jul-Sep) in which estimated mean water temperature in Babine River exceeded 18°C.

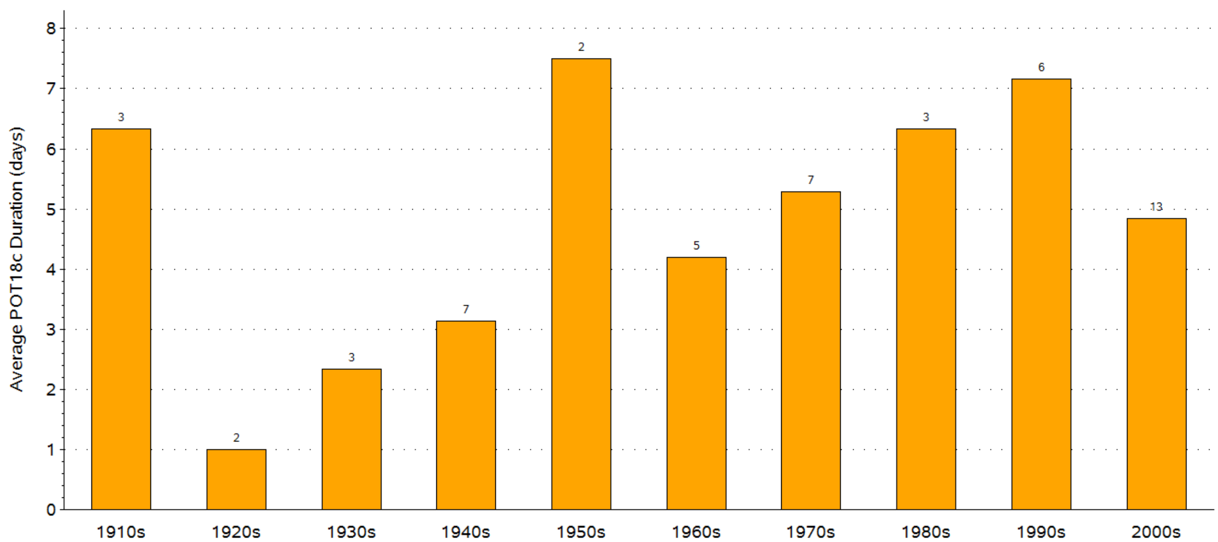


Figure 41. Mean length (days) and total decadal frequency of periods in which estimated daily mean water temperature (Jul-Sep) in Babine River continuously exceeded 18°C, by decade.

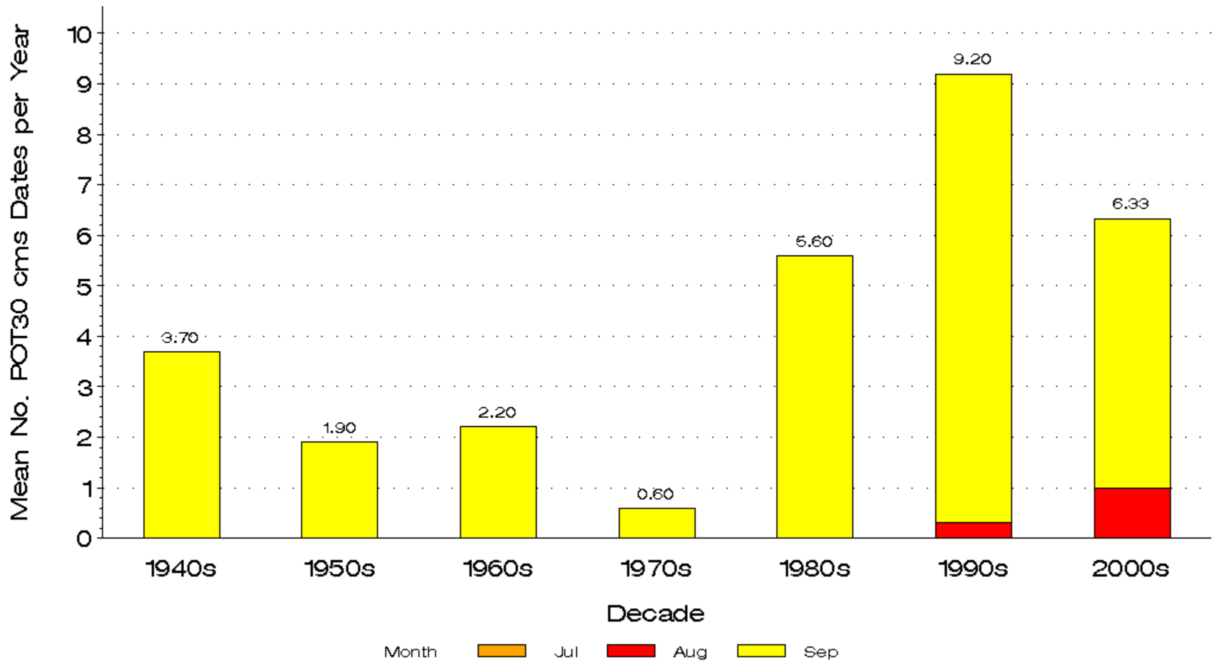


Figure 42. Frequency analysis of decadal mean number of “low flow” dates (i.e., < 10th percentile of July-September flows: ~30 cms) per month at BABINE AT NILKITKWA.

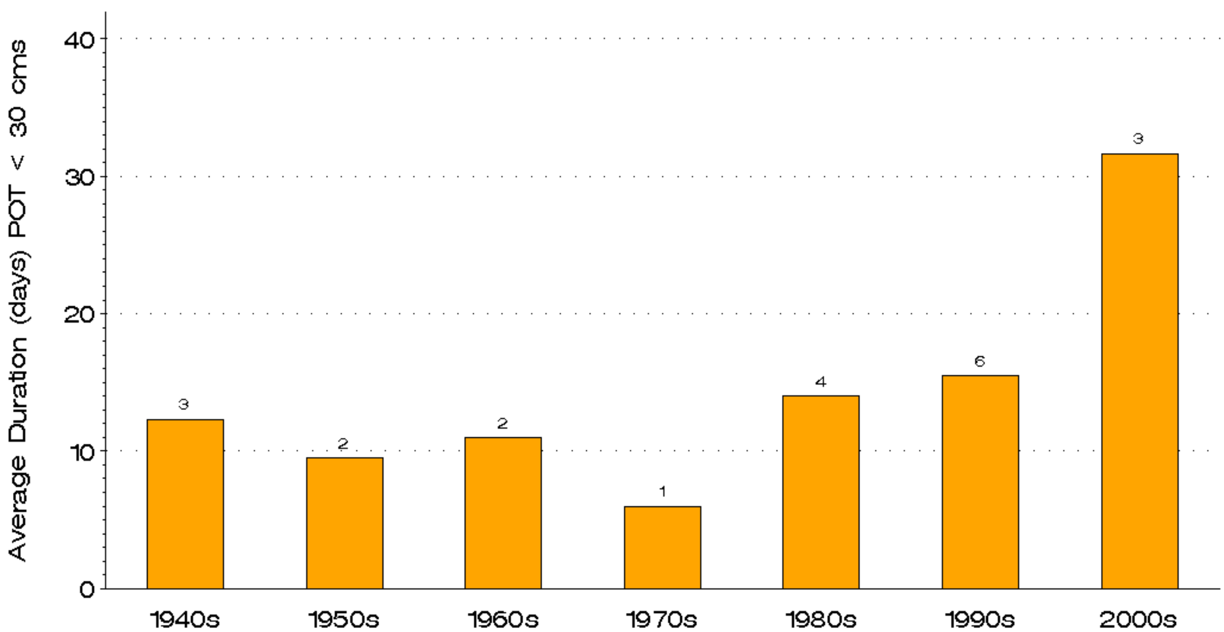


Figure 43. Mean length (days) and frequency of “low flow” periods in which BABINE AT NILKITKWA discharge continuously remained below the 10th percentile of July-September flows (~30 cms).

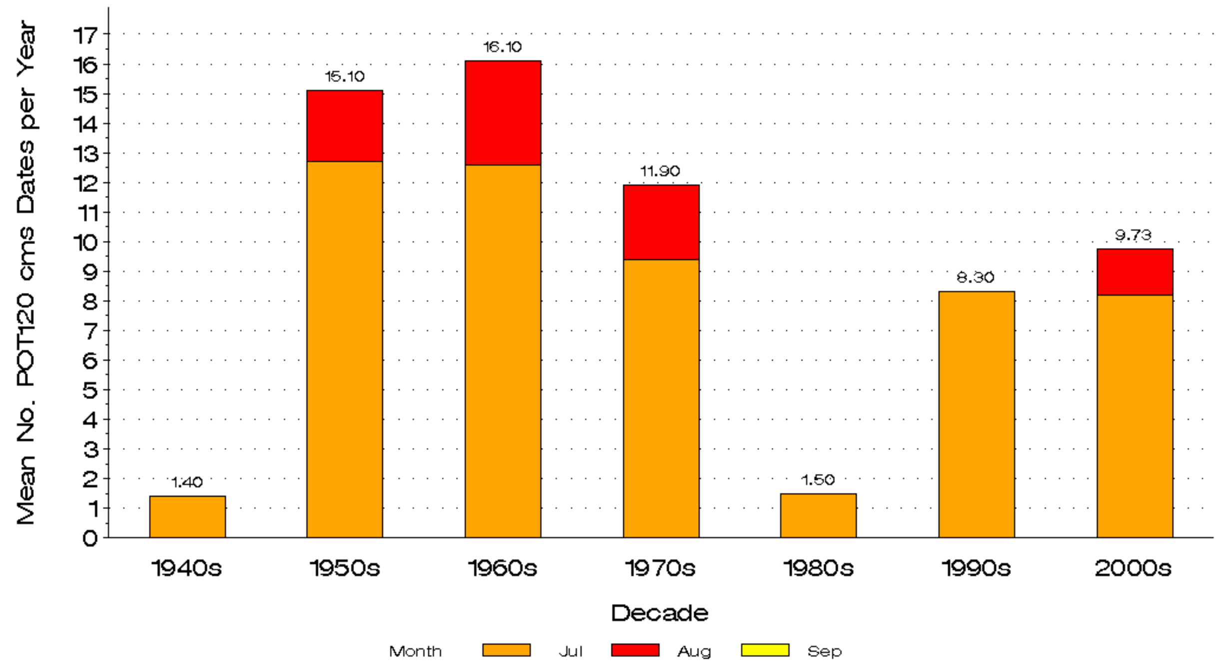


Figure 44. Frequency analysis of decadal mean number of “high flow” dates (i.e., >90th percentile of July-September flows: ~120 cms) per month at the Babine at Nilkitkwa.

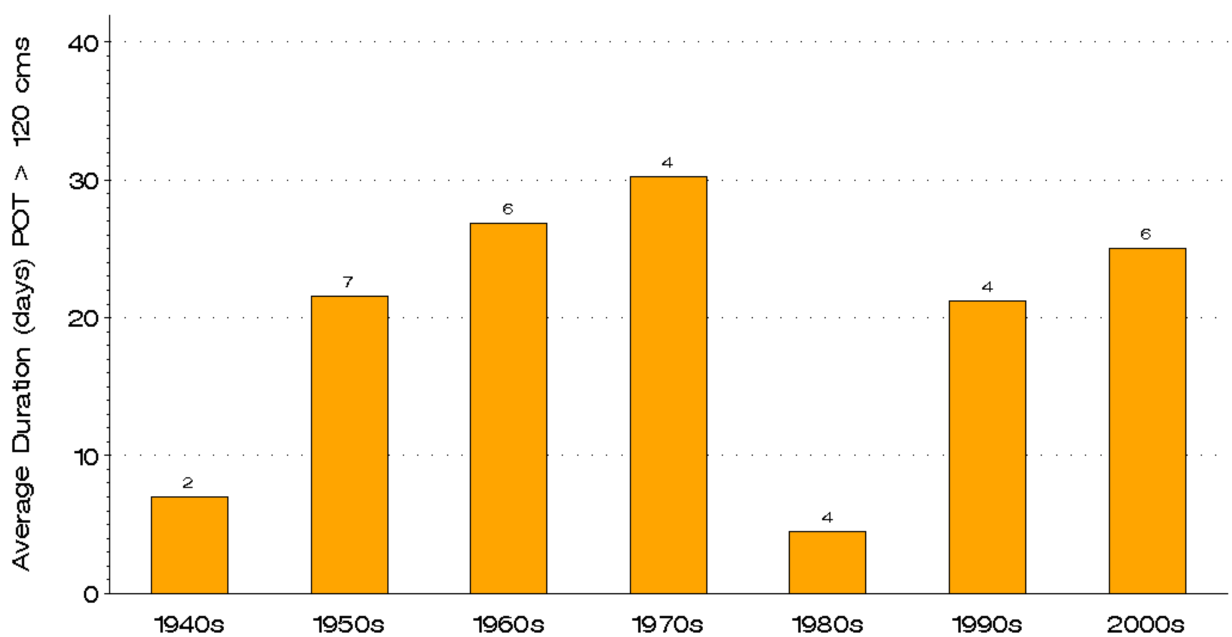
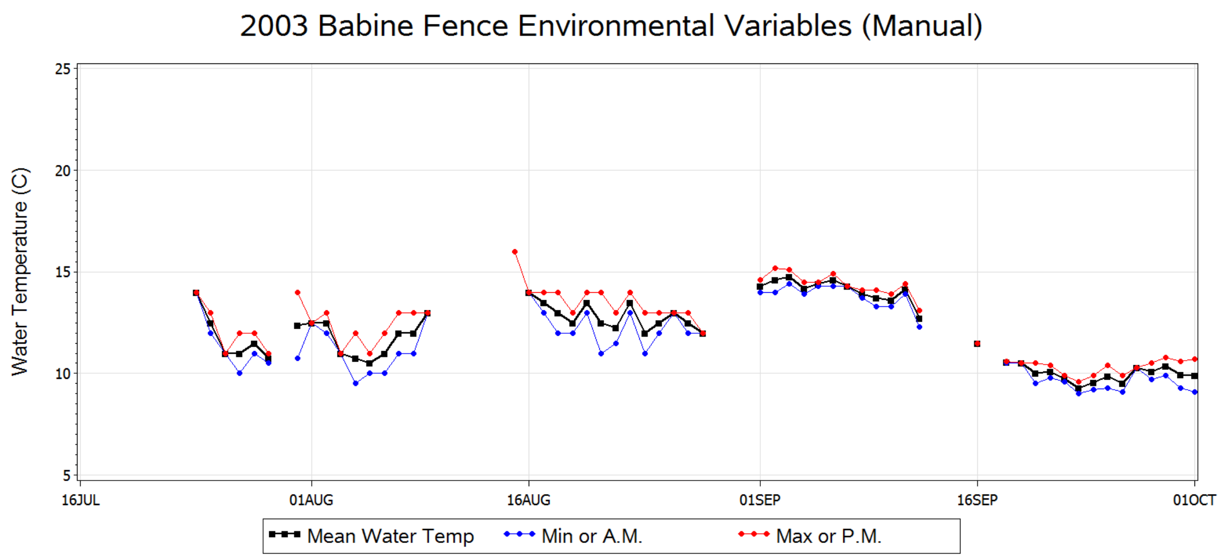
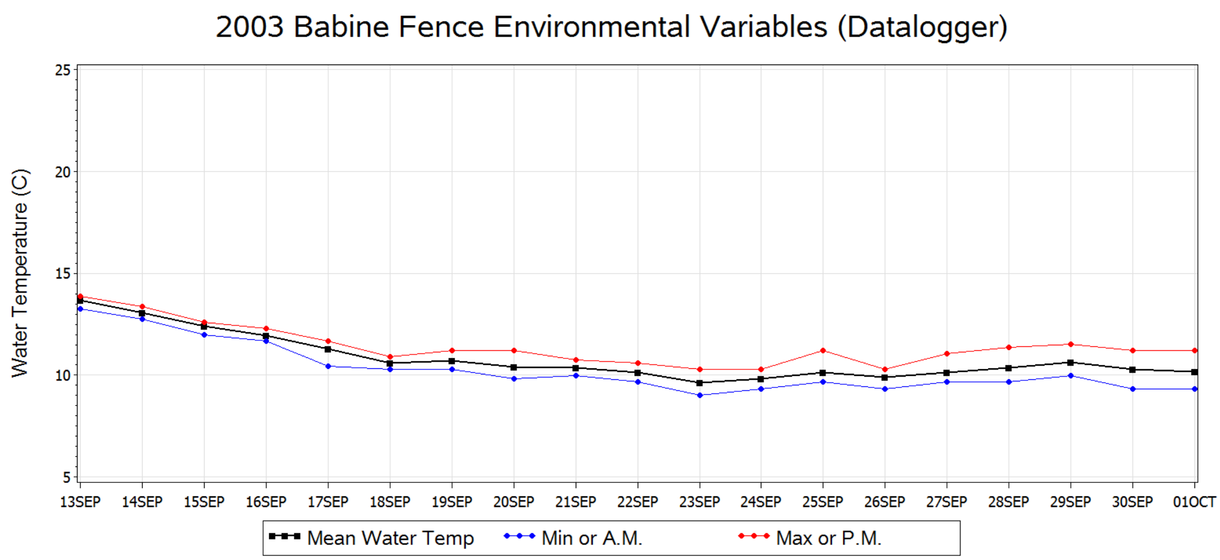


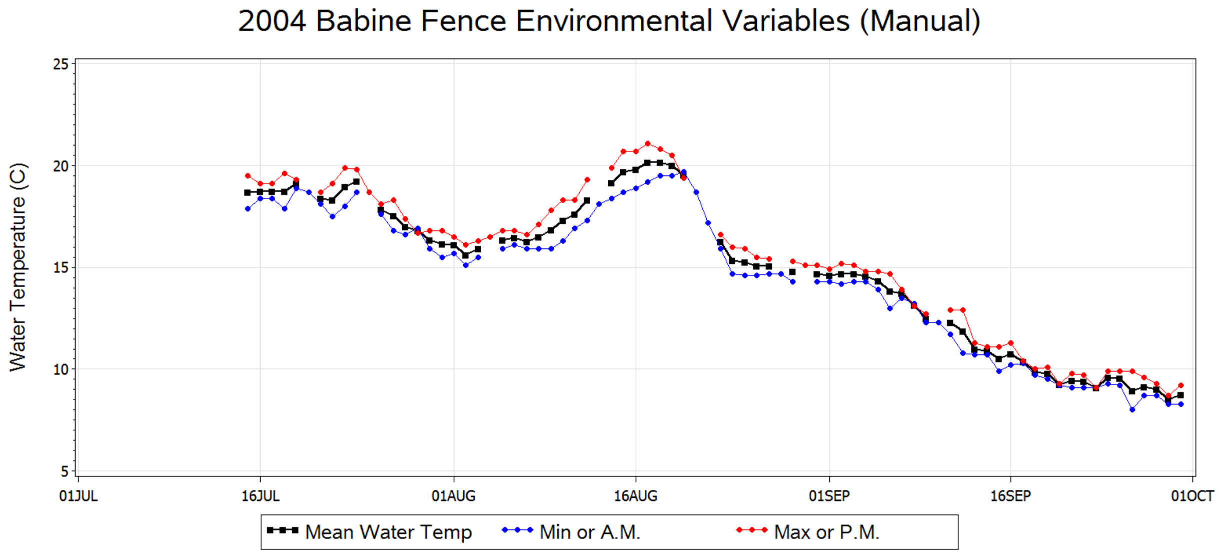
Figure 45. Mean length (days) and frequency of “high flow” periods in which Babine at Nilkitkwa discharge continuously remained above the 90th percentile of July-September flows (~120 cms).

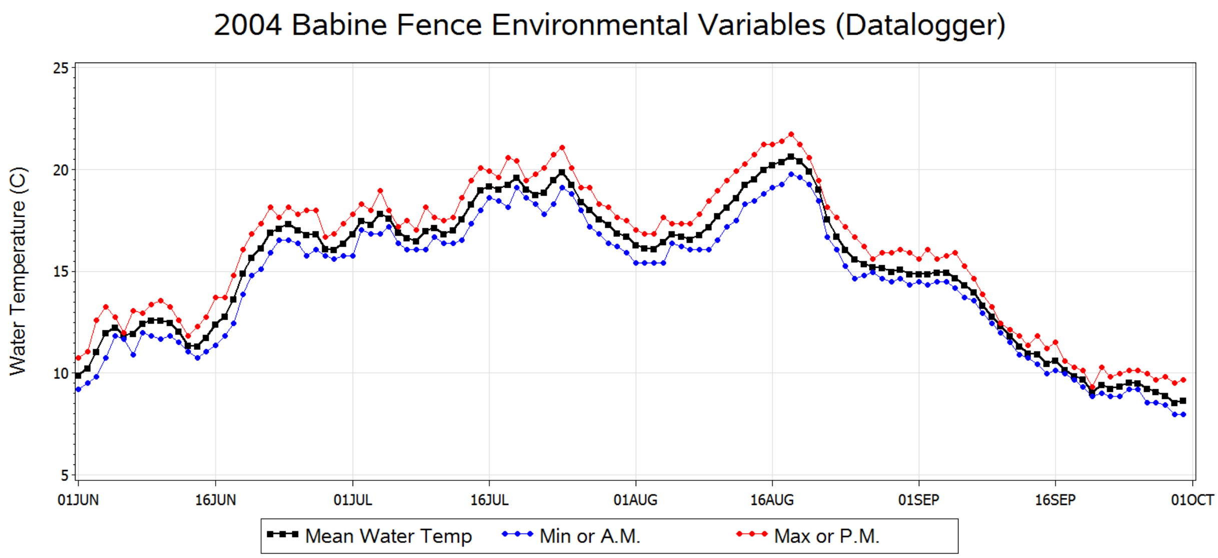
APPENDICES

Appendix A. Babine River water temperature observations, by year and data source, 2003-2014. Mean water temperature (black square) calculated from either daily minimum and maximum for data logger data, or morning and afternoon observations for manual thermometer data. In some cases, no mean was estimated due to missing or uncertain temperature readings. For some years of manual data, only a mean value was available, which was assumed to be based on multiple observations (i.e., morning and afternoon).

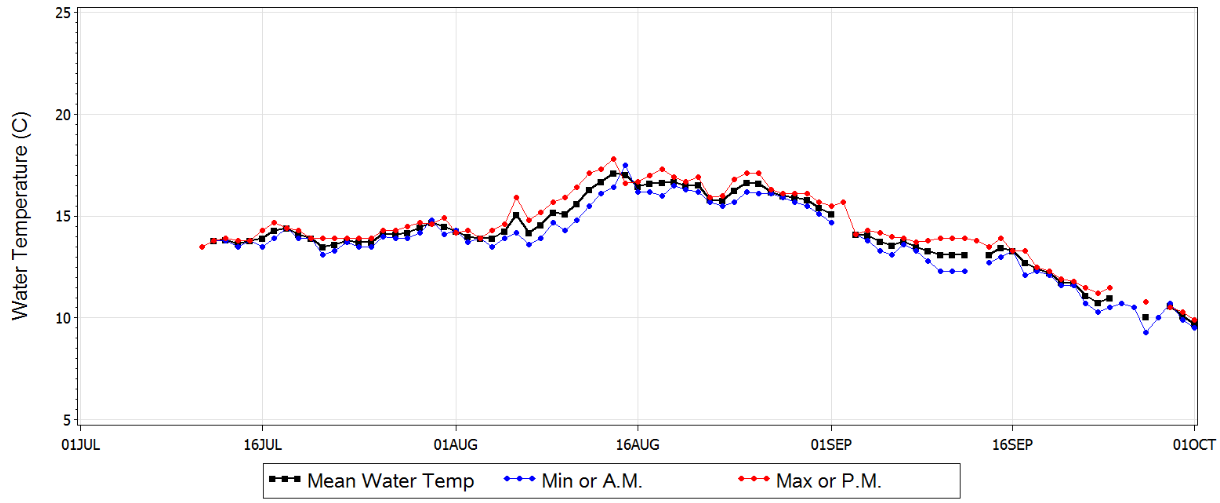




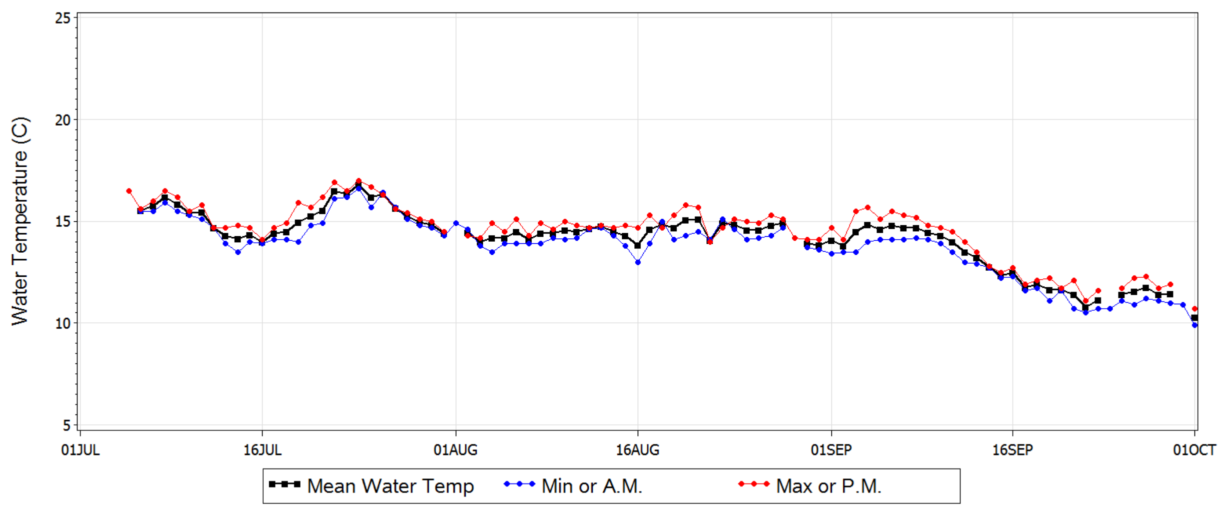

2004 Babine Fence Environmental Variables (Manual)
Water Temperature (C)
25
20
15
10
5
01JUL
16JUL
01AUG
16AUG
01SEP
16SEP
01OCT
Mean Water Temp
Min or A.M.
Max or P.M.


2004 Babine Fence Environmental Variables (Datalogger)
Water Temperature (C)
25
20
15
10
5
01JUN
16JUN
01JUL
16JUL
01AUG
16AUG
01SEP
16SEP
01OCT
Mean Water Temp
Min or A.M.
Max or P.M.

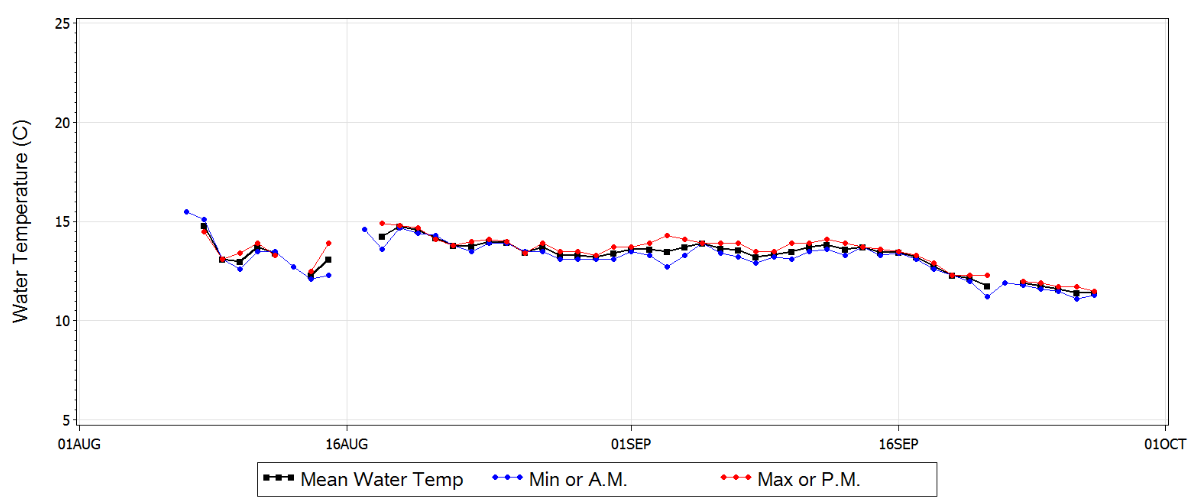
2005 Babine Fence Environmental Variables (Manual)

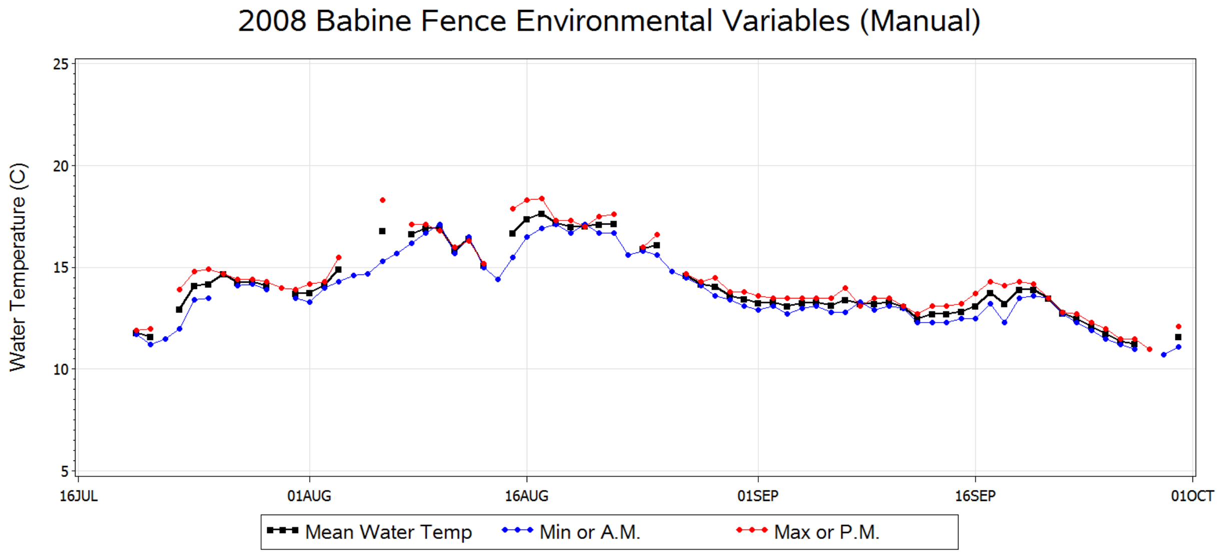


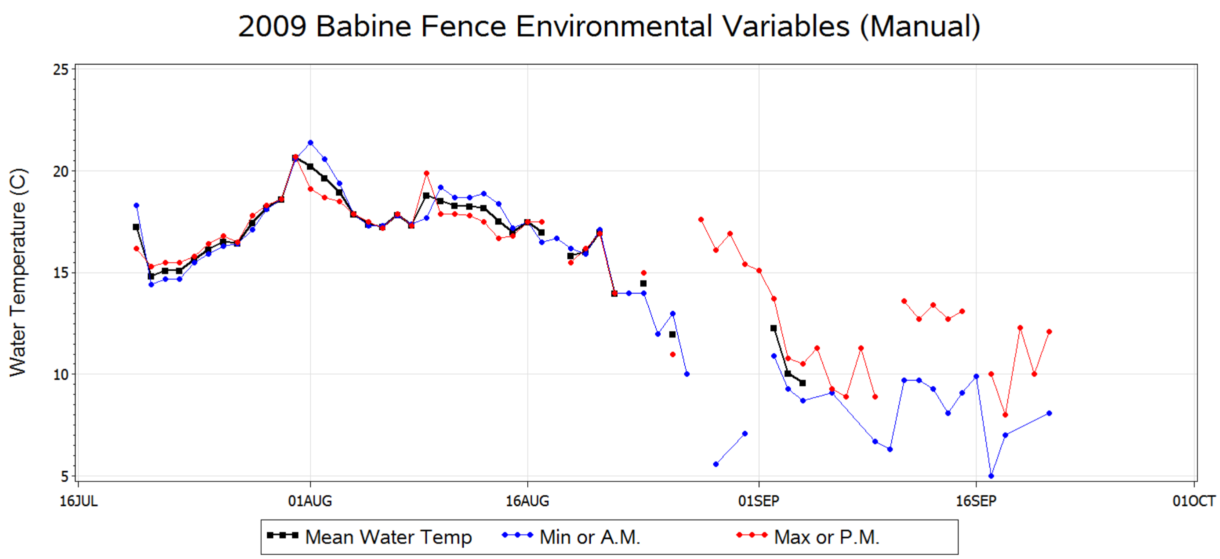
2006 Babine Fence Environmental Variables (Manual)



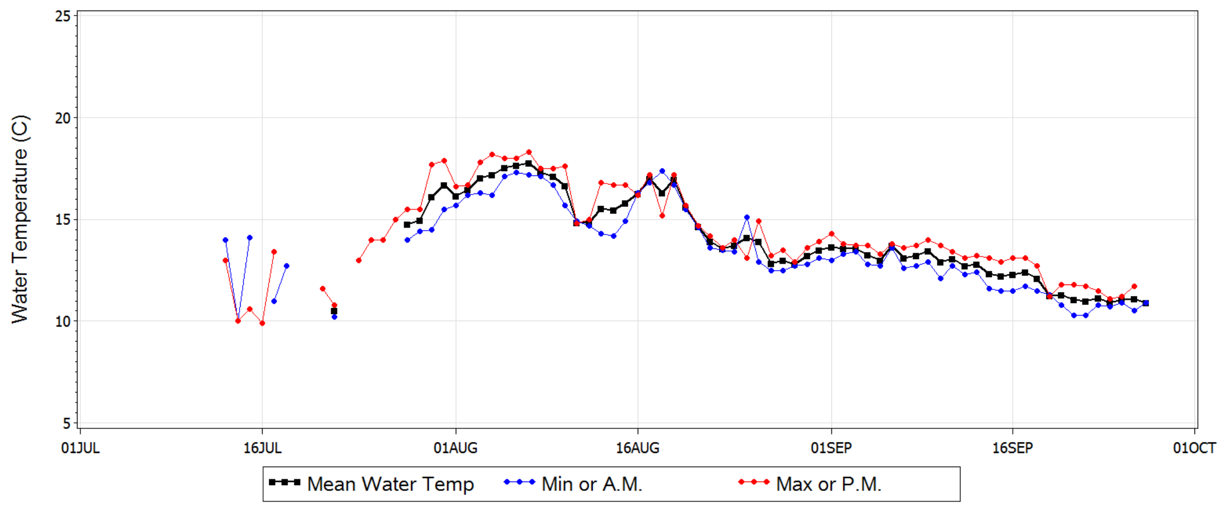
2007 Babine Fence Environmental Variables (Manual)



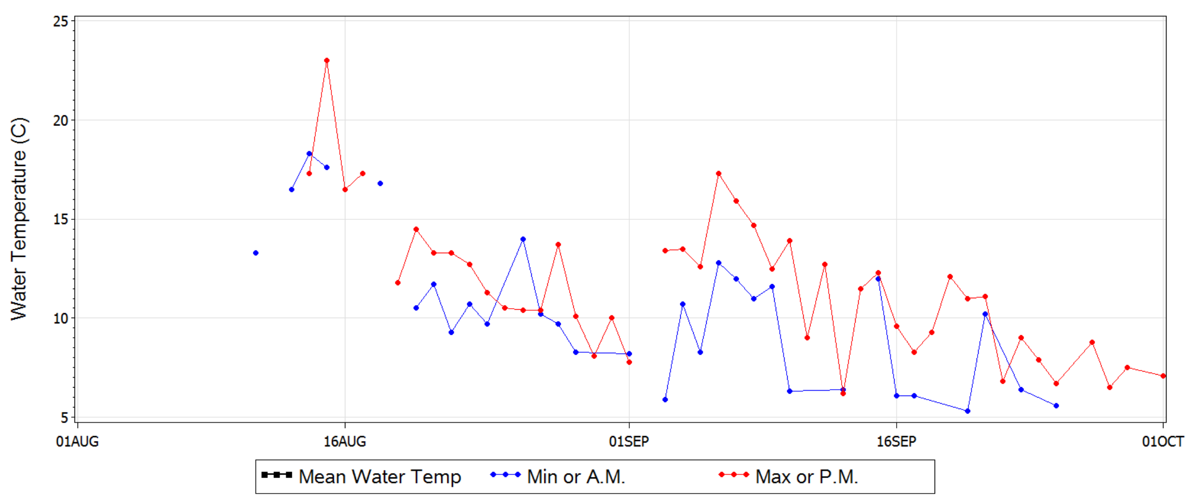

2008 Babine Fence Environmental Variables (Manual)
Water Temperature (C)
25
20
15
10
5
16JUL
01AUG
16AUG
01SEP
16SEP
01OCT
Mean Water Temp
Min or A.M.
Max or P.M.


2009 Babine Fence Environmental Variables (Manual)
Water Temperature (C)
25
20
15
10
5
16JUL
01AUG
16AUG
01SEP
16SEP
01OCT
Mean Water Temp
Min or A.M.
Max or P.M.

