Water Temperature, River Discharge, and Adult Sockeye Salmon Migration Observations in the Meziadin Watershed, 1966-2012

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WATER TEMPERATURE, RIVER DISCHARGE, AND ADULT SOCKEYE SALMON MIGRATION OBSERVATIONS IN THE MEZIADIN WATERSHED, 1966-2012

by

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ABSTRACT

Stiff, H.W., Hyatt, K.D., Stockwell, M.M., Cox-Rogers, S., Hall, P., Alexander, R., Kingshott, S.C., Percival, N., and Stewart, B. 2015. 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.

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 Meziadin River, British Columbia. Regional air temperature data collected at Stewart, B.C. were statistically related to intermittent water temperature time-series (1999-2012) sampled at the Meziadin fishway to hind-cast daily water temperature in Meziadin River for 1910-2012. Surprise Creek daily discharge (1967-2010) provided the best predictor of historical Meziadin River flows, though these data could not replicate some observed Meziadin extremes. Frequency distributions of historical migration dates (1966-2012), weighted by the daily migration rate, were used to discern possible environmental thresholds defining high versus low migration classes. Peak-over-threshold analyses were applied to reconstructed time-series to review long-term trends in temperature and flow by site.

The climatology remains cool in this northern watershed, with estimated daily mean water temperatures of 14.1°C (maximum 19.5°C) during Sockeye migration. Low daily migration rates (<1.25% of total escapement) were associated with water temperatures above 18°C. The average duration of “warm water” periods (>18°C) was < 1-2 days for recent decades, and is not trending. While “low flow” events (Surprise Creek discharge < 10th percentile of historic flows), which mainly occur after peak Sockeye migration, were not particularly associated with low daily migration rates, “high flows” (> 90th percentile) were often associated with delayed migration, migration stoppages, and low daily migration rate. Migration rates were near-zero at high water temperature and high flow combinations. The frequency of high flow events increased in the 2000s relative to previous decades, along with the mean and maximum duration of high flow periods.

RÉSUMÉ

Stiff, H.W., Hyatt, K.D., Stockwell, M.M., Cox-Rogers, S., Hall, P., Alexander, R.F., Kingshott, S.C., Percival, N. et Stewart, B. 2015. Water temperature, river discharge, and adult Sockeye salmon migration observations for the Meziadin watershed, 1966-2012. Rapp. manus. can. sci. halieut. aquat. 3019: v + 147 p.

Nous avons 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 Meziadin, en Colombie-Britannique. Les données régionales sur la température de l'air recueillies à Stewart, C.-B., ont été reliées statistiquement aux séries chronologiques intermittentes relatives à la température de l'eau (1999-2012) échantillonnées dans la passe migratoire de Meziadin en vue de prévoir *a posteriori* la température quotidienne de l'eau dans la rivière Meziadin de 1910 à 2012. Le débit journalier du ruisseau Surprise (1967-2010) s'est révélé le meilleur indicateur des débits passés de la rivière Meziadin, mais ces données n'ont pas pu reproduire certains des extrêmes observés dans la Meziadin. Nous avons utilisé les distributions des fréquences des dates de migration passées (1966-2012), pondérées par le taux de migration journalier, pour cerner des seuils environnementaux possibles définissant les classes de migration forte et basse. Des analyses des dépassements des seuils ont été appliquées aux séries chronologiques reconstituées pour examiner les tendances à long terme des températures et du débit par site.

La climatologie demeure fraîche dans ce bassin hydrographique du nord de la Colombie-Britannique, avec une température de l'eau journalière moyenne estimée de 14,1 °C (maximum de 19,5 °C) pendant la migration du saumon rouge. Les taux journaliers bas de migration (<1,25 % de l'échappée totale) ont été associés aux températures de l'eau supérieures à 18 °C. La durée moyenne des périodes d'eau « chaude » (>18 °C) était < 1-2 jours au cours des dernières décennies et ne constitue pas une tendance. Si les phénomènes de « faible débit » (débit du ruisseau Surprise < 10^{e} percentile des débits historiques), qui se produisent surtout après le pic de migration du saumon rouge, n'ont pas été spécialement associés aux taux journaliers bas de migration, les « débits forts » (> 90^{e} percentile) ont souvent été liés à une migration retardée, des arrêts de la migration et un faible taux journalier de migration. Les taux de migration étaient proches de zéro lorsqu'une température élevée de l'eau était combinée à un débit fort. La fréquence des débits forts a augmenté dans les années 2000 par rapport aux décennies précédentes, tout comme la durée moyenne et maximale des périodes de débit fort.

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 (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. 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 Meziadin watershed, the primary source of Sockeye production (70-80%) in the Nass system in northern British Columbia (Bocking et al. 2002). It 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 Nass River is 380 km in length, with a drainage area of 20,839 km^2 (Figure 1). The 6 km Meziadin River, situated 50 km east of Stewart, B.C., drains 530 km^2, including Meziadin Lake (37 km^2; maximum depth 135 m), into the Nass River, 180 km from its mouth at Portland Inlet in Dixon Entrance on the northwest coast of B.C. Meziadin Lake is situated at 244 m above sea level (Gilbert & Butler 2004).

The Meziadin watershed is located in the Kinskuch watershed in the COAST MOUNTAINS eco-province, in the productive coniferous forests of the INTERIOR CEDAR-HEMLOCK biogeoclimatic zone. The climate is primarily cool and wet as it is strongly influenced by air masses flowing east from the Pacific Ocean, in conjunction with high altitudes of the coastal Nass Mountain range (Figure 2). Coastward of Meziadin, average temperatures range from 2.3-9.7ºC (at *Stewart*; 1971-2000) with annual precipitation of 1,842 mm (including 571 cm of snow); interior stations record cooler and drier climate normals (0.7-10ºC at *Nass Camp*, with 1,066 mm total precipitation (300 cm snow)). Basin hydrology is seasonally-driven by nival and glacial melt, with peak flows usually between May-July (Gilbert & Butler 2001).

METHODS

DATA SOURCES AND ANALYSIS

Sockeye Migration

Meziadin River water temperature and stage height observations were made at the Meziadin fishway, where adult Sockeye enumeration is carried out by personnel operating the Meziadin fishway from July to September. The Meziadin fishway, located < 5 km from the lake outlet, was constructed to allow migrating salmon to bypass Victoria Falls to access upstream spawning grounds, while providing a method of estimating the spawning escapement of Sockeye salmon in the Meziadin system. The current facility, constructed in 1966 by the federal department of Fisheries and Oceans, replaced a fish ladder built in 1914 at the same location. The 220 m vertical slot design bridges the upper and lower falls with 33 ascending pools. A concrete weir at the lower falls directs fish into the fish ladder.[1]

Daily Meziadin Lake Sockeye escapement estimates at the fishway (1966-2012) were provided by FISHERIES AND OCEANS CANADA (DFO).[2] These data are finalized post-season as daily totals of large (> 44 cm fork length) and small ("jack") Sockeye[3] by DFO personnel.[4]

To standardize the annual adult migration time-series for inter-year and inter-stock comparisons, daily percentages of total Meziadin Sockeye migrants were calculated relative to the total annual stock escapement. Annual plots of daily and cumulative migration rate (% 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.

Univariate statistical analyses were used to characterize the historical stock migration data (location, number of observations; central tendency e.g. 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 low ($0\text{-}75^{th}$ percentile), medium ($75\text{-}90^{th}$ percentile) and high ($90\text{-}100^{th}$ percentile) categories for daily migration rate classification. Quartiles of the Julian dates of migration in the historical data were used to categorize daily migrant data into early ($0\text{-}25^{th}$ percentile), middle ($25\text{-}50^{th}$ percentile), and late ($75\text{-}100^{th}$ percentile) observations. Daily migration rate (%) data were transformed using the arcsin function to normalize the percentage data where appropriate for parametric analyses (Sokal and Rohlf, 1969).

Environmental Data

Meteorological, hydrological, and water temperature data necessary for derivation of

[1] Regional District of Kitimat-Stikine: http://www.rdks.bc.ca/content/meziadin-river-fish-ladders.
[2] Meziadin fence counts published online by DFO NORTH COAST STOCK ASSESSMENT DIVISION: http://www.pac.dfo-mpo.gc.ca/fm-gp/northcoast-cotenord/meziadin-eng.htm; downloaded 23 Oct 2012.
[3] No Meziadin jack Sockeye count data were available for 1966. Count based on large Sockeye only.
[4] Total Nass system Sockeye returns are also available from NTC FISHERIES for large Sockeye returning to the mouth of the Nass River, 1982-2012 (NISGA'A FISHERIES 2010, 2011, 2012).

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., B.C. MINISTRY of ENVIRONMENT, ENVIRONMENT CANADA, WATER SURVEY OF CANADA (WSC), NISGA'A TRIBAL COUNCIL FISHERIES (NTC)[5], FISHERIES AND OCEANS CANADA (DFO) and environmental consultants (LGL Ltd, Sidney, BC).

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 9.2; 2008) was used to assemble data from MICROSOFT EXCEL® spreadsheets and analyze the data. The resulting datasets were stored in a relational MICROSOFT ACCESS® FRESHWATER ENVIRONMENTAL VARIABLES DATABASE and are available from DFO upon request.[6]

Hydrology

Except for a brief period in 1956, Meziadin River remains an un-gauged waterbody, and daily discharge data were not available for the Meziadin watershed from WSC for an interval matching available salmon migration data. Meziadin fishway technicians recorded water levels multiple times per day during the Sockeye migration season (July-October) for the years 1998-2012 (NTC FISHERIES[7]). Daily mean water level (m) data were derived from approximately 4 to 6 readings per day recorded between 0800hrs and 1800hrs, depending on migration levels (i.e., reduced monitoring during low migration periods; pers. comm., R. Alexander, LGL Ltd)[8].

As potential estimators of flow conditions in the Meziadin system, mean daily discharge data (m^3/s or cms) were obtained from the web archives of the WATER SURVEY OF CANADA (WSC)[9] for relevant stations in the Nass/Kinskuch/Meziadin watersheds from the ENVIRONMENT CANADA web site (Figure 2):

- *Meziadin River* Station 08DA003 (56.04°N x 129.20°W; drainage area 521 km^2) was only operational in 1956, consisting of 35 observations between June and October, of which 31 observations were in July.
- *Surprise Creek* Station 08DA005 (56.11°N x 129.48°W) is an active station in the Kinskuch watershed, a tributary to the Strohn River which drains into the west end of Meziadin Lake, recording daily flow volumes for a drainage area of 218 km^2 (1967-2010).

[5] NISGA'A LISIMS GOVERNMENT, New Aiyansh, BC
[6] Contact Howard.Stiff@dfo-mpo.gc.ca or Kim.Hyatt@dfo-mpo.gc.ca.
[7] c/o Richard Alexander, LGL Ltd.
[8] Other potentially relevant hydrological data not used in this analysis: the NISGA'A FISHERIES FISHWHEEL PROGRAM has monitored daily water level since 1994 at Gitwinksihlkw in the lower Nass River, using a staff gauge mounted to a rock-face located downstream of Fishwheel 2 (Baxter and Stewart 2005).
[9] ENVIRONMENT CANADA – WATER SURVEY OF CANADA website: http://www.wsc.ec.gc.ca/applications/H2O/HydromatD-eng.cfm.

- *Nass River Above Shumal* Station 08DB001 (55.26°N x 129.09°W) is a long-term active station (1929-2012), recording daily flow volumes for a gross drainage area of 18,400 km^2. Real-time data for 2012 were appended to the archived data retrieved for 1929-2011.

Simple least-squares regression models (linear: $y = a + bX$; power: $y = aX^b$; and polynomial curvilinear: $y = a + bX + cX^2$) were derived for estimating historical daily Meziadin water levels as a function of the more extensive time-series from the WSC station discharge data for *Surprise Creek* and *Nass River above Shumal*. Model selection was based on highest correlation and lowest root mean square error (RMSE), and goodness-of-fit was assessed using correlation of observed versus predicted Meziadin data and subjective examination of time-series plots.

Univariate statistical analyses were used to characterize Meziadin River daily water level and nearby WSC station discharge data (number of observations, central tendency e.g. 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 migration period (July-September).

Water Temperature

The most extensive Meziadin water temperature readings were supplied courtesy of NTC FISHERIES for the years 1998-2012. These data were collected at the Meziadin fishway during the Sockeye migration period (July-October), approximately 4 - 6 times per day between 8 am and 6 pm using a standard thermometer, and averaged by date (pers. comm., Richard Alexander, LGL Ltd).