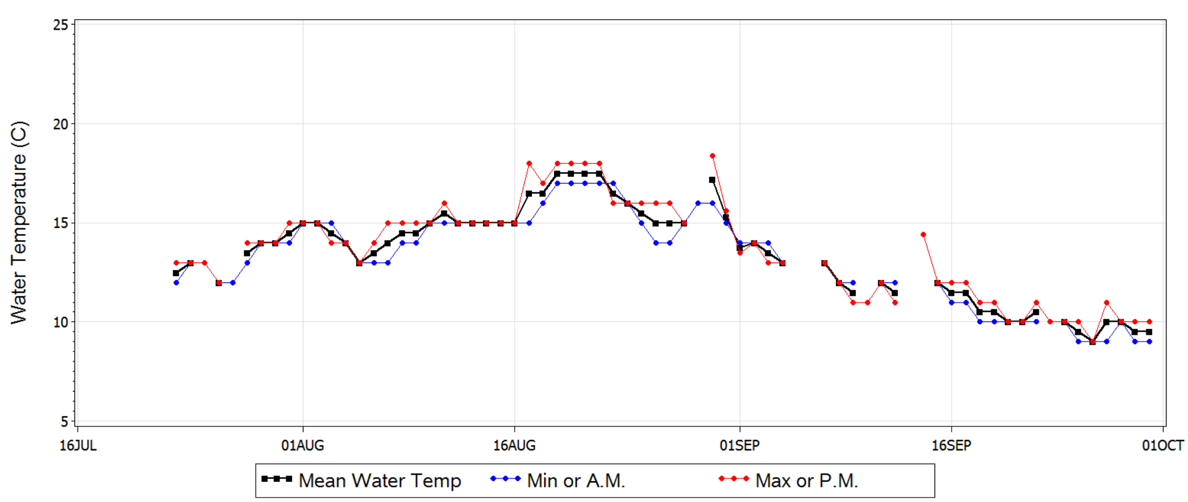
2010 Babine Fence Environmental Variables (Manual)



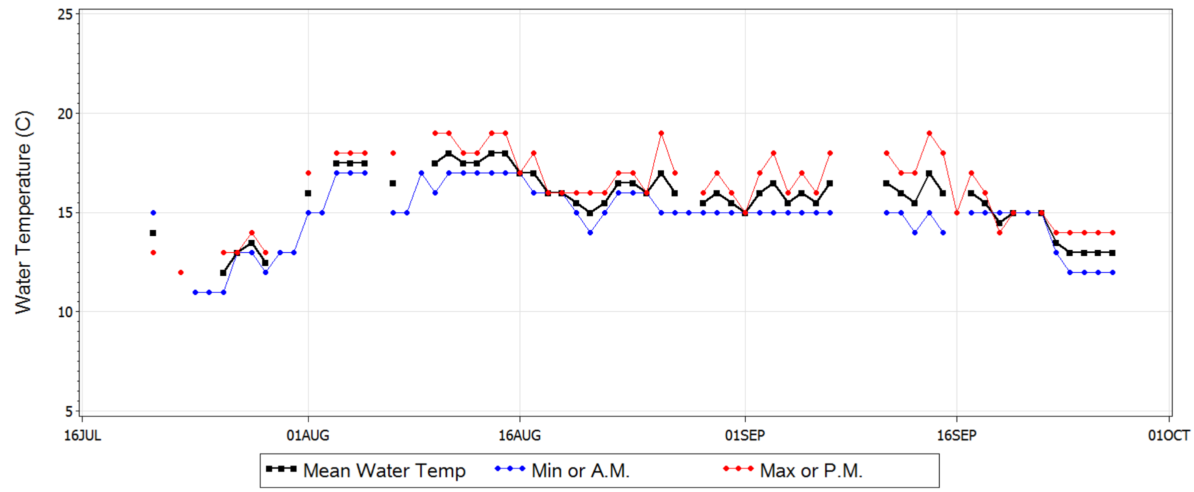
2011 Babine Fence Environmental Variables (Manual)



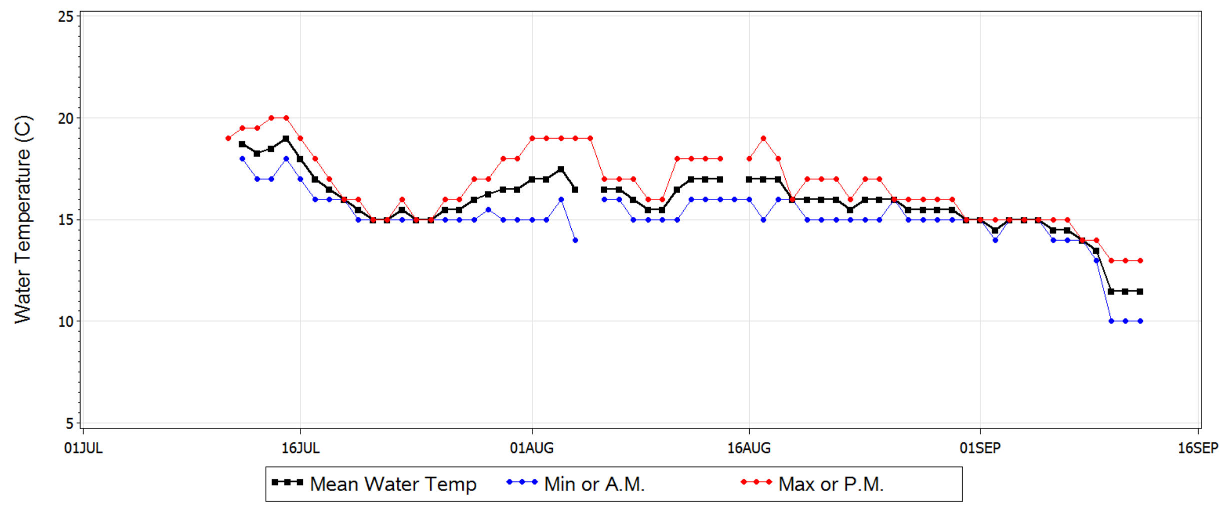
2012 Babine Fence Environmental Variables (Manual)



2013 Babine Fence Environmental Variables (Manual)

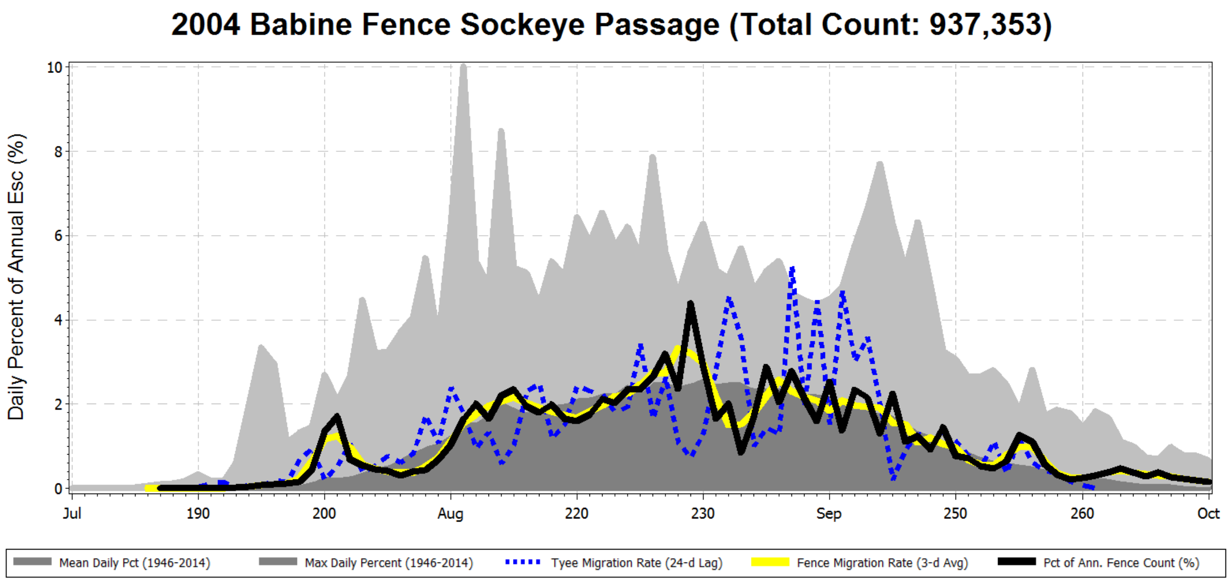


2014 Babine Fence Environmental Variables (Manual)

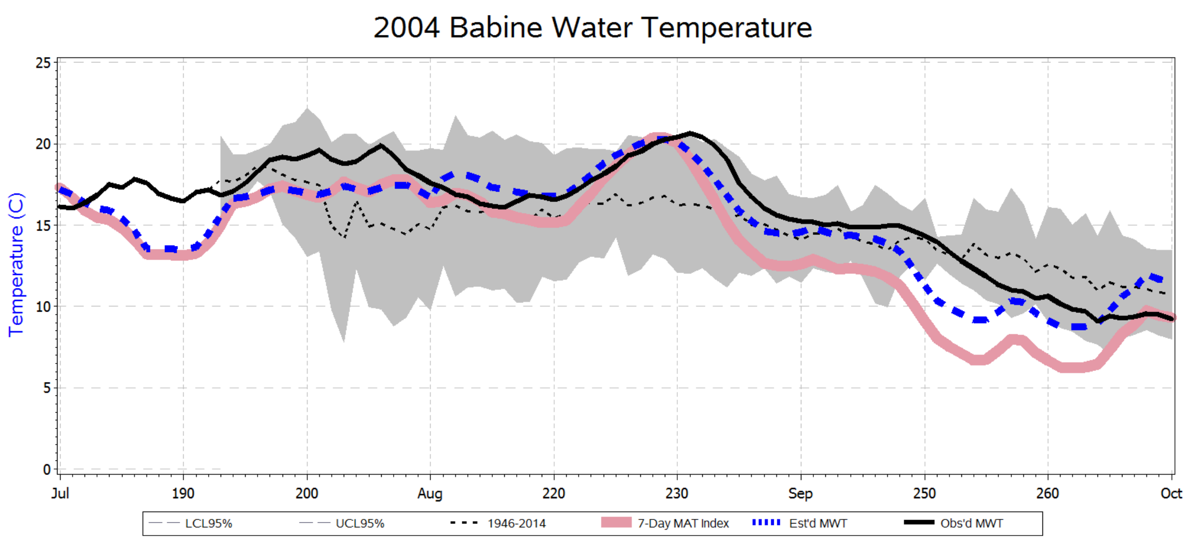


Appendix B. Multi-panel plots of daily Babine Sockeye migration in relation to environmental variables, by year, 1946-2014.

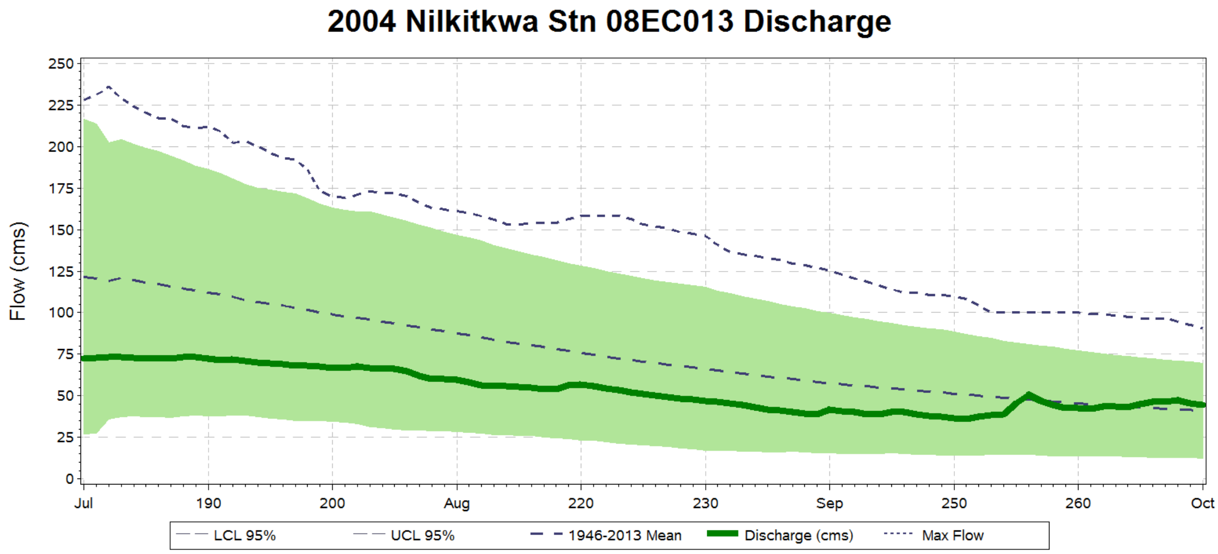
Sample plots for the year 2004 (below) display legend with vertical axis variates and horizontal axis with day of year (month label is *approximate* start of each month). Annual plots (following pages) are organized in a multi-panel format for cross-comparison of the following co-variates:



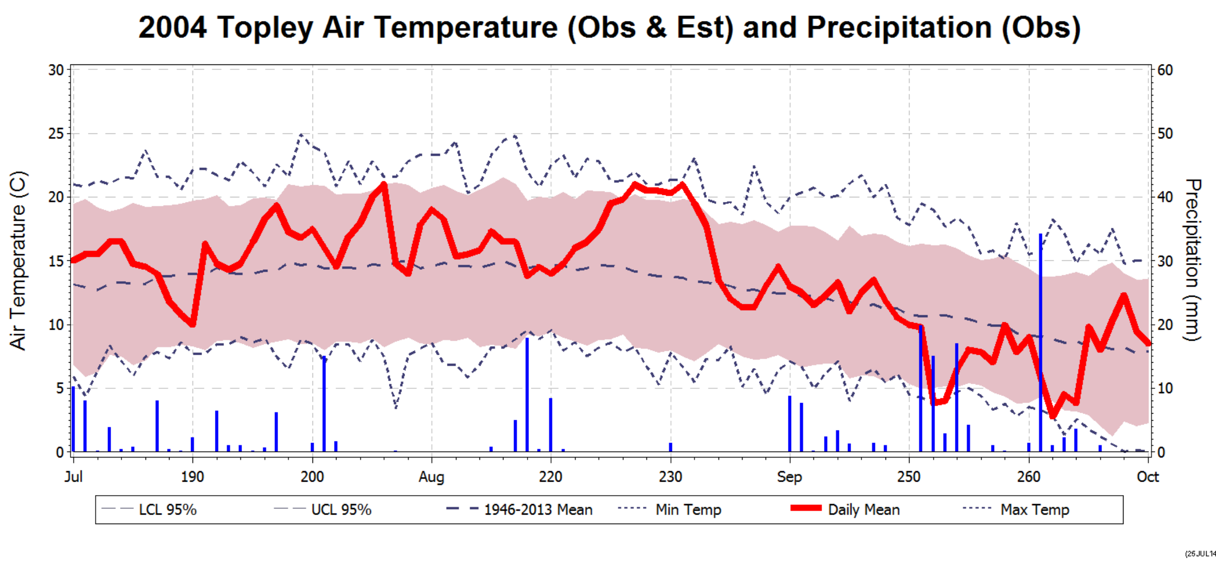
1. Daily migration rates (black line) as a percent (%) of annual counts from daily Sockeye (adult + jack) migrants counted at the Babine fence (may include fence-based harvest operations, 198x-2014). Historical mean daily migration rate (dark gray area) and maximum daily migration rate (light gray area) for years 1946-2014. Daily TYEE INDEX (blue dashed line) as a percent (%) of total annual index, lagged 24 days.



2. Observed (solid black line) and estimated (dashed blue line) daily mean water temperature at the Babine fence, with historical daily MWT and variance (dashed line and gray area), 2003-2006, and 7-day daily mean air temperature index (pink).

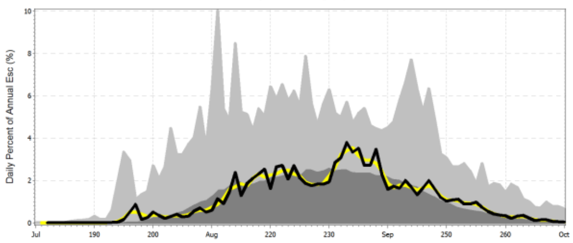


3. Daily mean discharge (cms) in the lower Babine River at WSC station BABINE RIVER BELOW NILKITKWA LAKE (green line), with historical daily mean and variance (dashed line and green area), 1946-2013. Observed data were available from 1973-2013; proxy data based on statistical relations with WSC data at BABINE RIVER BELOW BABINE LAKE station (upper Babine River) were used to infill missing data for 1946-1972.

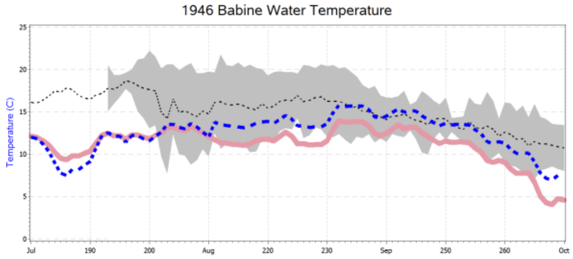


4. Observed precipitation (mm, blue bars), and regional daily mean air temperature (°C, red line) based on EC meteorological station TOPLEY LANDING (Babine Lake) with historical daily mean and variance (dashed line and red area), 1946-2012. Observed data at TOPLEY were available from 1966-2012; proxy data based on statistical relations with AHCCD data at (a) SMITHERS and (b) STEWART stations were used to infill missing TOPLEY air temperature data (but not precipitation) in 1946-1961, 1963-1965, 2008-2010. Non-AHCCD data from SMITHERS were used to estimate TOPLEY temperatures for 2013-2014.

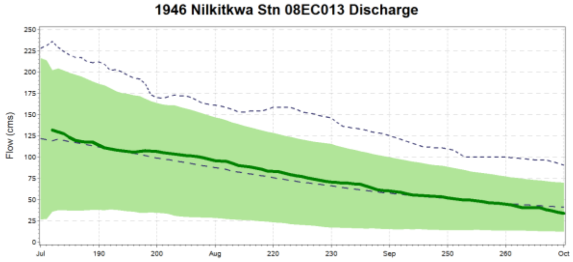
1946 Babine Fence Sockeye Passage (Total Count: 475,705)



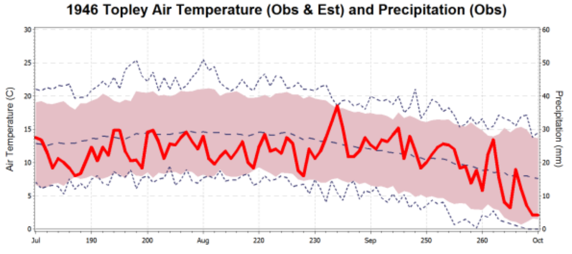
1946 Babine Water Temperature



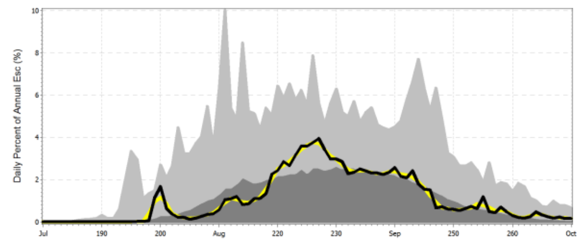
1946 Nilkitkwa Stn 08EC013 Discharge



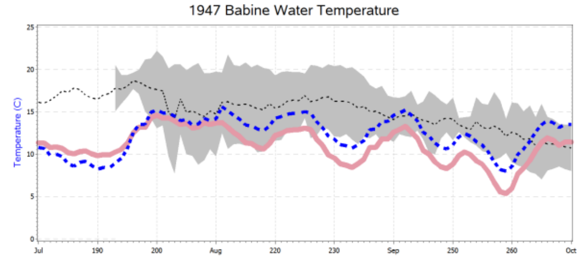
1946 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



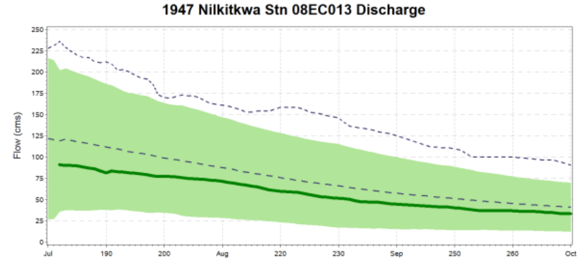
1947 Babine Fence Sockeye Passage (Total Count: 522,561)



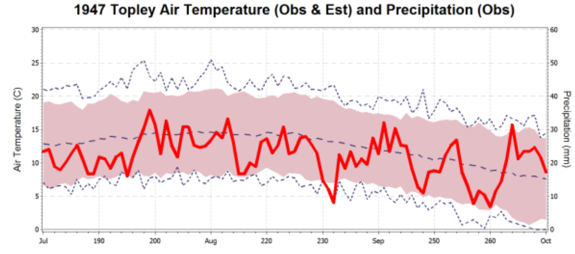
1947 Babine Water Temperature



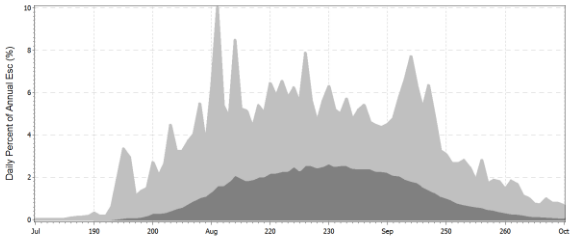
1947 Nilkitkwa Stn 08EC013 Discharge



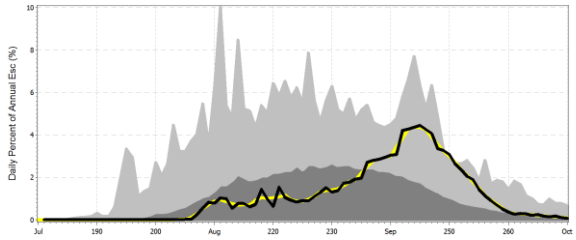
1947 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



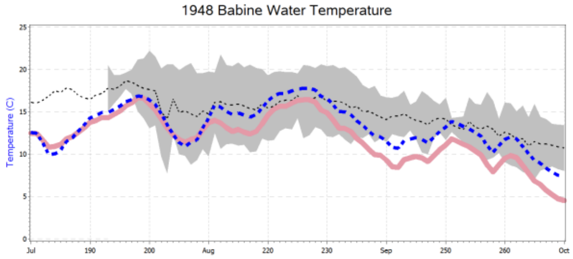
1948 Babine Fence Sockeye Passage (Total Count: .)



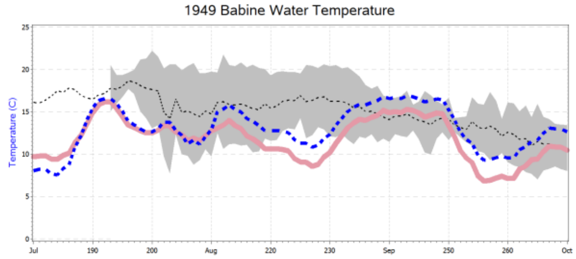
1949 Babine Fence Sockeye Passage (Total Count: 509,132)



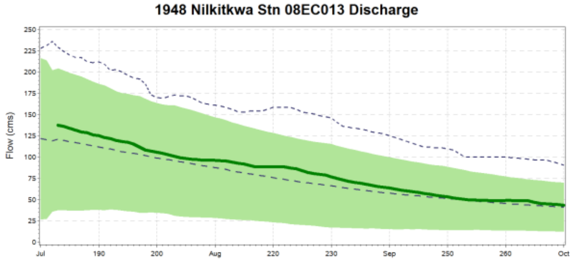
1948 Babine Water Temperature



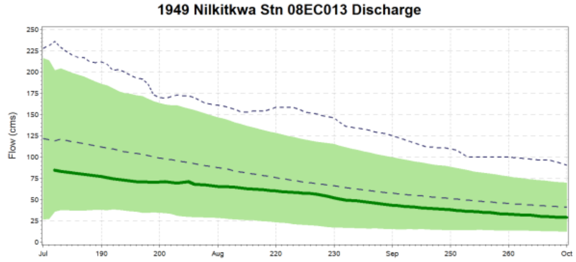
1949 Babine Water Temperature



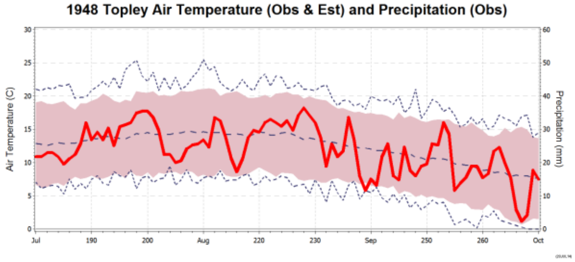
1948 Nilkitkwa Stn 08EC013 Discharge



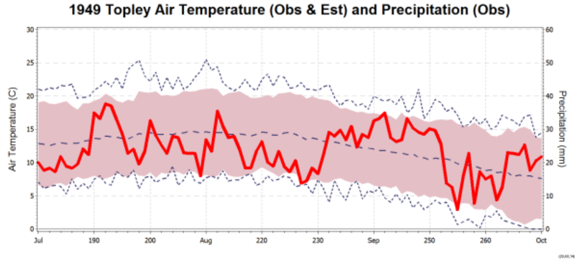
1949 Nilkitkwa Stn 08EC013 Discharge



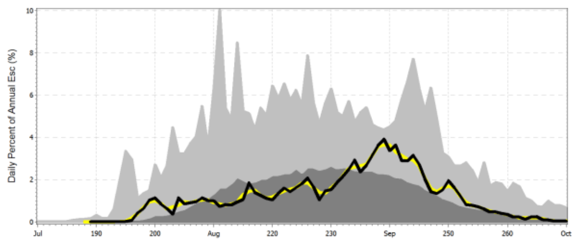
1948 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



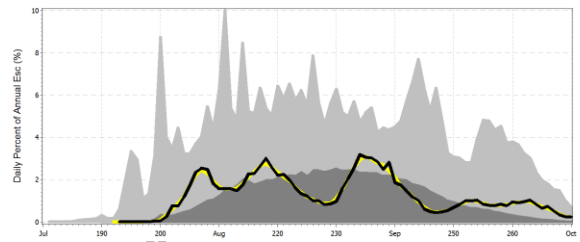
1949 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



1950 Babine Fence Sockeye Passage (Total Count: 543,668)

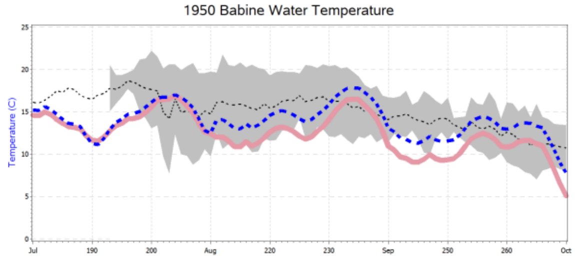


1951 Babine Fence Sockeye Passage (Total Count: 152,457)

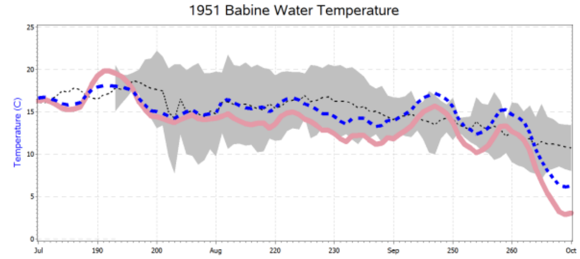


[55]

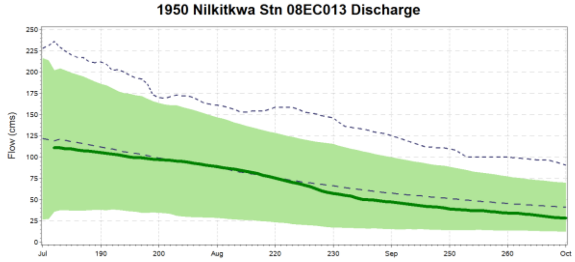
1950 Babine Water Temperature



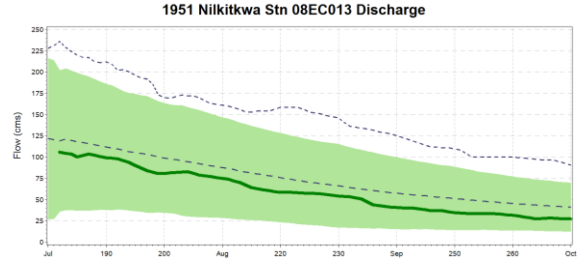
1951 Babine Water Temperature



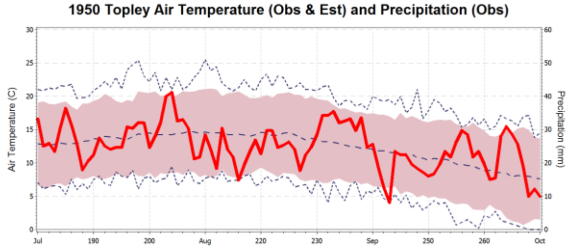
1950 Nilkitkwa Stn 08EC013 Discharge



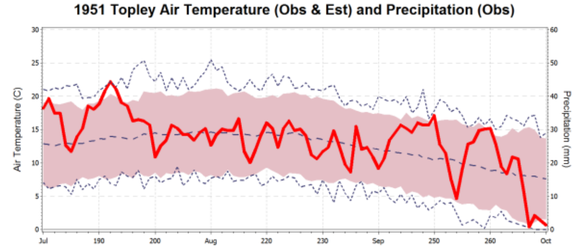
1951 Nilkitkwa Stn 08EC013 Discharge



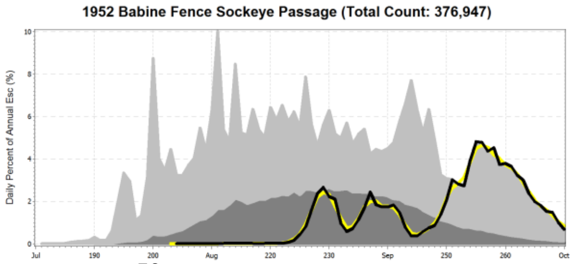
1950 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



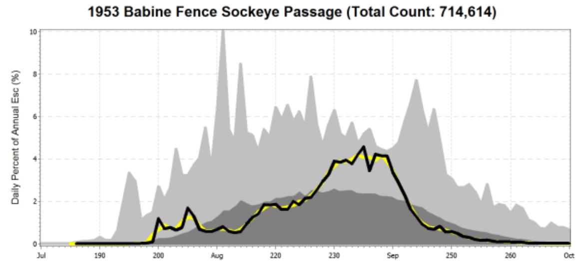
1951 Topley Air Temperature (Obs & Est) and Precipitation (Obs)

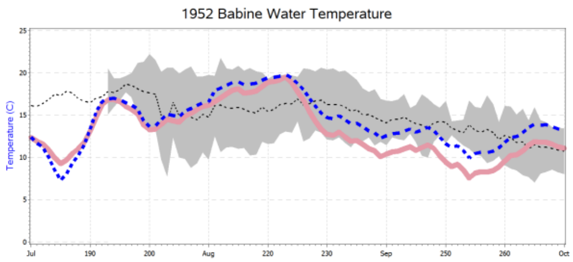


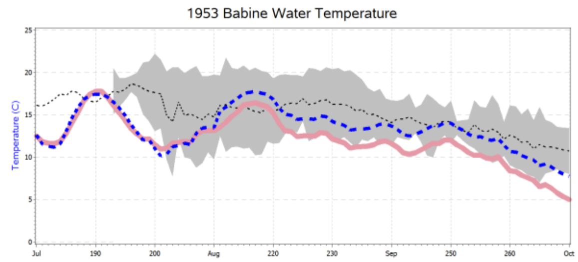
[55] Migration data excluded from analyses due to Babine Slide (1951-1952)

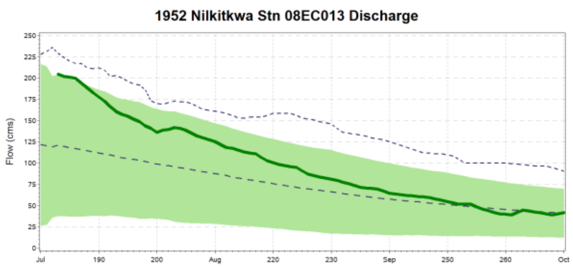


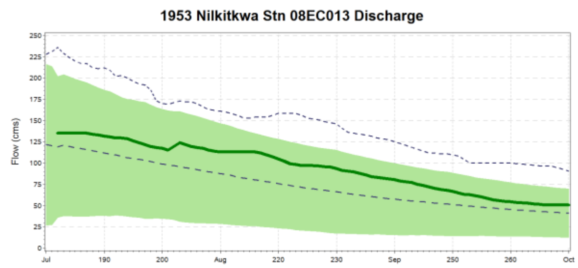
[56]

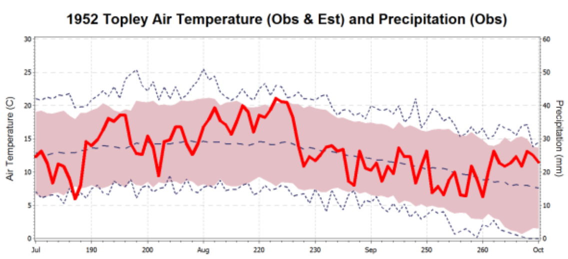


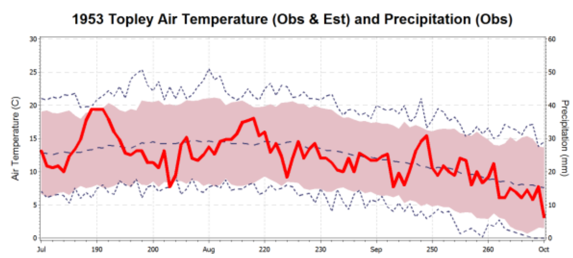






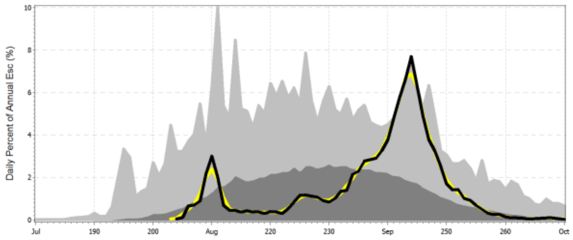




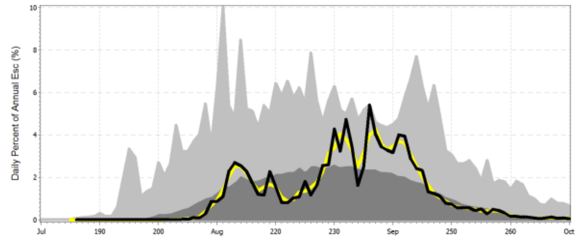


56 Migration data excluded from analyses due to Babine Slide (1951-1952)

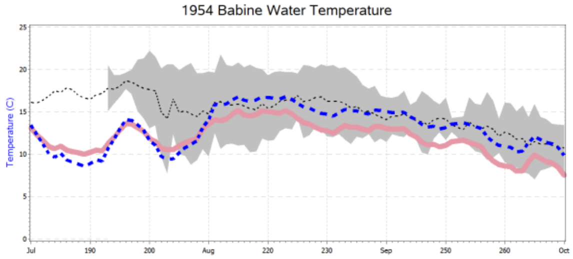
1954 Babine Fence Sockeye Passage (Total Count: 503,422)



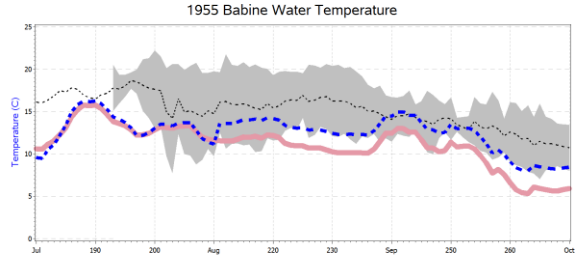
1955 Babine Fence Sockeye Passage (Total Count: 101,976)



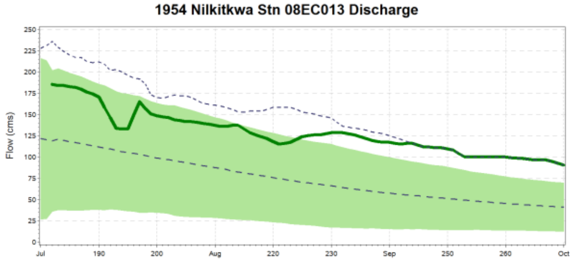
1954 Babine Water Temperature



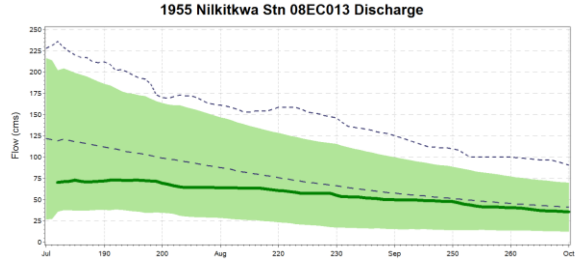
1955 Babine Water Temperature



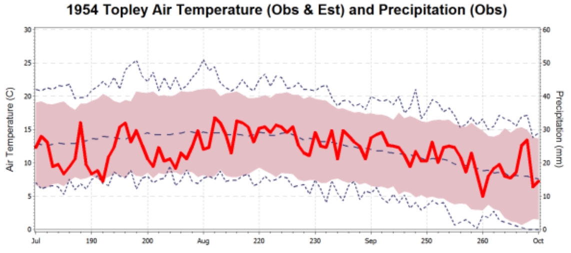
1954 Nilkitkwa Stn 08EC013 Discharge



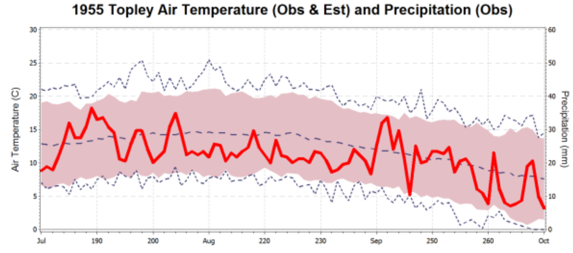
1955 Nilkitkwa Stn 08EC013 Discharge



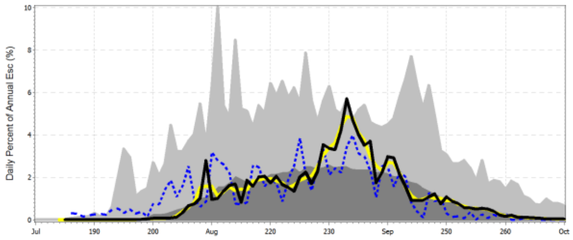
1954 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



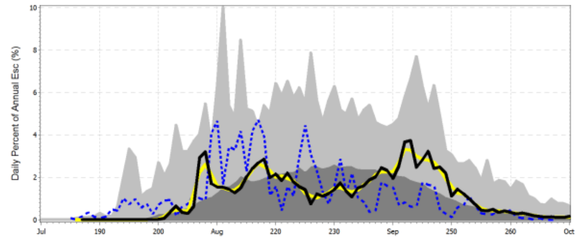
1955 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



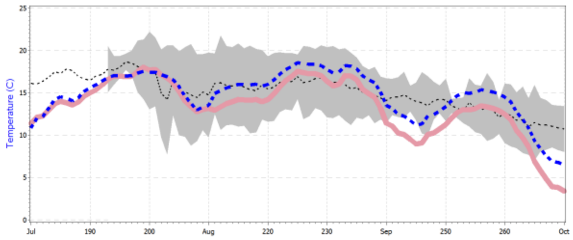
1956 Babine Fence Sockeye Passage (Total Count: 373,519)



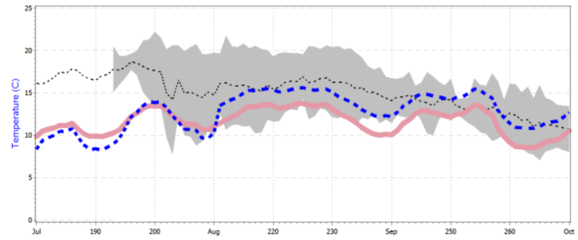
1957 Babine Fence Sockeye Passage (Total Count: 483,311)



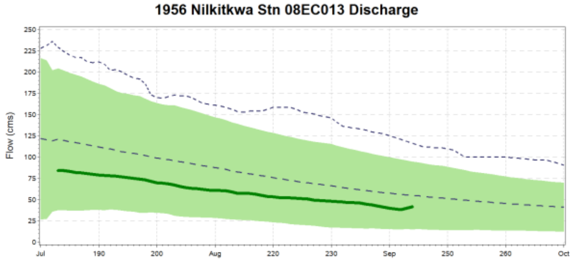
1956 Babine Water Temperature



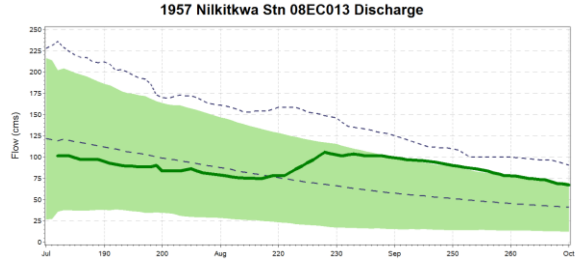
1957 Babine Water Temperature



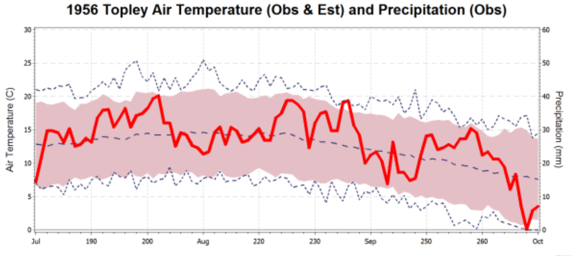
1956 Nilkitkwa Stn 08EC013 Discharge



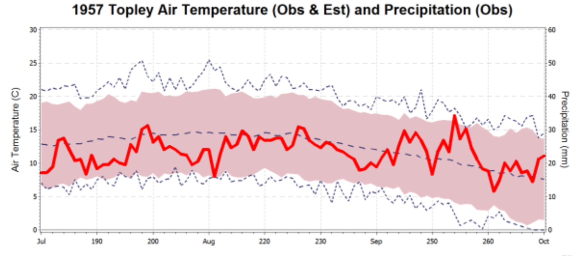
1957 Nilkitkwa Stn 08EC013 Discharge

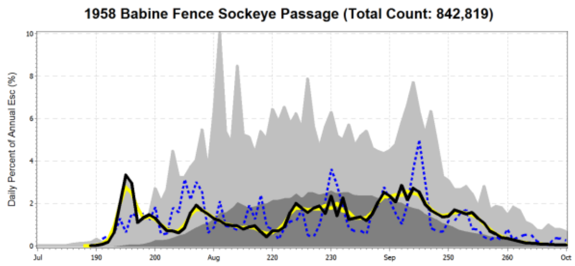


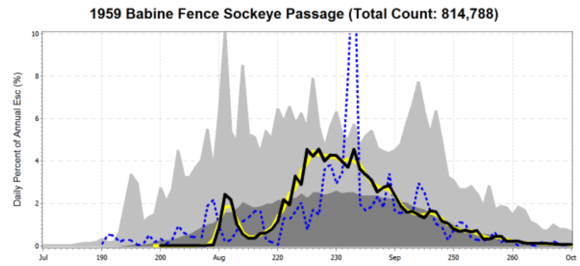
1956 Topley Air Temperature (Obs & Est) and Precipitation (Obs)

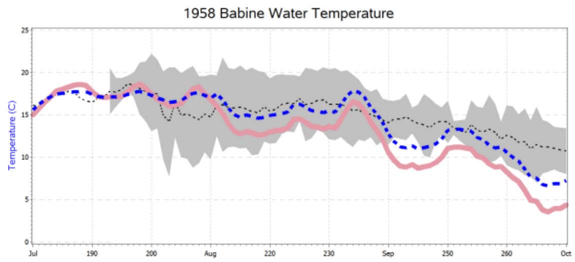


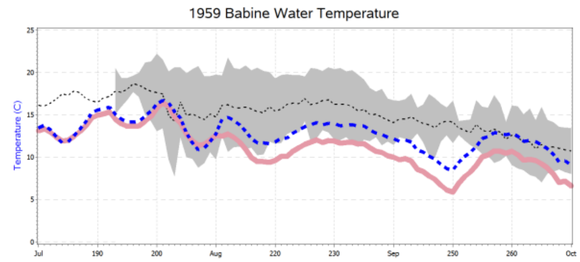
1957 Topley Air Temperature (Obs & Est) and Precipitation (Obs)

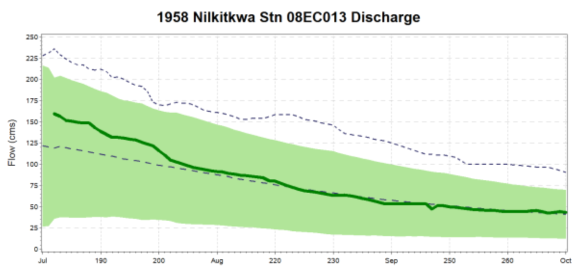


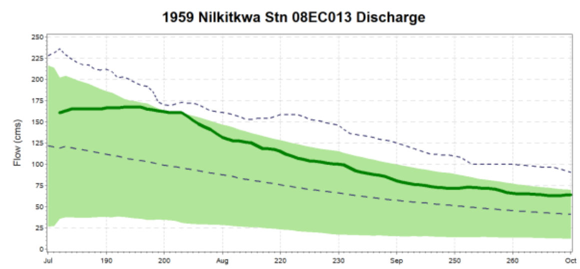

1958 Babine Fence Sockeye Passage (Total Count: 842,819)
Daily Percent of Annual Esc (%)

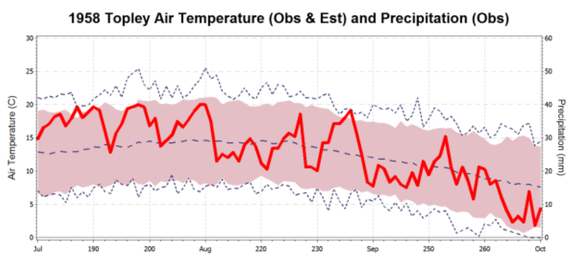

1959 Babine Fence Sockeye Passage (Total Count: 814,788)
Daily Percent of Annual Esc (%)

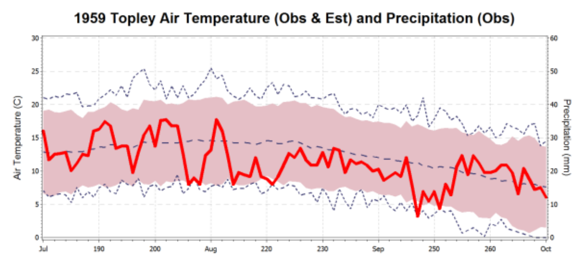

1958 Babine Water Temperature
Temperature (C)

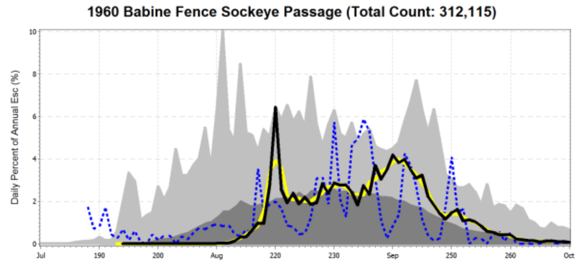

1959 Babine Water Temperature
Temperature (C)

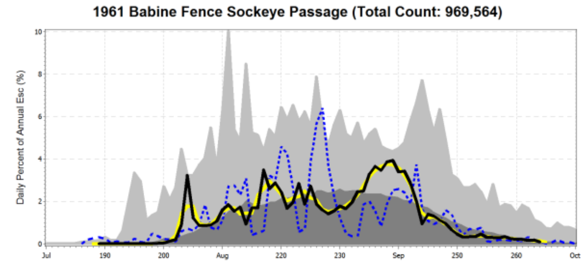

1958 Nilkitkwa Stn 08EC013 Discharge
Flow (cms)

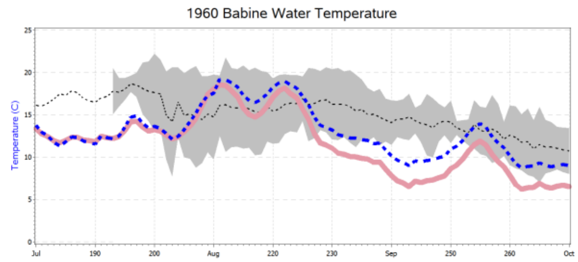

1959 Nilkitkwa Stn 08EC013 Discharge
Flow (cms)

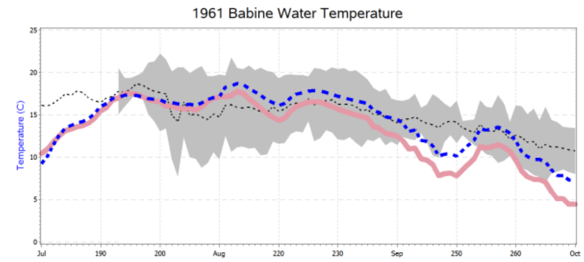

1958 Topley Air Temperature (Obs & Est) and Precipitation (Obs)
Air Temperature (C)
Precipitation (mm)

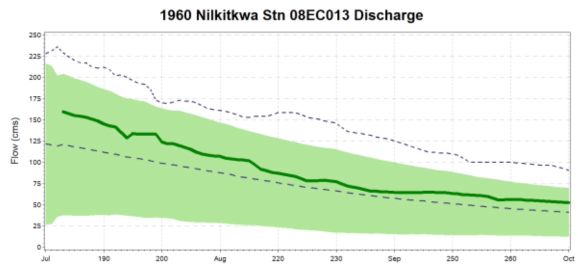

1959 Topley Air Temperature (Obs & Est) and Precipitation (Obs)
Air Temperature (C)
Precipitation (mm)

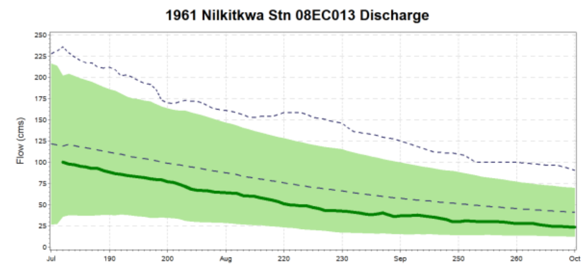

1960 Babine Fence Sockeye Passage (Total Count: 312,115)
Daily Percent of Annual Esc (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct

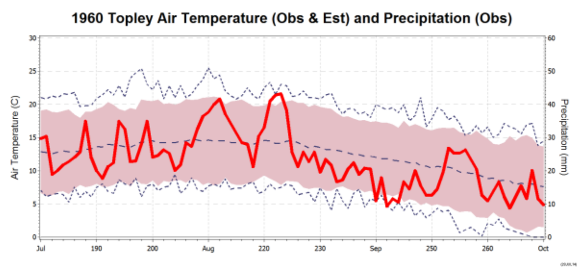

1961 Babine Fence Sockeye Passage (Total Count: 969,564)
Daily Percent of Annual Esc (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct

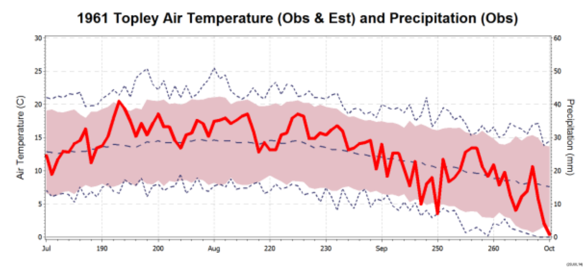

1960 Babine Water Temperature
Temperature (C)


1961 Babine Water Temperature
Temperature (C)

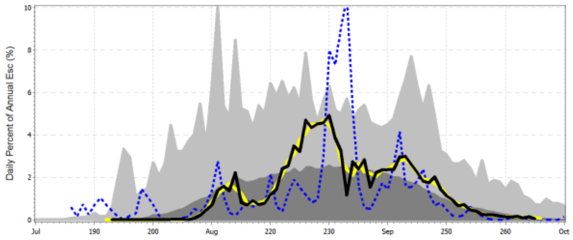

1960 Nilkitkwa Stn 08EC013 Discharge
Flow (cms)


1961 Nilkitkwa Stn 08EC013 Discharge
Flow (cms)

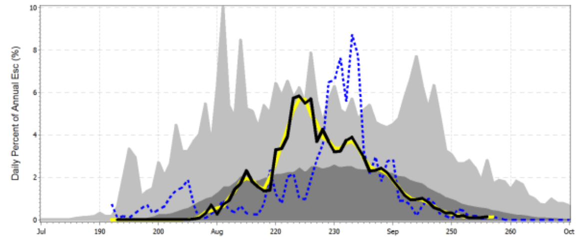

1960 Topley Air Temperature (Obs & Est) and Precipitation (Obs)
Air Temperature (C)
Precipitation (mm)


1961 Topley Air Temperature (Obs & Est) and Precipitation (Obs)
Air Temperature (C)
Precipitation (mm)

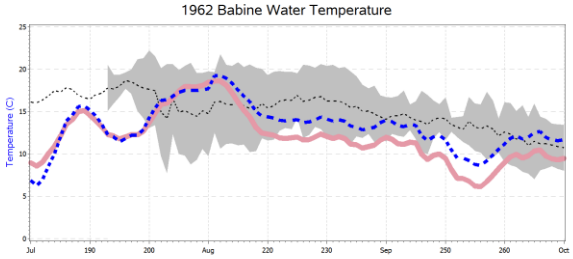
1962 Babine Fence Sockeye Passage (Total Count: 594,195)



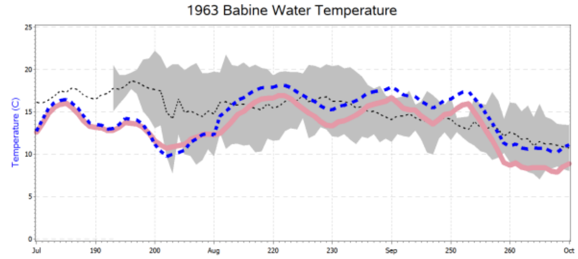
1963 Babine Fence Sockeye Passage (Total Count: 761,000)



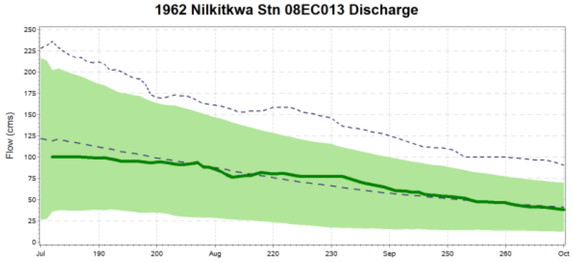
1962 Babine Water Temperature



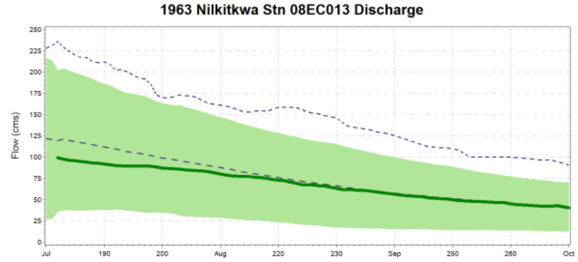
1963 Babine Water Temperature



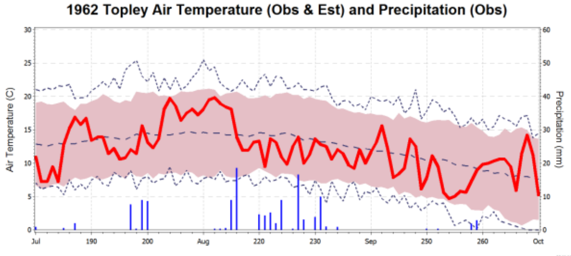
1962 Nilkitkwa Stn 08EC013 Discharge



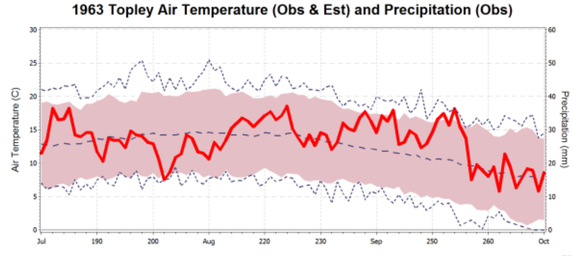
1963 Nilkitkwa Stn 08EC013 Discharge



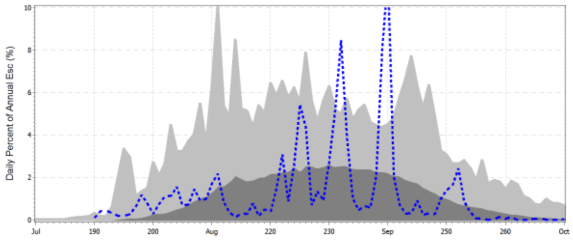
1962 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



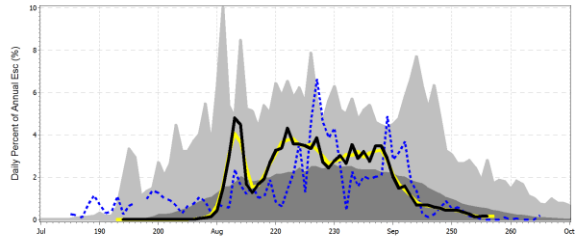
1963 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



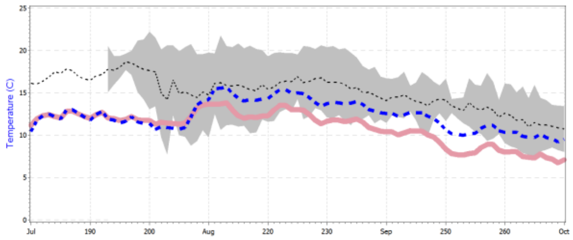
1964 Babine Fence Sockeye Passage (Total Count: .)



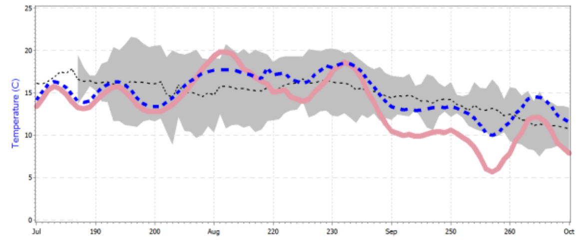
1965 Babine Fence Sockeye Passage (Total Count: 644,300)



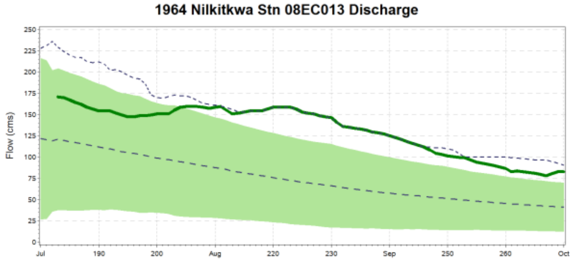
1964 Babine Water Temperature



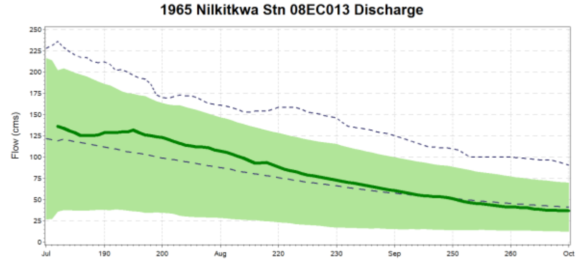
1965 Babine Water Temperature



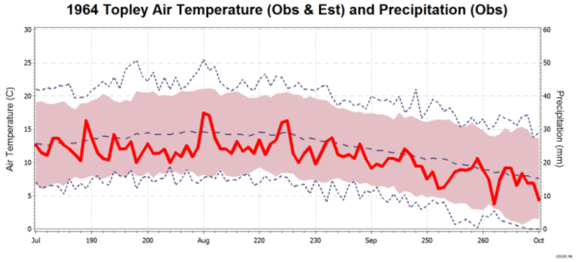
1964 Nilkitkwa Stn 08EC013 Discharge



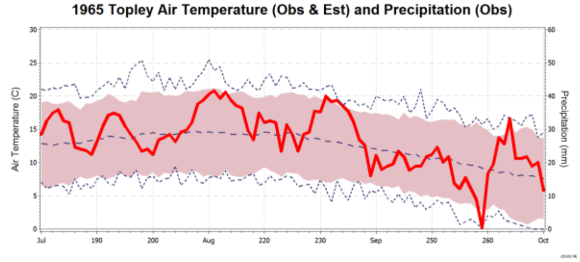
1965 Nilkitkwa Stn 08EC013 Discharge



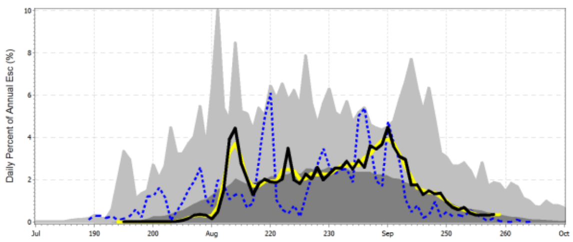
1964 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



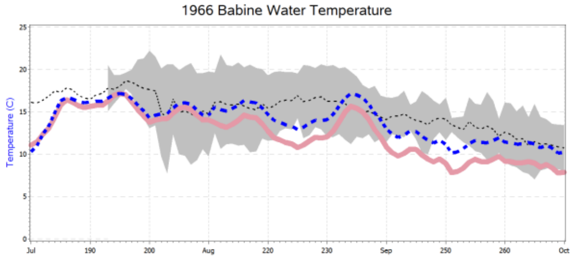
1965 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



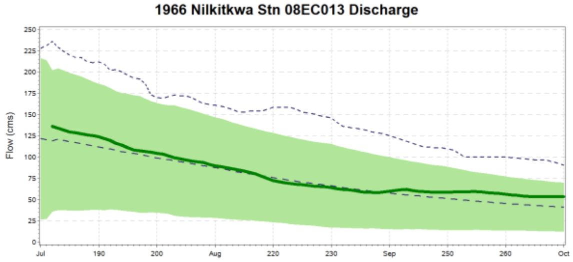
1966 Babine Fence Sockeye Passage (Total Count: 571,000)



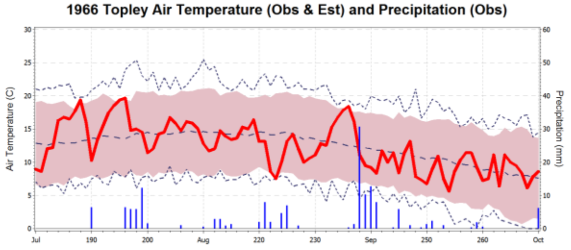
1966 Babine Water Temperature



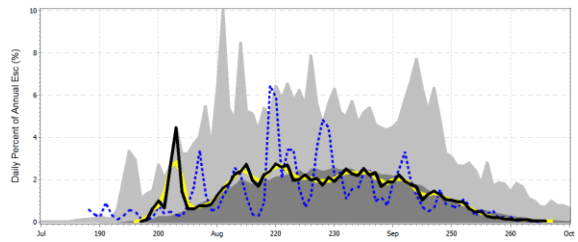
1966 Nilkitkwa Stn 08EC013 Discharge



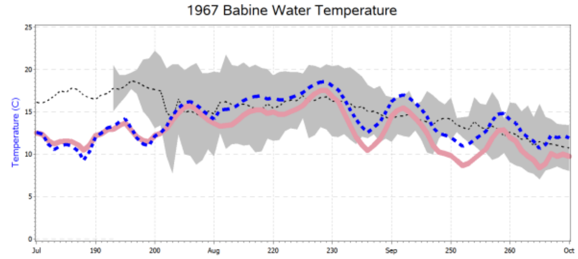
1966 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



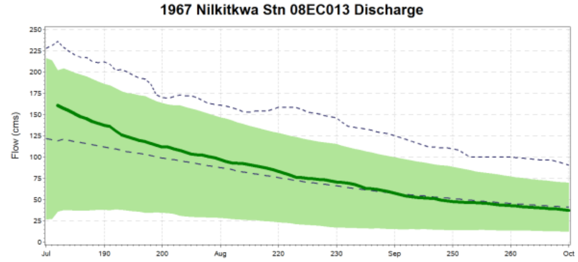
1967 Babine Fence Sockeye Passage (Total Count: 632,135)



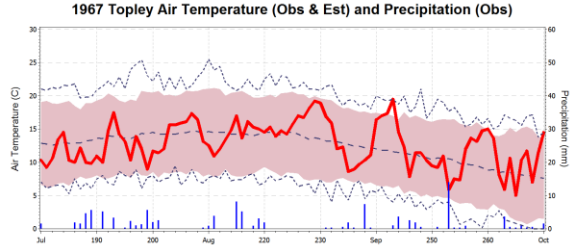
1967 Babine Water Temperature



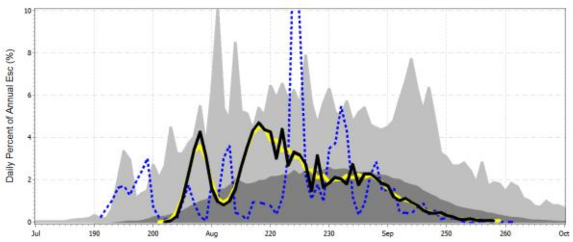
1967 Nilkitkwa Stn 08EC013 Discharge



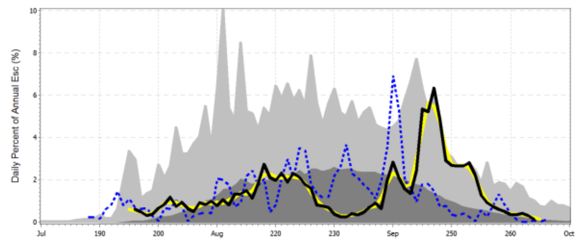
1967 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



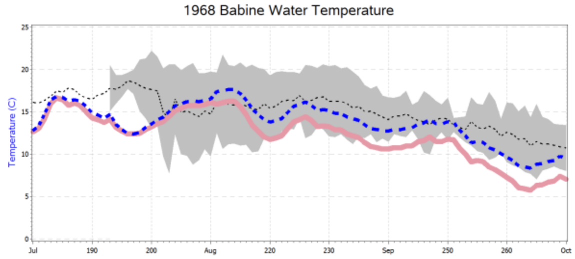
1968 Babine Fence Sockeye Passage (Total Count: 605,400)



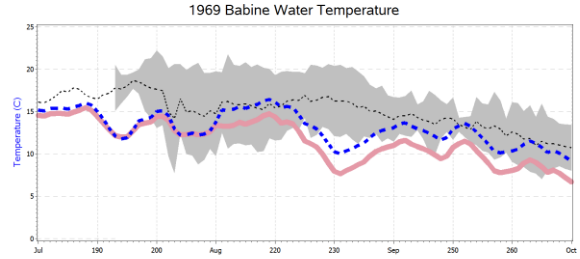
1969 Babine Fence Sockeye Passage (Total Count: 787,900)



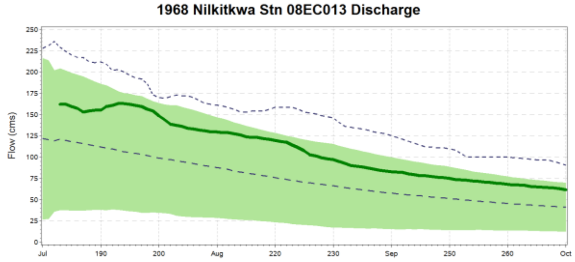
1968 Babine Water Temperature



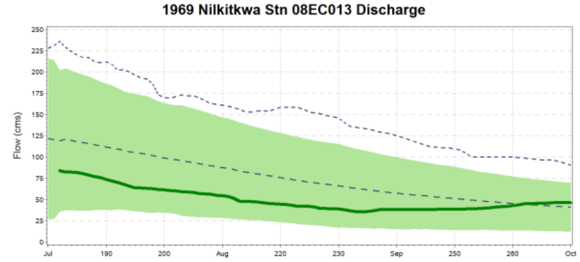
1969 Babine Water Temperature



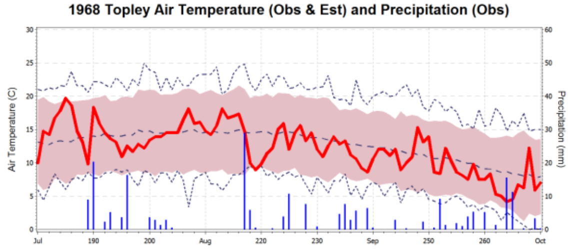
1968 Nilkitkwa Stn 08EC013 Discharge



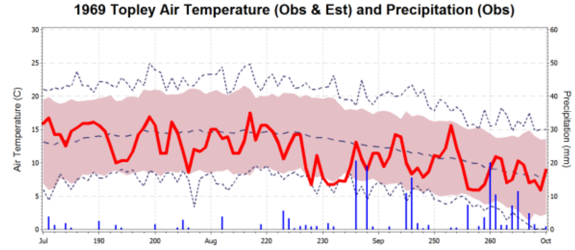
1969 Nilkitkwa Stn 08EC013 Discharge



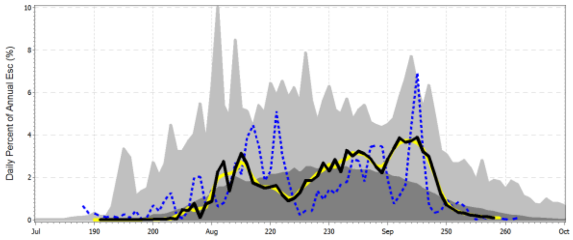
1968 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



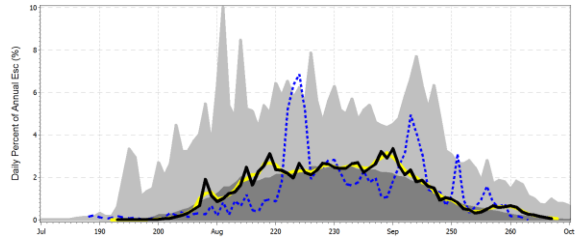
1969 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



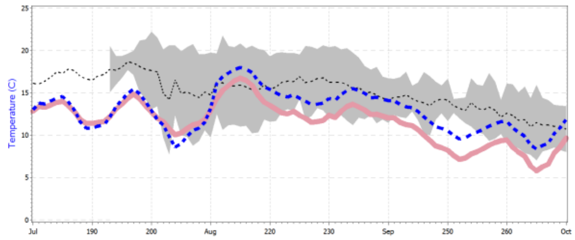
1970 Babine Fence Sockeye Passage (Total Count: 828,000)



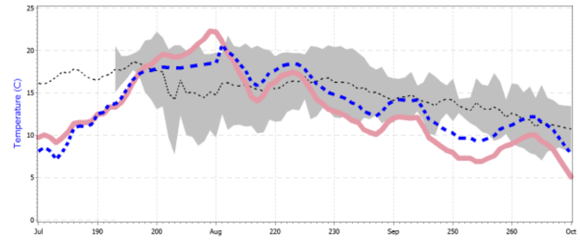
1971 Babine Fence Sockeye Passage (Total Count: 870,600)



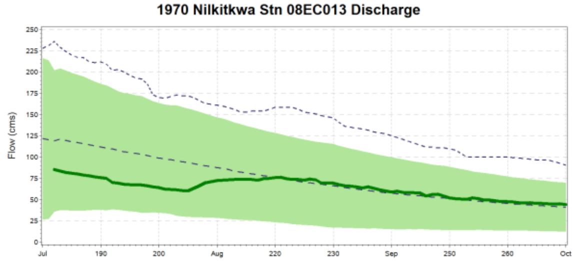
1970 Babine Water Temperature



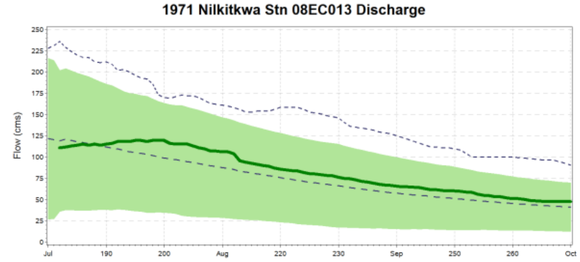
1971 Babine Water Temperature



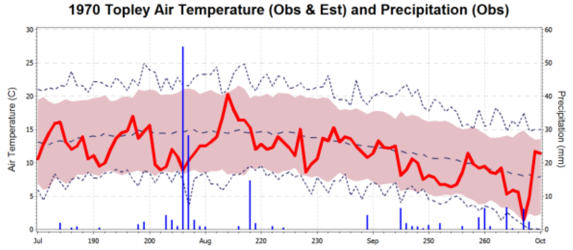
1970 Nilkitkwa Stn 08EC013 Discharge



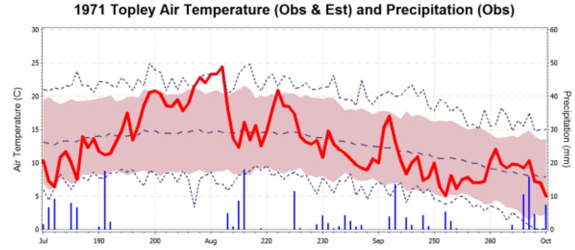
1971 Nilkitkwa Stn 08EC013 Discharge



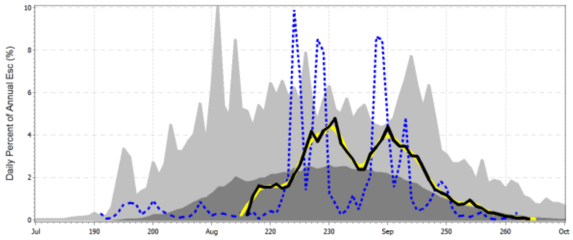
1970 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



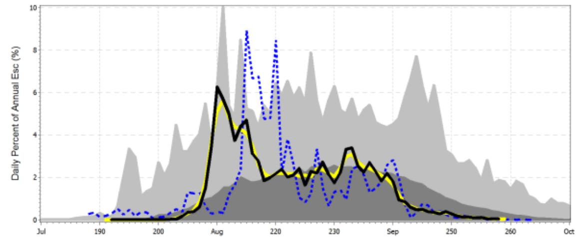
1971 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



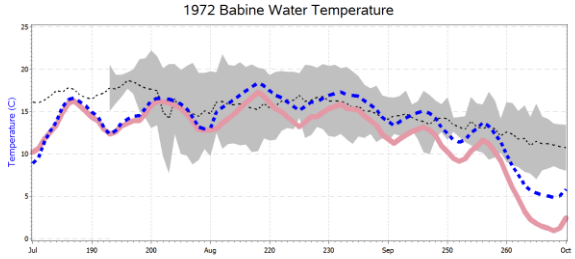
1972 Babine Fence Sockeye Passage (Total Count: 918,827)



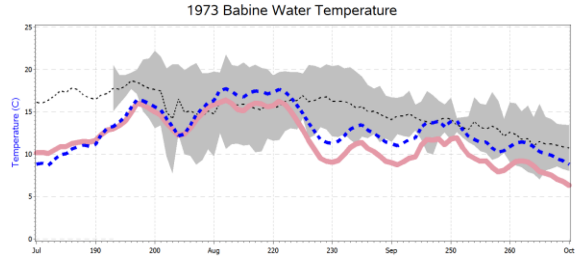
1973 Babine Fence Sockeye Passage (Total Count: 1,005,811)



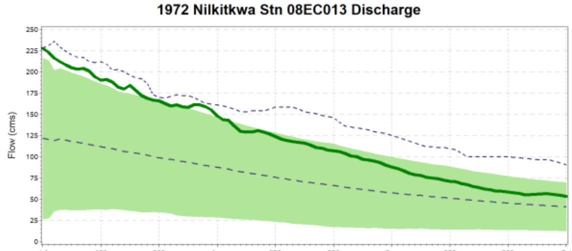
1972 Babine Water Temperature



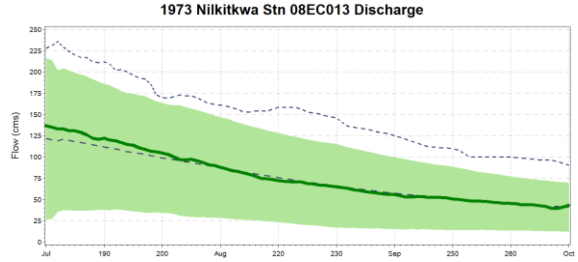
1973 Babine Water Temperature



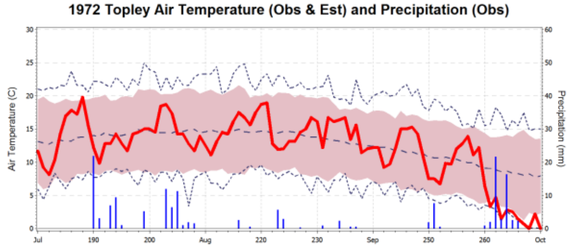
1972 Nilkitkwa Stn 08EC013 Discharge



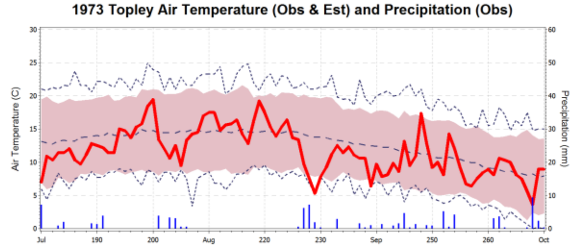
1973 Nilkitkwa Stn 08EC013 Discharge



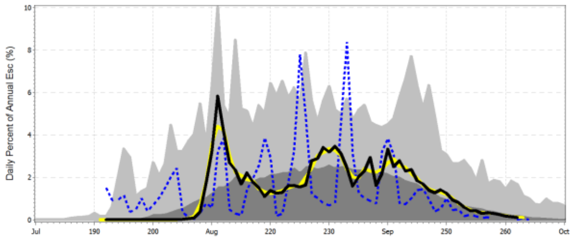
1972 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



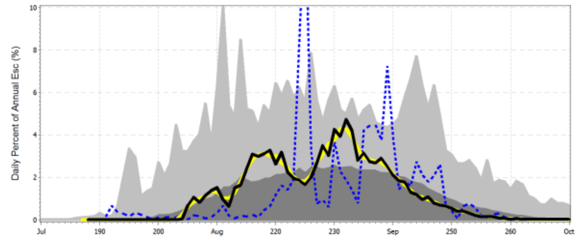
1973 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



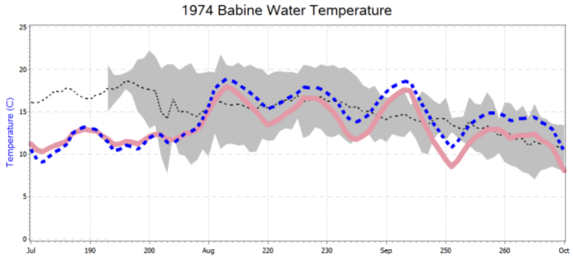
1974 Babine Fence Sockeye Passage (Total Count: 983,762)



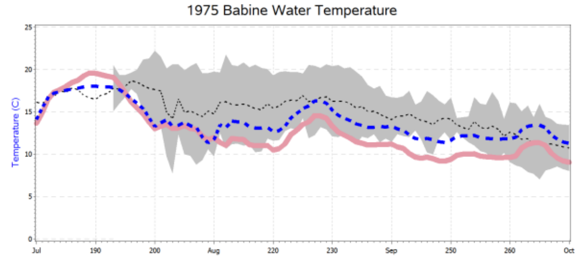
1975 Babine Fence Sockeye Passage (Total Count: 958,191)



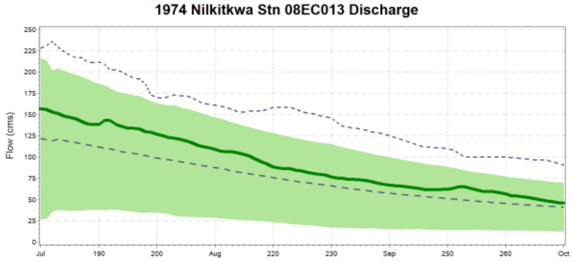
1974 Babine Water Temperature



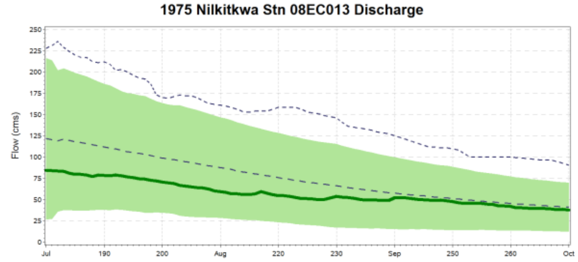
1975 Babine Water Temperature



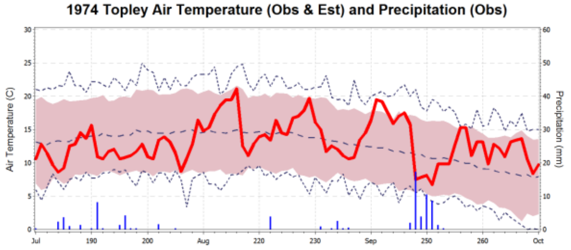
1974 Nilkitkwa Stn 08EC013 Discharge



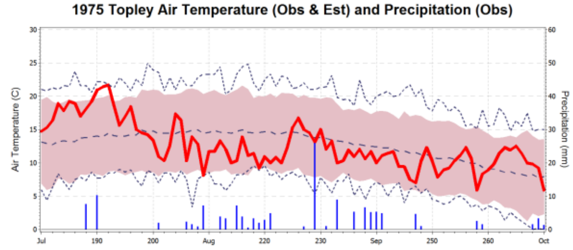
1975 Nilkitkwa Stn 08EC013 Discharge



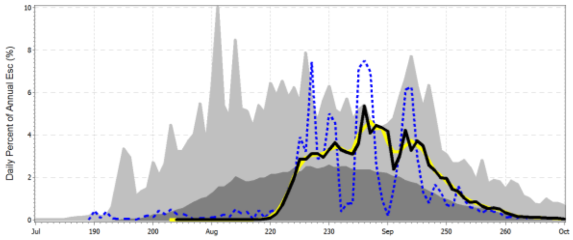
1974 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



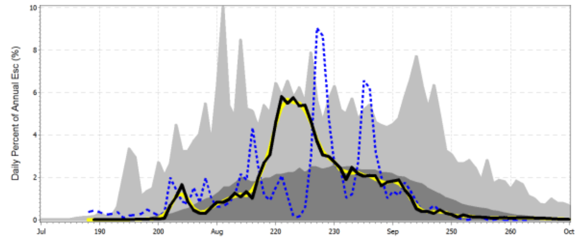
1975 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



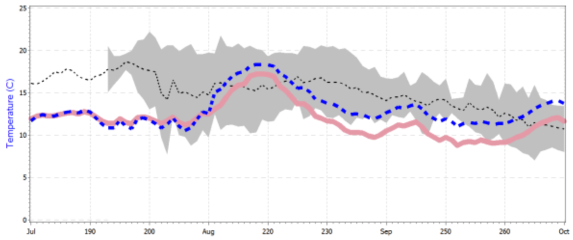
1976 Babine Fence Sockeye Passage (Total Count: 836,055)



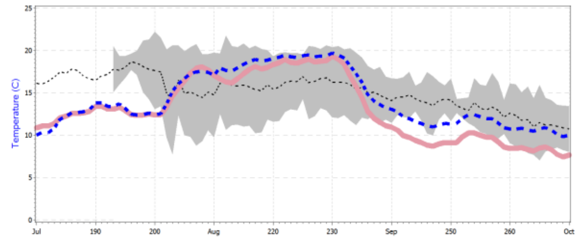
1977 Babine Fence Sockeye Passage (Total Count: 985,689)



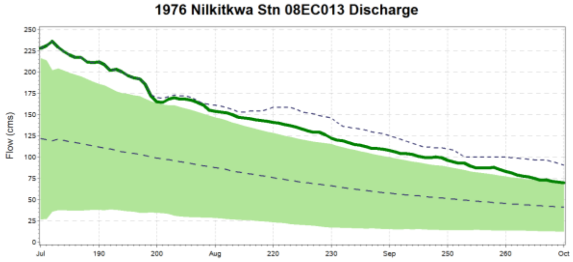
1976 Babine Water Temperature



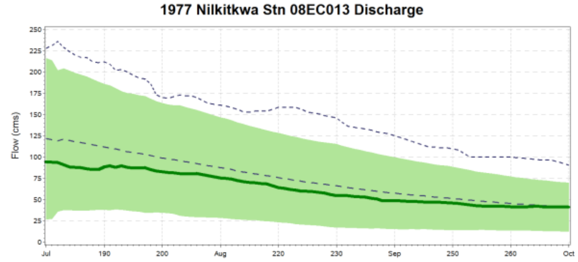
1977 Babine Water Temperature



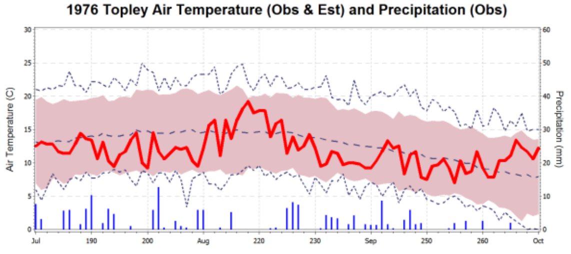
1976 Nilkitkwa Stn 08EC013 Discharge



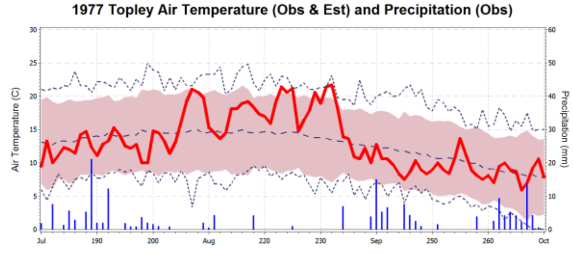
1977 Nilkitkwa Stn 08EC013 Discharge



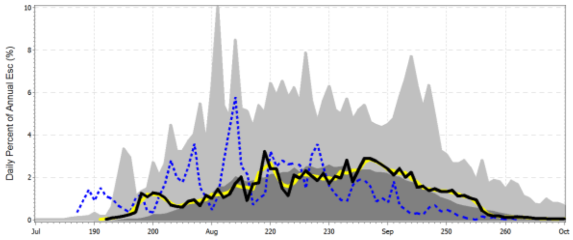
1976 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



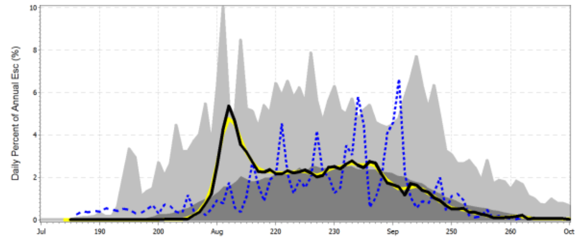
1977 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



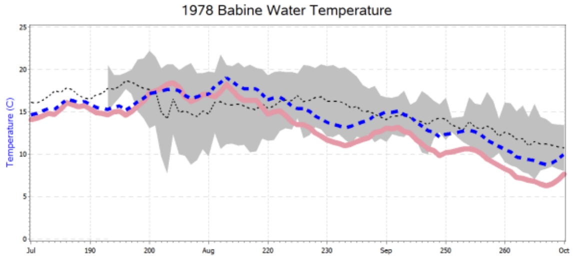
1978 Babine Fence Sockeye Passage (Total Count: 697,592)



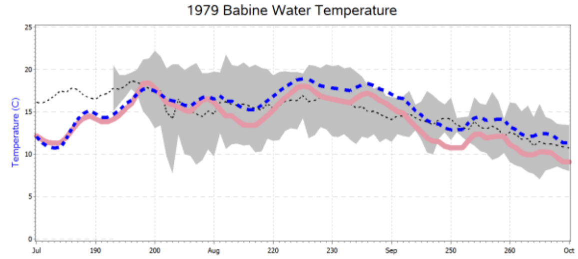
1979 Babine Fence Sockeye Passage (Total Count: 1,251,475)