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 e.g., mean, median, mode, etc), scale (range, variance, extreme values and outliers), and shape (skewness, kurtosis).

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. Unusually high variability between dates: July 12-16, 1999; and July 21 - August 12, 2000.
2. Unusually low variability between dates: August 12-25, 2002; September 2006; September 2007; August 29 – September 26, 2008; Oct 14-23, 2011.

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

Water temperature datasets for other locations in the Nass drainage not used in this analysis but documented in the FRESHWATER ENVIRONMENTAL VARIABLES DATABASE (Appendix A), include:

- Minimum and maximum daily water temperatures collected in the Nass River near Gitwinksihlkw, June-September 1994-2011[10], courtesy of NTC FISHERIES (c/o Richard Alexander & Anita Blakley, LGL Ltd).
- NTC FISHERIES installed automated water gauging data loggers in the Meziadin River (~0.5 km upstream of the fishway, adjacent to the White River bridge) between 1999 and 2004 to monitor hourly water levels, water temperature, and air temperature between April and November (Baxter 2000, 2001, 2002, 2003; Baxter and Stewart 2005). However, these data were not available in electronic form for this analysis.
- Water temperature from data loggers in Meziadin River and Tintina Creek (tributary to Meziadin Lake; sited at the Hwy 37 bridge crossing) may also be available for 2011 (unpub. data, S. Kingshott, LGL Ltd).
- Spot water temperatures also exist for the *Nass Shumal* WSC station (08DB001). These data are taken during sporadic site visits by departmental personnel, on average, less than once a month, from 1958-2011.[11]

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.

As there are no extended meteorological records available for the Meziadin watershed, daily precipitation data from *Stewart* AHCCD station 1067742 (1910-2011) were obtained from ENVIRONMENT CANADA.[12] Due to the highly localized and non-normal distribution of precipitation data, missing values were not interpolated, nor were time-series extendible based on parametric statistical relations with other stations.[13]

Air Temperature

Although MWT records for Meziadin River date back to the late 1990s, the relatively short length of the dataset and discontinuities in the timeline 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

[10] Only one temperature data point was taken from 1999-2011 (in the afternoon), corresponding more closely to daily maximum temperatures (pers. comm., A. Blakley, LGL Ltd).
[11] Source: Lauren.Wick@pyr.ec.gc.ca (WATER SURVEY DIVISION, ENVIRONMENT CANADA).
[12] 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.
[13] An alternative approach, not attempted here, may be to obtain daily precipitation data for multiple regional meteorological stations to derive an appropriate area average. Regional meteorological stations within 100 km of the Meziadin watershed can be found in Table 1. Source: NATIONAL CLIMATE DATA AND INFORMATION ARCHIVE (March 2013).

years, and 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.[14] 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 2).

For the majority of Canadian climate stations, air temperature measurements are taken from self-registering, maximum and minimum thermometers that record the extremes of each parameter within a 24-hour period. Daily mean temperature, where provided, 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.

As there were no climatological records available specifically for the Meziadin watershed, EC climate station *Stewart* 1067742 (55.93°N x 129.98°W) was selected for climate data retrieval on the basis of: (i) the quantity and quality of data available (1910-2012); (ii) proximity to Meziadin watershed (<60 km) (Figure 2); and (iii) the potential to routinely update data from an "active" climate station. In addition, ENVIRONMENT CANADA has refined the air temperature and precipitation time-series for this station, as part of the ADJUSTED AND HOMOGENIZED CANADIAN CLIMATE DATA (AHCCD)[15] group of climatological stations across Canada. These data incorporate a number of adjustments applied to the original station data to address non-climatological shifts related to changes in instruments and observation conditions or procedures, thus optimizing their use for climate research (Vincent et al. 2012).[16]

Gaps in the meteorological record for *Stewart* daily air temperature (e.g., Aug-Oct 1915; 1925-1928; May-Oct 1967, Sep 2009) were in-filled with estimated data based

[14] ENVIRONMENT CANADA Climate Data: http://climate.weatheroffice.gc.ca/climateData/canada_e.html

[15] 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.

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

on statistical relations with nearby AHCCD meteorological stations. Regression relations were generally linear at moderate temperatures (5-25°C) for *Stewart* and *Dease Lake* stations, and, to a lesser degree, coastal *Prince Rupert* (Figure 1). *Dease Lake* (1192340; 58.42°N x 130.00°W; 1944-2012) and *Prince Rupert* (1066483; 54.28°N x 130.45°W; 1908-2012). Spearman correlation coefficients (r_s) were derived to indicate the most correlated time-series for *Stewart* data for the May-October period at daily mean air temperatures greater than or equal to zero. Associated linear regression coefficients were then used to construct a dataset that included the original non-missing *Stewart* daily air temperature values, with missing *Stewart* values (May-Oct) estimated from: (i) the primary correlated station, *Dease Lake* (where data exist); or (ii) the secondary correlated station, *Prince Rupert* (where data exist).

STEWART 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 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)[17] while retaining a high Pearson correlation coefficient with a representative subset of the site daily mean water temperature. The multi-day *Stewart* 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.[18]

Selection of data for the calibration dataset was based on subjective and statistical examinations of the annual air and water temperature time-series plots and annual regression relationships. Years with consistent and apparently unbiased data logger readings associated with a maximum range of temperature values for both warming and cooling periods[19] were preferred for characterizing the all-year air/water temperature relationship. The remaining data were used for validation of statistical relations.

Correlation analysis was used to identify the most appropriate multi-day moving average index (*n* = 3, 5, 7, 10 days) for the *Stewart* AHCCD air temperatures, by comparing Pearson correlation coefficients for each index (including the regional daily mean air temperature variable (i.e., *n* = 1)) with daily mean water temperatures from Meziadin River, for the calibration data (Hyatt et al. 2015). The multi-day *Stewart* CMAT index with the lowest adjusted AKAIKE INFORMATION CRITERION (AICc) and the highest Pearson correlation coefficient for calibration data was used for

[17] *n* = 1 corresponds to the “observed” STEWART mean daily air temperature time-series.
[18] 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).
[19] Derivation of the seasonal flux point between warming and cooling “seasons” is described below.

subsequent air/water temperature regression relations.

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 MAT 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. The remaining water temperature data were used as a validation dataset to test the goodness of fit of air-to-water temperature models. Models with the relevant air and water temperature datasets for the Meziadin system:

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

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

T_a is the *STEWART 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 Meziadin River;

T_a is the STEWART 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[20] 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 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 2008). 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;

[20] 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.

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 Meziadin River as a function of the regional air temperature index (7-day centered *Stewart* MAT variate).

Calibration data were selected based on examination of annual air and water temperature time-series and correlation plots. Years of evident bias in the readings or anomalies (e.g., 2000, 2002) were excluded from the calibration dataset. A minimum of 5 years of representative data including sufficient observations at the upper end of the temperature range for both warming and cooling seasons were obtained from source MWT datasets partitioned as follows:

Calibration Years	Validation Years
2001, 2003-2005, 2008-2011	1999, 2000, 2002, 2006-2007, 2012

Due to a lack of late spring observations, the range of temperatures available were limited, hampering parameter estimation for logistic models. 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 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).[21] 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

[21] 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.

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 *Stewart* 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 Meziadin River reference site.

Trend and Exceedance Analyses

AIR TEMPERATURE

Historic mean daily air temperature data (based on STEWART 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 *Stewart* AHCCD climate data; 1910-2012) 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 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 Meziadin River were either less than the lower 10th percentile (~1.12 m), or greater than the upper 90th percentile (~1.44 m) 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.

A similar exceedance analysis was applied to daily discharge data from WSC station *Surprise Creek*, as a co-variate indicator of flow conditions in Meziadin River, based on threshold values set at the 10th percentile (12 cms) and 90th percentile (50 cms).

Migration, Temperature and Discharge

Estimated Meziadin daily mean water temperature and water level time-series were merged un-lagged with daily Meziadin Sockeye migration rate data for co-variation analyses.

To characterize the temperature and discharge conditions during historical stock migration, frequency distributions of observed active migration dates (i.e., filtered for non-zero migration rates) at varying levels of temperature, water level, and both temperature and level, were generated. By simply tallying the number of dates in the historical dataset at which some migratory activity occurred, these plots indicate the general distribution of temperature and water level conditions that were available during the migratory period.

A similar frequency distribution of active migration dates, weighted by the daily migration rate, indicate how much migration occurred at a given temperature, water level, or temperature x level combination. In contrast to the simple distribution of dates of migration, these plots indicate which water temperature and level conditions are associated with highest migration rates (i.e., presumably most favourable to salmon migration), and, by extension, the thermal and hydrological limits (if any) that differentiate high versus low rates of migration.

The 50th percentile migration rate was used to define whether a daily migration rate value is positive or negative in relation to the zero-line, and the 75th percentile of migration rates (1.66% per day) was used to define whether a positive migration rate was “high” or “low”. Thus, the anomaly threshold (“zero-line”) for migration data was set to the 50th percentile of the historical daily migration rate (0.77% of annual total escapement). The migration threshold value was subtracted from the historical daily migration rates to derive the anomaly for daily migration.

Environmental “limits” derived subjectively from the weighted frequency analyses were used to set threshold values for calculation of daily deviations in the modeled water temperature and discharge time-series, and combined with deviations in daily Sockeye migration rate on annual anomaly plots to examine the pattern of daily variation in each time-series in relation to each other.

The water temperature threshold was set to 17°C, based on an apparent drop in migration rate from high to low at and above that temperature. Utilizing *Surprise Creek* daily flows as an indicator of Meziadin River flows, discharge values of 10 and 50 cms were used as the zero-line threshold to review patterns of migration in relation to low and high flow periods. The difference between these thresholds and the daily mean values were plotted on a common axis (discharge rates were factored by 0.1 to fit on the y-axis).

RESULTS

SOCKEYE MIGRATION DATA

An average of ~170,000 Sockeye returned to the Meziadin watershed over the past 47 years (1966-2012), ranging from 40,000 – 600,000 in annual escapement (Table 2). Meziadin Sockeye migration typically commences in late June or early July and terminates by mid-to-late September (Table 2), with time-to-50% (TT50%) occurring approximately August 5th (Figure 4). Non-zero migrant counts averaged approximately 2,142 fish per day; maximum daily counts surpassed 50,000 fish in 1992. The median fish passage over the years has been 1,159 fish per day.

The corresponding all-year mean daily migration rate is 1.25% of total annual escapement. Annual peak daily rates are typically in the range of 5-10%; as much as 18% of the annual escapement occurred on one day in 1986 (Table 2). Annual time-series of Meziadin Sockeye daily migration rates (%) are plotted in Appendix C, along with mean and maximum daily migration rates across all years 1966-2012, displaying, in many years, late onset of migration (e.g., 1976, 1986, 2001) and/or multi-modal migration pulses separated by lengthy periods of relatively low migration (e.g., 1969-1971, 1982, 1989, 1994, 1996, 2000, 2009-2011), either of which might be evidence of environmental factors influencing migration patterns. Summarized across all years, a bi-modal pattern emerges, with a primary migration mode centered in the middle of July, and a secondary mode occurring in late August and early September (Figure 4). The time between these modes is normally characterized by peak water temperatures and falling discharge levels.

HYDROLOGY

<u>Meziadin Fishway</u>

Water levels measured at the Meziadin fishway (1998-2012) ranged from 0.65 - 2.6 m during the Sockeye migration period (July-Aug-Sep) with a mean of 1.28 ± 0.16 m (Table 3). The time-series typically display a steady drop in water levels through the peak Sockeye migration period of less than half a meter (Figure 5, Figure 6), indicating little variation in flows that might affect Sockeye migrants. Notable exceptions were 2000, 2004, 2007, and 2011, for which water levels exceeded statistical norms:

- In 2000, the Meziadin experienced both sub-average water levels for extended periods (in July) followed by above-average water levels from August 6th through to early October (Figure 5). Moderate to high migration rates (i.e., > 1.66% per day) were sustained from July 18-25th, suggesting that the July low flow event (minimum ~0.9 m) was not an impediment to Sockeye migration (Appendix C). Low migration rates (0.77 - 1.66% per day) were the norm from July 26th to the flood event beginning August 6th, but moderate migration levels commenced again on August 13th indicating that water levels of up to 1.7 m were also not an impediment. However, this migration event ended precipitously on August 23, coinciding with another flood event that increased Meziadin water levels to 1.8 - 2.2 m before returning to near-normal conditions by September 4th. This might suggest a possible upper hydrological limit for upstream migration, since a subsequent low migration event (~1.1%) from August 30-September 1st would suggest that ("significant") migration had not yet completed by August 23rd. Migration was "insignificant" (<0.77%) for the rest of September, and likely driven to zero by the final flood event of the month that commenced September 19th. (Note: Total escapement of ~138,000 Sockeye was below the all-year average of ~171,000 (Table 2).)

- In 2004, rapid decreases in Meziadin water levels to less than 0.75 m (minimum 0.65 m) occurred twice in mid-to-late September (Figure 5; Appendix C). A drop in migration rates from moderate (1.66 – 4.17%) to low (0.77-1.66%) may have been associated with the onset of the initial water level decrease (~September 5th). If so, this may suggest that Meziadin water levels of 0.65 – 0.75 m may be a lower hydrological limit for high migration rates. (Total escapement of ~144,000 Sockeye in 2004 was below the all-year average.)
- At the beginning of the migratory period in 2007, high water levels (maximum ~1.85 m) that did not return to normal until July 29th may have resulted in a delay to migration, which commenced on July 30th (Figure 5; Appendix C). This contrasts slightly with year 2000, when water levels of up to 1.7 m did not impede high migration. Missing data between July 1st and July 21st, 2007, obscure the date when Meziadin water level fell below the 1.7 m mark, but there is some evidence that high flows may have persisted through the month of July – discharge in Surprise Creek exceeded the 95% confidence interval between ~July 10-20th, and precipitation was recorded in Stewart throughout most of the month (Appendix C). (Total escapement of ~108,000 Sockeye was well below the all-year average.)
- In 2011, a rapid increase in water level (from ~1.1 to 1.4 m) in the last week of August may have driven already low migration rates to "zero" (i.e., < 0.77%) for a few days as of August 23rd (Figure 5; Appendix C). Moderate migration rates resumed as water levels returned to 1.2 m depth, but fell again to zero coincident with another peak water level event September 11-15th. (Total escapement of ~173,000 in 2011 Sockeye was close to the all-year average.)

Since the Meziadin site water level data are limited to the past two decades, WSC station data were reviewed for the purposes of extending the Meziadin dataset through statistical relations. Simple least-squares regression models (linear: $y = a + bX$; power: $y = aX^b$; or polynomial curvilinear: $y = a + bX + cX^2$) may be suitable for reconstructing historical Meziadin flows and/or water levels as a function of the more extensive time-series from *Surprise Creek* or *Nass River above Shumal* stations.

WSC Flow Stations

Discharge at *Meziadin River* WSC Station 08DA003 ranged from 55-88 cms (mean 69). These data were limited to 31 observations in July 1956 (Table 4; Figure 7), and were therefore inadequate for analyses with available migration data.

Discharge statistics for flow data from the *Nass River (above Shumal)* WSC Station 08DB001 indicated historic daily mean flows (1929-2012) of 1,246 ± 522 cms (Table 5; Figure 8, Figure 9). Recent high water level years observed at the Meziadin fishway (2000, 2007, 2011) were also marked by above average daily flows in Nass River, ranging from 1,453 cms (2007) to 1,581 cms (2011). Corresponding maximum flows in those years ranged from 3,720 to 5,910 cms. Similar "high flow" conditions in the Nass for years that pre-date the Meziadin water level time-series include: 1967 (low Meziadin escapement year: 41,842 Sockeye), 1976 (late Meziadin run timing), 1985, 1987, 1992.

Surprise Creek WSC Station 09DA005 demonstrated high daily flows also in 2007 (mean 37 cms, maximum 117 cms) corresponding to high Meziadin water levels, but had similar flow levels also in 2008 (not shared by Meziadin). In 2000, *Surprise Creek* flows (mean 35 cms; maximum 67 cms) were slightly higher than its long term average (30±15 cms). Other years with either high mean or maximum flows include: 1981, 1987, 1992, 1994, and 2001 (Table 6; Figure 10, Figure 11).

Regression analysis of *Meziadin River* daily discharge (Table 4) as a function of *Nass River Above Shumal* discharge (Table 5) indicated that the log-linear power model (*Meziadin* = a • *NassShumal* ^{b}) provided the best fit based on highest correlation (r^2 = 0.34; P < .0001; n = 1,461) and lowest RMSE (Figure 13). Though predicted values were reasonably correlated with observed values (r_s = 0.56; P = 0.0005), the resulting model appears inadequate for estimating missing Meziadin discharge (Figure 14), due to the statistical limitations inherent in the limited amount of overlapping data (n=35 observations in 1956, mostly in July), which restrict the predictive power of this relationship to one summer month. Even within the month of July, the model overestimates low Meziadin flows and underestimates high flows, likely due to the 20-fold difference of water volumes between the two stations for the period of overlap (minimum, median, and maximum for Meziadin River: 55, 69 and 88 cms; versus Nass River: 1050, 1660, 2010 cms).

Since no dates of overlap exist for *Meziadin River* flows as a function of the more comparable (in terms of volume of discharge and size of drainage area) and proximal *Surprise Creek* station (Table 6), a similar analysis could not be performed between those two stations.

Water level data taken at the Meziadin fishway provide a more extensive time-series to relate to regional flows (Table 3).

Regression analysis of Meziadin fishway water levels as a function of *Nass River Above Shumal* discharge indicated that the log-linear power model (*Meziadin* = a • *NassShumal* ^{b}) provided the best fit based on highest correlation (r = 0.59, P < .0001) and lowest RMSE (Figure 15 - Figure 16). The significance level of the relationship may be a function of the large sample size (n = 1,461), since there is a significant lack-of-fit component in the error term, and a large number of outliers

(Figure 16). Comparison of observed versus predicted Meziadin water levels indicated how this poor fit manifests in the estimates: though average water levels are reasonably well predicted by Nass River discharge (e.g., 1998-1999), extremes in Meziadin water levels may or may not be, depending on whether local Meziadin water level conditions (presumably accurately captured in the data) are reflected at the regional scale that determines the flow volumes in the much larger Nass drainage (e.g., 2011 versus 2000, 2004; Figure 17 - Figure 18).

An attempt to model Meziadin water levels based on *Surprise Creek* WSC data yielded a similar result. Regression analysis indicated that the log-linear power model ($Meziadin = a \bullet Surprise^{b}$) provided the best fit, though statistical correlation with *Surprise Creek* was actually lower ($r = 0.33$, $n = 1353$; Figure 19, Figure 20) than with *Nass Above Shumal*, and modeled output indicated a similar inability to adequately capture extremes in Meziadin flow (Figure 22).

Due to these statistical limitations, Meziadin fishway water levels were not estimated or extended based on relationships with WSC data. However, *Surprise Creek* data were selected as a proxy indicator under the assumption that this station reflected local and/or upstream hydrological events, which are more common than large-scale downstream events that cause high water levels in the Nass system to block Meziadin discharge. Thus, Surprise Creek data were analyzed directly as a simple substitute for Meziadin River flows for trend and exceedance analyses.

WATER TEMPERATURE DATA

Meziadin River

The annual (1999-2012) time-series for water temperature data obtained at the Meziadin fishway are displayed in Appendix C, condensed in Figure 23, and summarized for the months of peak migration (July-August) by year in Table 7. Average temperatures during migration were 14.1°C, with rare occasions surpassing 20°C (Figure 24). The warmest year since 1999 was 2004 (mean water temperature 16.0°C; maximum 21.0°C). Water temperatures were also above average in 2003, 2005, 2006 and 2009.

WATER TEMPERATURE TIME-SERIES RECONSTRUCTION

Seasonal Turn-Around Point

The mid-year seasonal turn-around point for all reference sites was in week 31 – approximately day 217, or August 2nd – based on maximum mean weekly air and water temperatures (Figure 25). The “warming season” therefore extends from April 1 to August 2nd, followed by the “cooling season” from day 218-329, i.e., August 7th - November 25th.

Multi-Day Air Temperature Index

The multi-day *Stewart* 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). The 7d-CMAT scored the highest correlation for Meziadin water temperatures in the cooling season, relative to the 3d-, 5d-, 10d-, and simple daily MAT air temperature indices (Figure 26). 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 *Stewart* 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. Calibration and validation data years, and the number of observations available for analyses by season, are identified for the Meziadin watershed reference site in Table 8.

Hysteresis was not detected in the logistic relations, but was detected in the linear relations: Type III sum of squares for *season* effect (test for equal intercepts) and *season* interaction effect (test for equal slopes) were marginally and highly significant, respectively, indicating that air/water temperature relationships were best modeled using separate seasonal models (Logistic model: Figure 27; Linear models: Figure 28). Due to insufficient data in the warming season, the 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 9. Linear regression model output for seasonal air/water temperature relationships and calibration data are provided in Table 10.

Predictive estimates of daily mean water temperature were generated for each model type and season for the extent of the air temperature record. Correlation analyses between observed and predicted daily MWT values for the validation years were used to compare the predictive skill of logistic versus linear models. Season-specific Pearson (least squares) and Spearman (rank) correlation coefficients for the validation data are contrasted in Table 11. Validation data correlations indicate that the two model types are essentially equivalent in their skill at predicting Meziadin River water temperatures, with marginally improved predictive power for linear over logistic model types, likely due to the abbreviated time-series, with observations mostly limited to the linear range of air/water temperatures (e.g., logistic fit for the cooling season dataset appears virtually linear).

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 29. The modeled estimates tend to predict average conditions reasonably well (e.g., 1999), but underestimate water temperatures in warm years (e.g., 2004), 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 30), the analogous estimated Meziadin mean water temperature indicated a corresponding warming trend of ~0.014 degrees per year (or 0.14ºC per decade) (r = 0.17, P < .0001; Table 12, Figure 31). Mean summer water temperature remains below 15ºC, however.

Mean July-September water level at the fishway showed a declining trend in recent decades (1998-2012): *Y = 17.5 - 0.008 * Year*; r = 0.20; P < .0001); the negative trend appears to be largely driven by high water levels in 2000 (Table 13, Figure 32).

Surprise Creek discharge (Figure 33, Figure 34) did not share the Meziadin highs or lows in 2000, the below-average flows in 2004, or the above-average flows in the first week of July 2007 (Figure 32). Omitting 2000, 2004, and July 1-9, 2007 significantly improved the relationship (Figure 35), but did not improve the predictive power of the model to estimate extremes at Meziadin River fishway, however, since the extremes were excluded from the analysis.

As Meziadin fishway water levels were not easily estimable (specifically the extremes that are of interest regarding Sockeye migration patterns), the time-series could not be extended to encompass historic daily Sockeye migration data. Co-variation and trend analyses utilized WSC station *Surprise Creek* as a proxy dataset for Meziadin flows.

Migration in Relation to Temperature and Discharge

An un-weighted tally of non-zero migration dates indicated that approximately 77% of the historic migration dates occur when flows in *Surprise Creek* WSC station are ~20-40 cms (Figure 36). Weighting the frequency distribution by the daily migration rate indicated that the highest daily migration rates (>1.5% per day) at the Meziadin fishway occur when *Surprise Creek* flows are ~30-50 cms, and rates are significantly reduced above 60 cms (Figure 37).

Dates of migration activity are normally-distributed around 15°C, with the majority of dates (72%) characterized by water temperatures of 13-16°C (Figure 38). However, moderate to high average migration rates occurred up to 17°C, and low migration rates occurred at 18°C, while no significant migration occurred at 19°C, the maximum estimated Meziadin daily mean water temperature (Figure 39).

A weighted two-way frequency distribution based on combined flow and temperature ranges showed that highest migration rates for Meziadin Sockeye occurred at less than 17°C and flow rates of 40-50 cms at *Surprise Creek* WSC station (Figure 40).

Anomaly plots of migration, water temperature and discharge deviations based on these environmental thresholds are inconclusive regarding the exact temperature level that constitutes a critical threshold between low and high migration rates for Meziadin Sockeye (Appendix D). However, many years indicate that a threshold of 17-18°C is associated with lower migration (e.g., 1980, 1990, 1991, 1994, 2005), and lower temperatures with higher migration (1972-1974, 1977, 1982, 1993). In

1973, for example, a strong migration pulse in mid-July tapered off rapidly as water temperatures warmed to almost 17°C, and then rebounded as temperatures fell back below 15°C (Figure 41). In 1996, the two main migration pulses were basically delineated by a brief period of 17°C water temperatures at the beginning of August.