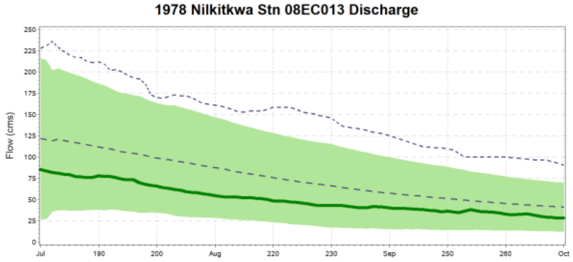
1978 Babine Water Temperature



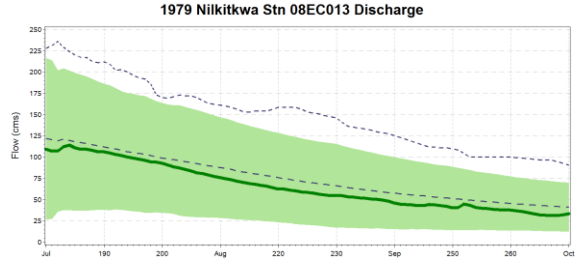
1979 Babine Water Temperature



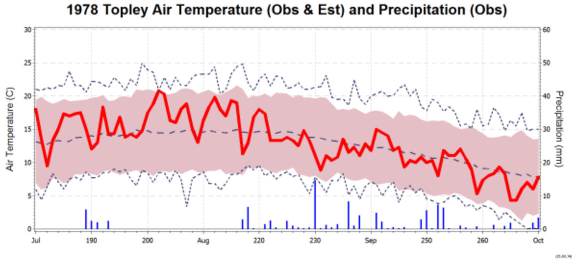
1978 Nilkitkwa Stn 08EC013 Discharge



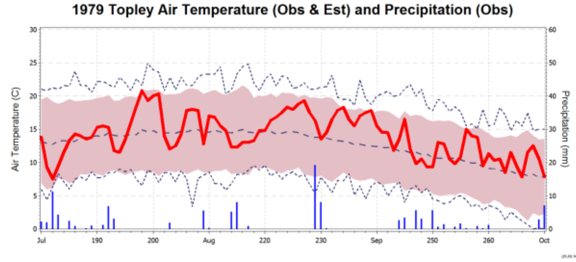
1979 Nilkitkwa Stn 08EC013 Discharge



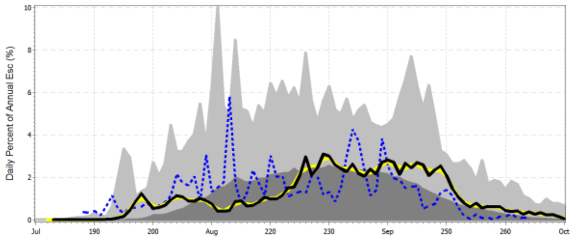
1978 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



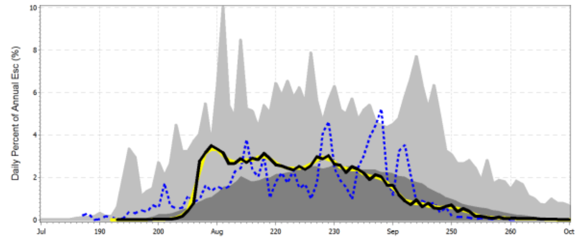
1979 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



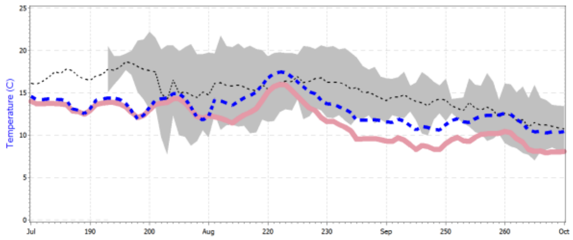
1980 Babine Fence Sockeye Passage (Total Count: 760,145)



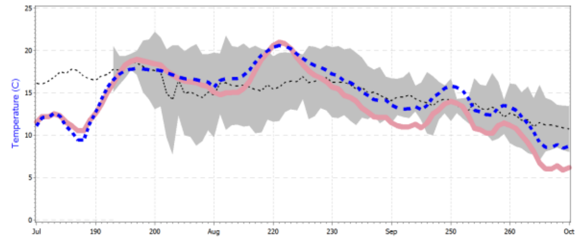
1981 Babine Fence Sockeye Passage (Total Count: 1,588,129)



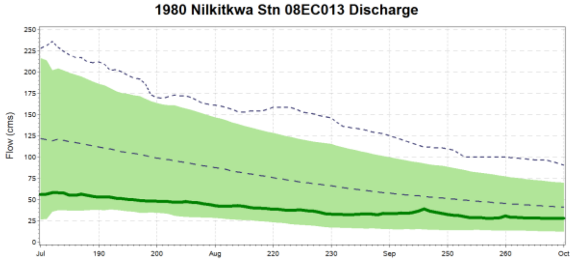
1980 Babine Water Temperature



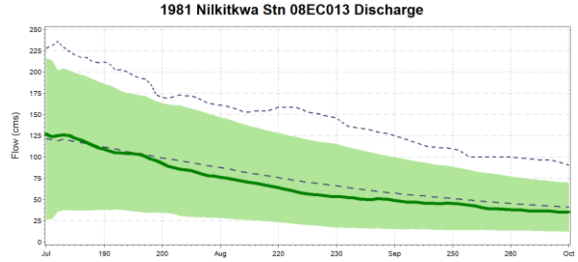
1981 Babine Water Temperature



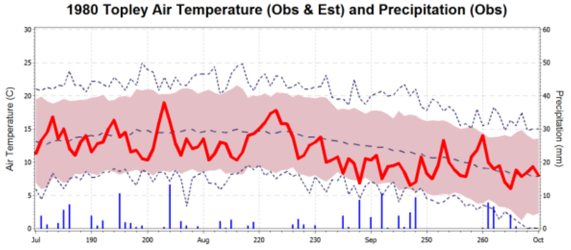
1980 Nilkitkwa Stn 08EC013 Discharge



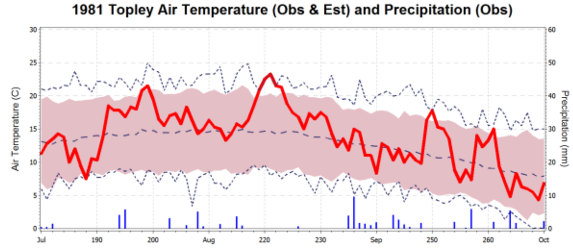
1981 Nilkitkwa Stn 08EC013 Discharge



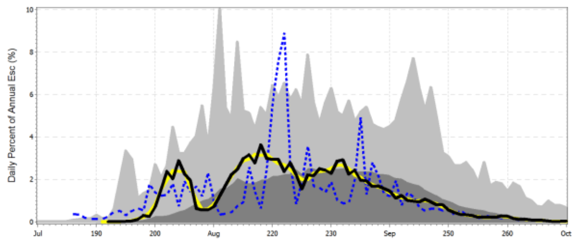
1980 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



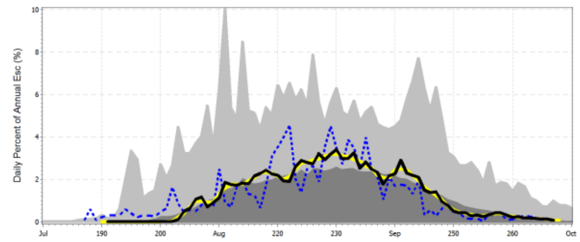
1981 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



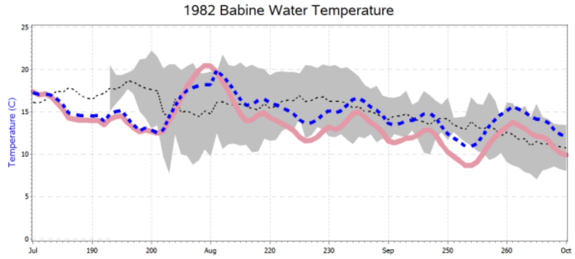
1982 Babine Fence Sockeye Passage (Total Count: 1,197,058)



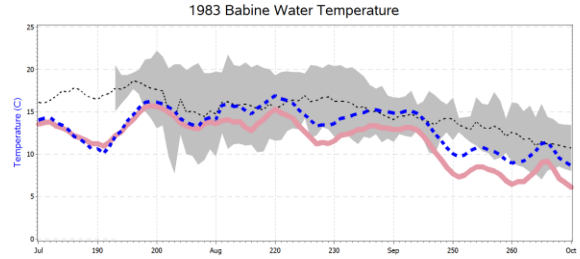
1983 Babine Fence Sockeye Passage (Total Count: 1,239,528)



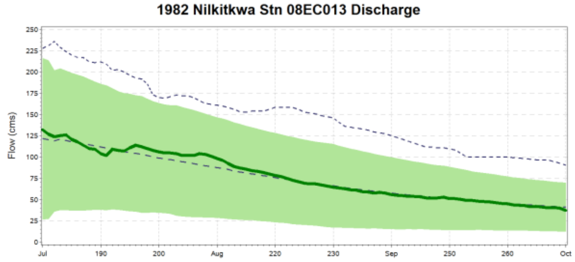
1982 Babine Water Temperature



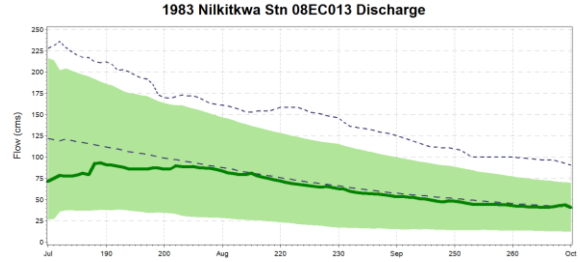
1983 Babine Water Temperature



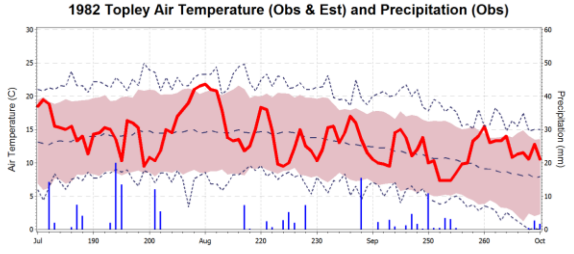
1982 Nilkitkwa Stn 08EC013 Discharge



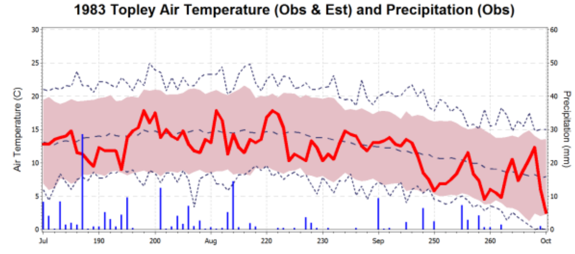
1983 Nilkitkwa Stn 08EC013 Discharge



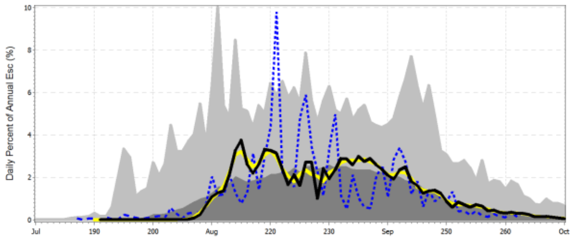
1982 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



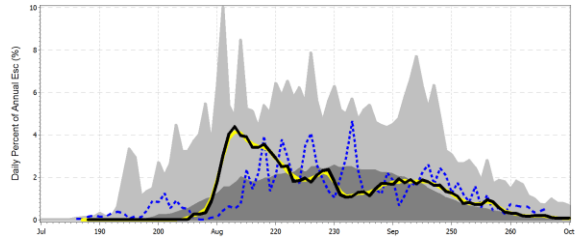
1983 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



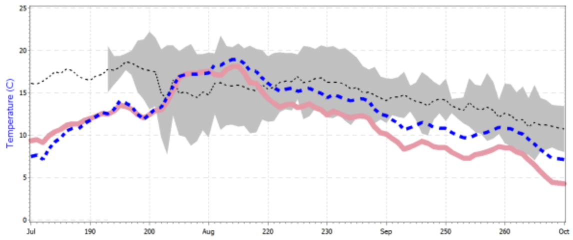
1984 Babine Fence Sockeye Passage (Total Count: 1,173,137)



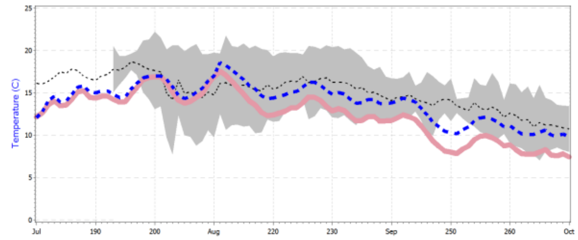
1985 Babine Fence Sockeye Passage (Total Count: 2,214,758)



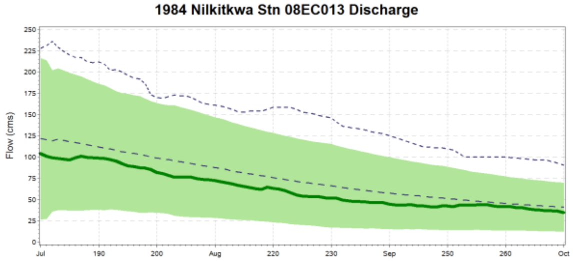
1984 Babine Water Temperature



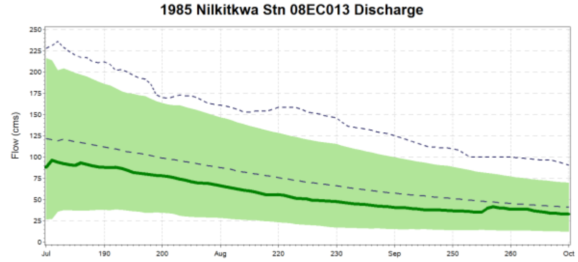
1985 Babine Water Temperature



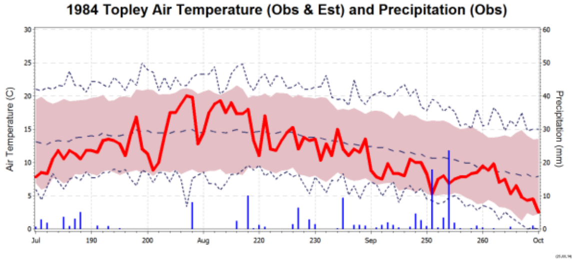
1984 Nilkitkwa Stn 08EC013 Discharge



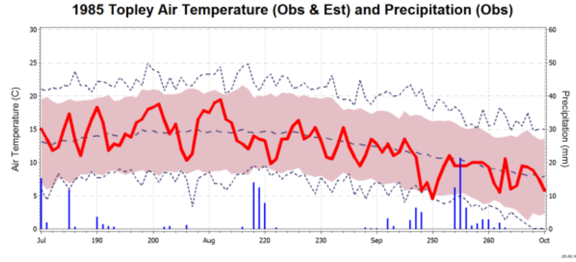
1985 Nilkitkwa Stn 08EC013 Discharge



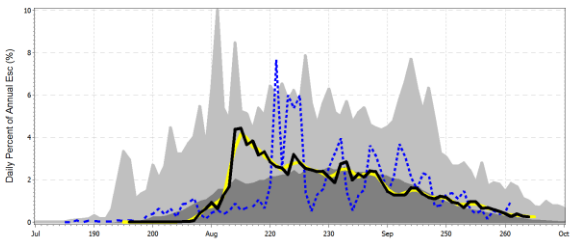
1984 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



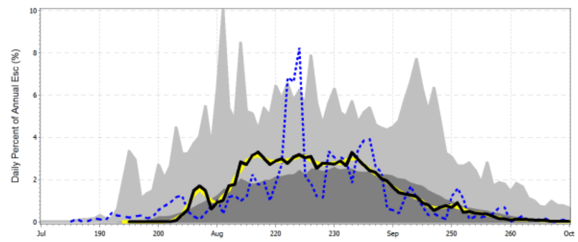
1985 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



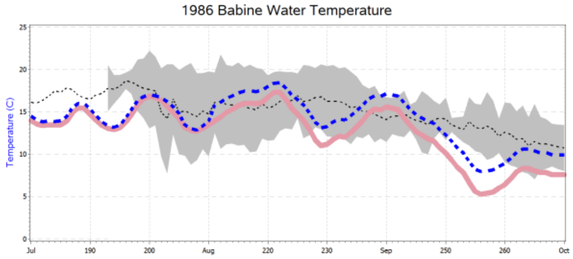
1986 Babine Fence Sockeye Passage (Total Count: 789,632)



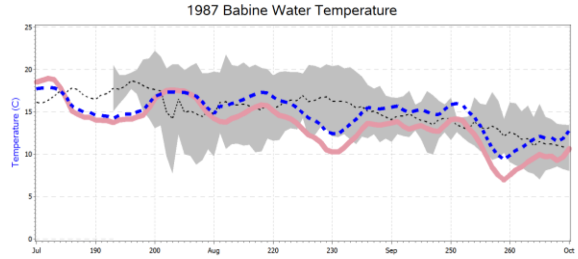
1987 Babine Fence Sockeye Passage (Total Count: 1,946,493)



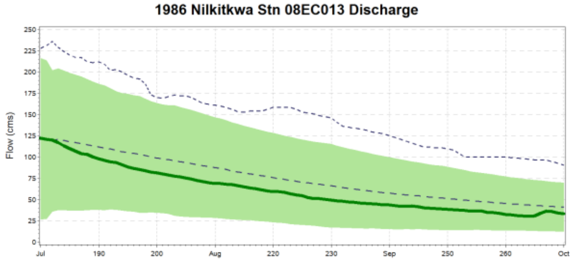
1986 Babine Water Temperature



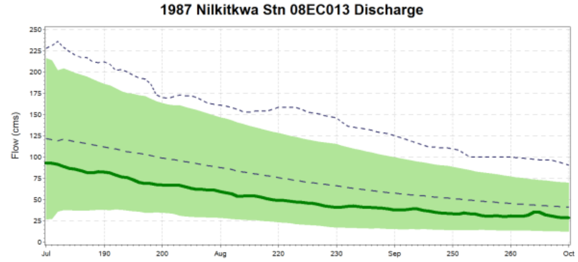
1987 Babine Water Temperature



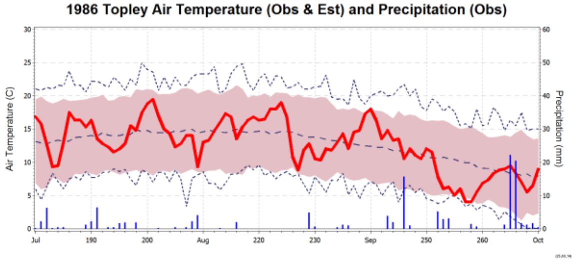
1986 Nilkitkwa Stn 08EC013 Discharge



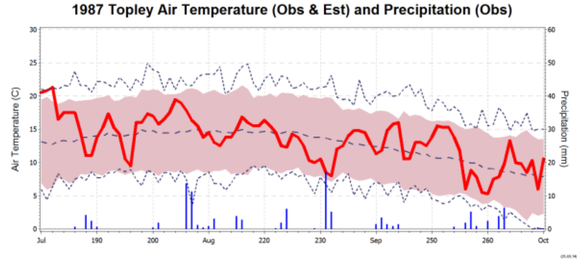
1987 Nilkitkwa Stn 08EC013 Discharge



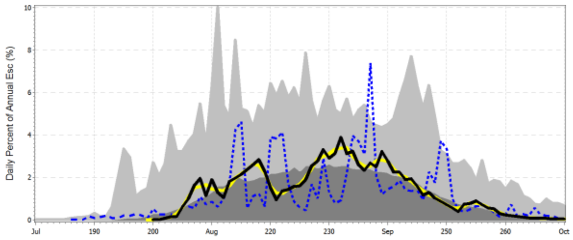
1986 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



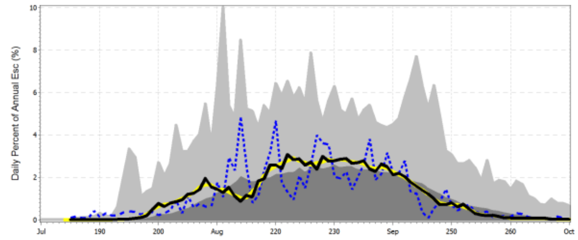
1987 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



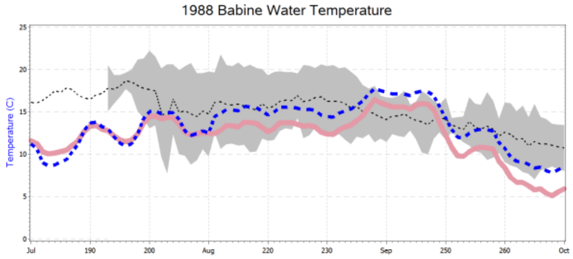
1988 Babine Fence Sockeye Passage (Total Count: 1,486,510)



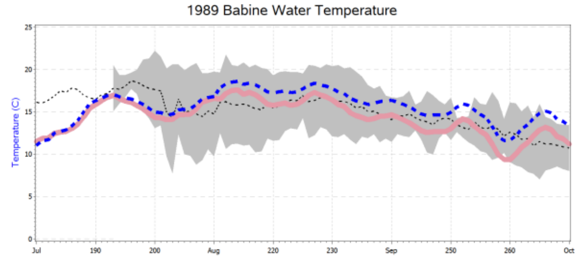
1989 Babine Fence Sockeye Passage (Total Count: 1,255,027)



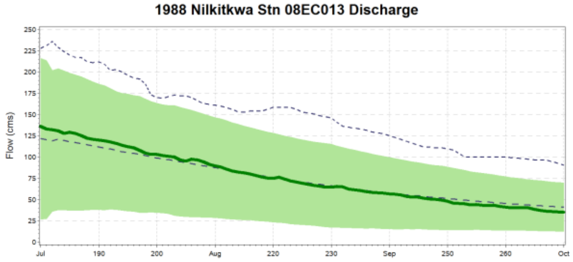
1988 Babine Water Temperature



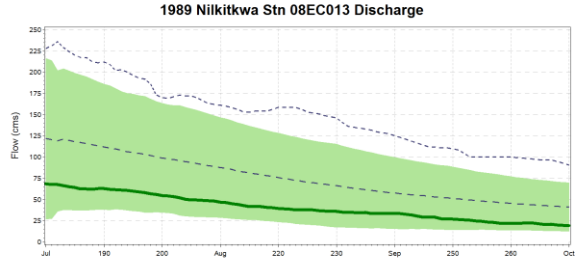
1989 Babine Water Temperature



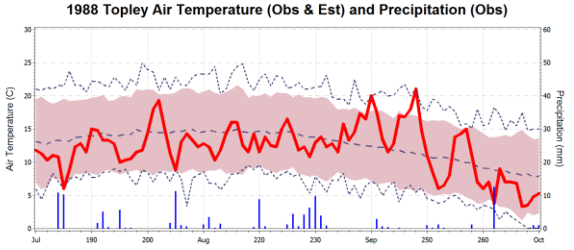
1988 Nilkitkwa Stn 08EC013 Discharge



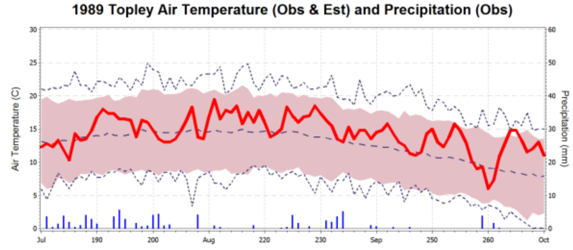
1989 Nilkitkwa Stn 08EC013 Discharge



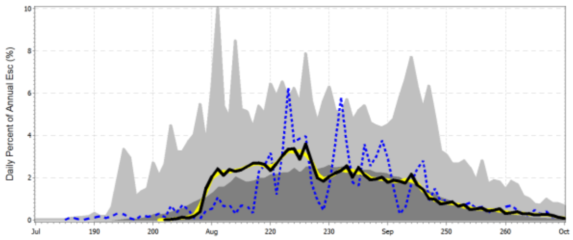
1988 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



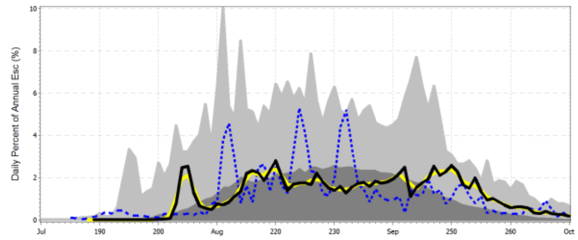
1989 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



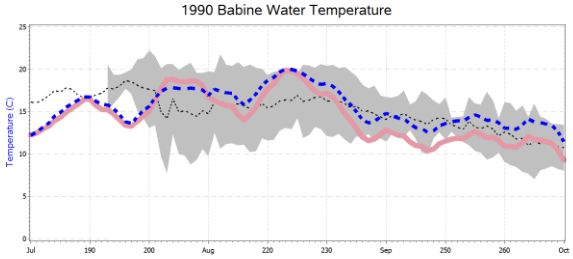
1990 Babine Fence Sockeye Passage (Total Count: 1,068,277)



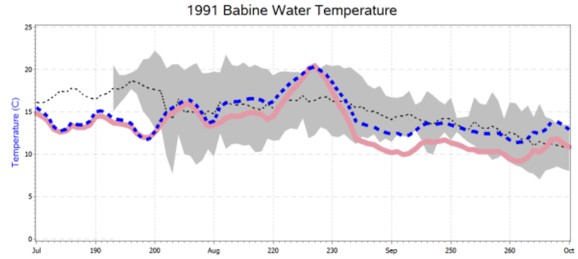
1991 Babine Fence Sockeye Passage (Total Count: 1,592,367)



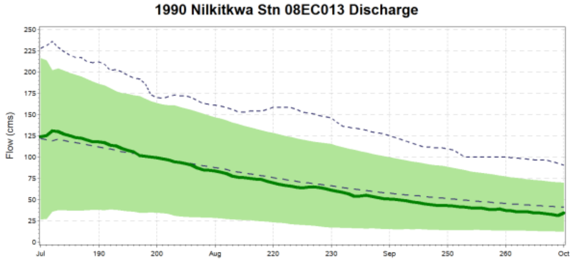
1990 Babine Water Temperature



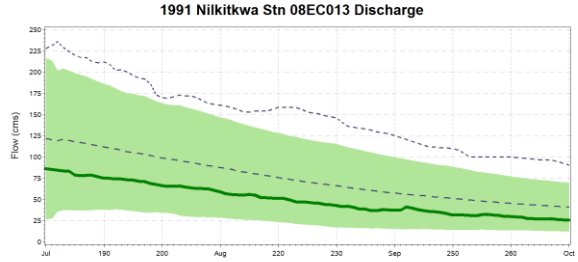
1991 Babine Water Temperature



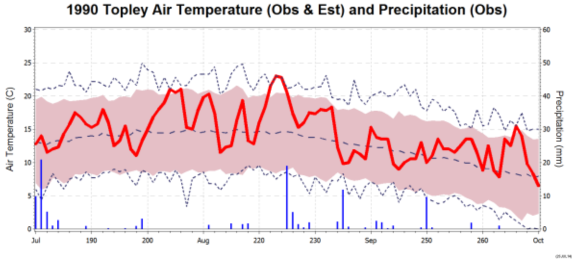
1990 Nilkitkwa Stn 08EC013 Discharge



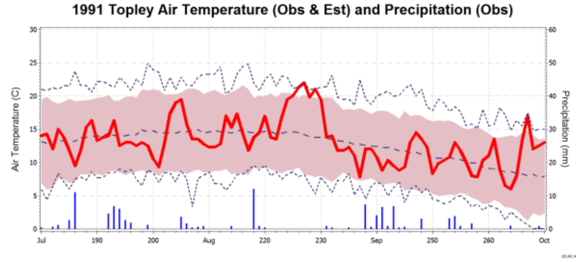
1991 Nilkitkwa Stn 08EC013 Discharge



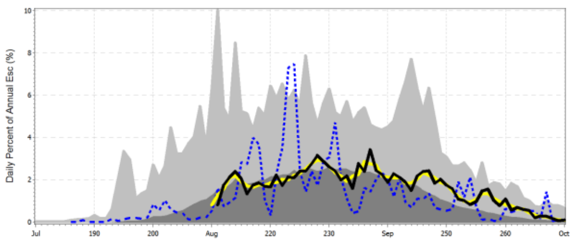
1990 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



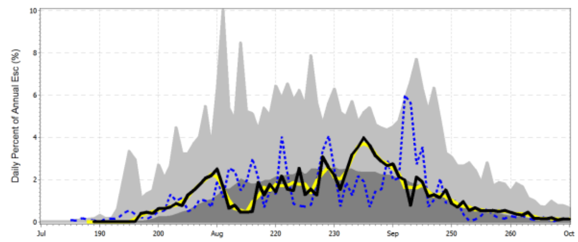
1991 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



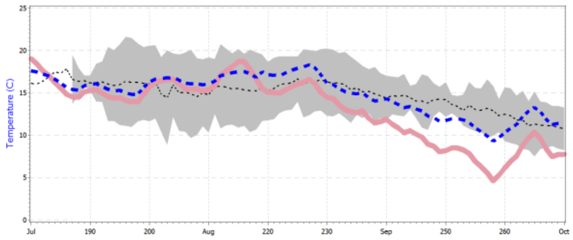
1992 Babine Fence Sockeye Passage (Total Count: 1,401,156)



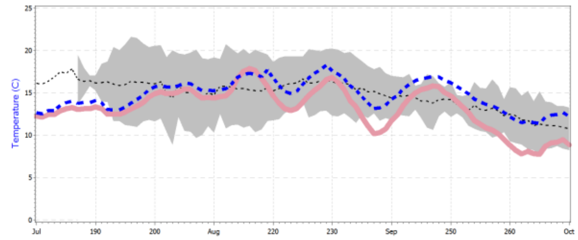
1993 Babine Fence Sockeye Passage (Total Count: 1,828,006)



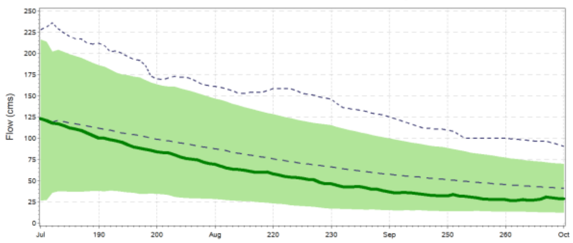
1992 Babine Water Temperature



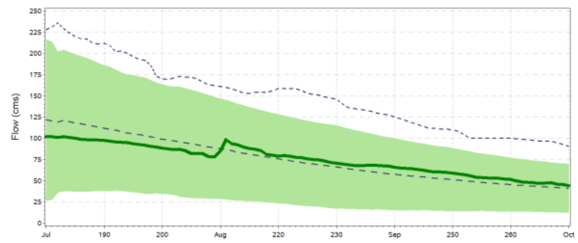
1993 Babine Water Temperature



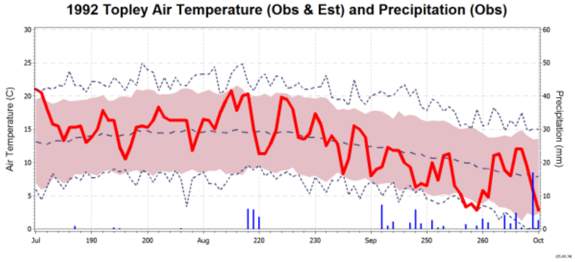
1992 Nilkitkwa Stn 08EC013 Discharge



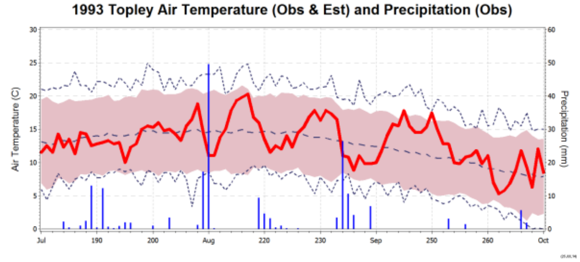
1993 Nilkitkwa Stn 08EC013 Discharge



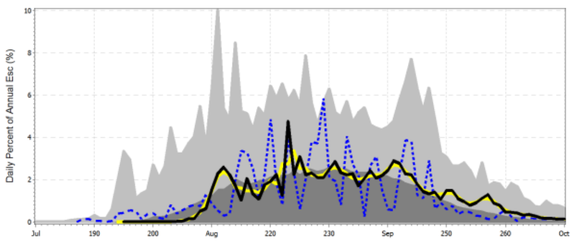
1992 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



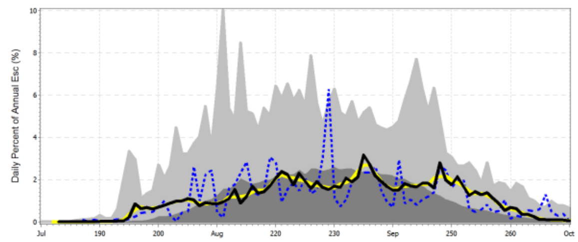
1993 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



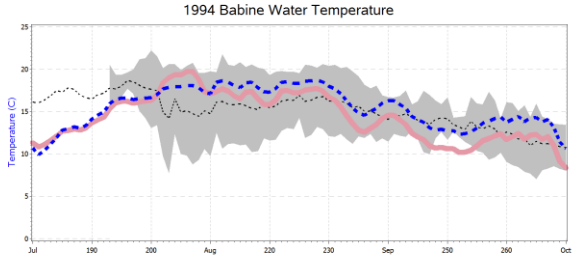
1994 Babine Fence Sockeye Passage (Total Count: 1,373,709)



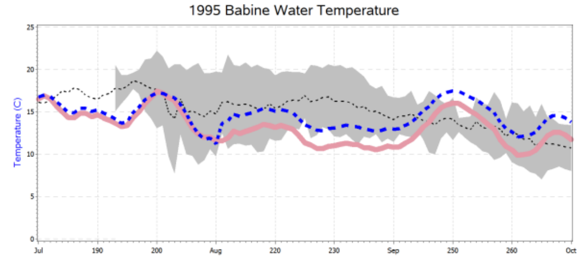
1995 Babine Fence Sockeye Passage (Total Count: 2,279,904)



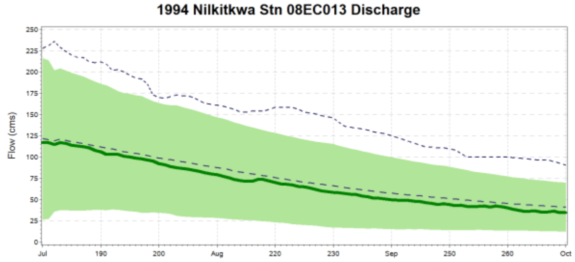
1994 Babine Water Temperature



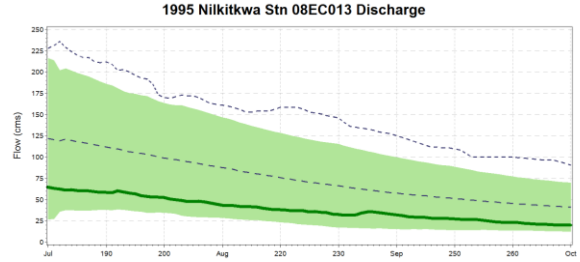
1995 Babine Water Temperature



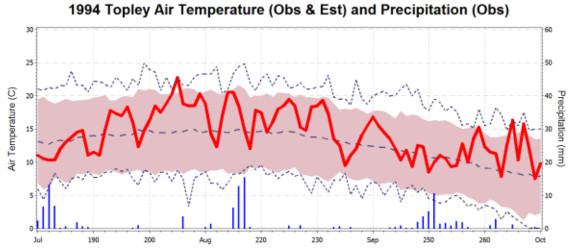
1994 Nilkitkwa Stn 08EC013 Discharge



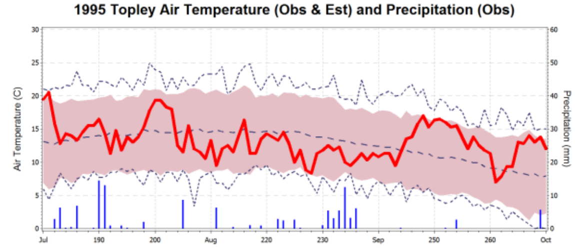
1995 Nilkitkwa Stn 08EC013 Discharge



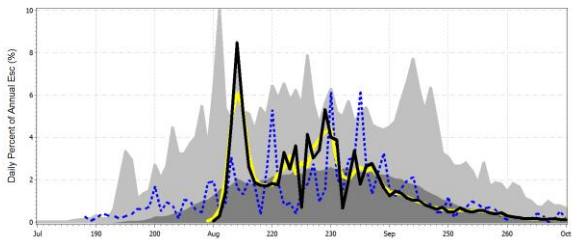
1994 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



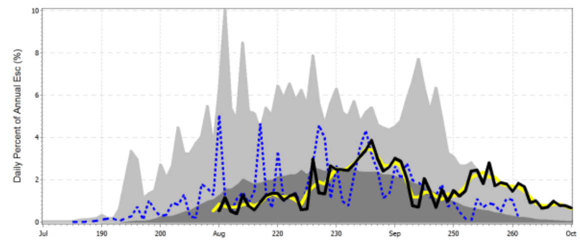
1995 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



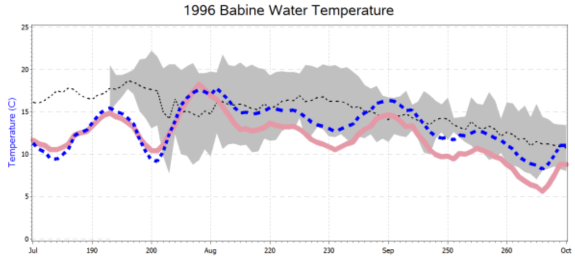
1996 Babine Fence Sockeye Passage (Total Count: 1,944,067)



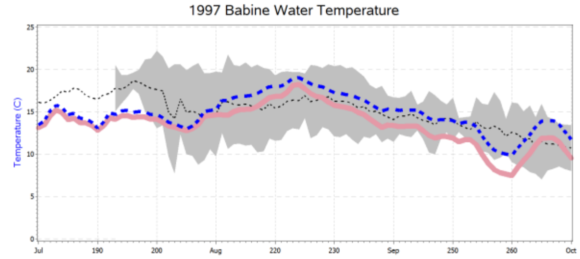
1997 Babine Fence Sockeye Passage (Total Count: 1,001,495)



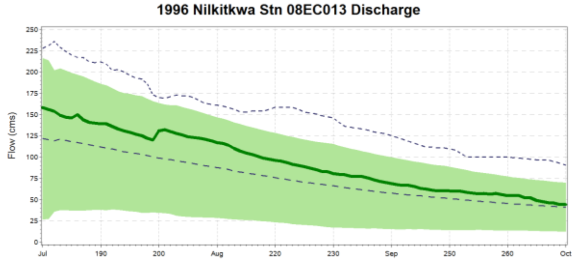
1996 Babine Water Temperature



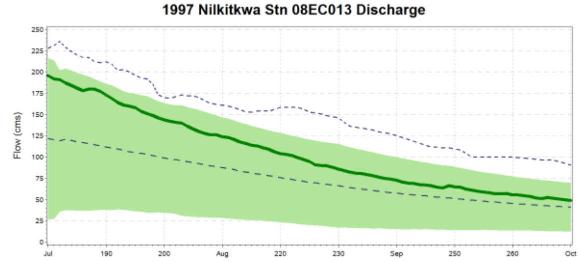
1997 Babine Water Temperature



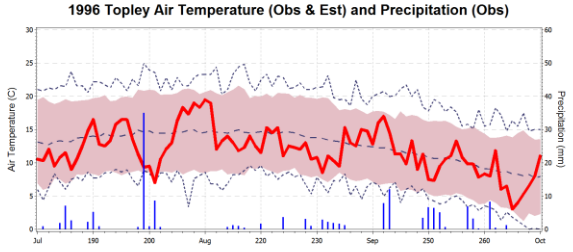
1996 Nilkitkwa Stn 08EC013 Discharge



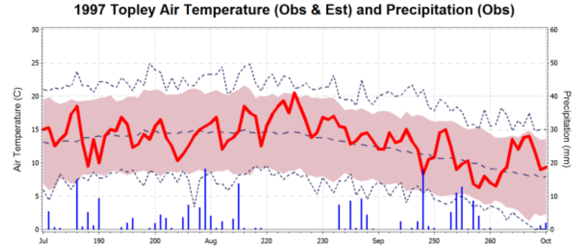
1997 Nilkitkwa Stn 08EC013 Discharge



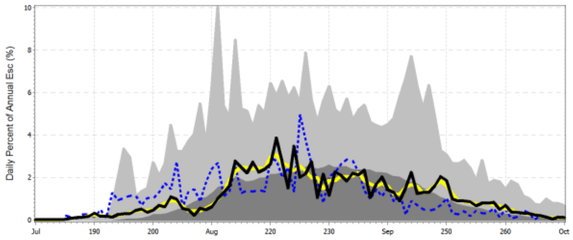
1996 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



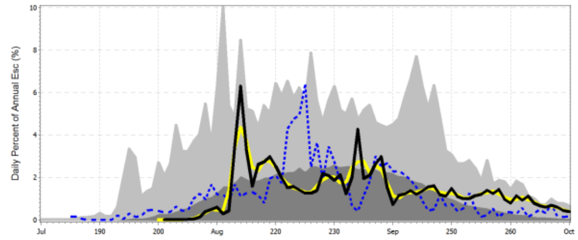
1997 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



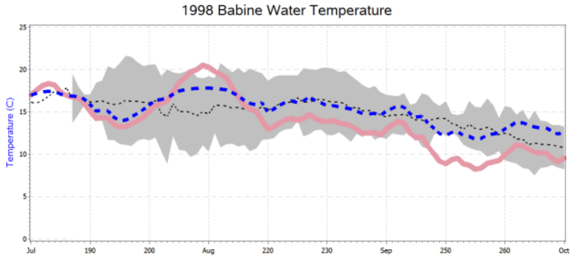
1998 Babine Fence Sockeye Passage (Total Count: 558,873)



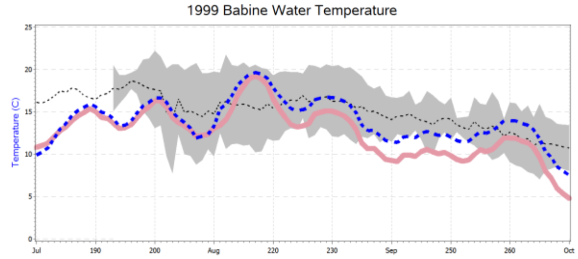
1999 Babine Fence Sockeye Passage (Total Count: 780,823)



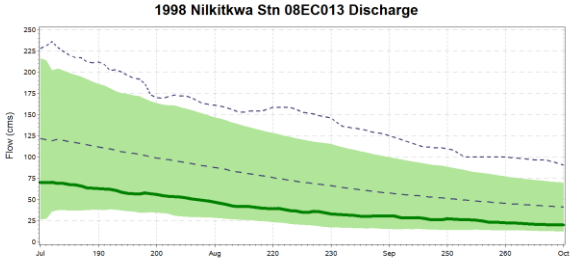
1998 Babine Water Temperature



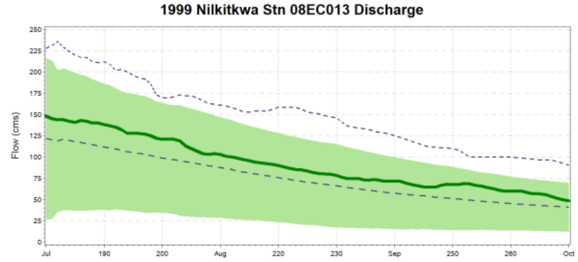
1999 Babine Water Temperature



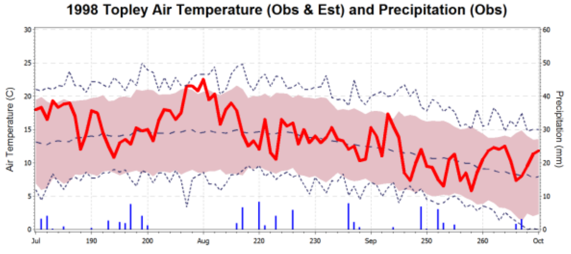
1998 Nilkitkwa Stn 08EC013 Discharge



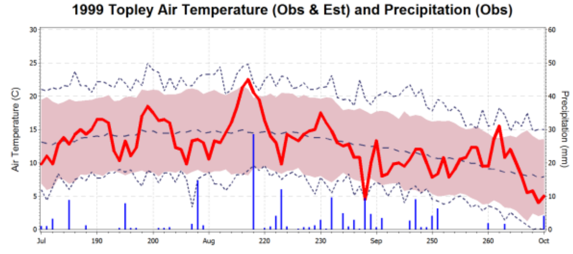
1999 Nilkitkwa Stn 08EC013 Discharge



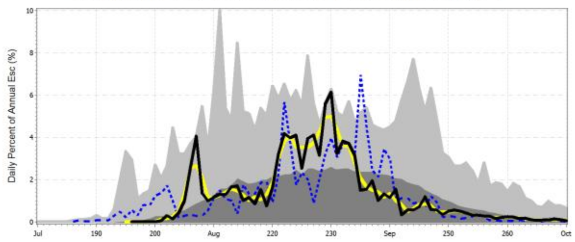
1998 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



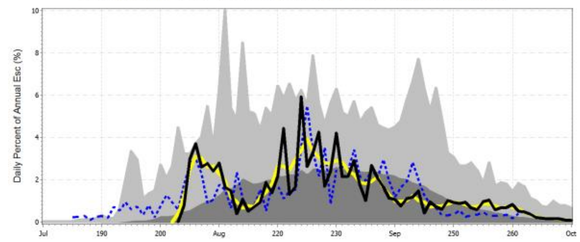
1999 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



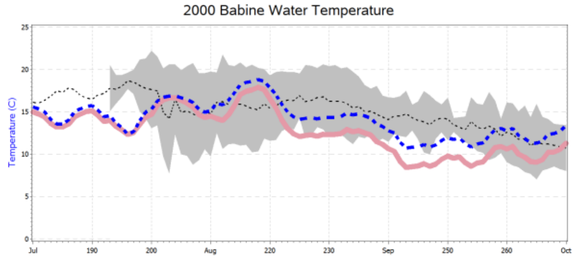
2000 Babine Fence Sockeye Passage (Total Count: 1,848,681)



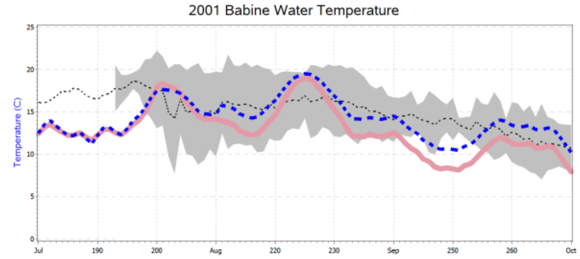
2001 Babine Fence Sockeye Passage (Total Count: 2,060,596)



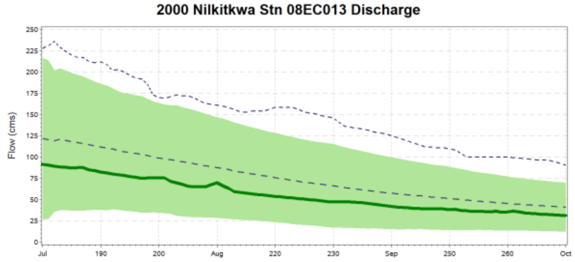
2000 Babine Water Temperature



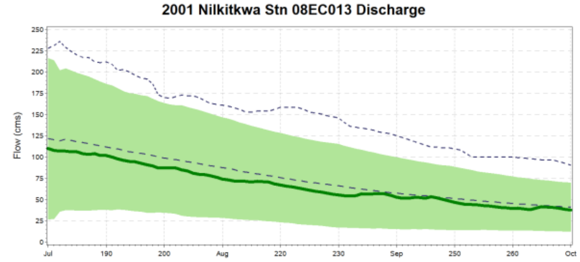
2001 Babine Water Temperature



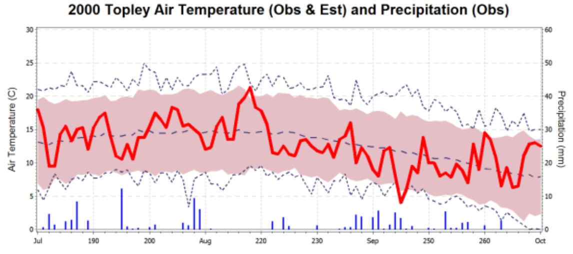
2000 Nilkitkwa Stn 08EC013 Discharge



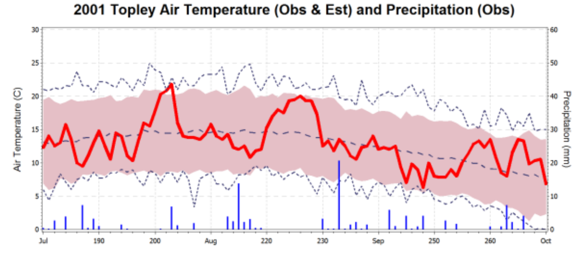
2001 Nilkitkwa Stn 08EC013 Discharge



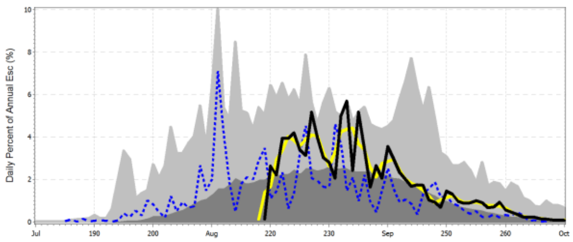
2000 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



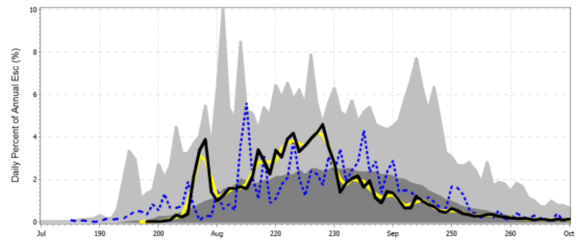
2001 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



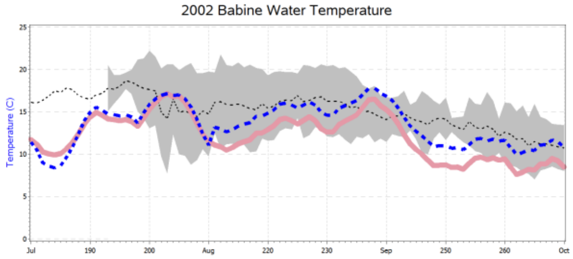
2002 Babine Fence Sockeye Passage (Total Count: 447,745)



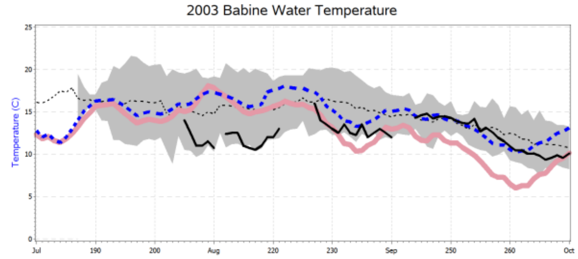
2003 Babine Fence Sockeye Passage (Total Count: 1,302,014)



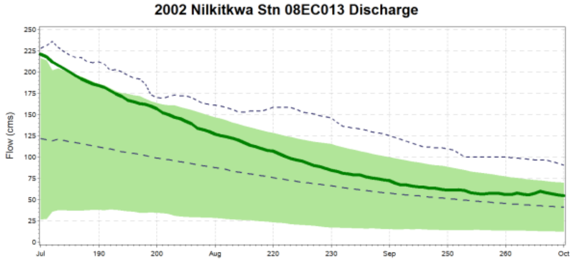
2002 Babine Water Temperature



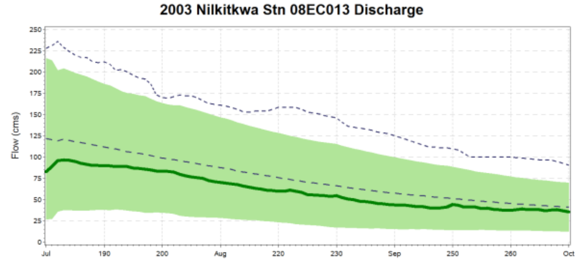
2003 Babine Water Temperature



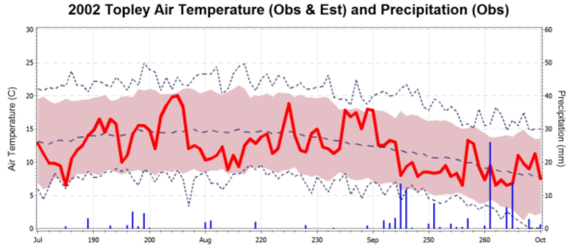
2002 Nilkitkwa Stn 08EC013 Discharge



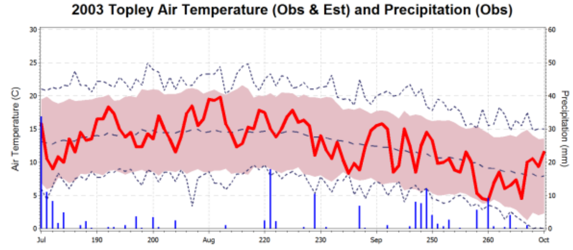
2003 Nilkitkwa Stn 08EC013 Discharge



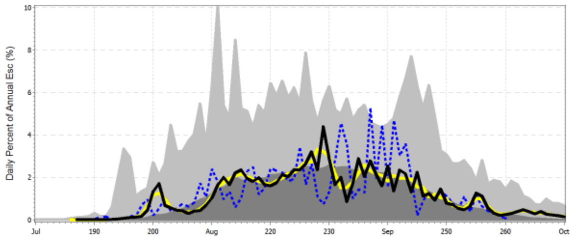
2002 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



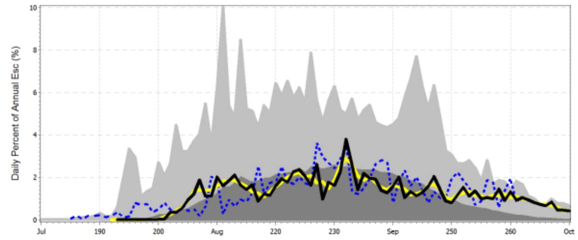
2003 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



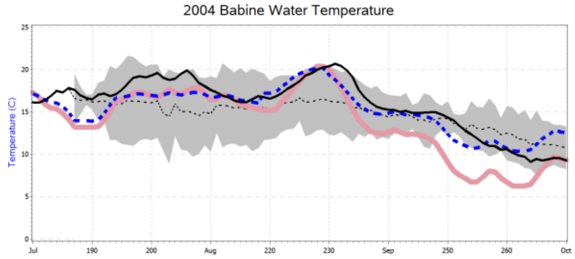
2004 Babine Fence Sockeye Passage (Total Count: 937,353)



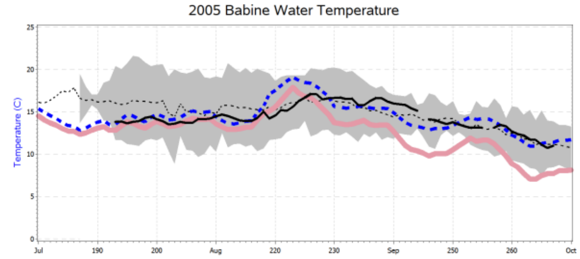
2005 Babine Fence Sockeye Passage (Total Count: 864,447)



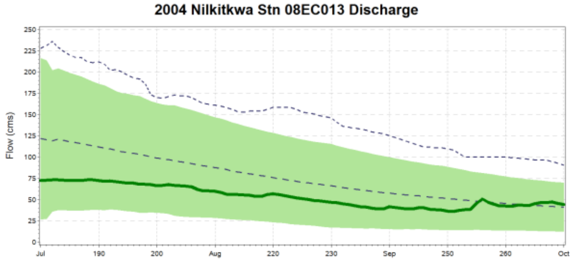
2004 Babine Water Temperature



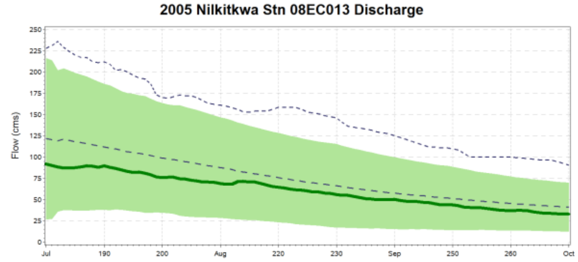
2005 Babine Water Temperature



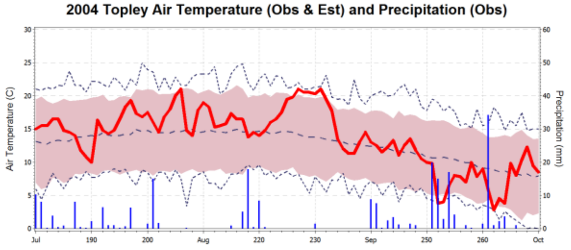
2004 Nilkitkwa Stn 08EC013 Discharge



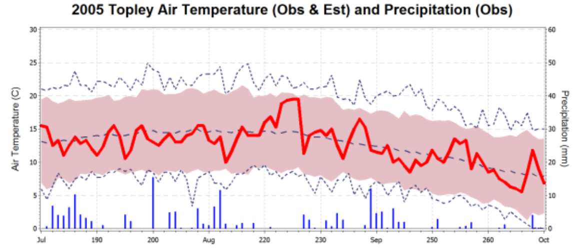
2005 Nilkitkwa Stn 08EC013 Discharge



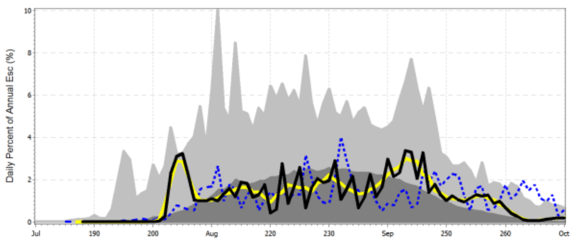
2004 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



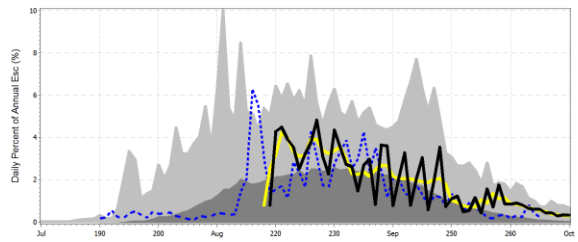
2005 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



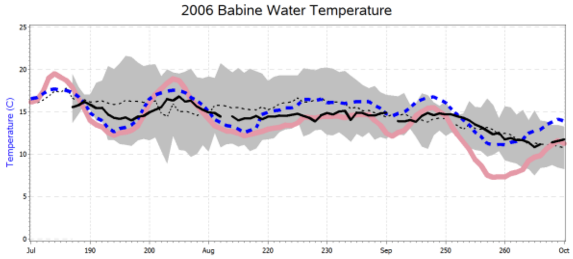
2006 Babine Fence Sockeye Passage (Total Count: 1,420,537)



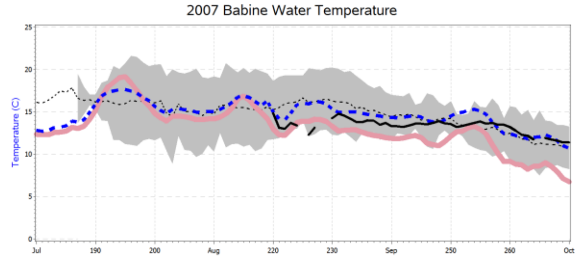
2007 Babine Fence Sockeye Passage (Total Count: 491,605)



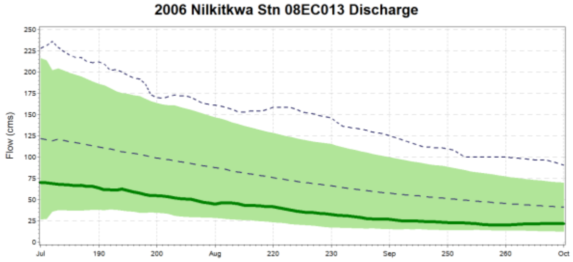
2006 Babine Water Temperature



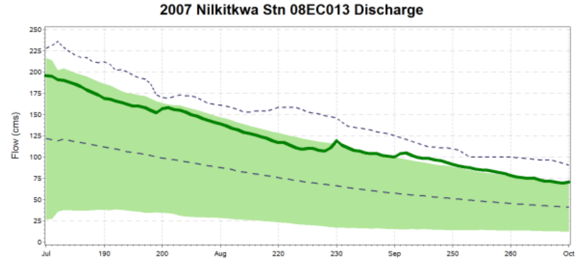
2007 Babine Water Temperature



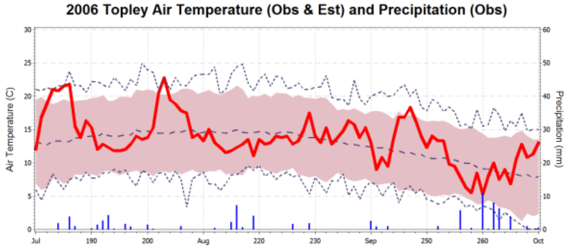
2006 Nilkitkwa Stn 08EC013 Discharge



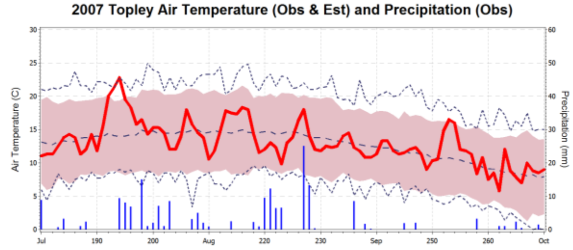
2007 Nilkitkwa Stn 08EC013 Discharge



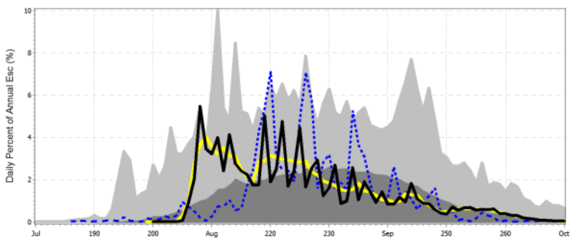
2006 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



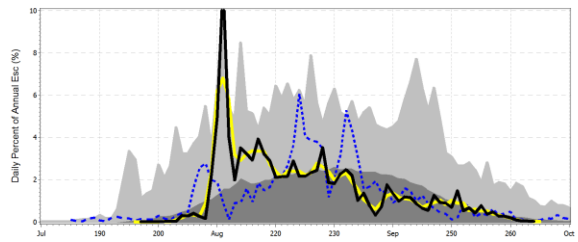
2007 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



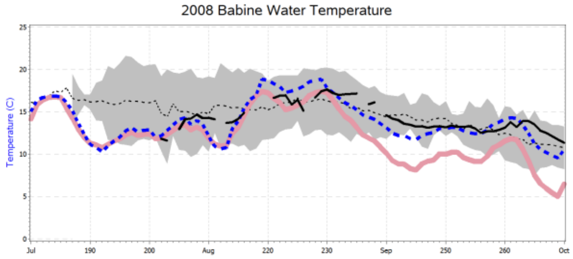
2008 Babine Fence Sockeye Passage (Total Count: 1,104,171)



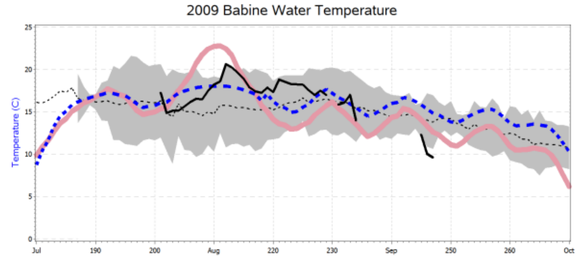
2009 Babine Fence Sockeye Passage (Total Count: 698,749)



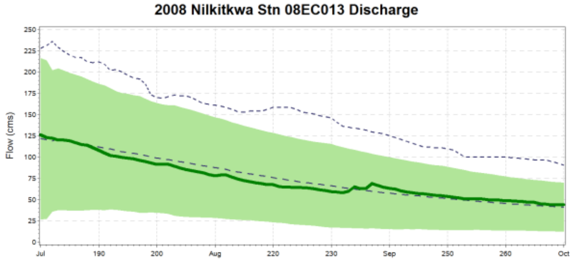
2008 Babine Water Temperature



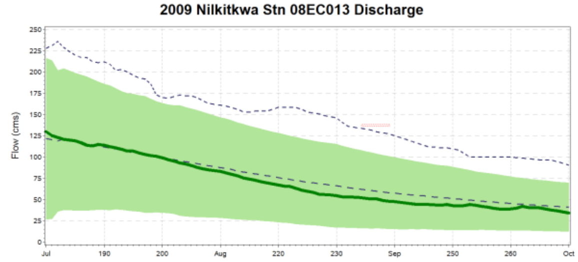
2009 Babine Water Temperature



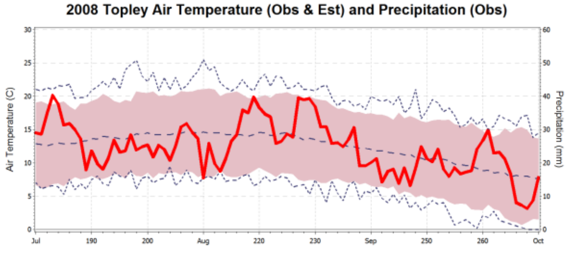
2008 Nilkitkwa Stn 08EC013 Discharge



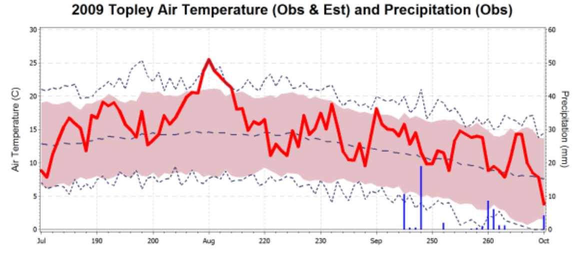
2009 Nilkitkwa Stn 08EC013 Discharge

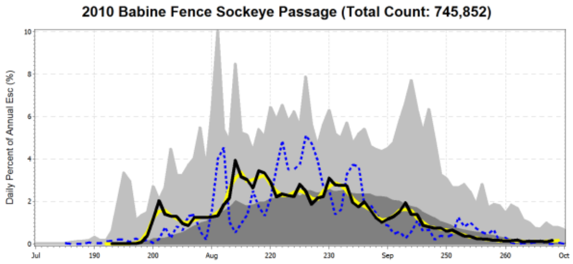


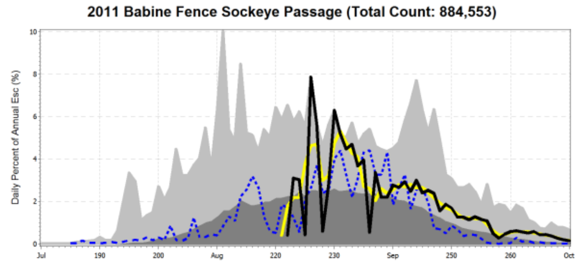
2008 Topley Air Temperature (Obs & Est) and Precipitation (Obs)

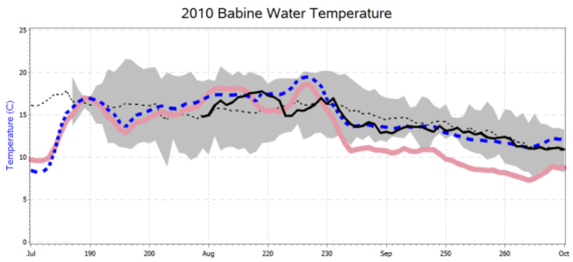


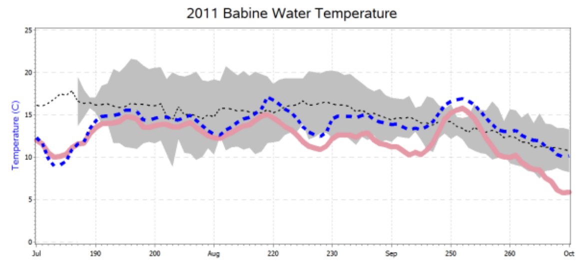
2009 Topley Air Temperature (Obs & Est) and Precipitation (Obs)

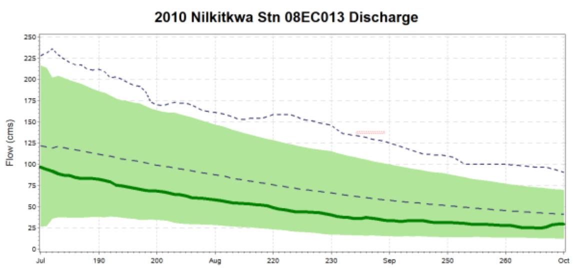


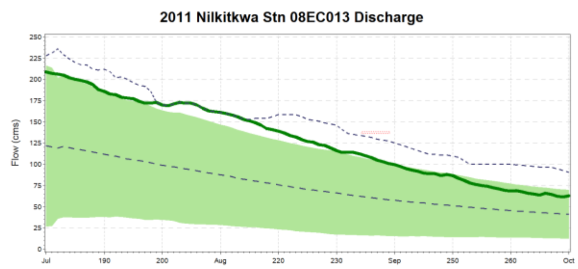

2010 Babine Fence Sockeye Passage (Total Count: 745,852)
Daily Percent of Annual Esc (%)

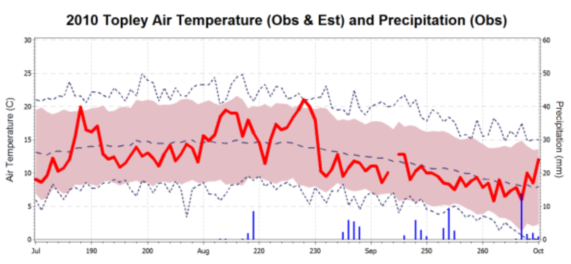

2011 Babine Fence Sockeye Passage (Total Count: 884,553)
Daily Percent of Annual Esc (%)

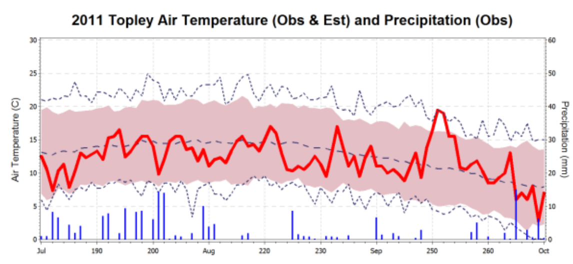

2010 Babine Water Temperature
Temperature (C)


2011 Babine Water Temperature
Temperature (C)

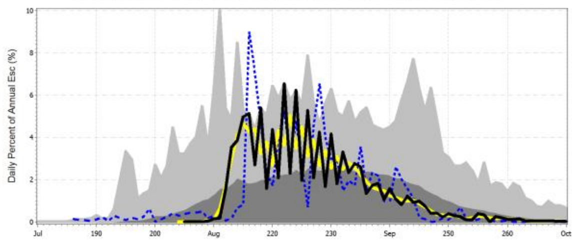

2010 Nilkitkwa Stn 08EC013 Discharge
Flow (cms)


2011 Nilkitkwa Stn 08EC013 Discharge
Flow (cms)

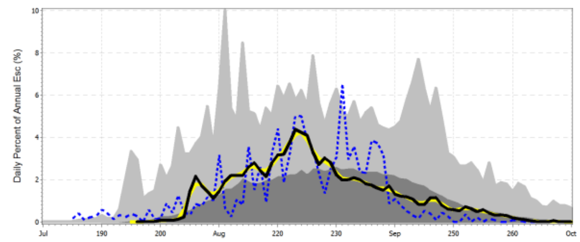

2010 Topley Air Temperature (Obs & Est) and Precipitation (Obs)
Air Temperature (C)
Precipitation (mm)


2011 Topley Air Temperature (Obs & Est) and Precipitation (Obs)
Air Temperature (C)
Precipitation (mm)

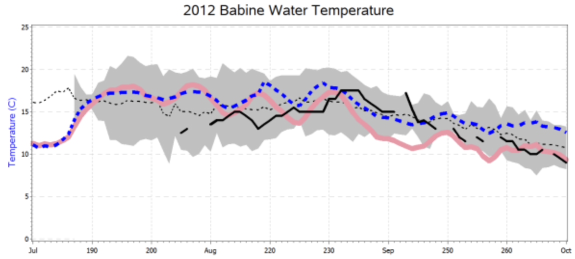
2012 Babine Fence Sockeye Passage (Total Count: 1,366,779)



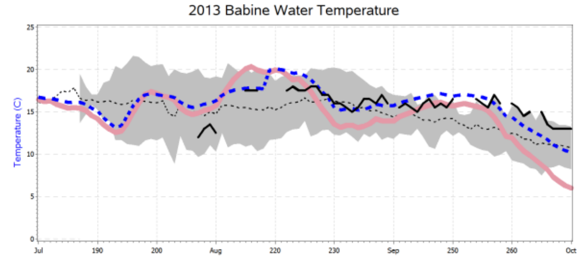
2013 Babine Fence Sockeye Passage (Total Count: 633,337)



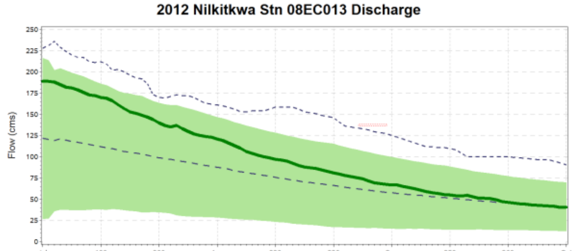
2012 Babine Water Temperature



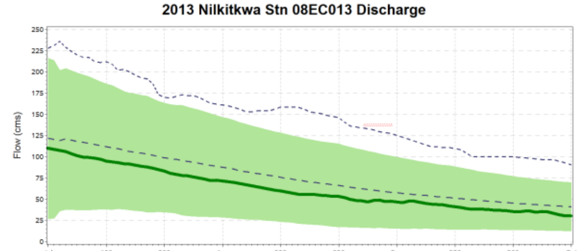
2013 Babine Water Temperature



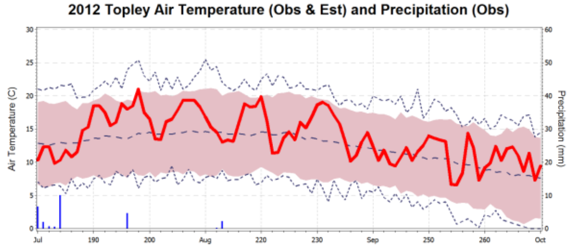
2012 Nilkitkwa Stn 08EC013 Discharge



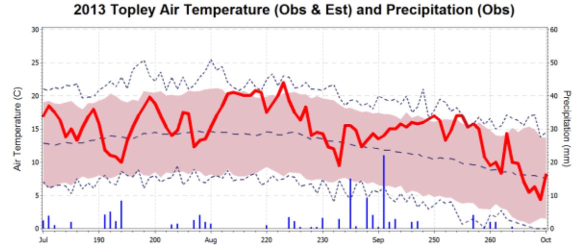
2013 Nilkitkwa Stn 08EC013 Discharge



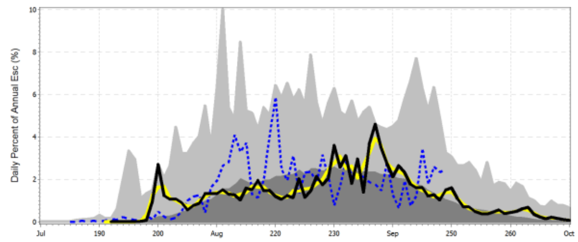
2012 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



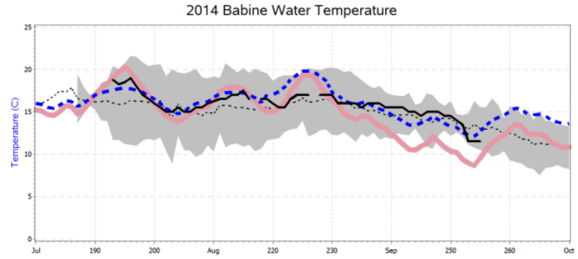
2013 Topley Air Temperature (Obs & Est) and Precipitation (Obs)



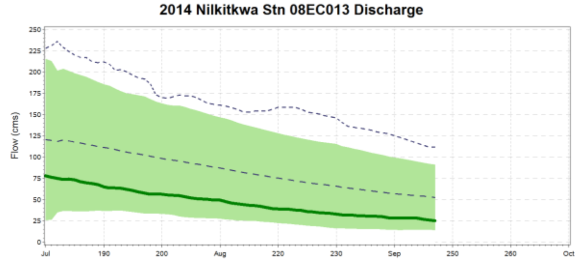
2014 Babine Fence Sockeye Passage (Total Count: 2,217,293)



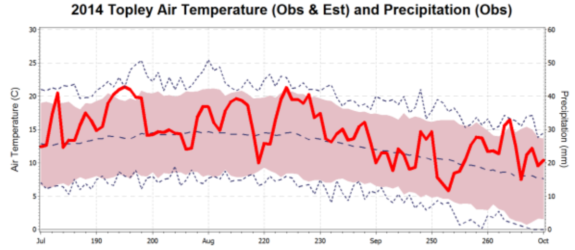
2014 Babine Water Temperature



2014 Nilkitkwa Stn 08EC013 Discharge



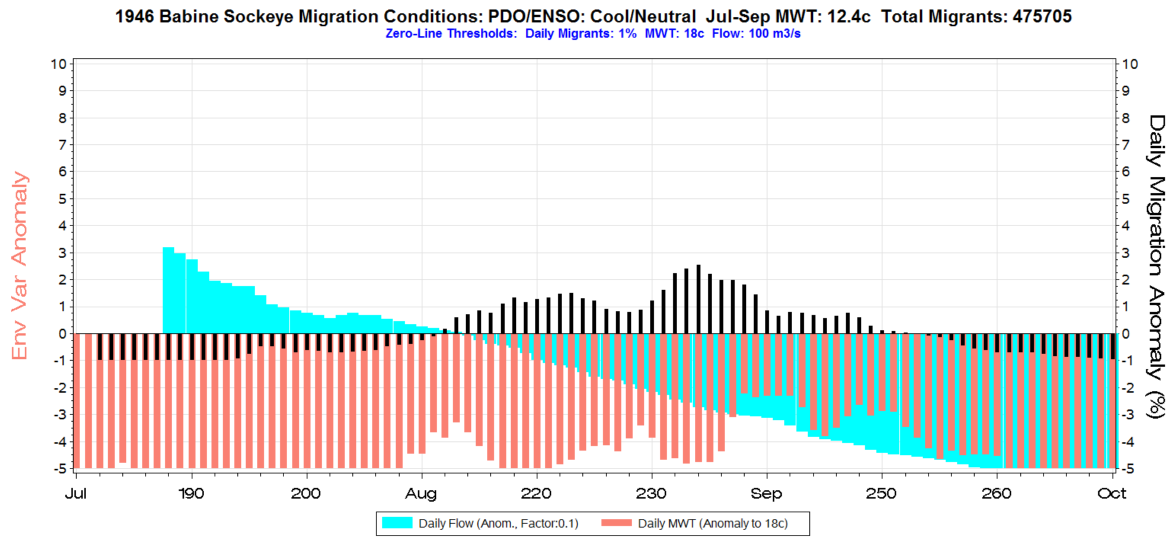
2014 Topley Air Temperature (Obs & Est) and Precipitation (Obs)

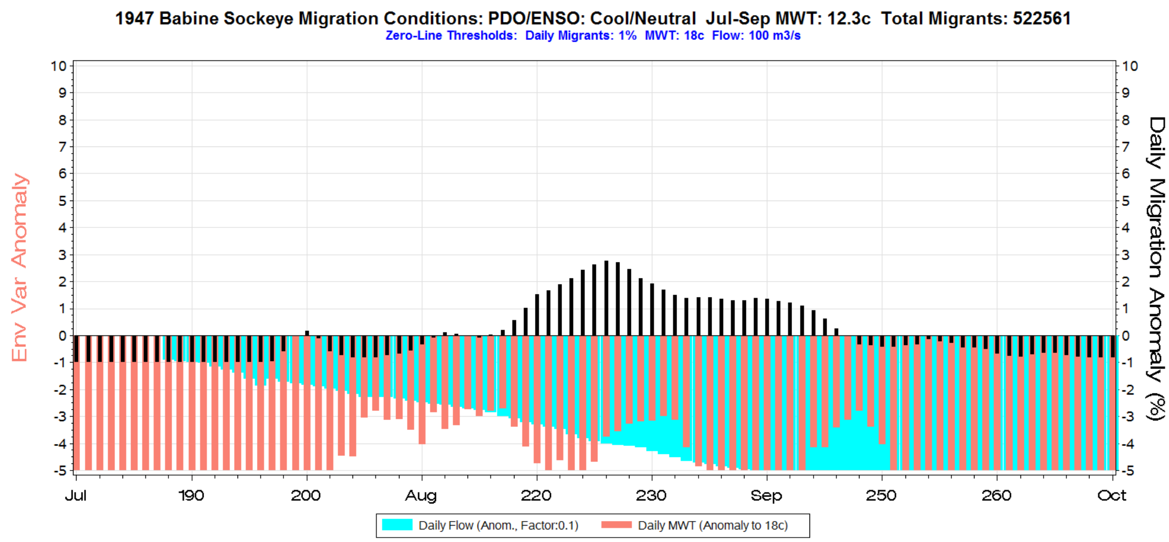


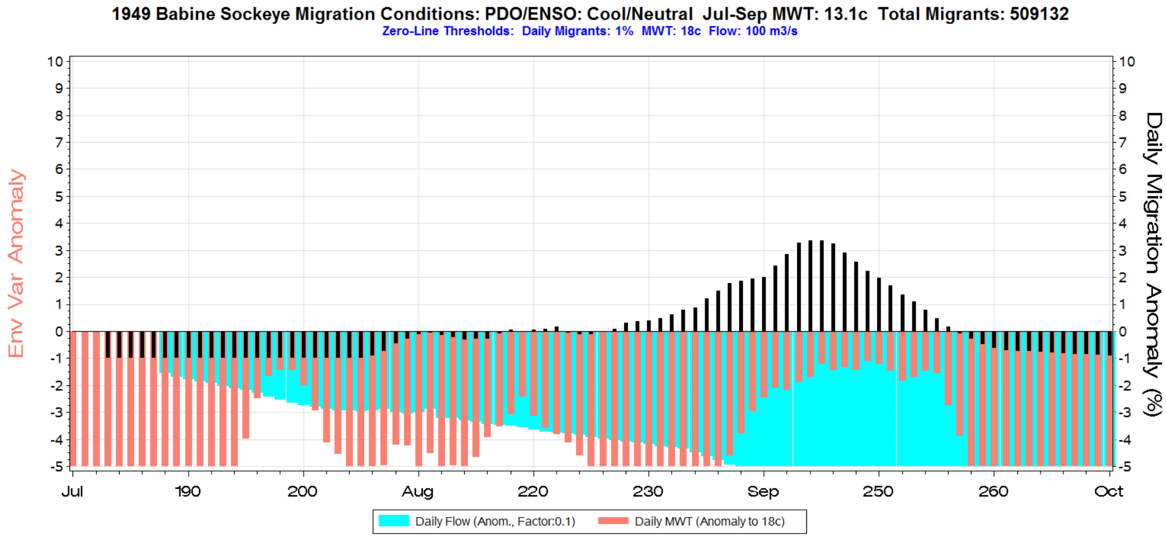
Appendix C. Annual anomaly plot for Babine Sockeye migration (black bars) versus Babine River water temperature (estimated; red bars) and discharge (factored by 0.1 to fit on y-axis; blue bars), 6 days earlier, 1946 - 2014.