Exceptions to the rule were found in 2001, 2003, and 2010, where migration pulses persisted in August, despite almost a week of temperatures above 17°C.

There may be an interaction effect between temperature and flow levels on migration. For example, the above “exceptions” were also characterized by moderate discharge levels (near the all-year mean of 30 cms) of the *Surprise Creek* flow indicator. Significant migration rates (i.e., positive anomalies) do not appear to be found with positive anomalies of water temperature (> 17°C) and flow (> 50 cms) combined. See for example mid July 1981; mid-August 1997; early August 2009. When flows are moderate, however, moderate migration can also occur (e.g., mid-August 1979).

Evidentially, flows > 50-60 cms may, without any temperature effect, impose a delay on migration (e.g., mid-August 1971; mid July 1973; mid-August 1981; 2000; mid July 2006; 2008), and are rarely associated with high migration. In 1976, migration was likely delayed three weeks by high flows (40-80 cms), which may have suppressed apparent migration efforts in early August (Figure 42).[22] On the other hand, low flows (< 25th percentile, i.e., < 20 cms) do not appear to be limiting to significant migration rates (e.g., September 1969; September 1971, September 1980, August 1982, August 1998; September 2003). In 1976, when migration finally commenced (around 30 cms of the *Surprise Creek* flow index), flows continued to drop to 10 cms while daily migration rates ranged from 4-8% (Figure 42). Other low flow periods with moderate (>1.66%) to high migration rates (>4%) occurred in 1969, 1971, 1980, 1982, 1984, 1989, 1993, 1994, 1998, 2003 and 2005 (not shown).

Temperature Exceedance Analyses

A frequency analysis of regional daily mean air temperature indicates that the cumulative total number of $POT_{>20°C}$ dates per year has averaged less than 1 day per year in the past century (Table 14, Figure 43). The duration of continuous $POT_{>20°C}$ periods was less than two days on average (Figure 44). Peak temperature conditions occurred in the 1990s with cooler temperatures prevailing in the last decade.

A similar frequency analysis based on estimated daily mean water temperature exceeding 18ºC indicated that the cumulative total number of $POT_{>18°C}$ dates per year is also negligible, with no evident trend (Figure 45). The combined average number of $POT_{>18°C}$ dates across all migration months (July-September) has fluctuated around 0-3 days per year on average, mostly in August, with no obvious trends (Table 15).

The average length of $POT_{>18°C}$ periods was < 1-2 days for most decades, and is not trending (Figure 46, Table 15). Maximum period length, however, has on occasion,

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[22] Perhaps incurring significant en-route mortality in combination with water temperatures of 16-17ºC – total escapement in 1976 was only 105,000 fish, significantly below the all-year average.

extended more than a week (e.g., 1920s, 1970s, 1990s, 2000s), indicating that in at least one year in each decade, direct or indirect thermal impacts may be accruing. In 1977, for example, an 11-day $POT_{>18°C}$ event occurred in mid-August (Table 16); Sockeye migration was negligible during this period, and significant migration did not recur until temperatures dropped to ~15°C (see Appendix C and Appendix D). A similar 7-day event occurred in 1994 during which migration did not occur, and in 2004, migration remained at low (though significant) levels until an 8-day $POT_{>18°C}$ event in mid-August was over (Table 16, Appendix D).

Discharge Exceedance Analyses

Extremes in observed Meziadin River water levels indicate no obvious trends since 1998 (Figure 47, Figure 48). Low water levels (< 10th percentile of ~1.1 m) occurred on average ~10 days per year, principally in September after peak Sockeye migration[23] (Table 17). Although the overall mean duration of low periods was 7-8 days (Figure 47), continuous low flow events of 14-18 days characterized 5 of the 9 years since 2004, including 2005-2007, 2010 and 2012 (Table 18).

High water events (> 1.44 m) during the Sockeye migration period are normally infrequent, typically lasting less than a week, most often in July (Table 17, Table 18). The flood year in 2000 was exceptional in that the high waters occurred through August and September, after the primary migration pulse. Two other years with higher water levels than average in July were 1999 and 2007 (Figure 48).

A similar exceedance analysis based on 10th and 90th percentile thresholds (i.e., ~12 and ~50 cms) for the more extended Surprise Creek daily flow dataset indicated that low flows were more common in the 1970s and 1980s than in subsequent decades (Figure 49). 1976, 1977, 1983 and 1985 were particularly dry years, with multiple periods of 3 weeks or more at low flow levels (Figure 50, Table 19), principally in September.

The frequency and variability of high flows in Surprise Creek (> 50 cms) may be on the rise. A steady increase in the average number of POT_{50} dates per year has occurred since the 1980s (Figure 51, Table 20), accompanied by a minor trend in average period length from 2.3 days (1980s) to 3.0 days (2000s) and mean maximum length from 3.2 days to 5.8 days. Maximum peak flow period lengths occurred in 2007 (13 days), 1999 (10 days), and 1981 (10 days) (Figure 51, Table 20).

Low flow events in Surprise Creek showed only weak association with low water level events in Meziadin River for the period of overlapping data (1999-2010), presumably due to the buffering capacity of Meziadin Lake. Flooding in the Meziadin in 2000 due to high waters in the Nass was also not reflected in Surprise Creek flows. Certain high flow events (1999 and 2007), however, were captured in both datasets (Figure 52), presumably indicating weather events that exceeded the buffering capacity of the lake.

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[23] The "flood year" of 2000 was a notable exception: low flows occurred in July during peak migration (without apparent effect on migration rate which reached 10% of total migrants: Appendix CAppendix D).

DISCUSSION

Sockeye Migration and Water Temperature Conditions

Choice of linear or logistic model to utilize for air-to-water temperature conversion may depend on specific analytical needs. Bias analyses suggest that, relative to observed data, the linearly-estimated time-series tends to over-estimate water temperatures in July and September, with no significant difference occurring in August, when water temperatures are warmest. The selected logistic model tends to over-estimate daily MWT in June, and to under-estimate it in July and August. Thus, the results of analyses regarding peak temperatures (e.g., frequency and duration thereof) using the logistic model might be considered more conservative than linearly-derived results, though any inter-annual and decadal trends should be consistent between these conversion methods.

Given these qualifications, it appears that estimated mean water temperatures in the Meziadin during the Sockeye migratory period are rising slowly, at a rate of about 0.14°C per decade, but currently remain below 15°C. 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 4-5 days. However, the maximum length of such periods may be a better indicator of the potential cumulative stress on migrants. In 1977, for example, an 11-day POT>18°C event occurred in mid-August (Table 16); Sockeye migration was negligible during this period, and significant migration did not recur until temperatures dropped to ~15°C (see Appendix C and Appendix D). A similar 7-day event occurred in 1994 during which migration did not occur, and in 2004, migration remained at low (though significant) levels until an 8-day POT>18°C event in mid-August was over (Table 16, Appendix D).

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, as is widely anticipated (Abdul-Aziz et al. 2011; Littell et al. 2011). However, it is not possible from the data to conclude that migration was actually affected in these cases, since it is unknown if significant migrants were present in the lower Meziadin, or pooling in the Nass River below the confluence at the time. A study using archival button tags to track the ambient water temperatures during fish migration might be useful, in conjunction with accurate temperature data obtained at the fishway, to discern how Meziadin Sockeye respond to rising water temperatures.

High resolution water temperature data at the fishway, collected 24 hours a day by automated data loggers, would not only be key to resolving this question, but would also improve the confidence in the site air/water temperature relationships, which currently rely on instantaneous “spot” temperature measurements taken during summer daylight hours only, which may therefore be positively biased. In addition, only eight of the fourteen years of data available were suitable for this analysis due to unresolved issues in the data for six of the years. An automated data logger maintained at the fishway from March/April to November, and (for comparison) another in the Nass River below the confluence, would serve to improve the water temperature estimation procedures, and bench-mark any thermal signals evident in archival tag data monitoring Sockeye migratory behaviour and movement into the Meziadin system.

Sockeye Migration and Flow Conditions

Under the assumption that Surprise Creek discharge data captures at least some of the local/upstream flow events that affect Meziadin water levels, preliminary results utilizing Surprise Creek flows in this analysis suggest that high flow conditions may have been a factor affecting adult migration historically, and that the frequency and duration of high flow conditions may be increasing. The frequency and duration of low water events (< 10^{th} percentile) have been low but variable in the 2000s relative to previous decades, with no discernible impacts on daily migration rates at the range of water levels recorded. High flows (> 90^{th} percentile), however, were associated with delayed migration, migration stoppages, and low daily migration rates, and appear to have an interaction effect with water temperatures: while moderate- and high migration rates were observed at water temperatures up to 18ºC when flows were average or low, combinations of high water temperature and high flow levels were associated with near-zero migration rates. The frequency of high flow events increased in the 2000s relative to previous decades, along with the mean and maximum duration of high flow periods.

These results are largely based on flow data from Surprise Creek, a remote gauged watershed upstream of Meziadin Lake, which are not highly correlated with Meziadin River conditions. For example, observed Meziadin data (1998-2012) suggest declining trends in mean water levels, but this trend conflicts with Surprise Creek data which indicate positive trends in discharge over the same time period as well as over the extended period beginning in 1967. Evidently, the two sites do not always experience the same weather systems, or else react hydrologically differently to weather events, perhaps due to the buffering capacity of the intermediate Meziadin Lake. Thus local precipitation events may briefly intensify flows in Surprise Creek, but not be reflected strongly in Meziadin River water levels (e.g., 2008). Conversely, large or distant weather systems amplifying Nass flows upstream of the Meziadin confluence may back up flows in Meziadin River but not correlate hydrologically with upstream tributaries that are buffered by Meziadin Lake (e.g., 2000, 2007, 2011; pers. comm., R. Alexander, LGL Ltd.).

The inability to reliably hind-cast or forecast Meziadin hydrology may also limit climate analyses that depend on suitable baseline reference data for downscaling of climate model outputs to local conditions. Continuous high-resolution monitoring at the Meziadin fishway via automated data loggers, including outside the Sockeye migration season (when discharge levels are typically more variable) might improve statistical relations with other locations, but might not address the nonlinear differences between stations. Since high water events in the Meziadin may be driven by either local / upstream precipitation or regional / downstream events affecting the Nass system, a more sophisticated multi-factor analysis may provide more predictive power. Non-parametric approaches (e.g., categorical models, extreme values analysis, or hydrological modeling) may also be necessary.

The Nass River system is one of the most important Sockeye watersheds in British Columbia. The Meziadin Sockeye stock comprises an average of 75% of the Sockeye production in the Nass, representing nearly $10 million in landed value (Bocking et al. 2002). Monitoring of the physical environment appears to be under-resourced. Enhanced monitoring of environmental variables in this watershed via automated data logger installations, combined with advances in the analysis of how these factors co-vary with Meziadin Sockeye behaviour and migration patterns, might be considered a wise investment in this valuable resource.

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Station	Prov	Proximity (km)	Data Interval	Day	Month	Year	
ALICE ARM	BC	49.47	Daily	30	Sep	1964	Go
KITSAULT MINESITE	BC	62.63	Daily	30	Apr	1972	Go
ALICE ARM	BC	69.15	Daily	30	Sep	1978	Go
NASS RIVER	BC	71.26	Daily	31	Jul	1956	Go
KITSAULT MINESITE	BC	72.59	Daily	31	Oct	1969	Go
STEWART	BC	74.70	Daily	30	Apr	1967	Go
STEWART BCHPA	BC	74.70	Daily	31	May	1976	Go
STEWART A	BC	75.07	Hourly	1	May	2013	Go
PREMIER	BC	77.13	Daily	30	Sep	1996	Go
NASS CAMP	BC	90.65	Daily	31	Jan	2013	Go
ANYOX	BC	90.84	Daily	30	Jun	1935	Go
AIYANSH	BC	91.30	Daily	30	Sep	1971	Go
KITSAULT TOWNSITE	BC	92.23	Daily	31	Jul	1967	Go
AIYANSH 2SE	BC	96.35	Daily	31	Aug	1985	Go
KITSAULT MILLSITE	BC	99.19	Daily	31	Oct	1967	Go

Table 1. ENVIRONMENT CANADA meteorological stations within 100 km of the Meziadin watershed with daily mean air temperature and precipitation data.