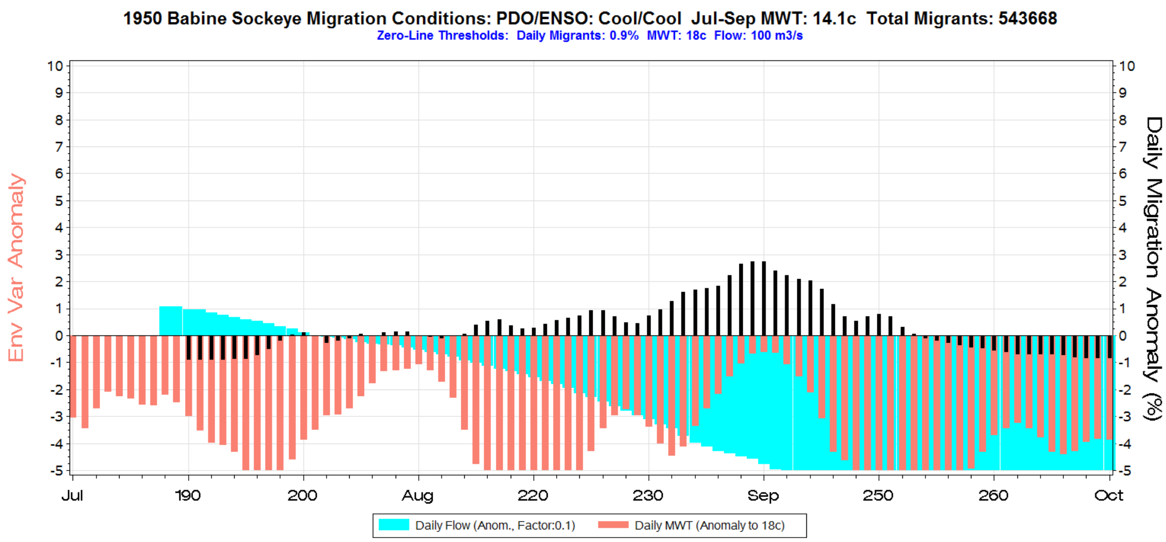
Zero-line thresholds: (a) Daily migration rate = 1.0% (50th percentile of non-zero daily migration rates (1953-2014); (b) water temperature = 18°C (~90th percentile); discharge = 100 cms (~90th percentile).

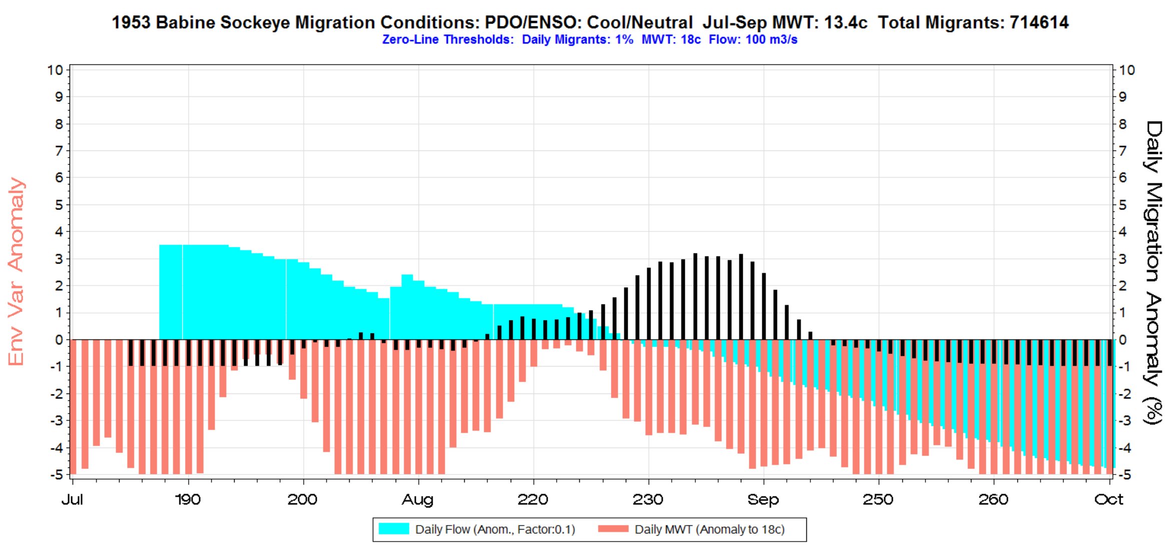
To read the plot: environmental variate anomalies are read from the primary y-axis; migration anomalies are read from the secondary y-axis. Red bars are the estimated daily mean water temperature minus the 18°C threshold (e.g., 15°C →15-18 = -3). Blue bars are the observed or estimated daily discharge (at Nilkitkwa) minus the 100 cms threshold, and divided by 10 to fit the axis (e.g., 130 cms → (130-100)/10 = +3; 80 cms →(80-100)/10 = -2). Black bars are the daily migration rate (%) minus the threshold 1% (e.g., 2.5% → 2.5-1 = 1.5%).

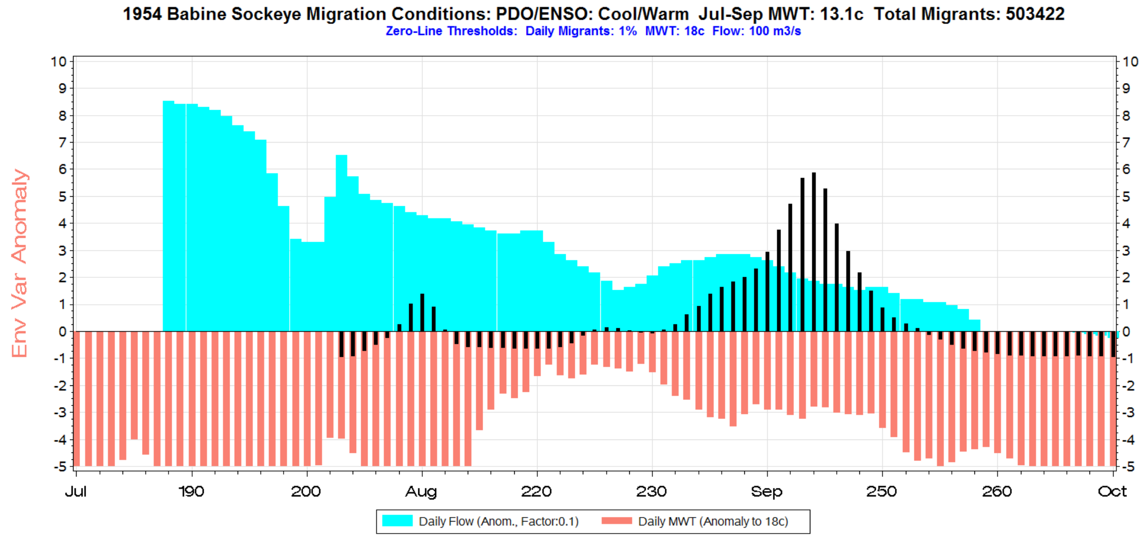


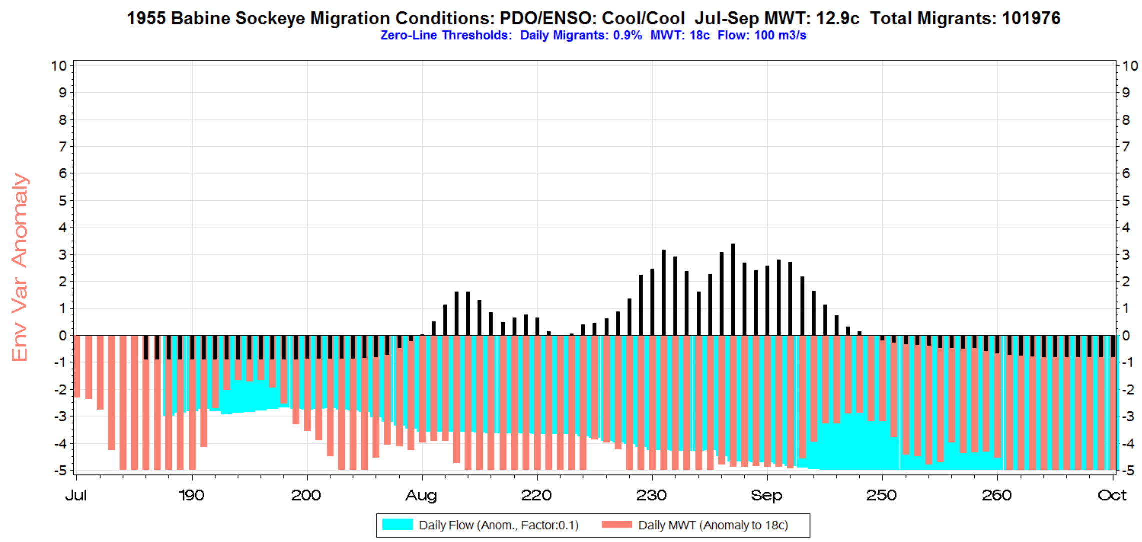


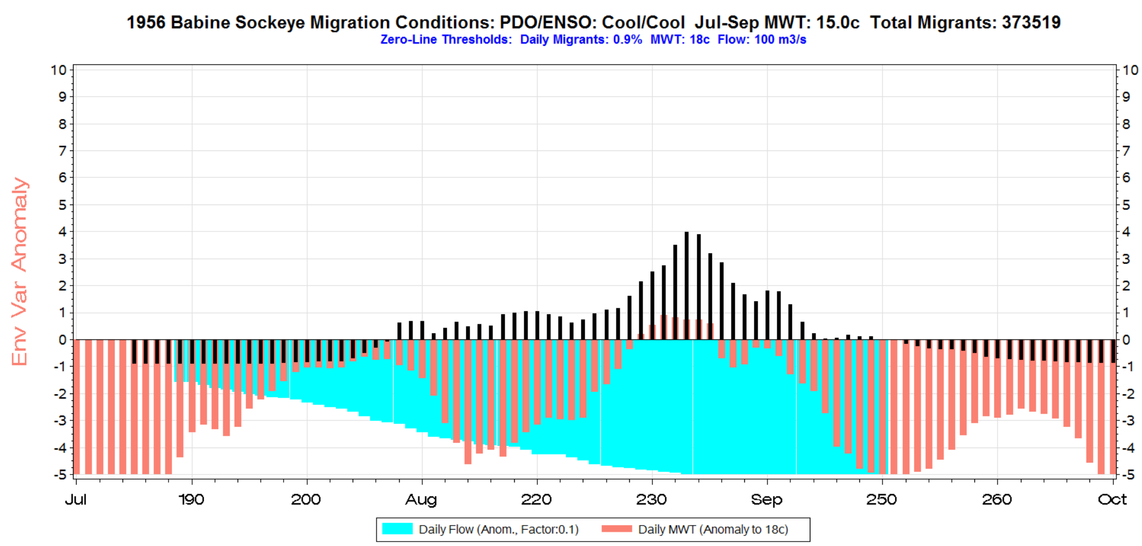

1949 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 13.1c Total Migrants: 509132
Zero-Line Thresholds: Daily Migrants: 1% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


1950 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 14.1c Total Migrants: 543668
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

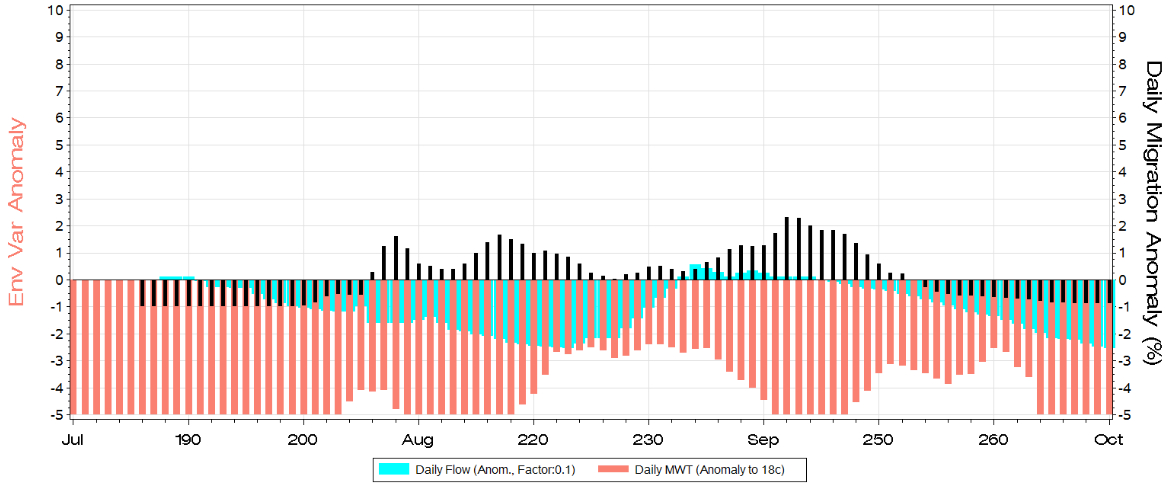

1953 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 13.4c Total Migrants: 714614
Zero-Line Thresholds: Daily Migrants: 1% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


1954 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Sep MWT: 13.1c Total Migrants: 503422
Zero-Line Thresholds: Daily Migrants: 1% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

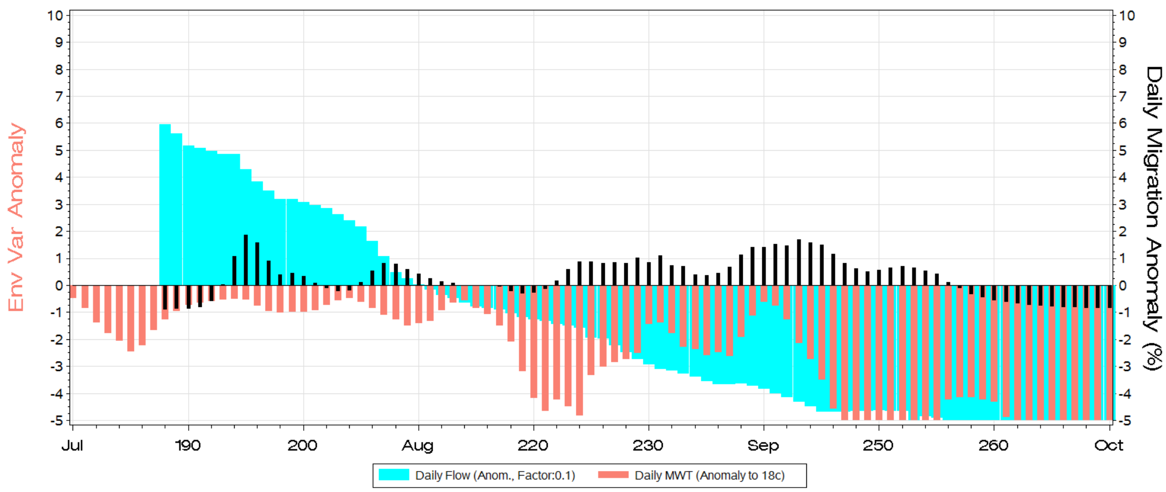

1955 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 12.9c Total Migrants: 101976
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


1956 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 15.0c Total Migrants: 373519
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

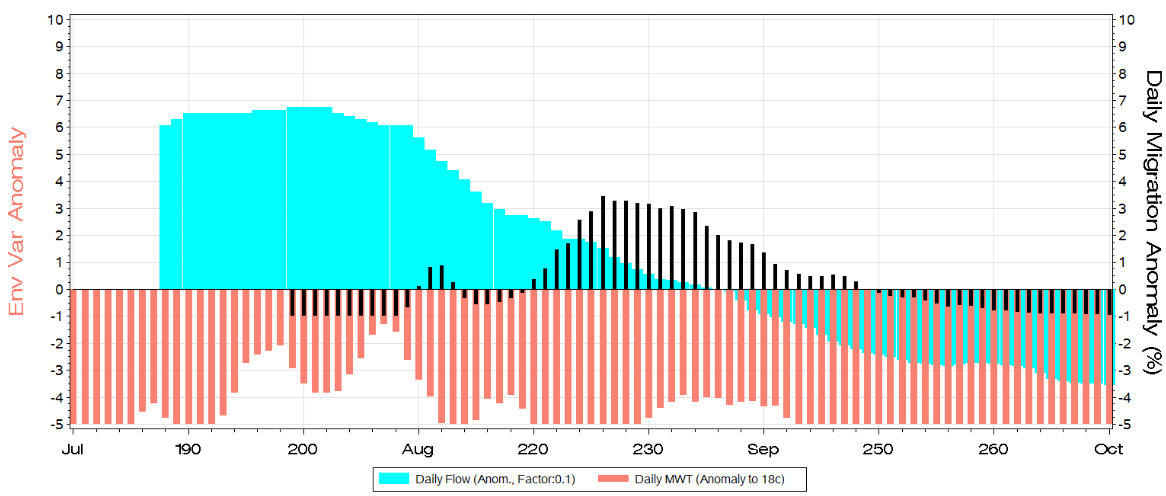
1957 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 12.8c Total Migrants: 483311
Zero-Line Thresholds: Daily Migrants: 1% MWT: 18c Flow: 100 m3/s

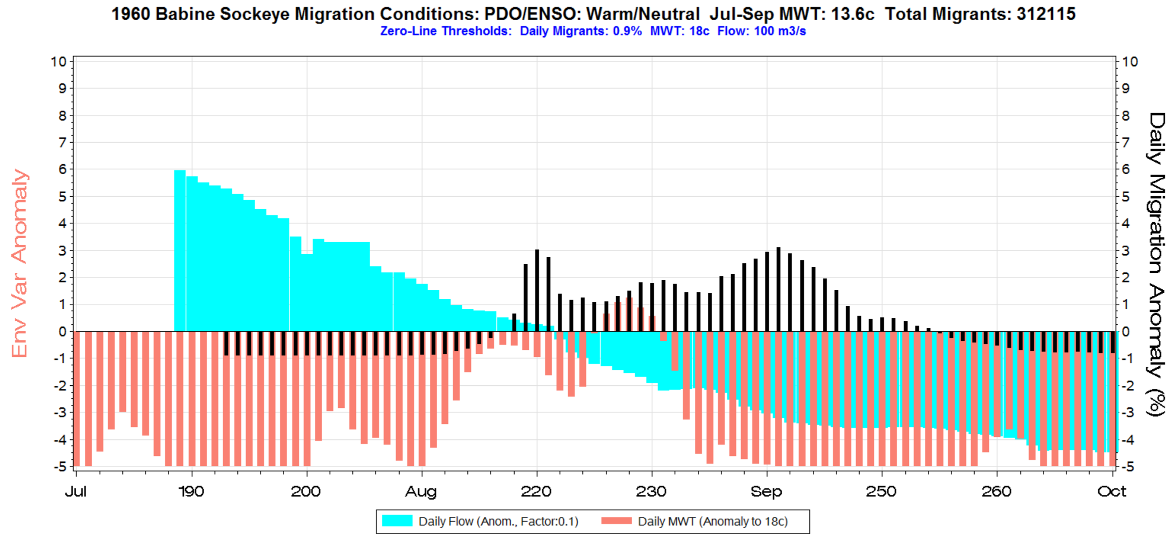


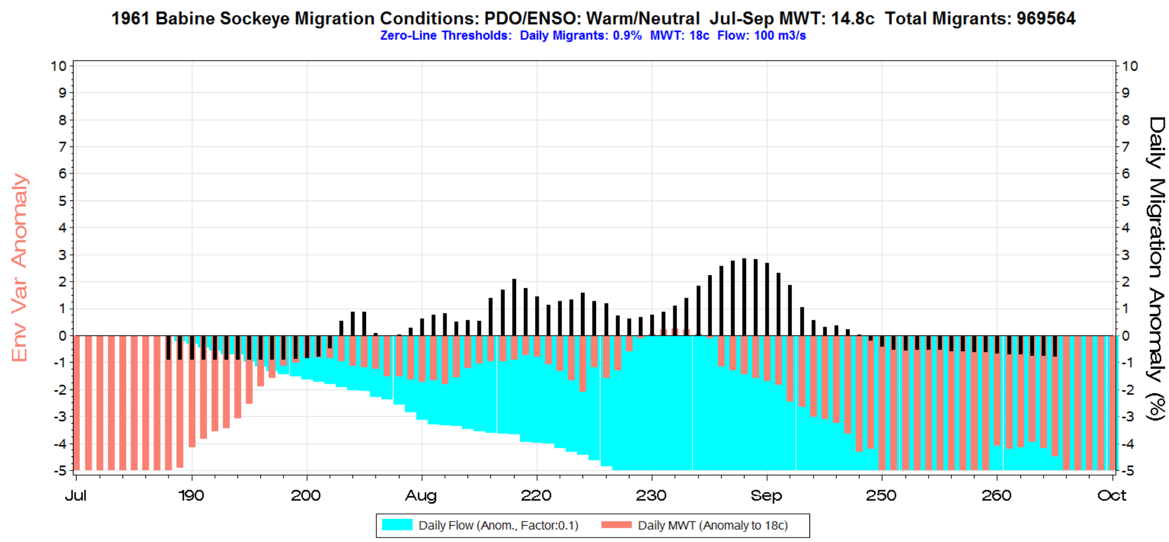
1958 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 14.7c Total Migrants: 842819
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

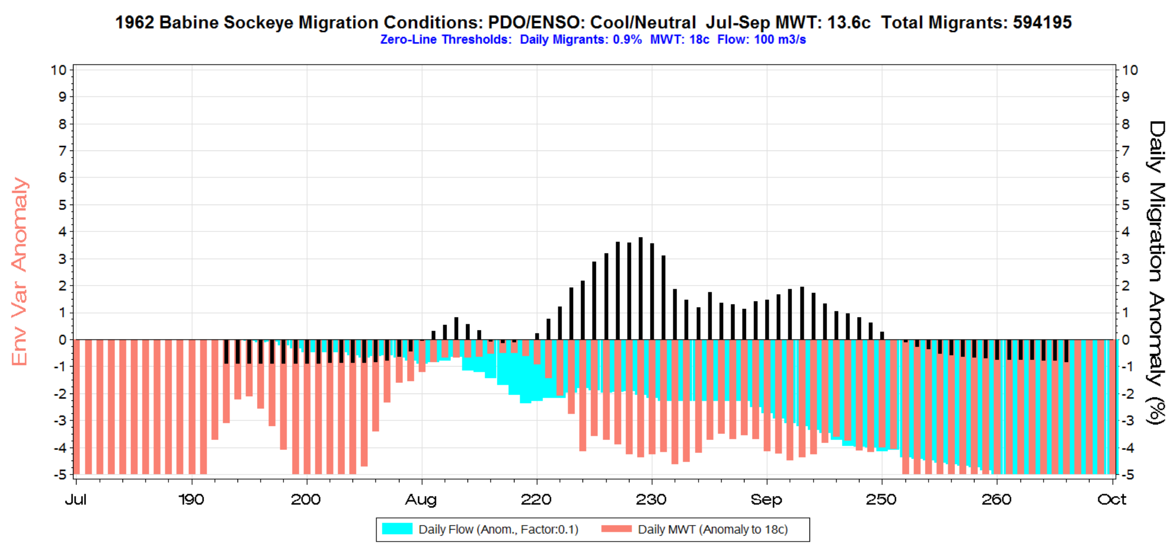


1959 Babine Sockeye Migration Conditions: PDO/ENSO: ????/Cool Jul-Sep MWT: 12.7c Total Migrants: 814788
Zero-Line Thresholds: Daily Migrants: 1% MWT: 18c Flow: 100 m3/s

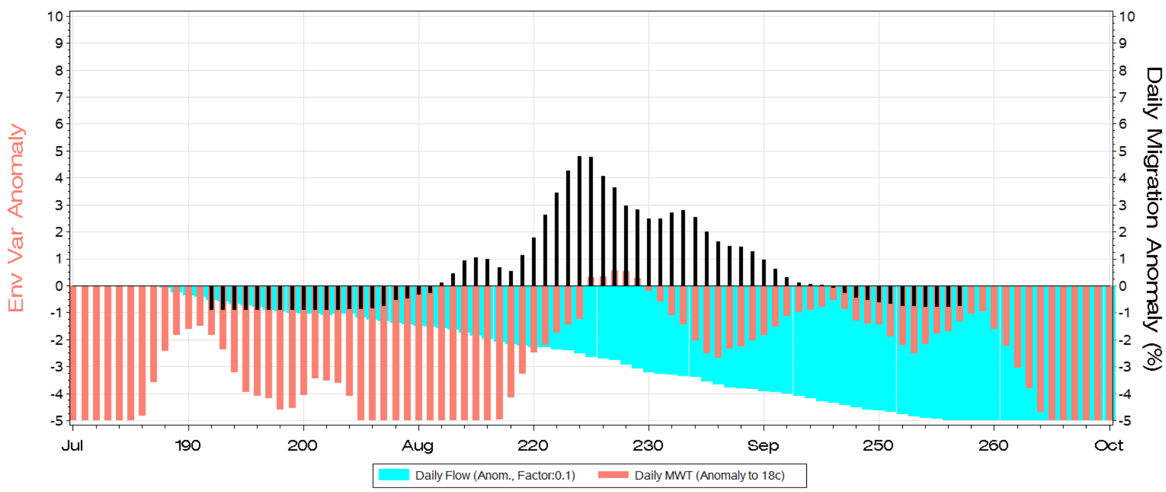



1960 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Sep MWT: 13.6c Total Migrants: 312115
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

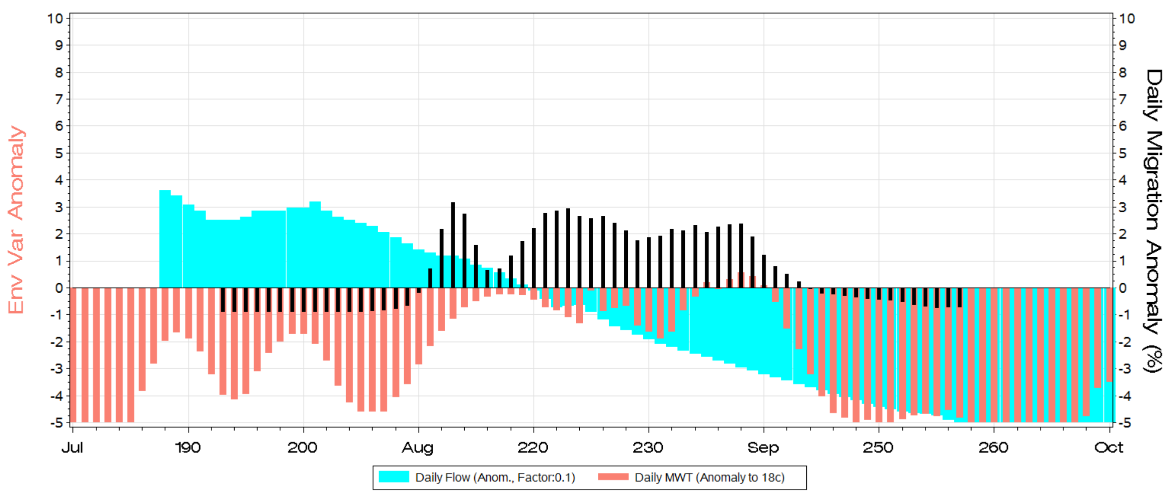

1961 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Sep MWT: 14.8c Total Migrants: 969564
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


1962 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 13.6c Total Migrants: 594195
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

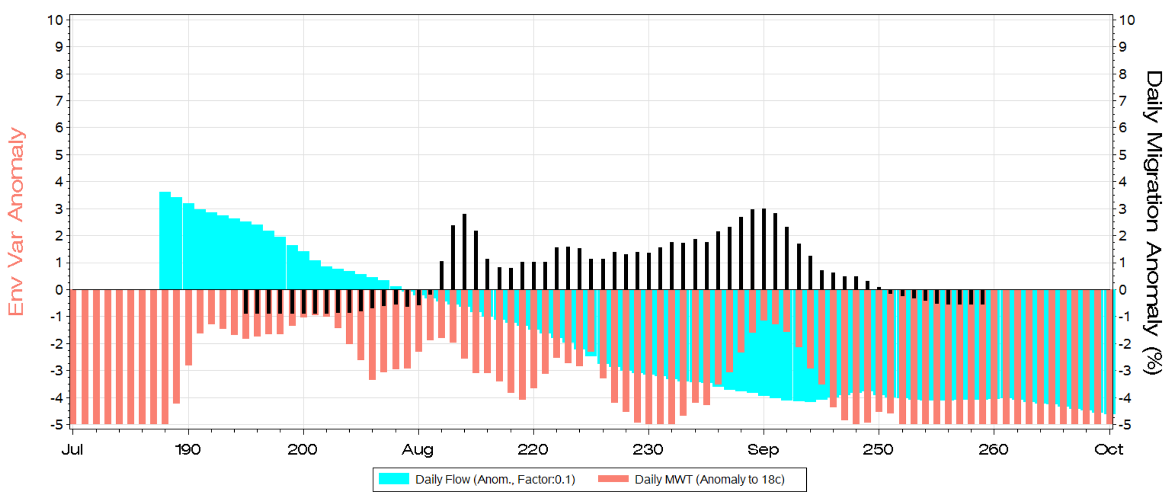
1963 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 14.8c Total Migrants: 761000
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



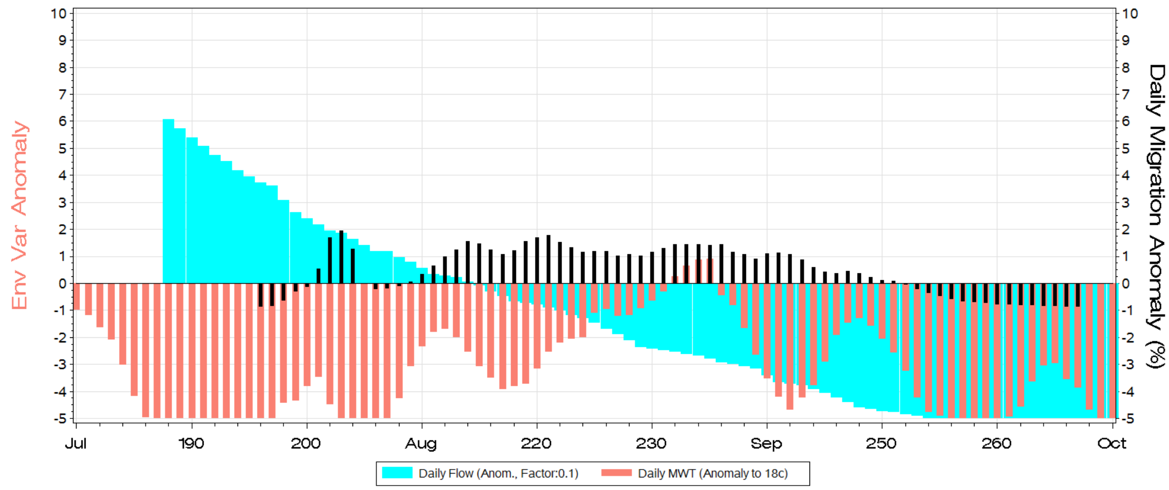
1965 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 15.0c Total Migrants: 644300
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



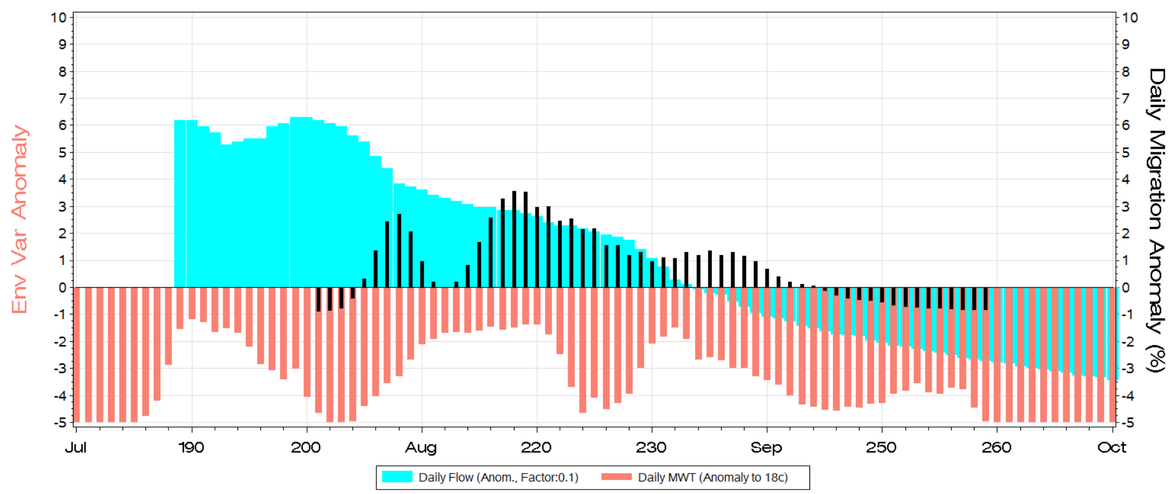
1966 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Sep MWT: 14.2c Total Migrants: 571000
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



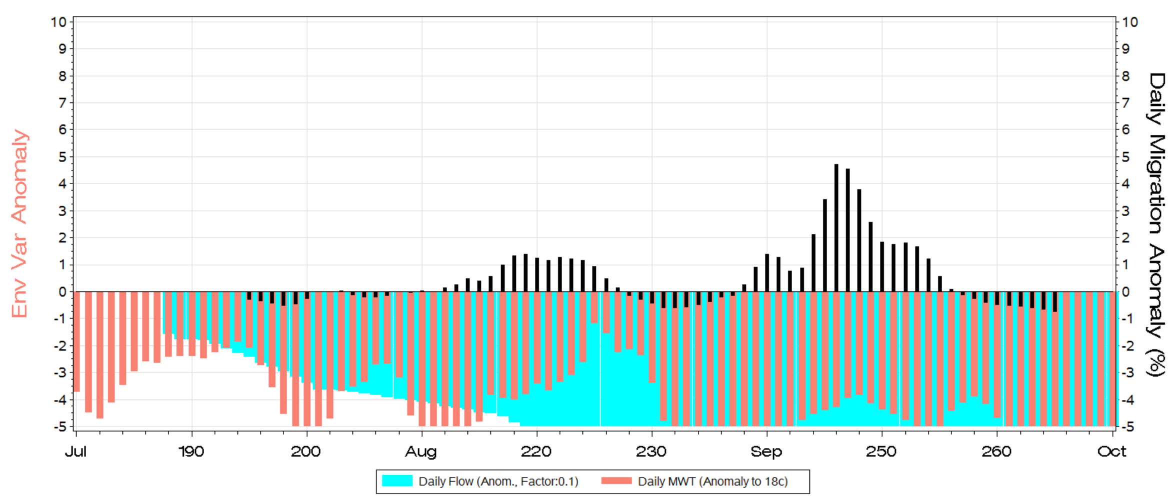
1967 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 14.3c Total Migrants: 632135
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



1968 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 14.1c Total Migrants: 605400
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

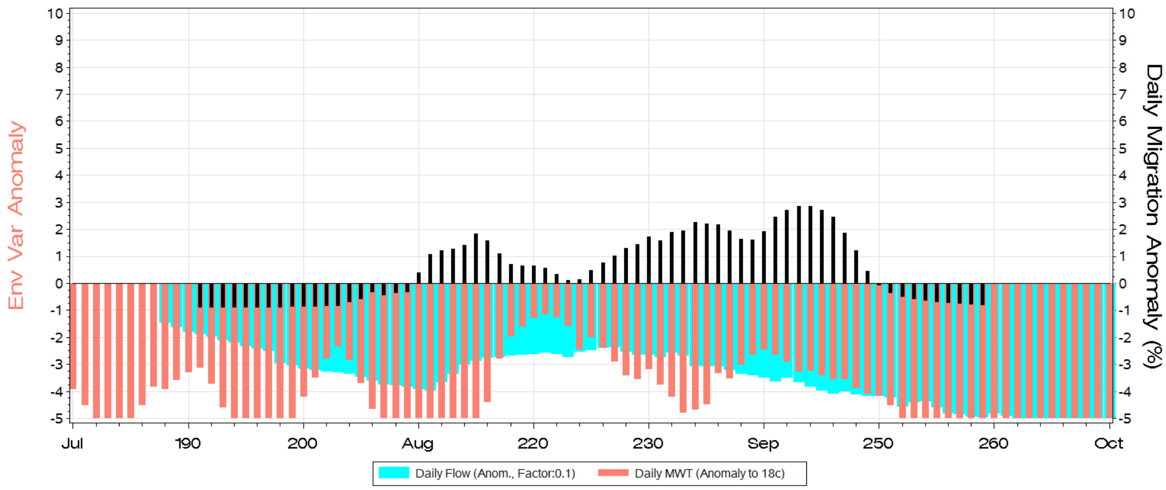


1969 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Sep MWT: 13.5c Total Migrants: 787900
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



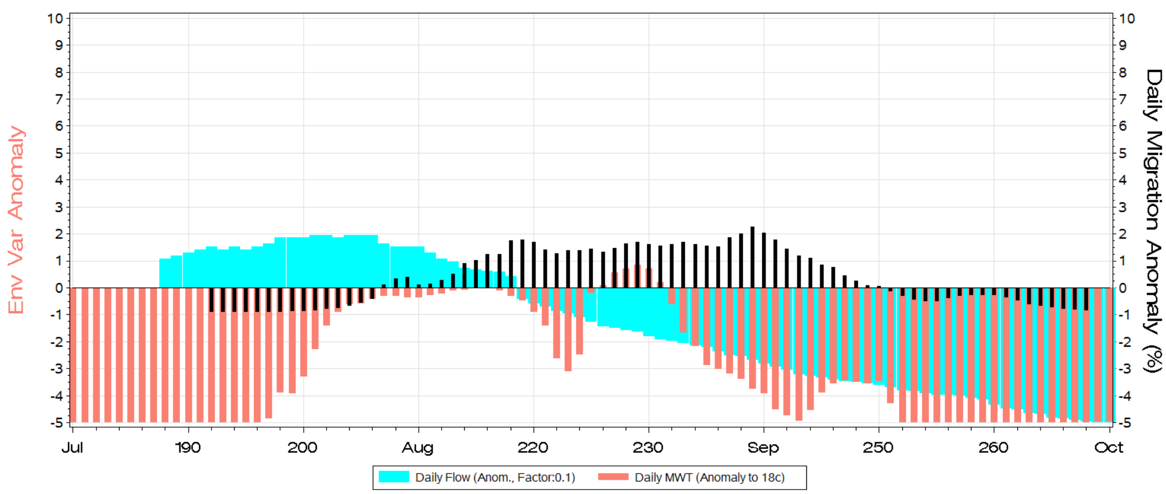
1970 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 13.3c Total Migrants: 828000

Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



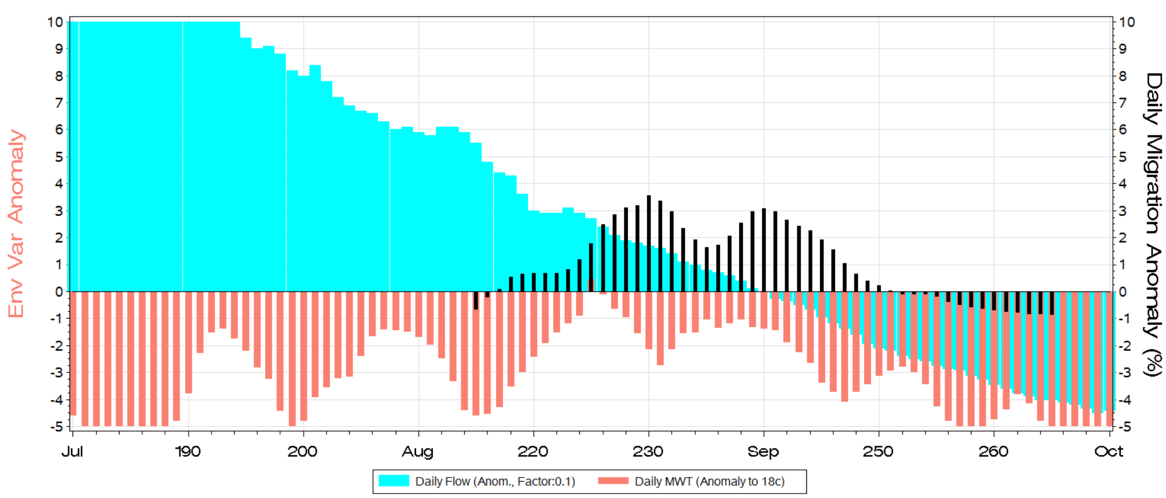
1971 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 14.2c Total Migrants: 870600

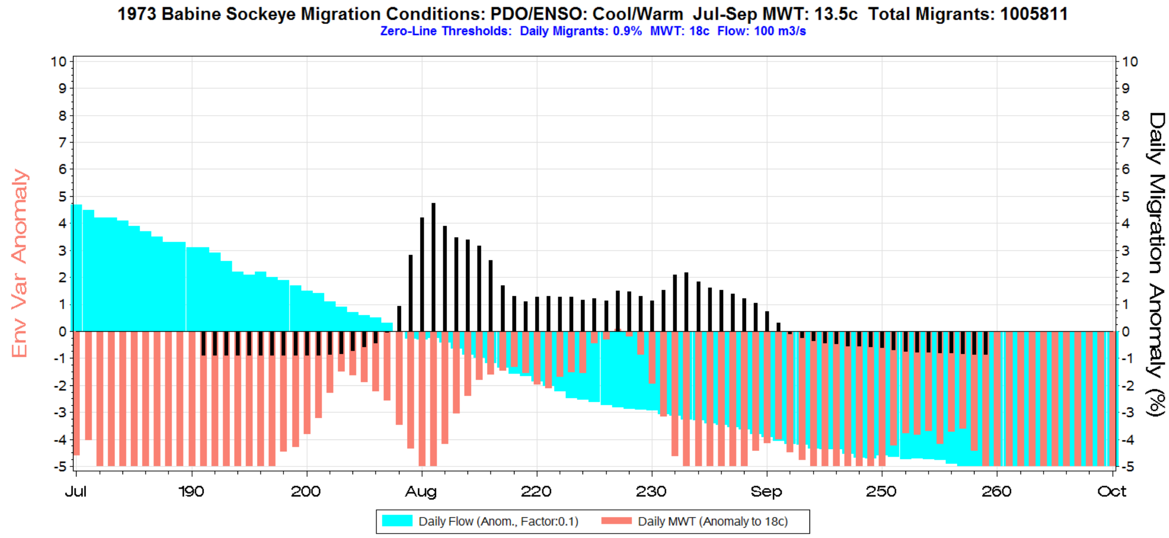
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