	Meziadin River										
	Date			Sockeye Migrants			Migration Rate (%)				
	Date Count	Min Date	Max Date	Mean Daily	Max Daily	Annual Total	P50	P75	P95	Mean Daily	Max Daily
Year											
1966	58	04JUL	30AUG	1,119	3,392	64,884	1.56	2.83	3.92	1.72	5.23
1967	73	07JUL	17SEP	573	2,930	41,842	0.96	1.78	4.39	1.37	7.00
1968	59	30JUN	27AUG	1,222	5,031	72,087	1.27	2.67	6.34	1.69	6.98
1969	73	03JUL	14SEP	1,860	19,225	135,798	0.81	1.44	4.75	1.37	14.16
1970	67	03JUL	07SEP	1,164	11,045	77,990	0.47	1.78	4.75	1.49	14.16
1971	72	06JUL	15SEP	2,692	14,568	193,823	1.02	1.68	3.91	1.39	7.52
1972	67	05JUL	09SEP	1,956	8,560	131,076	1.08	2.31	4.17	1.49	6.53
1973	70	02JUL	09SEP	3,360	29,338	235,187	0.83	1.74	3.85	1.43	12.47
1974	70	30JUN	07SEP	2,372	7,514	166,014	0.99	1.97	3.45	1.43	4.53
1975	53	08JUL	04SEP	1,041	6,866	55,170	1.41	2.23	5.79	1.89	12.45
1976	61	21JUL	19SEP	1,722	9,252	105,045	0.89	1.62	7.33	1.64	8.81
1977	75	29JUN	11SEP	3,235	33,717	242,640	0.68	1.22	5.57	1.33	13.90
1978	68	01JUL	06SEP	1,643	8,866	111,731	0.96	1.43	7.04	1.47	7.94
1979	78	01JUL	16SEP	2,511	8,527	195,850	1.28	1.69	2.91	1.28	4.35
1980	74	29JUN	10SEP	1,922	9,113	142,253	0.71	2.01	4.93	1.35	6.41
1981	72	06JUL	15SEP	2,825	8,913	203,374	1.02	2.09	3.94	1.39	4.38
1982	72	29JUN	12SEP	3,412	20,284	245,646	0.70	1.75	5.04	1.39	8.26
1983	65	05JUL	07SEP	2,593	12,161	168,552	1.10	2.00	4.18	1.54	7.21
1984	67	04JUL	08SEP	2,110	10,484	141,366	0.86	2.19	5.90	1.49	7.42

(Continued)

	Meziadin River										
	Date			Sockeye Migrants			Migration Rate (%)				
	Date Count	Min Date	Max Date	Mean Daily	Max Daily	Annual Total	P50	P75	P95	Mean Daily	Max Daily
Year											
1985	87	04JUL	02OCT	3,331	36,980	289,772	0.34	1.44	4.59	1.15	12.76
1986	81	07JUL	25SEP	1,436	21,308	116,281	0.71	1.12	2.25	1.23	18.32
1987	52	12JUL	02SEP	2,832	14,189	147,264	1.64	2.38	6.17	1.92	9.64
1988	62	06JUL	06SEP	1,896	5,535	117,577	1.44	2.52	3.56	1.61	4.71
1989	65	06JUL	08SEP	709	5,258	46,083	1.01	2.05	3.92	1.54	11.41
1990	68	08JUL	13SEP	1,823	17,232	123,958	0.92	1.57	5.15	1.47	13.90
1991	59	09JUL	05SEP	3,942	38,405	232,557	0.72	1.40	6.90	1.69	16.51
1992	82	16JUL	05OCT	7,326	50,043	600,743	0.48	0.97	7.42	1.22	8.33
1993	79	15JUL	01OCT	4,981	21,399	393,532	0.83	1.83	4.00	1.27	5.44
1994	79	13JUL	29SEP	2,082	10,207	164,462	0.88	1.90	4.42	1.27	6.21
1995	89	05JUL	01OCT	2,384	17,363	212,192	0.74	1.33	3.85	1.12	8.18
1996	85	05JUL	27SEP	2,159	12,318	183,542	0.96	1.66	3.46	1.18	6.71
1997	87	05JUL	29SEP	1,842	10,516	160,220	0.99	1.55	2.87	1.15	6.56
1998	116	29JUN	22OCT	1,467	8,269	170,177	0.38	1.33	3.41	0.86	4.86
1999	101	04JUL	15OCT	1,828	12,796	184,677	0.55	1.22	3.49	0.99	6.93
2000	97	06JUL	13OCT	1,424	13,280	138,128	0.29	1.10	4.70	1.03	9.61
2001	101	05JUL	14OCT	1,325	6,912	133,865	0.34	1.13	4.51	0.99	5.16
2002	103	05JUL	15OCT	3,263	25,937	336,067	0.41	1.33	4.37	0.97	7.72
2003	101	02JUL	10OCT	2,025	7,072	204,574	0.81	1.61	2.55	0.99	3.46
2004	92	04JUL	03OCT	1,563	8,307	143,783	0.73	1.56	3.79	1.09	5.78
2005	108	02JUL	17OCT	1,439	7,386	155,416	0.63	1.51	2.58	0.93	4.75
2006	103	02JUL	12OCT	1,433	6,868	147,610	0.84	1.37	2.67	0.97	4.65
2007	83	21JUL	11OCT	1,305	8,761	108,329	0.38	1.64	6.56	1.20	8.09
2008	98	01JUL	08OCT	1,565	11,527	153,342	0.48	1.59	4.02	1.02	7.52
2009	96	03JUL	06OCT	1,879	9,565	180,356	0.64	1.33	4.60	1.04	5.30
2010	115	01JUL	23OCT	1,423	7,104	163,688	0.39	1.64	3.31	0.87	4.34
2011	90	01JUL	06OCT	1,915	9,531	172,354	0.52	1.58	4.01	1.11	5.53
2012	88	08JUL	03OCT	1,667	7,576	146,668	0.42	1.92	3.83	1.14	5.17
All	3,761	04JUL	03OCT	2,142	50,043	8,057,545	0.77	1.66	4.17	1.25	18.32

Table 2. Annual migration statistics for Meziadin Sockeye daily migrants, 1966-2012 (filtered for non-zero observations), 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 (%) (Source: DFO North Coast Stock Assessment Division).

	Water Level (m)						Percentiles			
	Dates	Min	Mean	Max	Std	Skew	P25	P50	P75	P95
Year										
1998	105	1.16	1.26	1.40	0.06	0.45	1.23	1.26	1.29	1.39
1999	105	1.18	1.32	1.49	0.10	0.41	1.23	1.30	1.39	1.48
2000	105	0.90	1.50	2.50	0.36	0.58	1.20	1.50	1.70	2.15
2001	107	1.20	1.35	1.50	0.07	-0.13	1.30	1.35	1.40	1.45
2002	107	1.10	1.30	1.45	0.07	-0.08	1.25	1.30	1.35	1.40
2003	102	1.14	1.30	2.60	0.14	7.38	1.25	1.30	1.33	1.38
2004	95	0.65	1.21	1.38	0.15	-1.91	1.17	1.27	1.29	1.35
2005	109	1.04	1.22	1.43	0.09	0.28	1.16	1.20	1.28	1.36
2006	103	1.05	1.19	1.41	0.10	0.51	1.12	1.17	1.28	1.36
2007	103	1.04	1.29	1.85	0.21	1.24	1.13	1.20	1.35	1.75
2008	100	0.99	1.26	1.48	0.12	-0.12	1.17	1.27	1.35	1.45
2009	98	1.11	1.26	1.39	0.09	-0.10	1.17	1.28	1.34	1.39
2010	115	1.00	1.27	1.50	0.12	-0.33	1.18	1.28	1.35	1.48
2011	108	1.10	1.31	1.64	0.11	0.19	1.25	1.30	1.40	1.50
2012	89	1.07	1.24	1.45	0.13	0.34	1.10	1.22	1.39	1.44
All	1551	0.65	1.29	2.60	0.16	2.11	1.19	1.28	1.35	1.50

Table 3. Water level statistics for observed data from the Meziadin River fishway, July-October 1998-2012.

		Discharge (cms)						Percentiles					
		Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year	Month												
1956	6	3	48	52	55	3.7	-1.6	48	48	48	54	55	55
	7	31	55	69	88	10.3	0.8	56	60	61	65	79	88
	9	1	36	36	36			36	36	36	36	36	36
All		35	36	67	88	12.1	0.1	48	55	60	64	74	88

Table 4. Discharge statistics for observed data from the *Meziadin River* WSC Station 08DA003, 1956.

	Discharge (cms)						Percentiles					
	Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year												
1929	92	476	1,220	1,800	311.8	-0.7	487	881	1,050	1,270	1,420	1,670
1930	92	348	1,280	2,240	463.9	0.1	513	694	947	1,335	1,620	2,070
1931	92	487	1,460	2,970	613.1	0.2	513	538	1,075	1,400	1,900	2,540
1932	92	824	1,602	2,890	423.8	0.6	971	1,000	1,360	1,600	1,785	2,360
1933	92	476	1,331	2,790	572.1	0.3	538	617	753	1,400	1,700	2,360
1934	92	498	1,367	2,860	565.9	0.5	510	631	953	1,350	1,695	2,440
1935	92	439	1,138	2,800	511.0	1.0	510	547	762	1,060	1,370	2,110
1936	92	450	1,315	2,160	371.9	-0.2	521	886	1,100	1,320	1,480	2,000
1937	92	473	1,218	2,260	363.5	0.4	609	807	981	1,170	1,485	1,830
1938	92	716	1,269	2,330	402.8	1.0	824	869	976	1,100	1,585	2,240
1939	92	824	1,447	3,740	478.2	1.6	917	949	1,110	1,320	1,745	2,290
1940	92	629	1,479	2,680	559.9	0.2	702	762	941	1,515	1,895	2,410
1941	92	283	1,045	2,080	421.0	0.4	374	547	759	1,040	1,255	1,810
1942	92	470	1,101	2,040	350.3	0.4	606	694	800	1,070	1,330	1,690
1943	92	385	1,228	2,220	455.6	0.1	496	629	896	1,190	1,665	1,970
1944	92	442	1,188	2,160	400.6	0.0	515	646	880	1,210	1,490	1,850
1945	92	340	938	1,760	375.1	0.1	362	402	608	967	1,225	1,550
1946	73	558	1,091	2,020	310.7	0.6	595	705	841	1,090	1,280	1,560
1947	92	705	1,148	3,090	345.1	2.3	776	813	916	1,035	1,320	1,670

(Continued)

	Discharge (cms)						Percentiles					
	Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year												
1948	92	592	1,121	1,930	244.3	0.3	705	827	969	1,100	1,240	1,500
1949	92	597	1,305	2,410	418.0	0.6	682	850	983	1,280	1,545	2,120
1950	0											
1951	0											
1952	0											
1953	0											
1954	0											
1955	0											
1956	92	391	1,239	2,010	437.7	0.0	476	697	914	1,195	1,615	1,950
1957	92	498	1,169	1,780	340.4	-0.3	552	620	911	1,205	1,445	1,650
1958	92	467	1,066	1,900	373.7	0.0	521	572	714	1,105	1,370	1,670
1959	92	609	1,255	2,470	557.8	0.8	680	699	822	997	1,800	2,200
1960	92	504	1,455	4,110	803.1	0.7	515	575	701	1,450	1,970	2,790
1961	92	385	1,249	2,200	418.7	-0.0	583	674	973	1,235	1,580	1,890
1962	92	462	1,415	2,970	674.8	0.4	583	651	798	1,235	2,015	2,460
1963	92	617	1,437	3,340	621.3	1.3	691	850	1,005	1,250	1,665	2,830
1964	92	442	1,362	3,260	692.4	0.5	493	538	694	1,325	2,015	2,380
1965	92	292	1,160	2,530	616.1	0.5	354	408	595	1,180	1,545	2,330
1966	92	654	1,367	2,580	513.0	0.5	705	784	947	1,255	1,815	2,260

(Continued)

	Discharge (cms)						Percentiles					
	Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year												
1967	92	883	1,480	3,310	450.6	2.2	1,080	1,110	1,205	1,375	1,585	2,450
1968	92	646	1,282	2,530	488.1	1.0	722	784	895	1,155	1,510	2,380
1969	92	742	1,103	2,060	295.9	1.2	776	804	885	994	1,265	1,710
1970	92	453	1,270	2,250	500.0	-0.0	501	595	793	1,350	1,695	2,060
1971	92	445	1,310	1,930	392.0	-0.5	617	719	987	1,415	1,650	1,820
1972	92	271	1,406	2,890	665.7	0.3	377	566	888	1,365	1,925	2,660
1973	92	575	1,381	2,460	533.5	0.1	637	688	841	1,450	1,805	2,210
1974	92	620	1,298	2,480	385.3	0.8	733	841	1,035	1,270	1,480	2,060
1975	92	476	1,205	3,340	742.2	1.6	507	595	708	983	1,340	2,970
1976	92	657	1,651	4,300	827.8	0.6	680	756	857	1,525	2,340	2,970
1977	92	320	1,089	1,790	450.4	-0.4	399	447	586	1,270	1,440	1,670
1978	92	340	998	1,620	336.7	-0.1	445	532	709	1,010	1,245	1,570
1979	92	596	1,232	2,040	377.0	0.6	728	806	968	1,120	1,480	1,920
1980	92	546	1,061	1,790	305.6	0.2	652	676	764	1,110	1,275	1,570
1981	92	483	1,387	2,970	549.6	0.5	574	712	976	1,350	1,695	2,410
1982	92	380	984	2,190	386.5	0.9	511	558	669	934	1,255	1,670
1983	92	443	1,050	1,640	275.5	-0.5	512	594	929	1,090	1,250	1,490
1984	92	360	1,183	2,000	470.2	-0.0	419	580	782	1,160	1,575	1,930
1985	92	516	1,280	3,420	710.5	1.0	548	616	687	1,065	1,835	2,620

(Continued)

	Discharge (cms)						Percentiles					
	Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year												
1986	92	314	1,120	2,520	619.9	0.6	343	459	599	1,045	1,705	2,150
1987	92	623	1,425	3,680	695.7	1.2	652	699	891	1,200	1,850	2,770
1988	92	323	1,252	2,610	453.8	-0.1	403	562	967	1,360	1,545	1,820
1989	92	343	1,082	1,830	342.1	0.1	536	651	829	1,110	1,265	1,710
1990	92	547	1,208	2,180	457.7	0.5	616	631	802	1,170	1,495	2,020
1991	92	740	1,251	1,900	276.9	0.2	830	900	1,015	1,255	1,445	1,730
1992	92	361	1,211	3,800	766.4	1.4	416	509	634	1,075	1,440	2,970
1993	92	258	885	1,960	329.6	0.3	342	474	640	846	1,145	1,300
1994	92	503	1,280	2,810	445.2	0.4	590	664	985	1,320	1,500	2,150
1995	92	465	960	1,790	280.5	0.4	518	589	764	911	1,160	1,460
1996	92	362	1,199	2,030	442.6	-0.0	458	599	894	1,175	1,595	1,900
1997	92	401	1,157	2,310	374.6	0.3	543	706	873	1,150	1,380	1,820
1998	92	501	1,026	1,800	289.8	0.3	528	588	861	1,005	1,200	1,570
1999	92	557	1,168	1,940	389.8	0.3	608	674	857	1,100	1,530	1,820
2000	92	809	1,569	3,830	619.7	1.0	850	890	1,030	1,505	1,970	2,630
2001	92	639	1,486	2,820	547.7	0.5	670	714	1,160	1,330	1,920	2,470
2002	92	773	1,400	2,470	375.4	0.3	833	915	1,085	1,425	1,655	2,020
2003	92	644	1,182	2,150	344.1	0.8	680	816	948	1,150	1,360	1,930
2004	92	410	1,130	2,310	380.0	0.4	550	656	789	1,175	1,335	1,670
2005	92	529	1,114	2,270	318.7	0.8	590	703	938	1,070	1,285	1,690
2006	92	395	1,058	1,950	402.1	0.4	432	597	767	941	1,375	1,780
2007	92	512	1,453	3,720	787.3	1.2	651	726	871	1,220	2,000	3,300
2008	92	360	1,233	2,690	555.5	0.7	469	584	778	1,220	1,490	2,480
2009	92	672	1,305	2,240	466.8	0.4	709	731	868	1,255	1,645	2,160
2010	92	316	978	2,020	371.7	0.3	415	477	676	1,020	1,185	1,560
2011	92	643	1,581	5,910	951.0	2.9	750	856	1,130	1,315	1,705	3,010
2012	92	576	1,349	2,816	572.6	0.6	633	751	847	1,177	1,799	2,369
All	7157	258	1,246	5,910	521.6	1.2	545	645	876	1,180	1,520	2,180

Table 5. Discharge statistics for observed data from the *Nass River (above Shumal)* WSC Station 08DB001, July-September 1929-2012.

	Discharge (cms)						Percentiles					
	Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year												
1967	92	17	31	51	6.6	0.2	19	22	27	31	34	42
1968	92	12	29	51	9.3	0.2	14	17	22	28	36	45
1969	92	10	23	52	8.5	0.5	11	12	17	23	28	37
1970	12	12	26	44	10.5	0.3	12	15	18	22	34	44
1971	92	6	32	74	13.7	0.2	9	14	21	33	41	52
1972	92	5	31	88	19.6	1.2	5	8	18	26	38	82
1973	92	9	32	68	13.2	0.4	13	15	21	33	40	54
1974	92	9	33	60	9.1	0.1	20	21	28	33	37	48
1975	92	8	31	97	23.2	1.6	10	12	15	23	36	93
1976	92	6	28	84	20.3	0.8	7	8	10	23	47	67
1977	92	5	21	42	10.0	0.4	7	9	13	19	27	38
1978	92	7	26	53	12.6	0.3	8	11	15	26	35	50
1979	92	12	32	72	12.1	0.9	15	18	23	31	39	53
1980	92	8	20	48	9.3	0.6	9	10	11	19	27	35
1981	92	8	36	76	18.3	0.4	10	12	22	35	48	70
1982	92	4	22	54	11.3	0.9	11	11	13	17	30	43
1983	92	3	20	37	9.3	-0.3	4	6	11	22	27	33
1984	92	4	25	69	15.2	0.5	5	7	11	24	36	49
1985	92	9	24	62	12.7	1.1	11	12	14	21	30	53

(Continued)

	Discharge (cms)						Percentiles					
	Dates	Min	Mean	Max	Std	Skew	P5	P10	P25	P50	P75	P95
Year												
1986	92	7	31	68	17.9	0.6	8	10	17	27	44	64
1987	92	12	35	99	17.5	1.5	15	17	23	30	45	60
1988	92	6	32	79	13.4	0.0	7	11	25	35	40	52
1989	92	6	29	56	10.9	0.1	12	14	22	30	36	50
1990	92	10	29	56	12.1	0.3	12	15	18	28	40	51
1991	92	10	29	67	11.2	0.8	13	15	20	27	36	48
1992	92	5	31	94	20.1	1.4	7	11	18	28	37	78
1993	92	6	27	60	11.0	0.0	9	12	19	27	35	41
1994	92	11	38	82	15.8	0.1	13	16	22	41	48	65
1995	92	12	30	66	10.6	0.8	17	19	23	27	39	49
1996	92	6	30	57	12.8	-0.2	8	12	20	32	40	51
1997	92	6	26	63	12.7	0.5	8	10	15	25	34	50
1998	92	8	24	64	11.6	1.3	10	11	16	22	29	51
1999	92	8	34	64	16.8	0.1	11	13	17	33	49	60
2000	92	13	35	67	14.1	0.1	14	17	24	36	47	59
2001	92	13	38	98	18.0	1.1	15	16	27	34	46	75
2002	92	12	31	67	12.1	0.8	15	17	22	27	38	56
2003	92	13	30	55	11.4	0.3	14	17	20	29	38	50
2004	92	10	33	53	11.9	-0.6	11	15	23	37	42	48
2005	92	7	27	56	10.2	0.2	10	13	19	27	34	43
2006	92	5	30	66	13.9	0.5	7	13	21	27	38	54
2007	92	8	37	117	20.2	1.3	11	17	22	34	47	77
2008	92	8	37	114	19.6	1.1	12	14	21	36	44	76
2009	92	11	33	56	11.5	0.4	18	20	23	31	41	54
2010	92	9	33	90	14.0	0.7	12	15	19	34	41	55
All	3968	3	30	117	14.8	1.0	10	12	19	28	38	55

Table 6. Discharge statistics for observed data from *Surprise Creek* (draining into Meziadin Lake via Strohn Creek) WSC Station 08DA005, July-September 1967-2010.

	Water Temperature						Percentiles			
	Dates	Min	Mean	Max	Std	Skew	P25	P50	P75	P95
Year										
1999	77	9.00	14.19	20.00	2.34	0.09	13.0	14.0	16.0	18.0
2000	78	9.00	12.95	21.00	2.09	0.75	12.0	13.0	15.0	16.0
2001	88	10.00	13.14	17.50	2.12	0.17	11.0	13.0	15.0	17.0
2002	88	10.00	13.88	17.00	1.62	-0.84	13.0	14.5	15.0	16.0
2003	90	10.50	14.91	18.50	2.41	-0.35	13.0	15.0	17.0	18.0
2004	90	10.00	15.98	21.00	2.84	-0.44	13.5	17.0	18.0	20.0
2005	91	10.50	15.15	20.00	2.17	-0.03	14.0	15.0	17.0	19.0
2006	91	11.00	15.00	18.00	1.57	-0.71	14.5	15.0	16.0	17.0
2007	72	9.00	13.04	16.00	1.70	-0.66	11.5	13.3	14.0	15.0
2008	92	10.50	13.37	17.00	1.57	0.23	12.0	13.0	14.5	16.0
2009	92	9.10	14.76	20.00	2.44	-0.29	13.8	15.0	16.0	19.0
2010	92	10.00	13.95	19.00	2.19	0.17	12.0	14.0	15.5	18.0
2011	92	8.50	13.00	17.50	2.21	-0.38	12.0	13.0	15.0	16.0
2012	84	9.00	13.30	17.50	1.87	-0.06	12.0	13.5	14.5	16.0
All	1217	8.50	14.07	21.00	2.31	0.10	12.5	14.0	15.5	18.0

Table 7. Annual summary of daily mean water temperature data for Meziadin River at the fishway during Sockeye migration (July-September) (Source: Nisga'a Fisheries). MEAN is average of daily mean temperatures for #DATES times per year. MIN and MAX are minimum and maximum of the daily mean temperatures (i.e., not observed extremes).

	Calibration		Validation	
	Warming	Cooling	Warming	Cooling
	Observations	Observations	Observations	Observations
Year				
1999			30	49
2000			21	70
2001	32	71		
2002			32	71
2003	34	66		
2004	33	60		
2005	35	70		
2006			35	68
2007			16	67
2008	35	65		
2009	36	62		
2010	36	79		
2011	36	62		
2012			27	62

Table 8. Number of annual water temperature observations available for Meziadin air/water temperature analyses, partitioned into warming and cooling seasons 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.

Meziadin Air/Water Logistic (Intercept) Model - All Seasons 1999-2012 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	3	4507.4	1502.5	662.80	<.0001
Error	808	1831.6	2.2668		
Corrected Total	811	6339.0			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness
alpha	19.6711	0.8900	17.9240	21.4181	1.1154
beta	12.0965	0.4067	11.2982	12.8947	-0.3472
gamma	0.2792	0.0480	0.1850	0.3733	-0.0905
mu	6.3325	1.0491	4.2731	8.3919	-1.1645

Meziadin Air/Water Logistic (Intercept) Model - Warming Season 1999-2012 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	4	62228.6	15557.1	5633.49	<.0001
Error	273	753.9	2.7615		
Uncorrected Total	277	62982.5			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness	Label
alpha	18.8447	1.0692	16.7398	20.9496	1.3638	
beta	10.2567	0.3449	9.5776	10.9357	-0.4547	
gamma	0.2928	0.0693	0.1565	0.4292	0.1558	
mu	0	0	0	0	.	