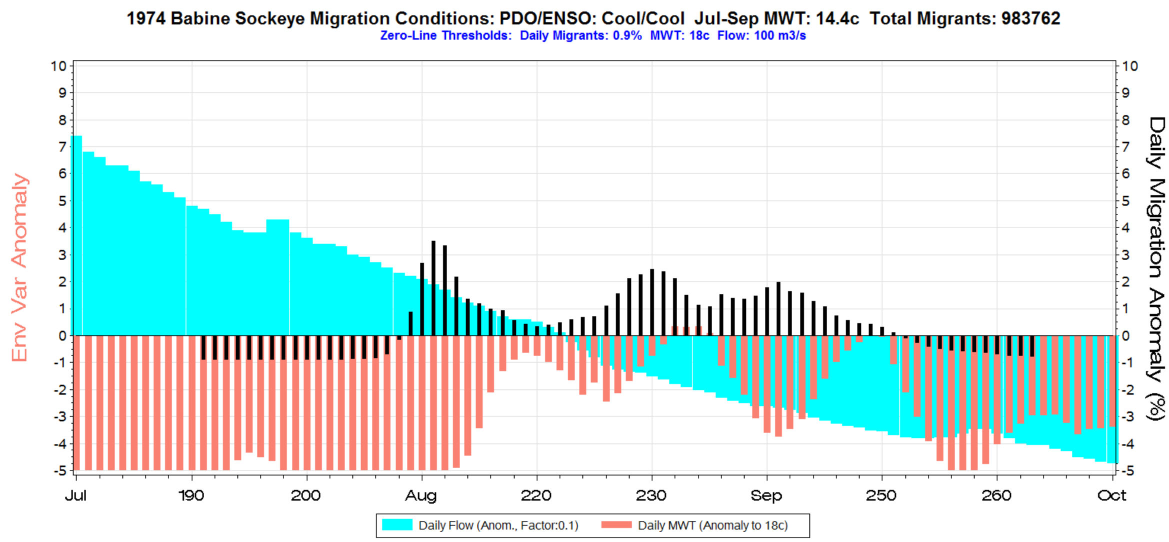


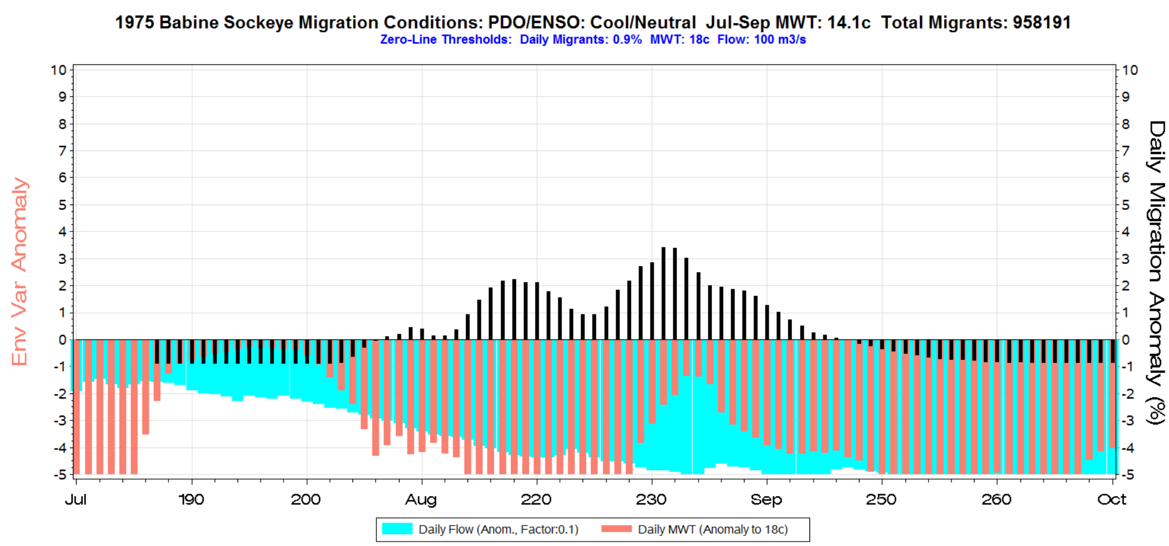
1972 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 14.2c Total Migrants: 918827

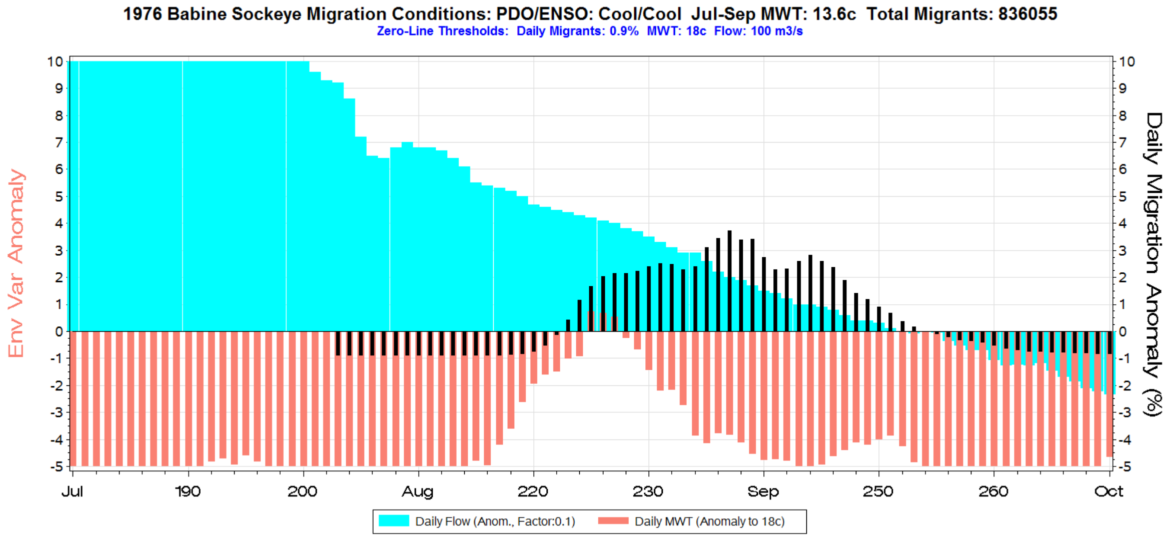
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

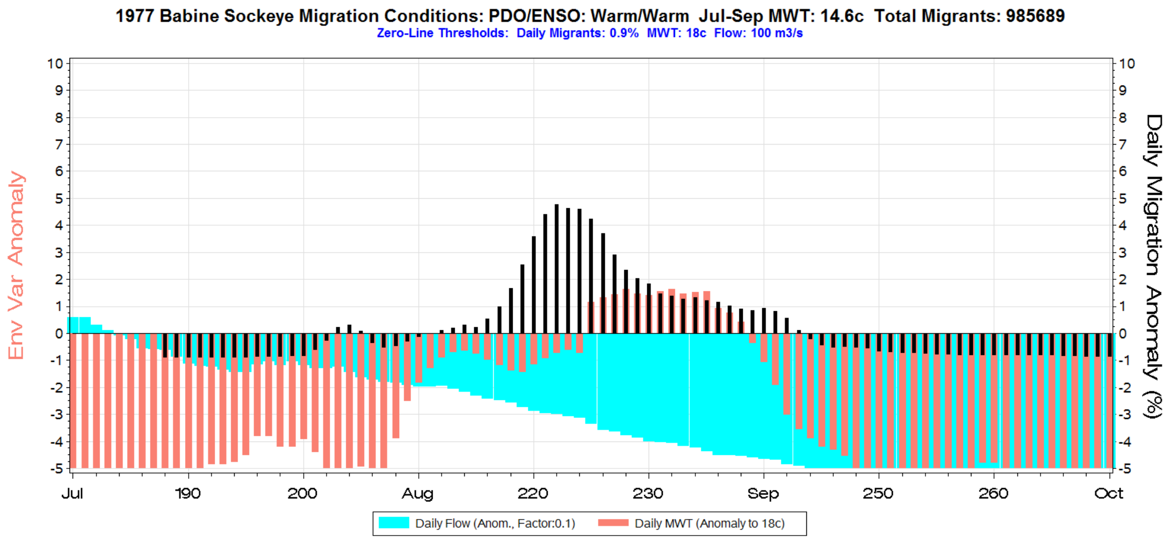


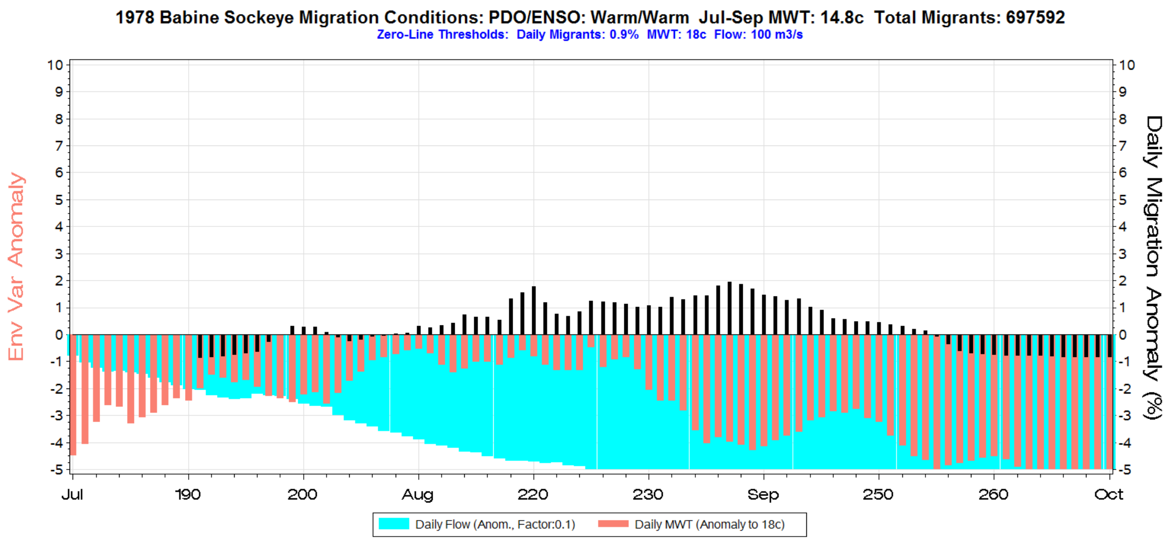

1973 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Sep MWT: 13.5c Total Migrants: 1005811
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

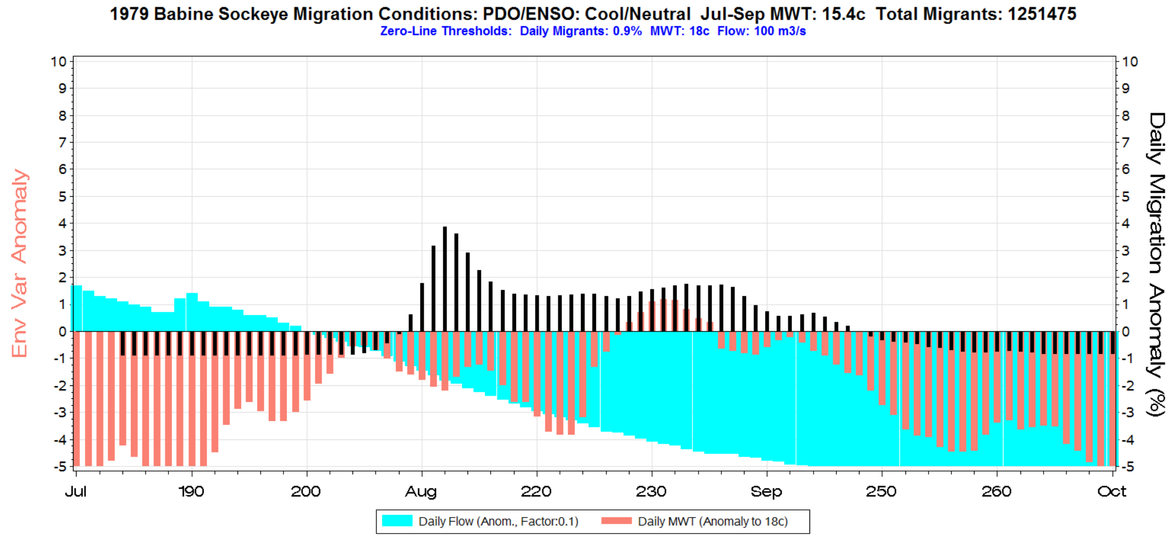

1974 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 14.4c Total Migrants: 983762
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

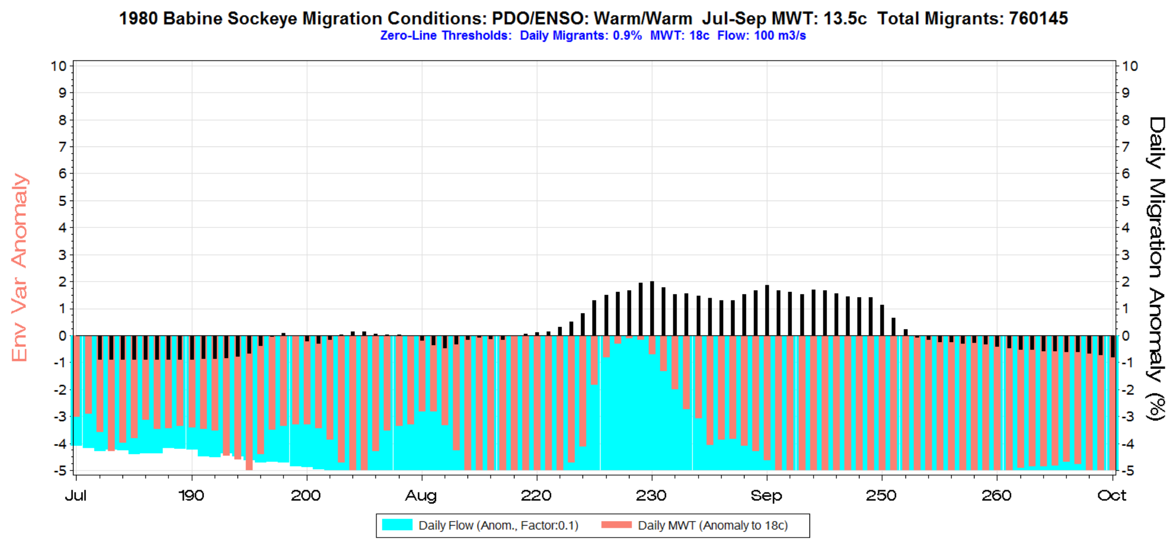

1975 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 14.1c Total Migrants: 958191
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

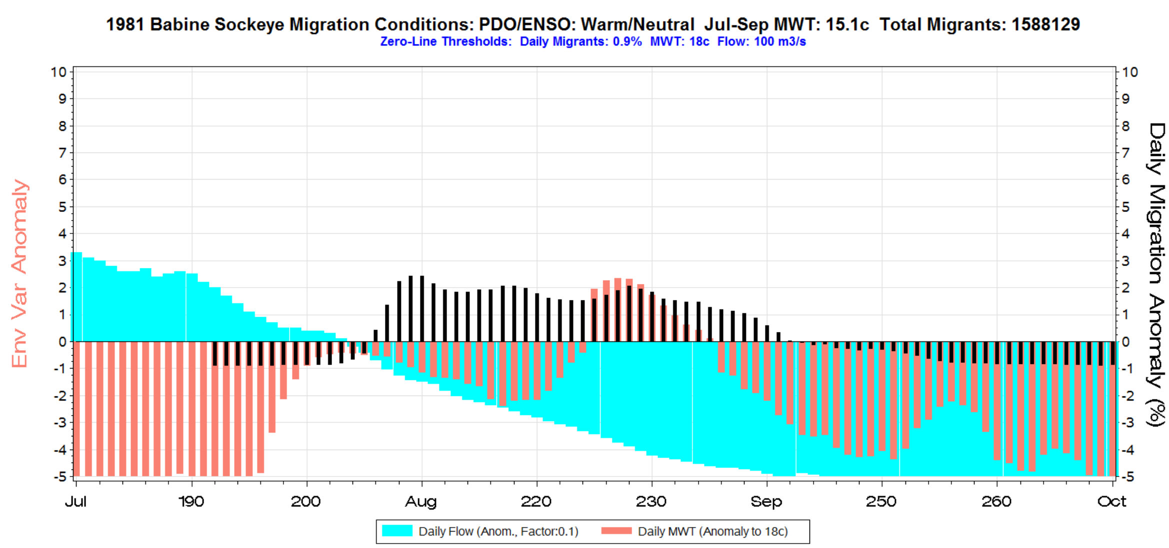

1976 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 13.6c Total Migrants: 836055
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


1977 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 14.6c Total Migrants: 985689
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

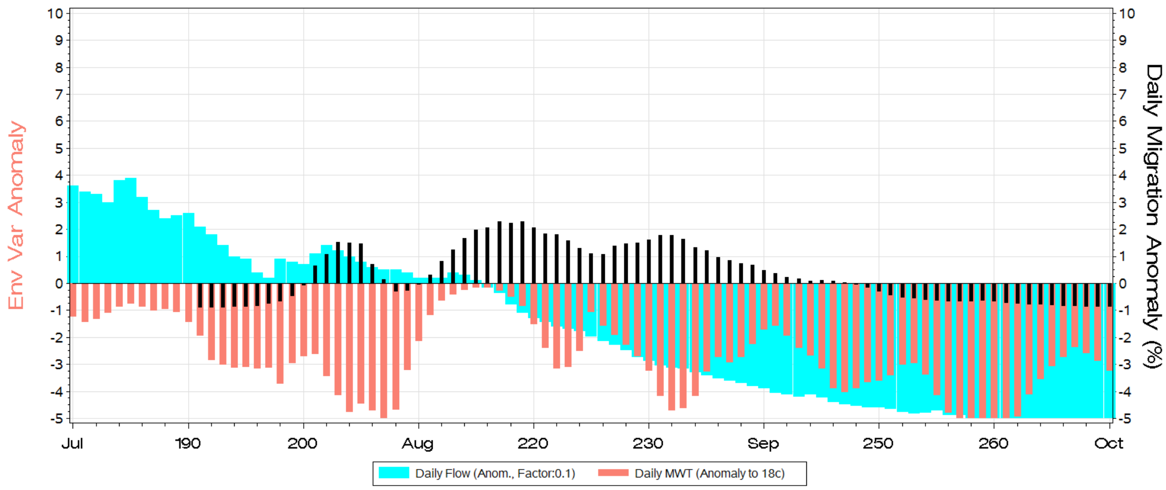

1978 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 14.8c Total Migrants: 697592
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


1979 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 15.4c Total Migrants: 1251475
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

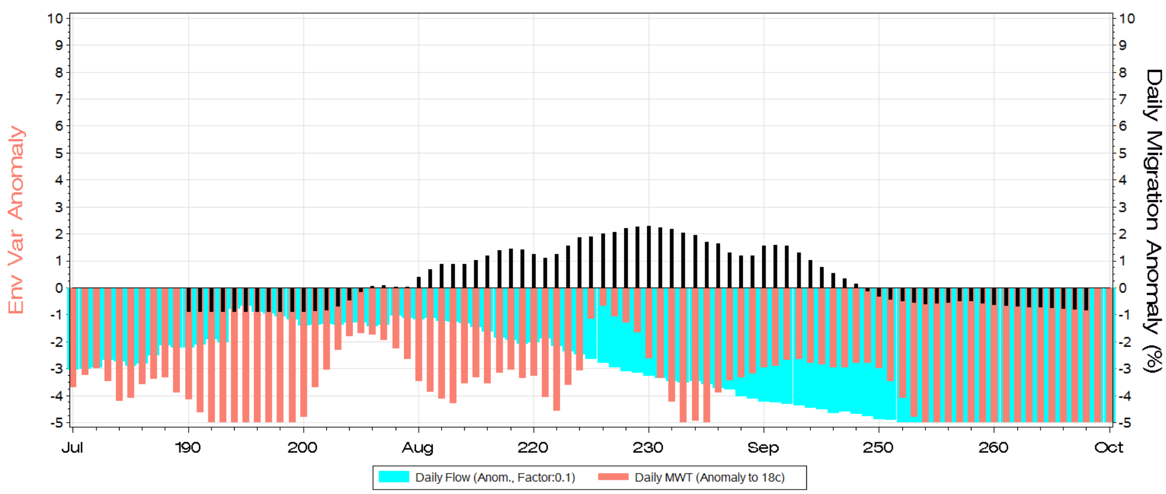

1980 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 13.5c Total Migrants: 760145
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


1981 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Sep MWT: 15.1c Total Migrants: 1588129
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

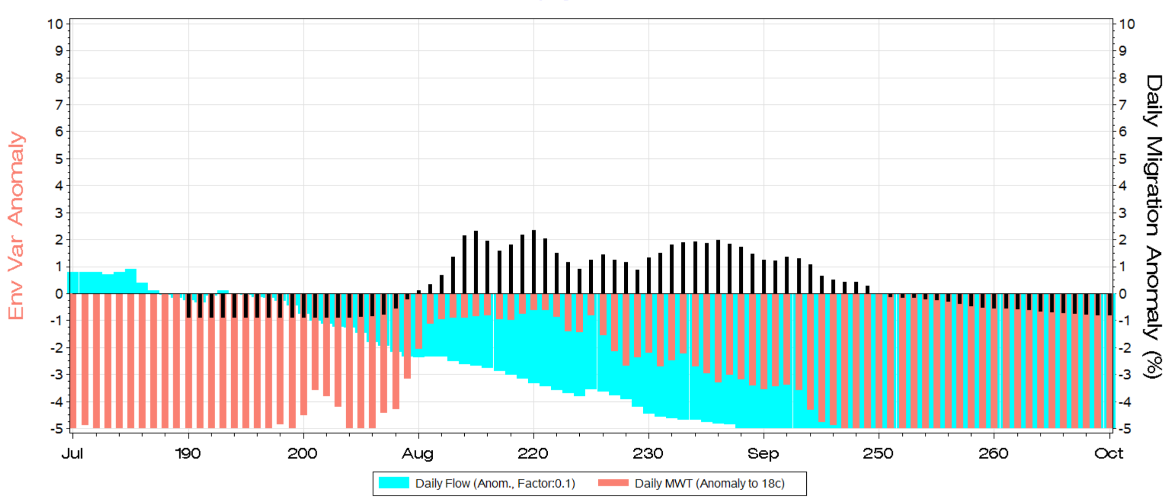
1982 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Sep MWT: 15.0c Total Migrants: 1197058
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



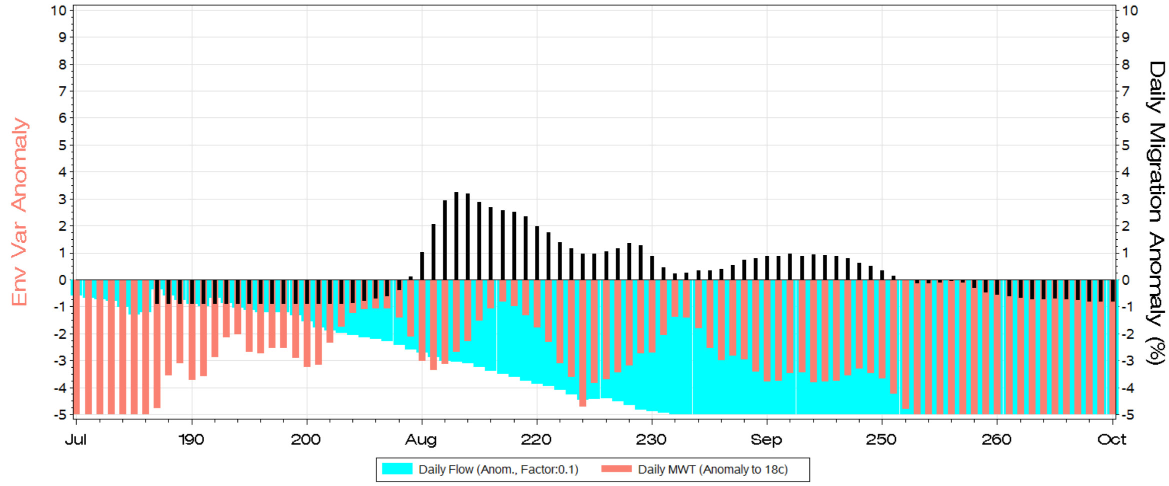
1983 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 13.7c Total Migrants: 1239528
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



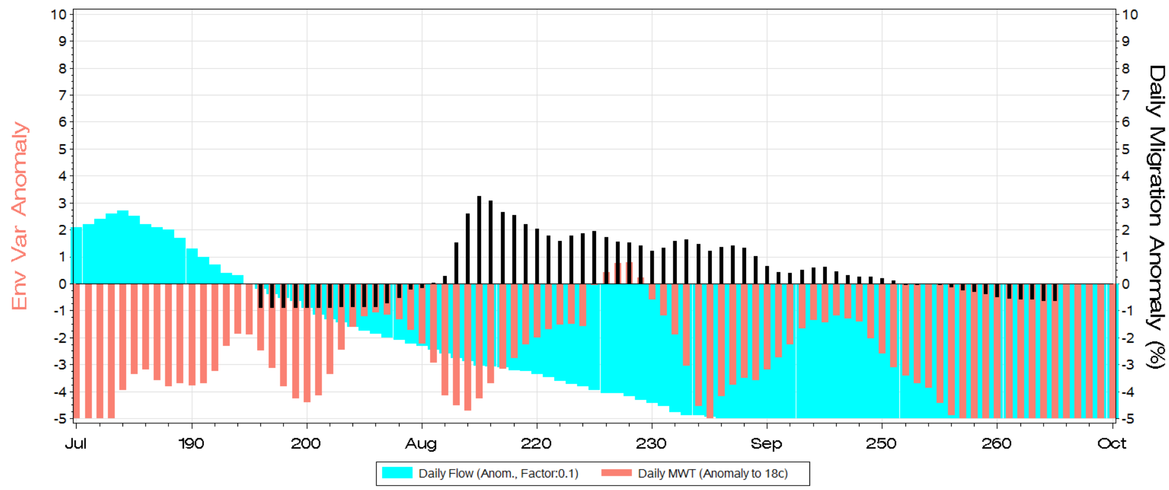
1984 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Cool Jul-Sep MWT: 13.3c Total Migrants: 1173137
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



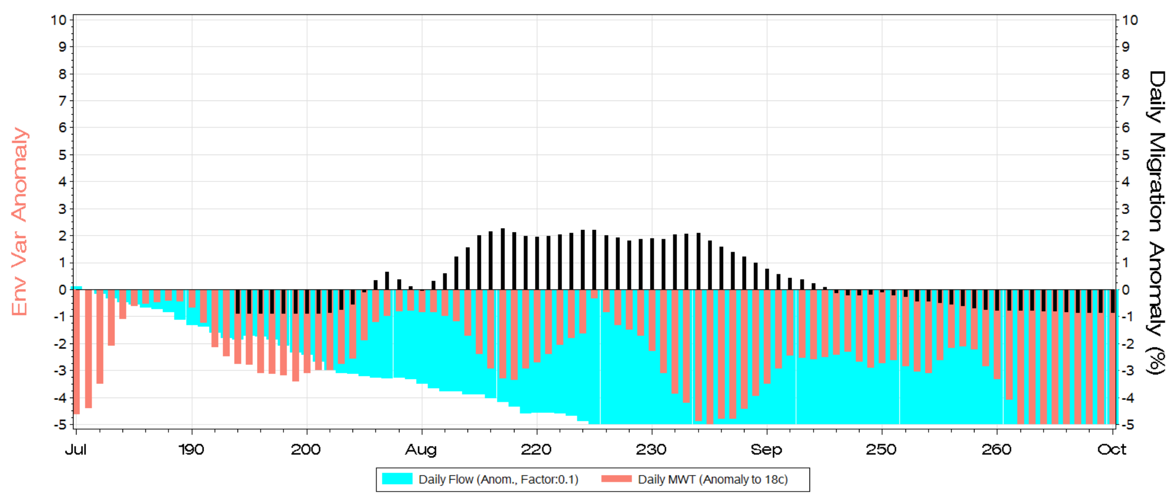
1985 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Cool Jul-Sep MWT: 14.3c Total Migrants: 2214758
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



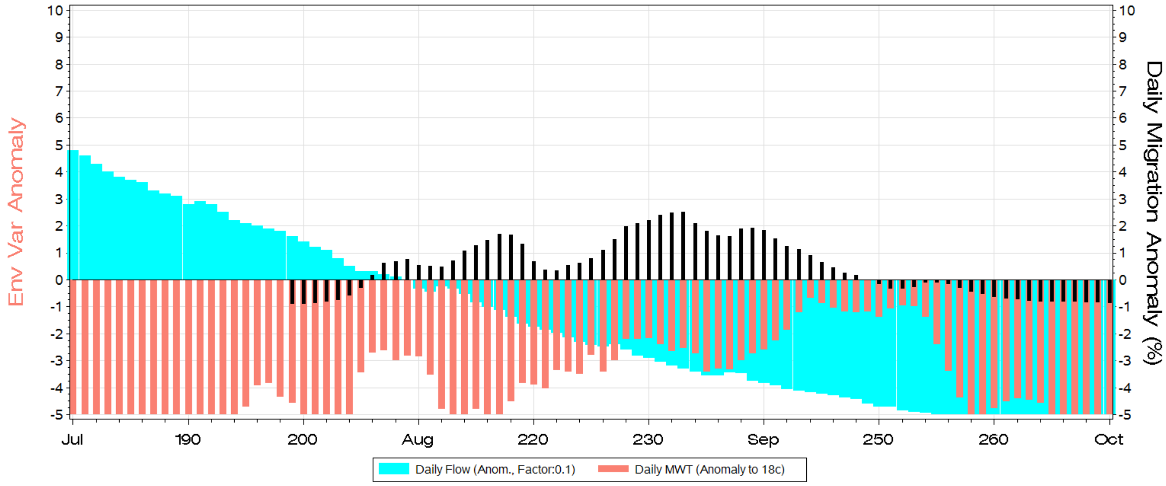
1986 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Sep MWT: 14.4c Total Migrants: 789632
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



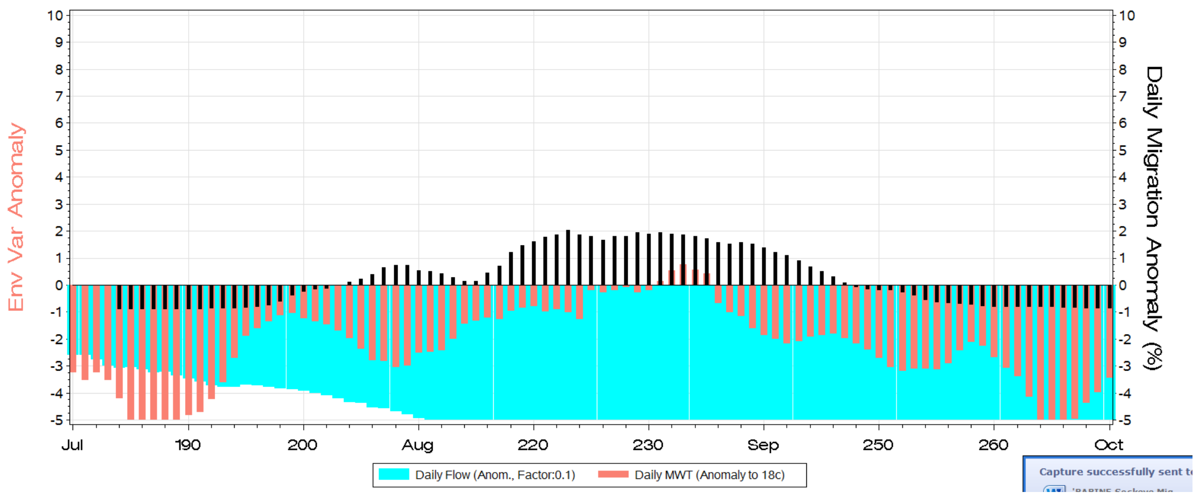
1987 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 15.0c Total Migrants: 1946493
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



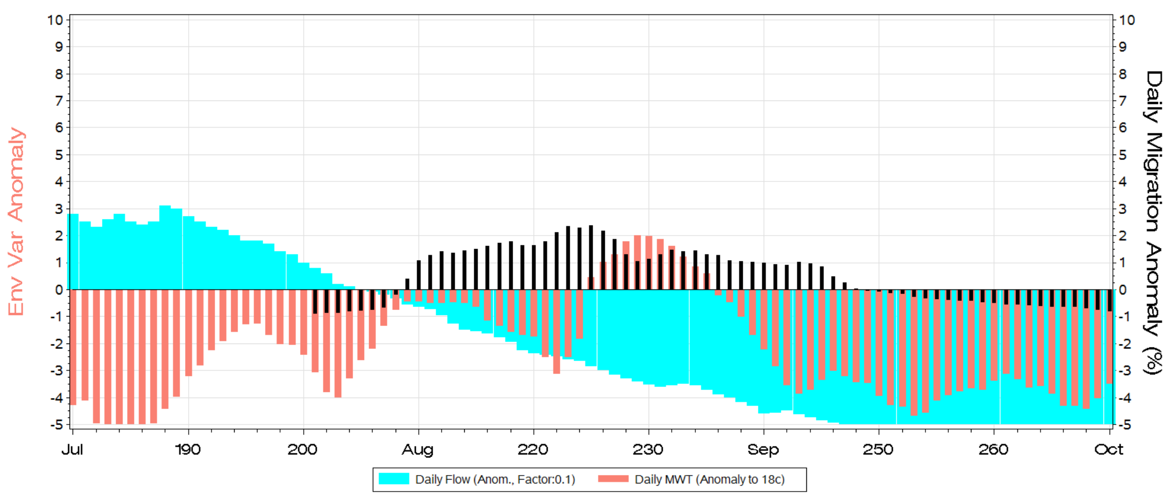
1988 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 13.7c Total Migrants: 1486510
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

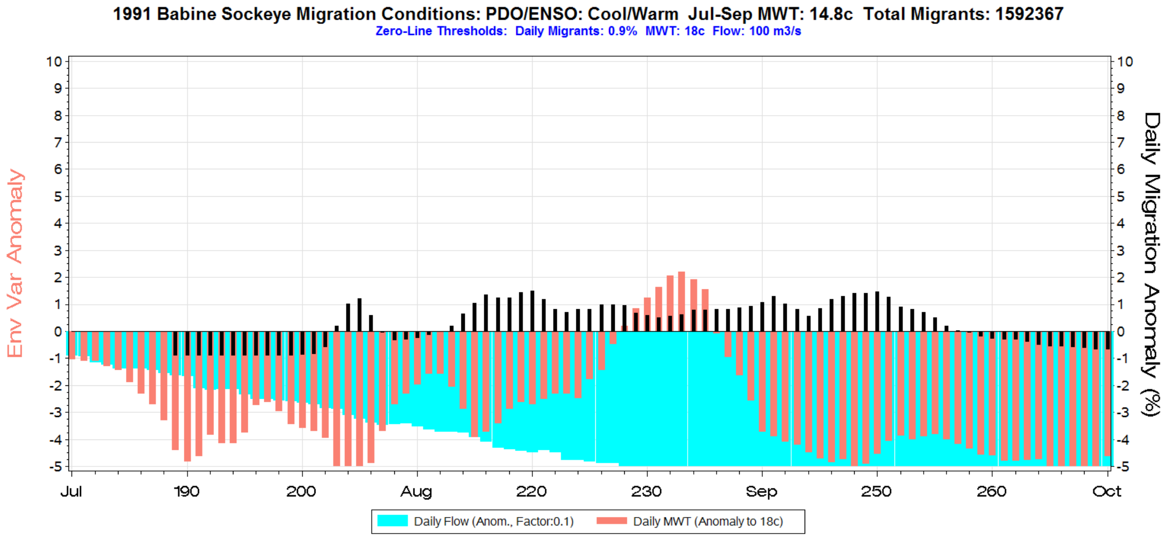


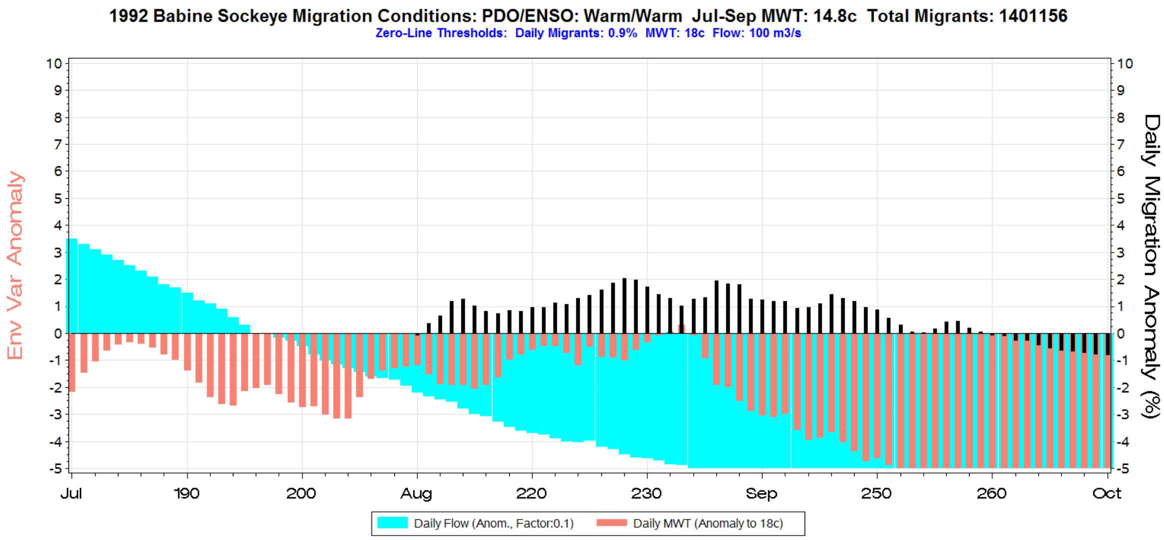
1989 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 15.7c Total Migrants: 1255027
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

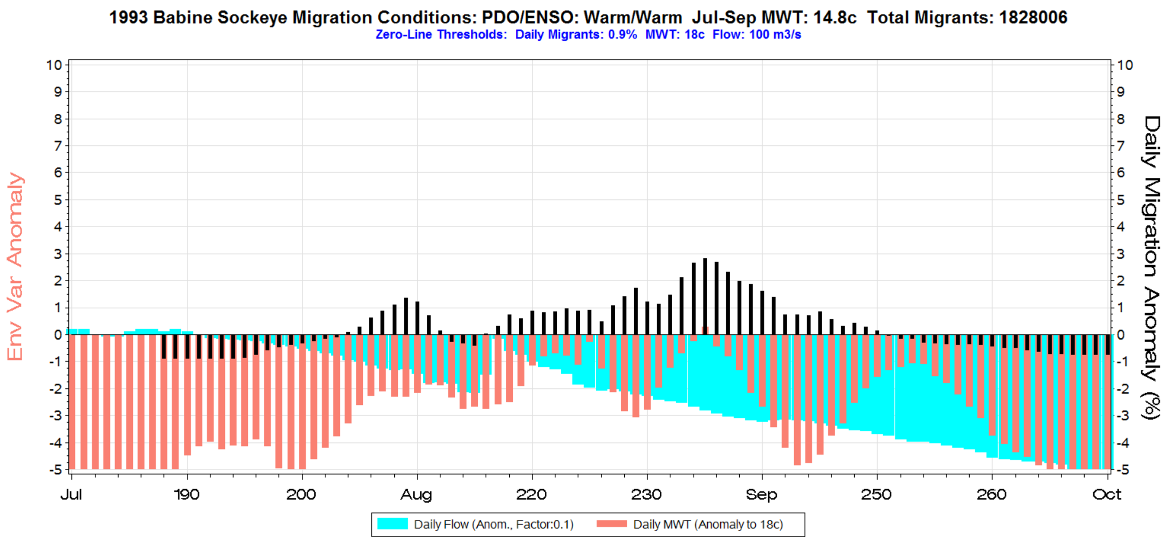


1990 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 15.6c Total Migrants: 1068277
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