Meziadin Air/Water Logistic (Intercept) Model - Cooling Season 1999-2012 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	3	3618.7	1206.2	729.36	<.0001
Error	531	878.2	1.6538		
Corrected Total	534	4496.9			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness
alpha	19.5373	0.6157	18.3278	20.7468	0.7412
beta	12.3500	0.2391	11.8803	12.8196	0.1704
gamma	0.3807	0.0470	0.2884	0.4730	0.0286
mu	7.5446	0.5195	6.5241	8.5651	-0.6668

Table 9. Logistic regression output for air/water temperature relationship between the *Stewart* 7d-CMAT (air temperature index) and calibration data for lower Meziadin River daily mean water temperatures: seasons combined (top); warming season (middle); cooling season (bottom). Due to insufficient data in the warming season, the 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 water temperatures in the winter and assist in model convergence. Hysteresis was not detected ($NSC_{seasonal} - NSC_{all}$ = 0.0067).

Meziadin Air/Water Linear Model - Warming Season 1999-2012 - Calibration

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	517.21752	517.21752	185.04	<.0001
Error	275	768.69042	2.79524		
Corrected Total	276	1285.90794			

Root MSE	1.67190	R-Square	0.4022
Dependent Mean	14.92419	Adj R-Sq	0.4000
Coeff Var	11.20260		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	2.67755	0.90589	2.96	0.0034
Stewart_7DMAT	7d-MAT	1	0.81359	0.05981	13.60	<.0001

Meziadin Air/Water Linear Model - Cooling Season 1999-2012 - Calibration

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	3558.30376	3558.30376	2020.73	<.0001
Error	533	938.55939	1.76090		
Corrected Total	534	4496.86315			

Root MSE	1.32699	R-Square	0.7913
Dependent Mean	13.17841	Adj R-Sq	0.7909
Coeff Var	10.06941		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	2.22149	0.25041	8.87	<.0001
Stewart_7DMAT	7d-MAT	1	0.91681	0.02040	44.95	<.0001

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

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Stewart_7DMAT	1	4068.492468	4068.492468	1920.00	<.0001
Season	1	148.434839	148.434839	70.05	<.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
Stewart_7DMAT	1	94.22609764	94.22609764	44.59	<.0001
Season	1	0.63182338	0.63182338	0.30	0.5846
Stewart_7DMAT*Season	1	7.02881068	7.02881068	3.33	0.0685

Table 10. Linear regression output for air/water temperature relationship between the *Stewart* 7d-CMAT (air temperature index) and calibration data for Meziadin 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) are marginally and highly significant, respectively, indicating that hysteresis exists.

------------------- Site=Meziadin Dataset=Validation Season=Warming -------------------

The CORR Procedure

1 With Variables: WaterT
2 Variables: LogisticModelWaterTemp LinearModelWaterTemp

Pearson Correlation Coefficients, N = 161
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.22943	0.25059
Daily MWT	0.0034	0.0013

Spearman Correlation Coefficients, N = 161
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.22115	0.22109
Daily MWT	0.0048	0.0048

------------------- Site=Meziadin Dataset=Validation Season=Cooling -------------------

The CORR Procedure

1 With Variables: WaterT
2 Variables: LogisticModelWaterTemp LinearModelWaterTemp

Pearson Correlation Coefficients, N = 387
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.84767	0.85358
Daily MWT	<.0001	<.0001

Spearman Correlation Coefficients, N = 387
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.84215	0.84214
Daily MWT	<.0001	<.0001

Table 11. 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). Analysis indicates marginally improved predictive power for linear over logistic model types.

		Air Temp						Est'd Water Temp				
		N	Min	P10	Med	P95	Max	Min	P10	Med	P95	Max
Decade	Year											
1960s	1960	92	6.3	8.8	12.2	16.7	19.1	9.2	10.3	13.1	16.5	17.9
	1961	92	4.4	8.2	12.2	18.2	20.4	8.5	9.6	14.2	17.1	17.5
	1962	92	3.2	4.4	11.2	16.1	18.7	7.9	8.1	12.0	15.9	17.0
	1963	92	8.5	10.2	14.0	17.9	19.6	10.5	11.6	14.3	17.8	18.3
	1964	92	5.1	8.3	11.1	14.6	17.4	8.5	9.8	11.9	14.4	15.6
	1965	92	8.0	10.1	14.1	16.3	18.6	10.2	11.5	14.2	16.8	17.2
	1966	92	8.6	10.6	12.6	16.7	18.6	10.7	11.7	13.5	16.0	16.4
	1967	92	7.5	9.0	12.6	15.4	17.3	9.7	10.3	13.6	15.4	16.7
	1968	92	5.0	6.7	11.1	16.4	19.2	8.6	9.2	12.9	15.4	16.3
	1969	92	6.2	9.2	11.7	14.5	16.7	10.3	10.9	12.2	14.5	15.6
	Total	920	3.2	8.5	12.3	16.5	20.4	7.9	10.0	13.2	16.2	18.3
1970s	Year											
	1970	92	3.1	9.2	12.3	15.6	19.5	8.7	10.6	13.3	14.9	16.3
	1971	92	7.0	9.5	12.7	16.9	20.6	9.7	10.6	13.5	16.2	17.3
	1972	92	4.5	8.1	13.9	17.3	21.7	8.5	9.3	14.9	16.6	17.1
	1973	92	6.1	9.5	12.3	16.7	18.6	9.4	10.8	12.9	15.8	17.0
	1974	92	6.1	10.9	13.9	17.8	19.5	8.8	12.4	14.9	17.6	18.5
	1975	92	9.5	10.0	12.3	15.9	20.6	11.0	11.6	13.3	16.1	16.7
	1976	92	7.3	9.8	12.1	15.3	18.9	9.6	11.1	13.0	15.9	16.9
	1977	92	7.4	10.0	13.6	19.0	21.8	9.3	11.6	14.4	18.2	18.9

(Continued)

		Air Temp						Est'd Water Temp				
		N	Min	P10	Med	P95	Max	Min	P10	Med	P95	Max
Decade	Year											
1970s	1978	92	6.0	9.1	13.6	17.5	18.8	9.3	10.3	15.0	16.5	16.7
	1979	92	7.7	10.5	14.6	17.4	19.6	10.0	11.7	15.5	17.6	18.1
	Total	920	3.1	9.7	13.1	17.2	21.8	8.5	11.0	14.1	16.6	18.9
1980s	Year											
	1980	92	8.5	9.9	12.7	15.9	21.9	11.0	11.4	13.6	16.3	18.5
	1981	92	8.8	10.7	14.1	17.9	20.2	9.5	12.4	14.9	17.3	18.2
	1982	92	6.9	11.0	13.9	16.8	19.6	10.3	12.0	14.7	16.4	17.2
	1983	92	4.9	8.9	12.9	15.4	18.8	9.0	10.1	13.9	15.7	16.8
	1984	92	4.4	9.0	12.7	15.4	18.4	9.0	9.9	12.8	15.5	16.2
	1985	92	6.9	10.0	12.8	16.4	21.0	9.7	10.9	13.9	15.7	16.2
	1986	92	7.7	9.5	13.6	16.5	17.7	10.3	11.1	14.5	16.0	16.8
	1987	92	7.1	9.5	14.0	17.4	20.2	9.7	11.1	15.1	17.1	17.5
	1988	92	5.8	9.3	12.9	16.1	18.2	9.5	10.3	13.6	15.9	16.7
	1989	92	7.2	11.0	14.4	17.6	21.1	10.5	12.0	15.7	16.5	17.1
	Total	920	4.4	9.8	13.3	16.8	21.9	9.0	11.1	14.3	16.4	18.5
1990s	Year											
	1990	92	8.5	11.2	14.4	18.2	22.4	10.1	13.1	15.7	17.3	18.5
	1991	92	6.9	10.7	13.3	16.7	21.3	10.1	12.4	13.9	16.7	18.0
	1992	92	3.7	8.7	14.1	17.1	19.8	8.8	9.6	15.1	16.5	17.4
	1993	92	7.3	10.6	14.6	18.6	19.7	10.4	11.6	15.5	17.1	18.3

(Continued)

		Air Temp						Est'd Water Temp				
		N	Min	P10	Med	P95	Max	Min	P10	Med	P95	Max
Decade	Year											
2000s	2012	92	6.9	10.8	13.7	16.4	18.7	9.9	11.9	14.9	16.1	17.5
	Total	1E3	5.2	10.1	13.4	16.7	23.6	9.0	11.3	14.3	16.5	18.7
Total		5E3	3.1	9.6	13.2	17.0	23.6	7.9	10.9	14.1	16.5	18.9

Table 12. Statistics for regional mean air temperature (*Stewart*) and estimated water temperature in Meziadin River for the months of July-September, 1960-2012.

	Observed Water Level (m)						
	N	Min	P10	Med	P95	Max	Std
Year							
1998	92	1.16	1.20	1.28	1.33	1.40	0.06
1999	92	1.18	1.21	1.32	1.47	1.49	0.09
2000	92	0.90	1.00	1.50	2.00	2.50	0.38
2001	92	1.20	1.28	1.36	1.45	1.50	0.07
2002	92	1.20	1.23	1.30	1.38	1.45	0.06
2003	92	1.14	1.19	1.30	1.37	1.40	0.06
2004	92	0.65	1.00	1.27	1.35	1.38	0.16
2005	92	1.04	1.10	1.20	1.35	1.43	0.08
2006	92	1.05	1.09	1.18	1.35	1.41	0.10
2007	92	1.04	1.10	1.23	1.67	1.85	0.22
2008	92	0.99	1.10	1.29	1.42	1.48	0.12
2009	92	1.11	1.14	1.29	1.38	1.39	0.09
2010	92	1.00	1.07	1.27	1.40	1.45	0.11
2011	92	1.10	1.15	1.30	1.42	1.64	0.11
2012	85	1.07	1.09	1.24	1.44	1.45	0.13
Total	1373	0.65	1.11	1.28	1.44	2.50	0.16

Table 13. Statistics for observed water level at the Meziadin fishway, July-September, 1998-2012.

Decadal Mean Monthly MAT Peaks > 20c

Site: Stewart Air

	Years in Decade	Mean No. Days			Mean Annual Total
		Jul	Aug	Sep	
Decade					
1920s	10	0.2	0.5	0.1	0.8
1930s	10	0.2			0.2
1940s	10	0.1	0.1		0.2
1950s	10	0.2	0.2		0.4
1960s	10	0.1			0.1
1970s	10	0.3	0.3		0.6
1980s	10	0.4	0.2		0.6
1990s	10	0.7	0.3		1.0
2000s	13	0.4	0.5		0.8

Annual Frequency & Mean Duration (days) for POT20c Events

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1920s	5	1	1.4	2	0.5
1930s	2	1	1.0	1	0.0
1940s	2	1	1.0	1	0.0
1950s	7	1	1.0	1	0.0
1960s	1	1	1.0	1	
1970s	4	1	1.3	2	0.5
1980s	5	1	1.2	2	0.4
1990s	8	1	1.6	3	0.7
2000s	8	1	1.4	3	0.7
Total	42	1	1.3	3	0.6

Table 14. Frequency analysis of decadal mean number of dates per month (July-September) in which regional daily mean air temperature at STEWART 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: Meziadin Lake/River

	Years in Decade	Mean No. Days			Mean Annual Total
		Jul	Aug	Sep	
Decade					
1900s	2				
1910s	10		0.5		0.5
1920s	10		3.0	0.5	3.5
1930s	10		0.3		0.3
1940s	10				
1950s	10				
1960s	10		0.8		0.8
1970s	10		1.8	0.1	1.9
1980s	10		0.6		0.6
1990s	10		1.4		1.4
2000s	13		1.3		1.3

Annual Frequency & Mean Duration (days) for POT18c Events

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1910s	1	5	5.0	5	
1920s	6	1	6.0	18	6.6
1930s	1	3	3.0	3	
1940s	0				
1950s	0				
1960s	2	2	4.0	6	2.8
1970s	4	1	4.5	11	4.5
1980s	2	2	3.0	4	1.4
1990s	4	1	3.5	7	3.0
2000s	4	2	4.8	8	2.8
Total	24	1	4.5	18	4.0

Table 15. Frequency analysis of decadal mean number of dates per month (July-September) in which estimated mean water temperature in the Meziadin 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					
1960s	1960	0				
	1961	0				
	1962	0				
	1963	2	2	4.0	6	2.8
	1964	0				
	1965	0				
	1966	0				
	1967	0				
	1968	0				
	1969	0				
	Total	2	2	4.0	6	2.8
1970s	Year					
	1970	0				
	1971	0				
	1972	0				
	1973	0				
	1974	1	4	4.0	4	
	1975	0				
	1976	0				

(Continued)

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1970s	1977	2	2	6.5	11	6.4
	1978	0				
	1979	1	1	1.0	1	
	Total	4	1	4.5	11	4.5
1980s	Year					
	1980	1	4	4.0	4	
	1981	1	2	2.0	2	
	1982	0				
	1983	0				
	1984	0				
	1985	0				
	1986	0				
	1987	0				
	1988	0				
	1989	0				
	Total	2	2	3.0	4	1.4
1990s	Year					
	1990	1	5	5.0	5	
	1991	0				

(Continued)

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1990s	1992	0				
	1993	1	1	1.0	1	
	1994	1	7	7.0	7	
	1995	0				
	1996	0				
	1997	1	1	1.0	1	
	1998	0				
	1999	0				
	Total	4	1	3.5	7	3.0
2000s	Year					
	2000	0				
	2001	0				
	2002	0				
	2003	0				
	2004	2	2	5.0	8	4.2
	2005	1	6	6.0	6	
	2006	0				
	2007	0				
	2008	0				
Decade	Year					
2000s	2009	0				
	2010	1	3	3.0	3	
	2011	0				
	2012	0				
	Total	4	2	4.8	8	2.8
Total		16	1	4.1	11	2.9

(Continued)

Table 16. Min., mean and max. length (days) and number of periods in which estimated mean Meziadin River water temperature continuously exceeded 18°C (July-September), by year (1960-2012).