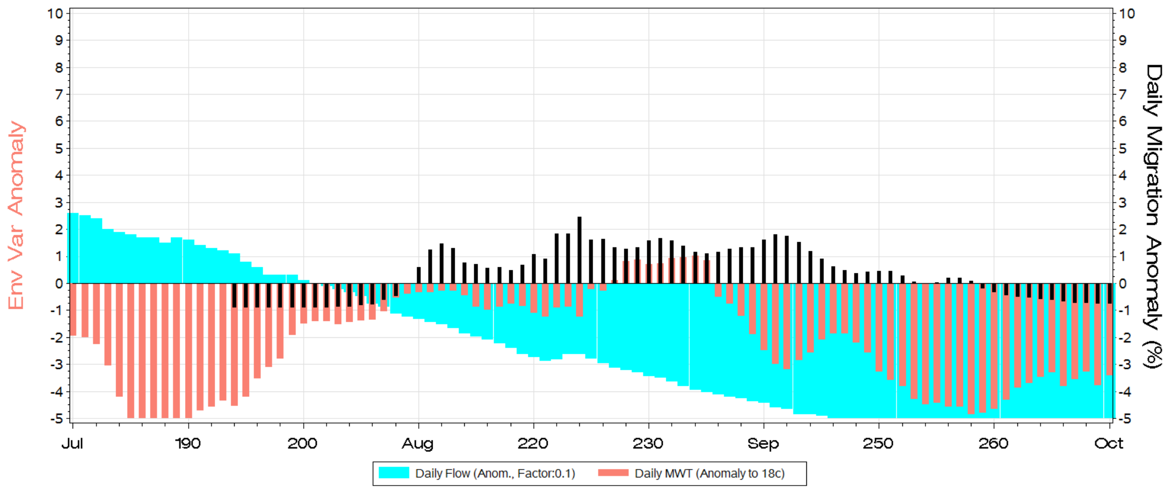



1991 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Sep MWT: 14.8c Total Migrants: 1592367
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

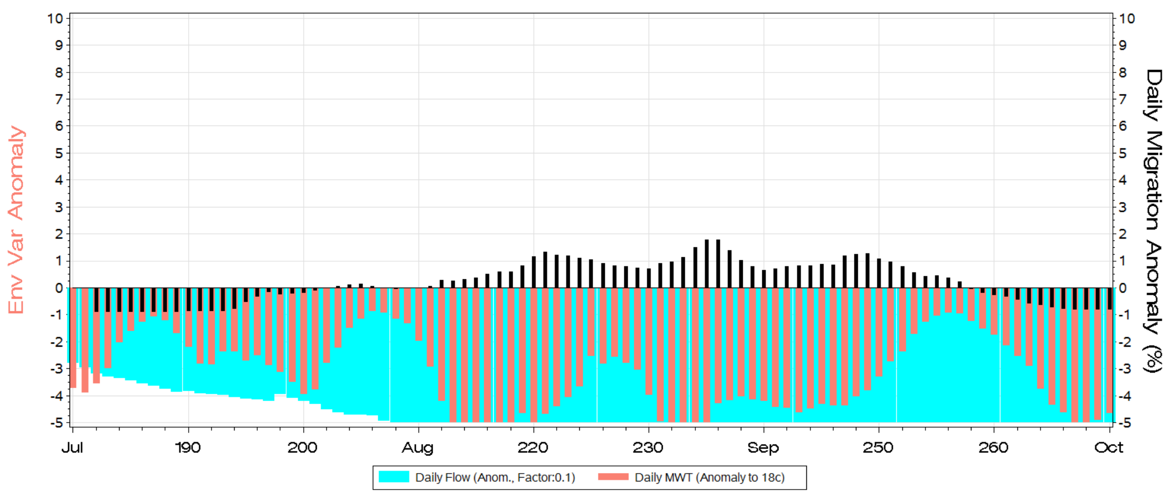

1992 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 14.8c Total Migrants: 1401156
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


1993 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 14.8c Total Migrants: 1828006
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

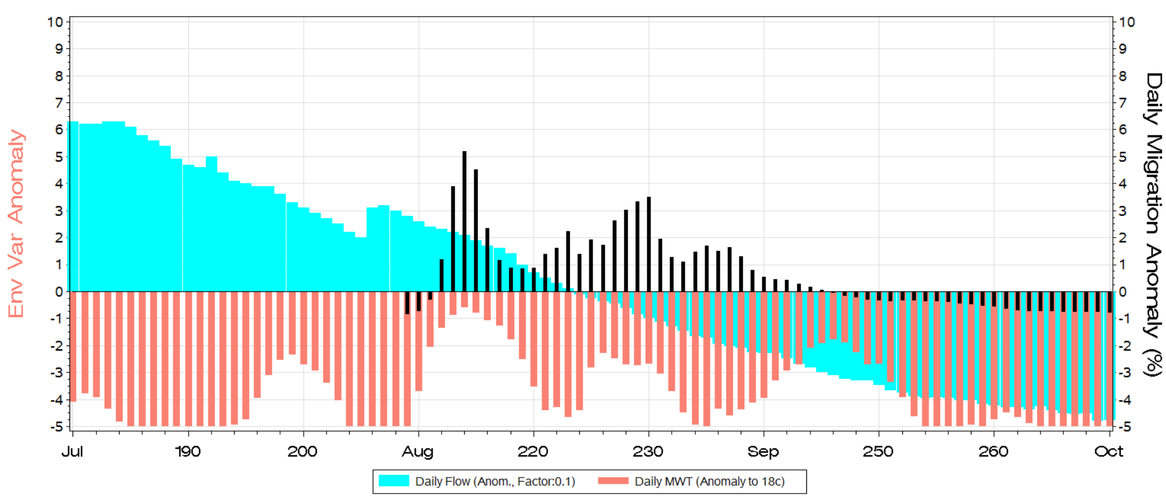
1994 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Sep MWT: 15.5c Total Migrants: 1373709
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



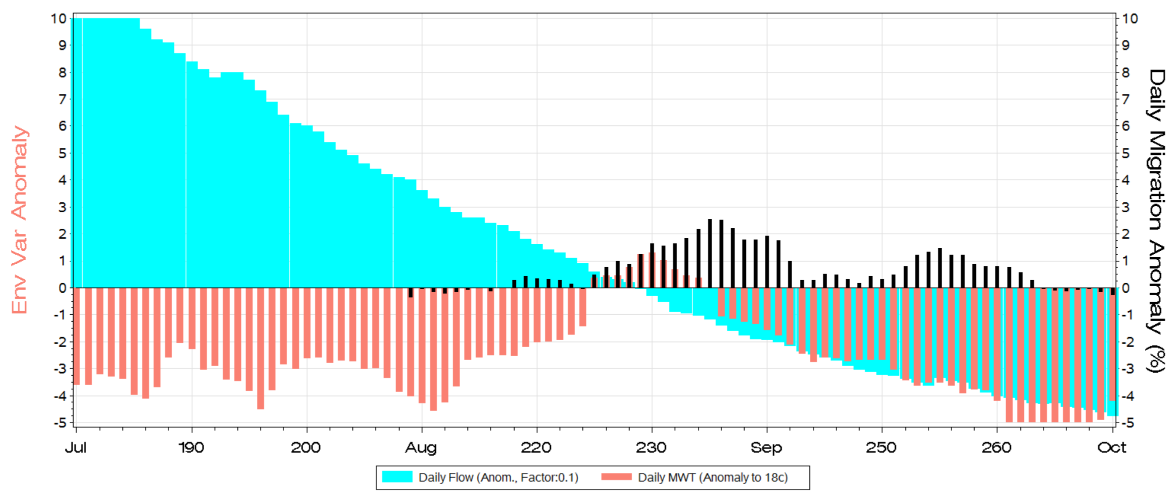
1995 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Sep MWT: 14.6c Total Migrants: 2279904
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



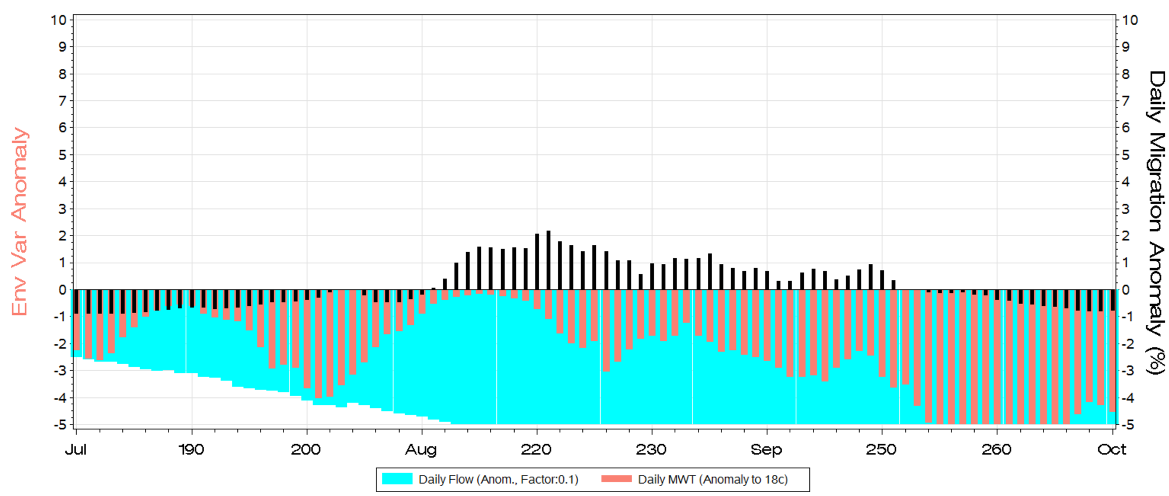
1996 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Sep MWT: 13.6c Total Migrants: 1944067
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



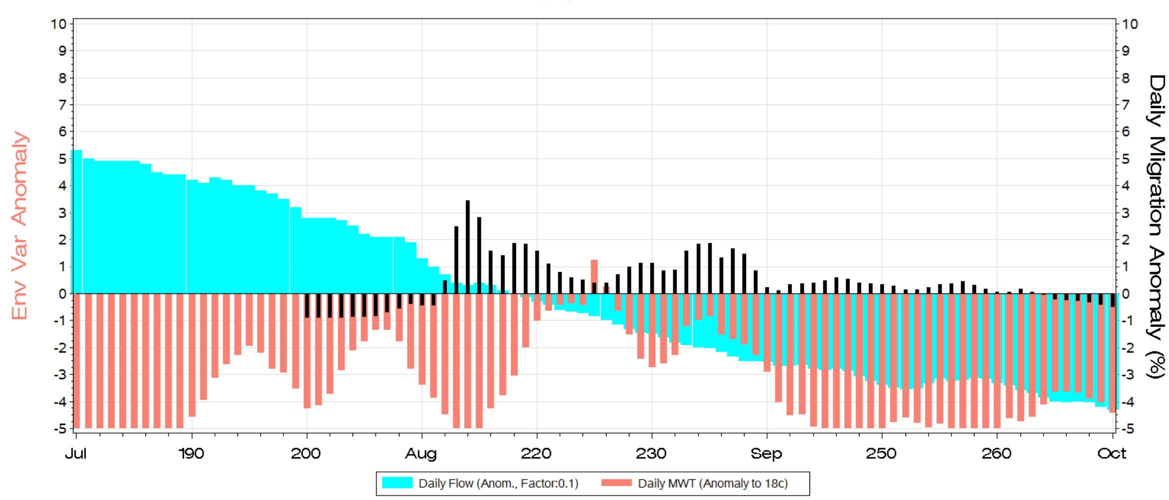
1997 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Sep MWT: 15.1c Total Migrants: 1001495
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



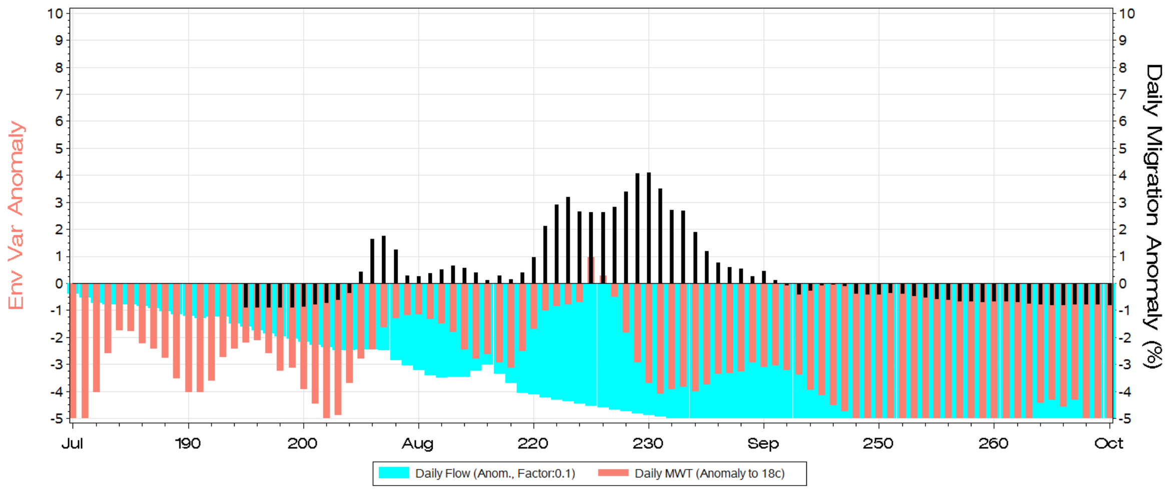
1998 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 15.2c Total Migrants: 558873
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



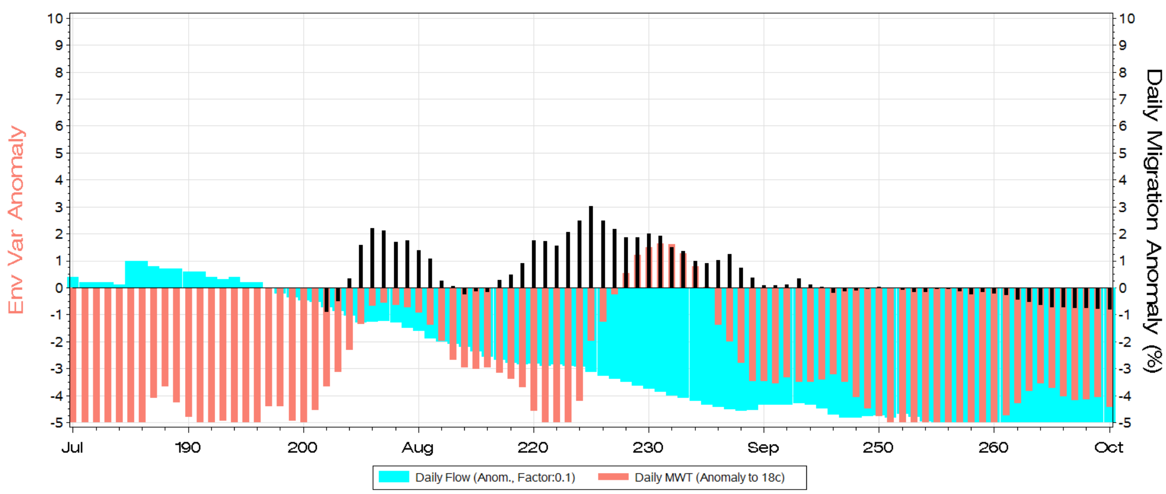
1999 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 14.3c Total Migrants: 780823
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s



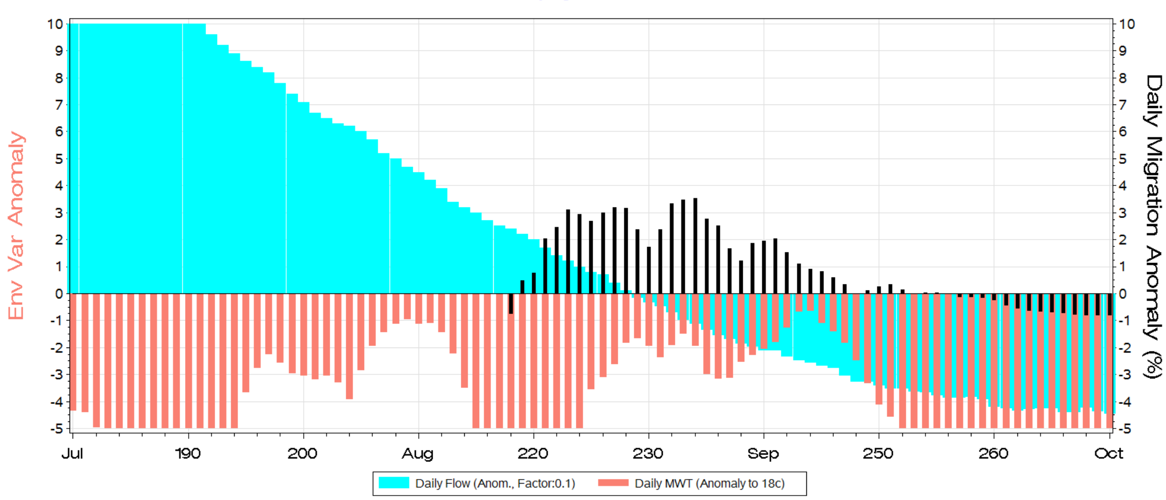
2000 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 14.4c Total Migrants: 1848681
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

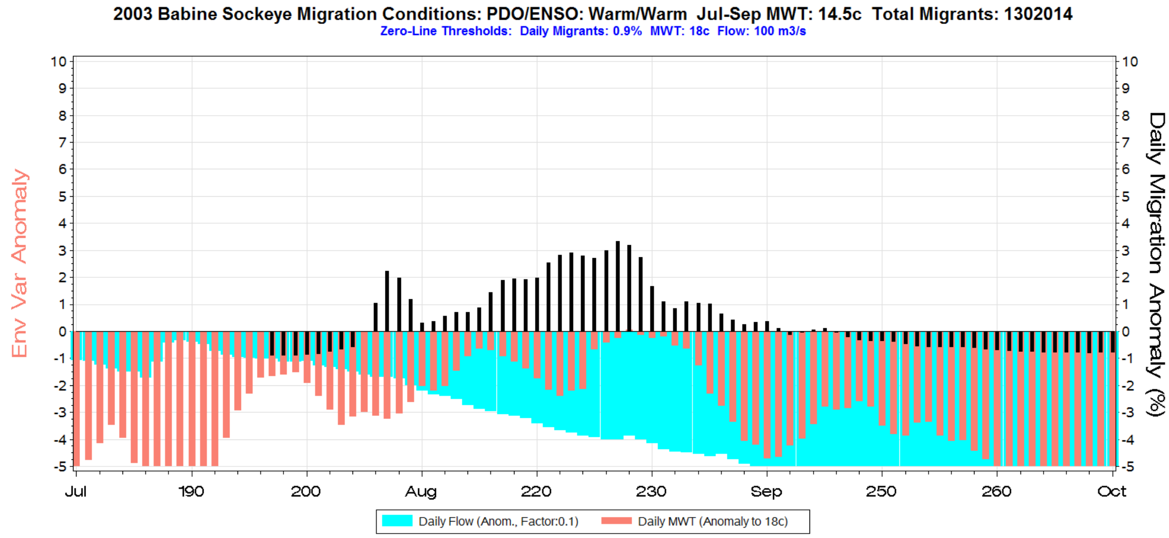


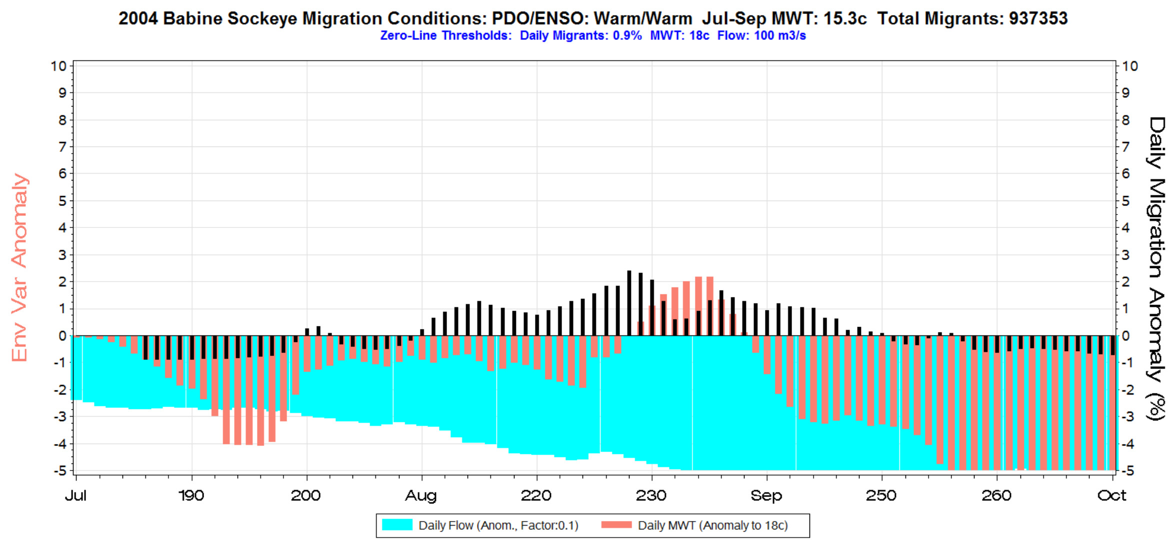
2001 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 14.5c Total Migrants: 2060596
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

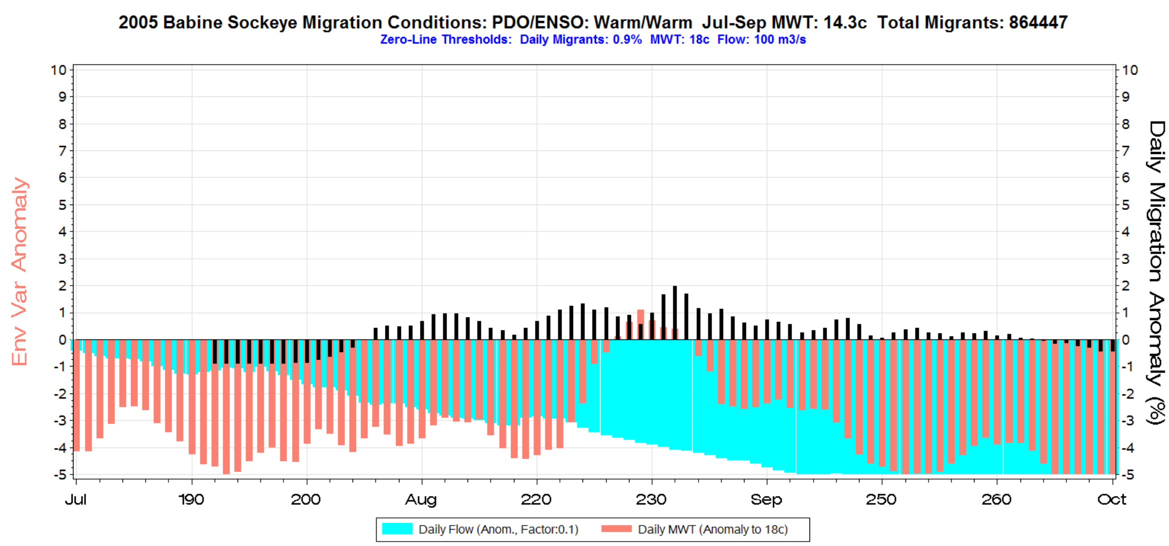


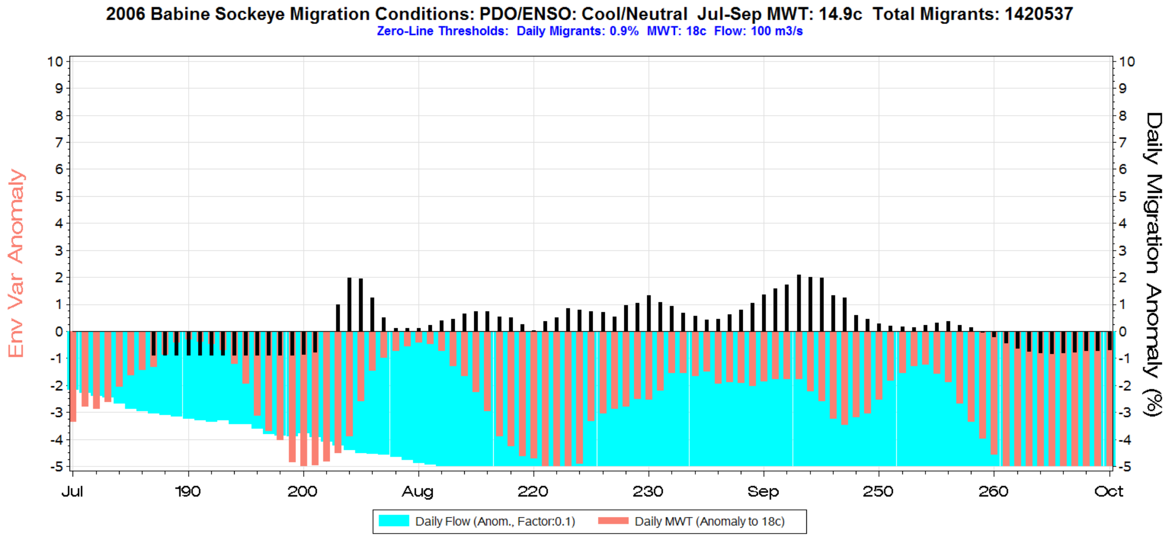
2002 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 13.7c Total Migrants: 447745
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s

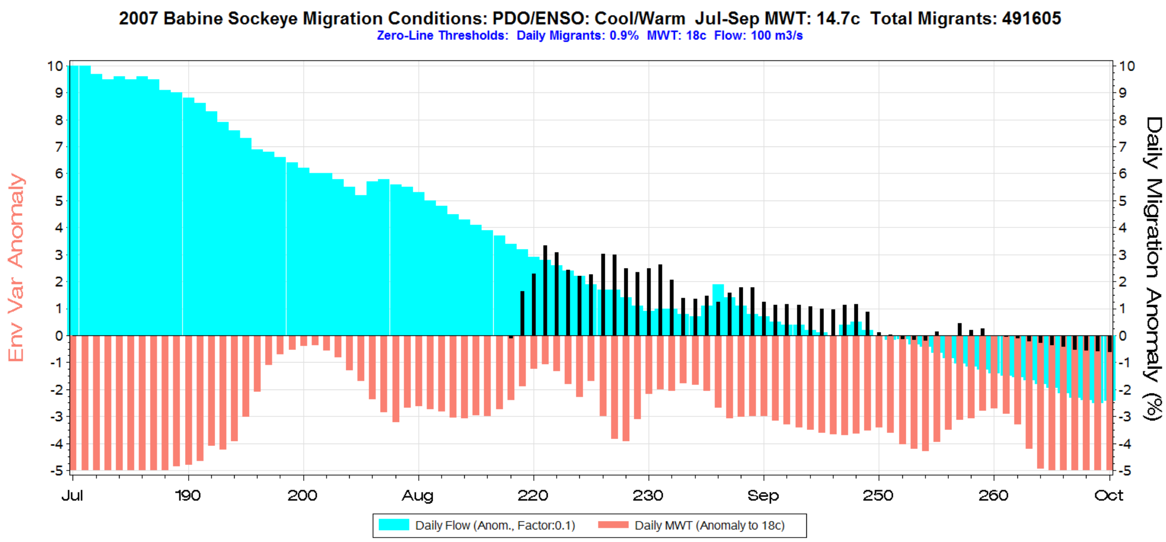


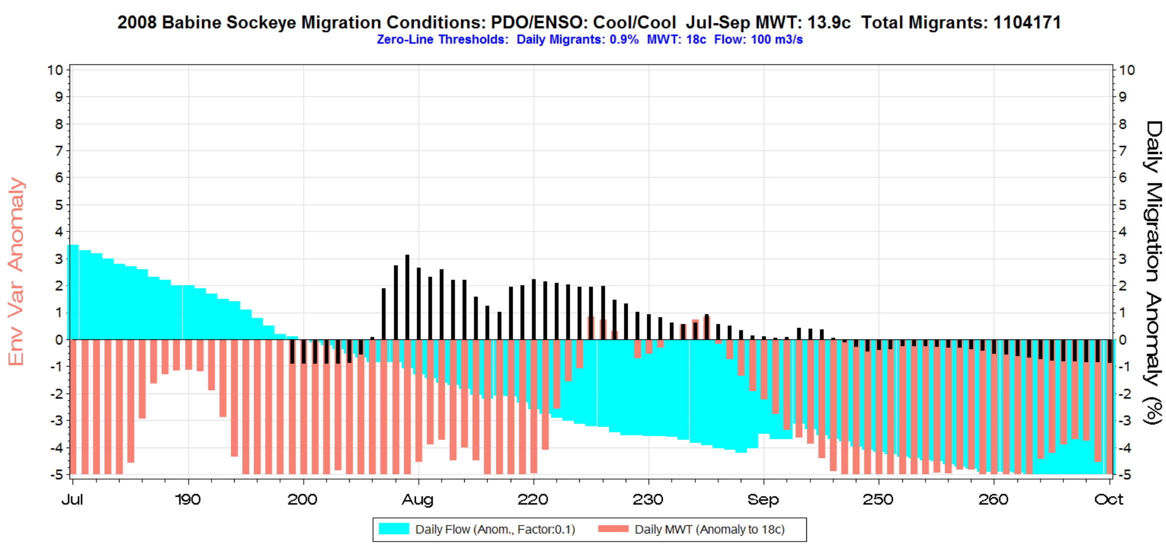

2003 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 14.5c Total Migrants: 1302014
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

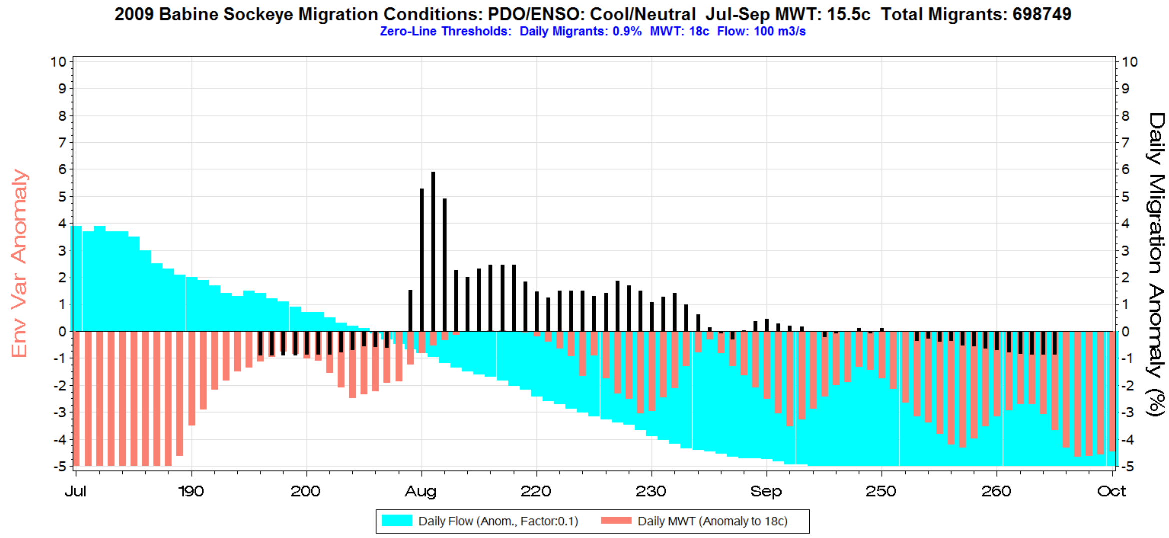

2004 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 15.3c Total Migrants: 937353
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

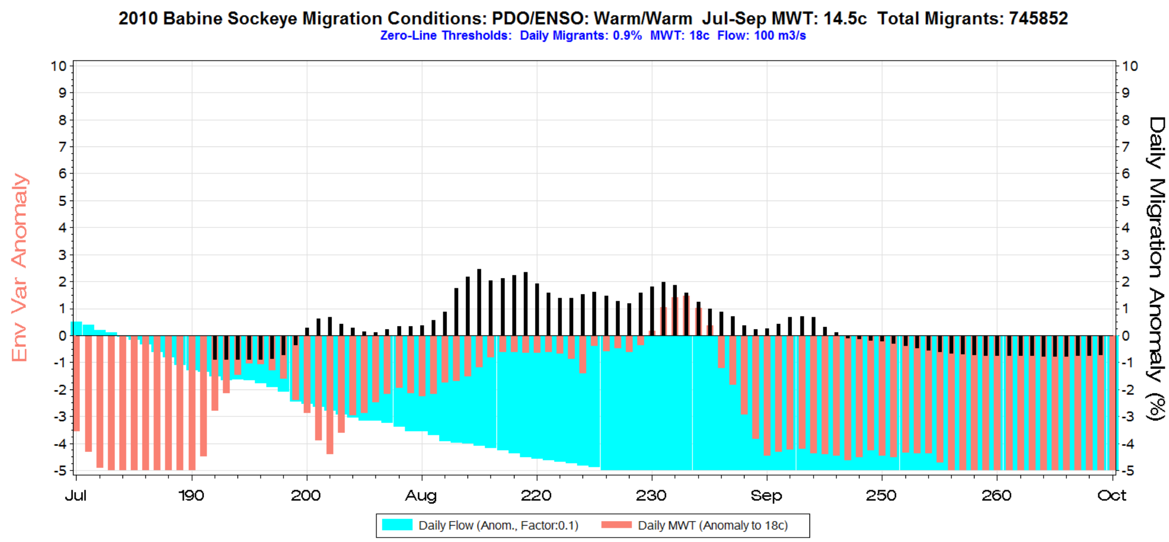

2005 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 14.3c Total Migrants: 864447
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

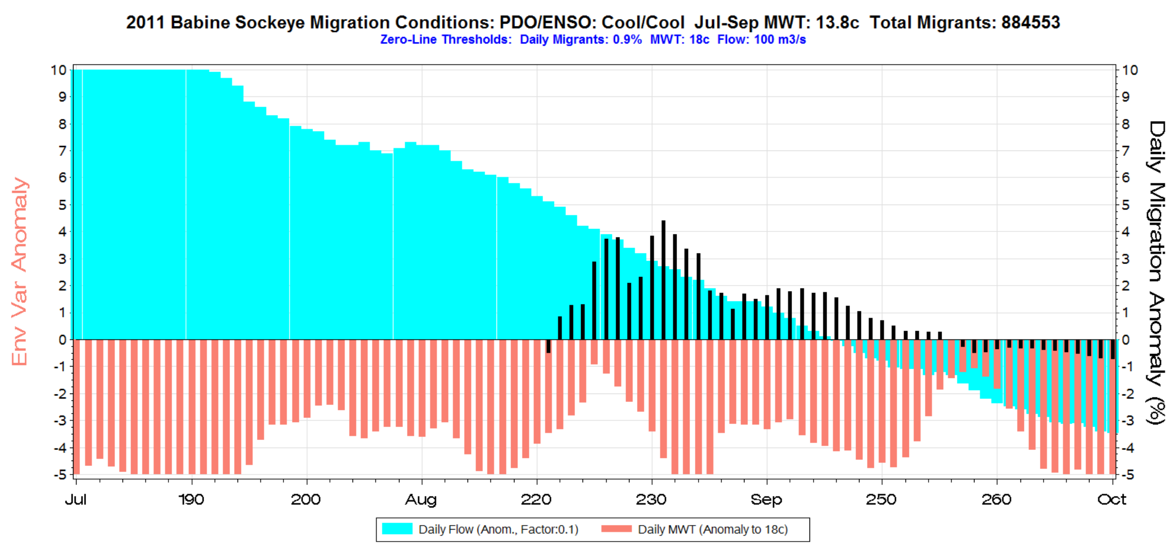

2006 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 14.9c Total Migrants: 1420537
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

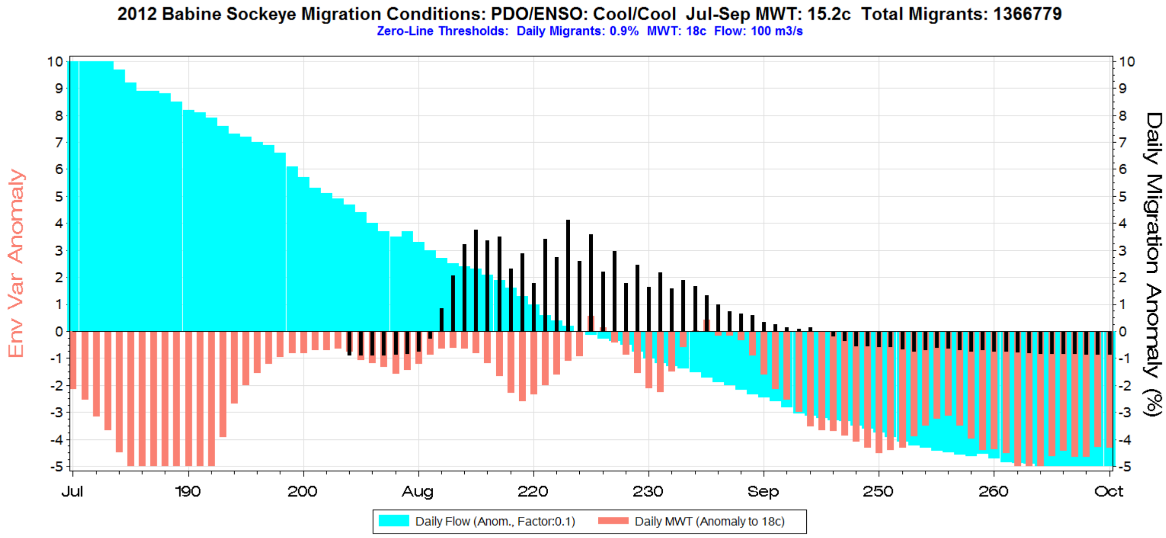

2007 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Sep MWT: 14.7c Total Migrants: 491605
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

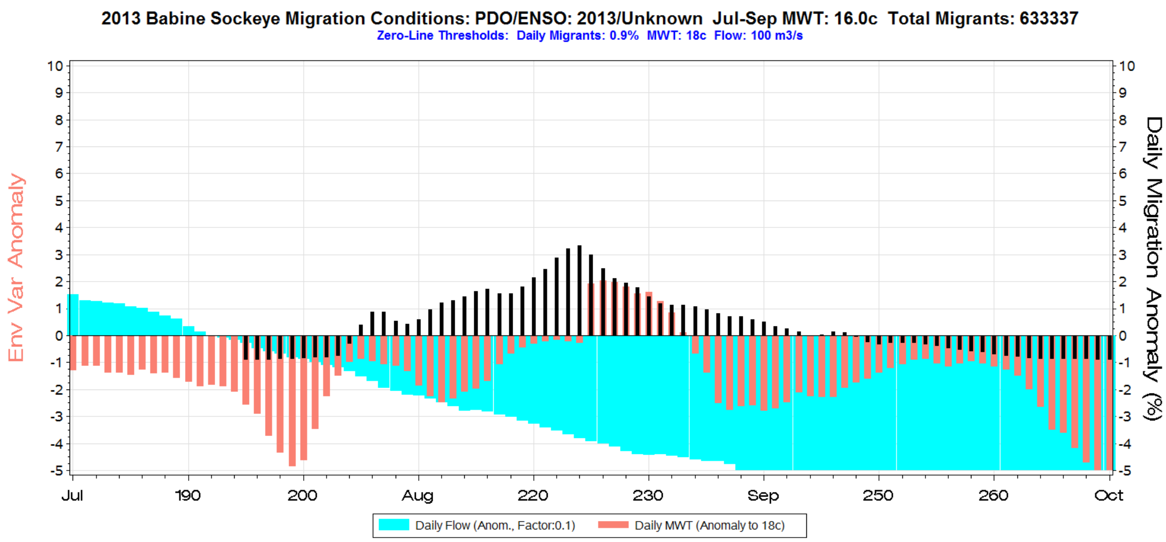

2008 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 13.9c Total Migrants: 1104171
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)

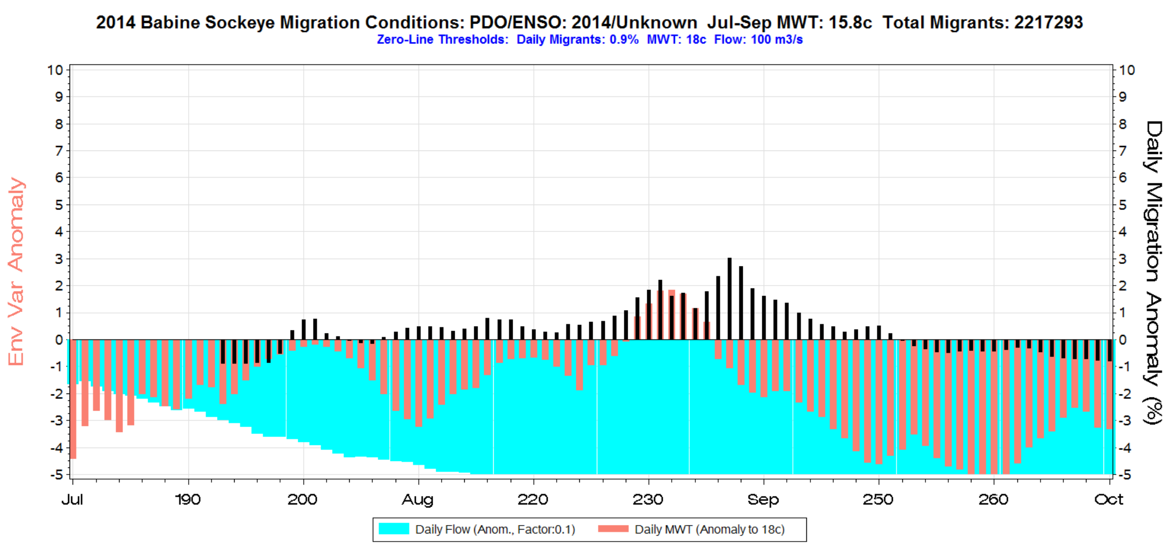

2009 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Sep MWT: 15.5c Total Migrants: 698749
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


2010 Babine Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Sep MWT: 14.5c Total Migrants: 745852
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


2011 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 13.8c Total Migrants: 884553
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


2012 Babine Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Sep MWT: 15.2c Total Migrants: 1366779
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


2013 Babine Sockeye Migration Conditions: PDO/ENSO: 2013/Unknown Jul-Sep MWT: 16.0c Total Migrants: 633337
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)


2014 Babine Sockeye Migration Conditions: PDO/ENSO: 2014/Unknown Jul-Sep MWT: 15.8c Total Migrants: 2217293
Zero-Line Thresholds: Daily Migrants: 0.9% MWT: 18c Flow: 100 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.1)
Daily MWT (Anomaly to 18c)