Monthly and Annual No. Dates < 112 cm

		Freq POT112 cm Dates			Total Days
		Jul	Aug	Sep	
Decade	Year				
1990s	1998				
	1999				
2000s	2000	14	5		19
	2001				
	2002				
	2003				
	2004			13	13
	2005			12	12
	2006			18	18
	2007		1	15	16
	2008			15	15
	2009			2	2
	2010		2	14	16
	2011		5		5
	2012			24	24

Monthly and Annual No. Dates > 144 cm

		Freq POT144 cm Dates			Total Days
		Jul	Aug	Sep	
Decade	Year				
1990s	1998				
	1999	18			18
2000s	2000		26	29	55
	2001	6	1	4	11
	2002	5			5
	2003				
	2004				
	2005				
	2006				
	2007	22			22
	2008	5	1		6
	2009				
	2010	2			2
	2011			9	9
	2012	1			1

Table 17. Annual mean number of dates per month (July-September) in which observed water level at the Meziadin fishway was less than 1.12 m (10^{th} percentile; left); or greater than 1.44 m (90^{th} percentile; right).

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
2000s	2000	2	6	9.5	13	4.9
	2004	2	6	6.5	7	0.7
	2005	2	3	9.5	16	9.2
	2006	3	3	8.7	18	8.1
	2007	4	1	4.5	14	6.4
	2008	2	8	8.5	9	0.7
	2009	2	1	3.0	5	2.8
	2010	2	4	9.0	14	7.1
	2011	1	8	8.0	8	
	2012	2	13	13.5	14	0.7
	Total	22	1	7.8	18	5.3
Total		22	1	7.8	18	5.3

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Month					
Jul	2	6	9.5	13	4.9
Aug	5	2	4.4	8	2.3
Sep	15	1	8.7	18	5.8
Total	22	1	7.8	18	5.3

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1990s	1999	2	2	9.0	16	9.9
	Total	2	2	9.0	16	9.9
2000s	Year					
	2000	2	22	30.0	38	11.3
	2001	4	2	3.3	6	1.9
	2002	1	5	5.0	5	
	2007	1	22	22.0	22	
	2008	2	2	3.5	5	2.1
	2010	1	2	2.0	2	
	2011	2	3	4.5	6	2.1
	2012	4	1	2.3	4	1.3
	Total	17	1	7.5	38	10.1
Total		19	1	7.6	38	9.9

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Month					
Jul	11	1	6.1	22	6.7
Aug	3	2	14.0	38	20.8
Sep	5	2	7.2	22	8.4
Total	19	1	7.6	38	9.9

Table 18. Min., mean and max. length (days) and number of periods in which observed water level at the Meziadin fishway (July-September) was less than 1.12 m (10^{th} percentile; left); or greater than 1.44 m (90^{th} percentile; right).

Decadal Mean Monthly Water Level < 12 cms

Site: Surprise Creek

Decade	Years in Decade	Mean No. Days Jul	Mean No. Days Aug	Mean No. Days Sep	Mean Annual Total
1960s	3		1.0	2.0	3.0
1970s	9		1.0	10.0	11.0
1980s	10		1.9	12.6	14.5
1990s	10			7.7	7.7
2000s	11			3.7	3.7

Decade	Year	POT Event Duration (days) N	Min	Avg	Max	Std
1960s	1969	4	1	3.3	8	3.2
	Total	4	1	3.3	8	3.2
1970s	1970	1	1	1.0	1	
	1971	1	8	8.0	8	
	1972	2	2	7.0	12	7.1
	1973	1	3	3.0	3	
	1974	1	2	2.0	2	
	1975	3	2	4.3	7	2.5
	1976	4	3	8.5	17	6.0
	1977	5	1	6.4	19	7.4
	1978	3	2	4.0	6	2.0
	Total	21	1	5.7	19	5.0
1980s	1980	3	7	9.7	12	2.5
	1981	1	7	7.0	7	
	1982	8	1	2.5	7	2.1
	1983	2	20	22.0	24	2.8
	1984	4	2	8.0	16	6.3
	1985	4	1	25.5	95	46.3
	1986	2	2	6.5	11	6.4
	1987	2	1	1.0	1	0.0
	1988	2	1	6.0	11	7.1
	1989	1	4	4.0	4	
	Total	29	1	9.1	95	17.6
1990s	1990	3	1	1.7	2	0.6
	1991	2	1	1.0	1	0.0
	1992	3	1	3.7	7	3.1
	1993	4	1	3.0	8	3.4
	1994	3	1	2.0	4	1.7
	1996	4	1	3.8	6	2.6
	1997	3	2	9.3	18	8.1
	1998	3	1	5.0	12	6.1
	1999	3	1	4.0	10	5.2
	Total	28	1	3.8	18	4.2
2000s	2002	1	2	2.0	2	
	2004	3	2	3.7	5	1.5
	2005	3	1	2.7	5	2.1
	2006	2	2	4.5	7	3.5
	2007	3	2	2.3	3	0.6
	2008	1	5	5.0	5	
	2009	1	7	7.0	7	
	2010	1	4	4.0	4	
	Total	15	1	3.5	7	1.9
Total		97	1	5.7	95	10.3

Table 19. Annual mean number of dates per month (July-September) in which observed discharge in Surprise Creek was less than 12 cms (10th percentile; top left); Min., mean and max. duration (days) of $POT_{<12\ cms}$ periods, by year.

Decadal Mean Monthly Water Level > 50 cms

Site: Surprise Creek

	Years in Decade	Mean No. Days			Mean Annual Total
		Jul	Aug	Sep	
Decade					
1960s	3	0.7		0.3	1.0
1970s	9	5.8	2.0	0.3	8.1
1980s	10	5.7	0.6	0.9	7.2
1990s	10	6.5	1.2	0.4	8.1
2000s	11	7.5	1.5	1.0	10.1

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1960s	1967	1	1	1.0	1	
	1968	1	1	1.0	1	
	1969	1	1	1.0	1	
	Total	3	1	1.0	1	0.0
1970s	Year					
	1971	3	1	1.7	2	0.6
	1972	3	1	3.7	7	3.1
	1973	4	1	2.0	5	2.0
	1974	2	1	2.0	3	1.4
	1976	4	2	4.0	7	2.2
	1978	2	1	2.0	3	1.4
	1979	2	2	3.5	5	2.1
	Total	20	1	2.8	7	1.9
1980s	Year					
	1981	6	1	3.2	10	3.5
	1982	1	1	1.0	1	
	1984	3	1	1.3	2	0.6
	1985	2	1	2.5	4	2.1
	1986	5	1	3.6	8	2.9
	1987	5	1	2.4	4	1.1
	1988	3	1	2.0	4	1.7
	1989	1	5	5.0	5	
	Total	26	1	2.7	10	2.3
1990s	Year					
	1990	3	1	1.7	3	1.2
	1991	3	1	1.3	2	0.6
	1992	1	1	1.0	1	
	1993	1	2	2.0	2	
	1994	9	1	2.0	5	1.5
	1995	2	1	1.0	1	0.0
	1996	2	1	2.5	4	2.1
	1997	2	1	1.5	2	0.7
	1998	3	1	2.0	4	1.7
	1999	3	3	7.3	10	3.8
	Total	29	1	2.3	10	2.3
2000s	Year					
	2000	8	1	1.8	3	1.0
	2001	5	2	3.2	7	2.2
	2002	4	1	1.8	3	1.0
	2003	2	1	2.0	3	1.4
	2004	1	1	1.0	1	
	2005	1	2	2.0	2	
	2006	2	5	5.5	6	0.7
	2007	2	1	7.0	13	8.5
	2008	4	1	3.5	7	3.0
	2009	3	1	4.0	8	3.6
	2010	3	2	3.0	5	1.7
	Total	35	1	3.0	13	2.6
Total		113	1	2.7	13	2.3

(Continued)

Table 20. Decadal mean number of dates per month (July-September) in which observed discharge in Surprise Creek exceeded 50 cms (~90th percentile; top left); Min., mean and max. duration (days) of $POT_{>50\ cms}$ periods, by year.

FIGURES

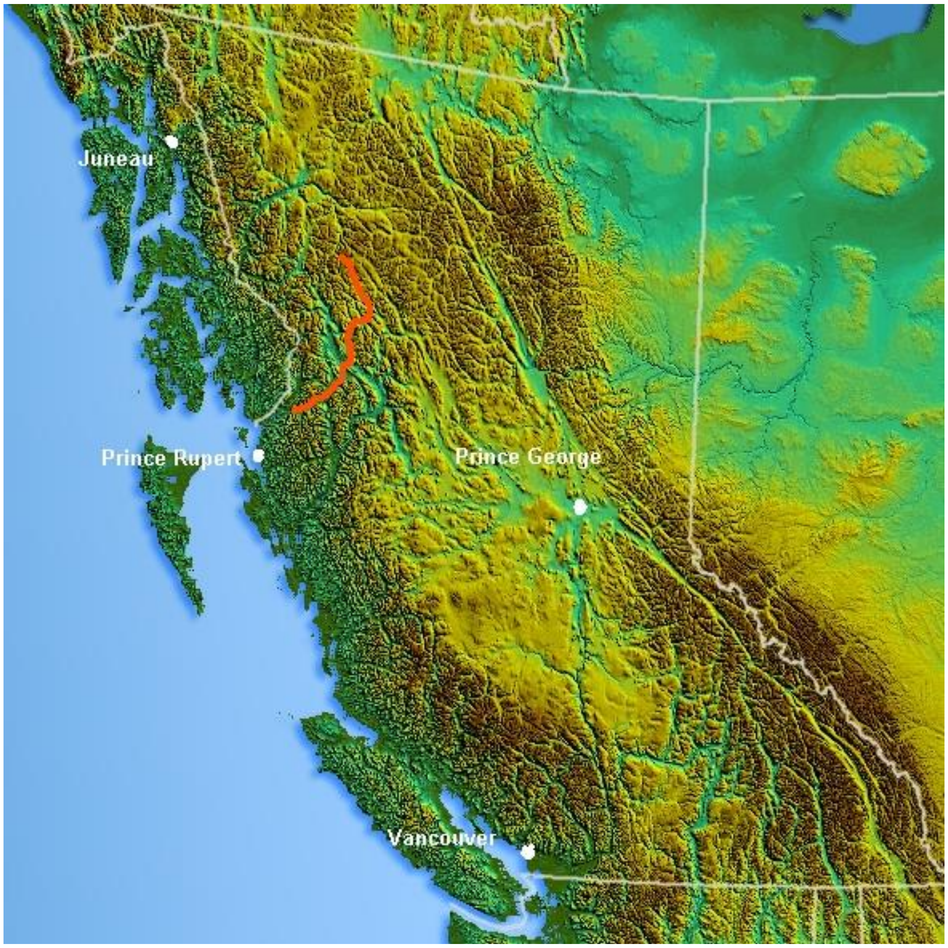


Figure 1. Nass River watershed, British Columbia (source: Wikipedia).

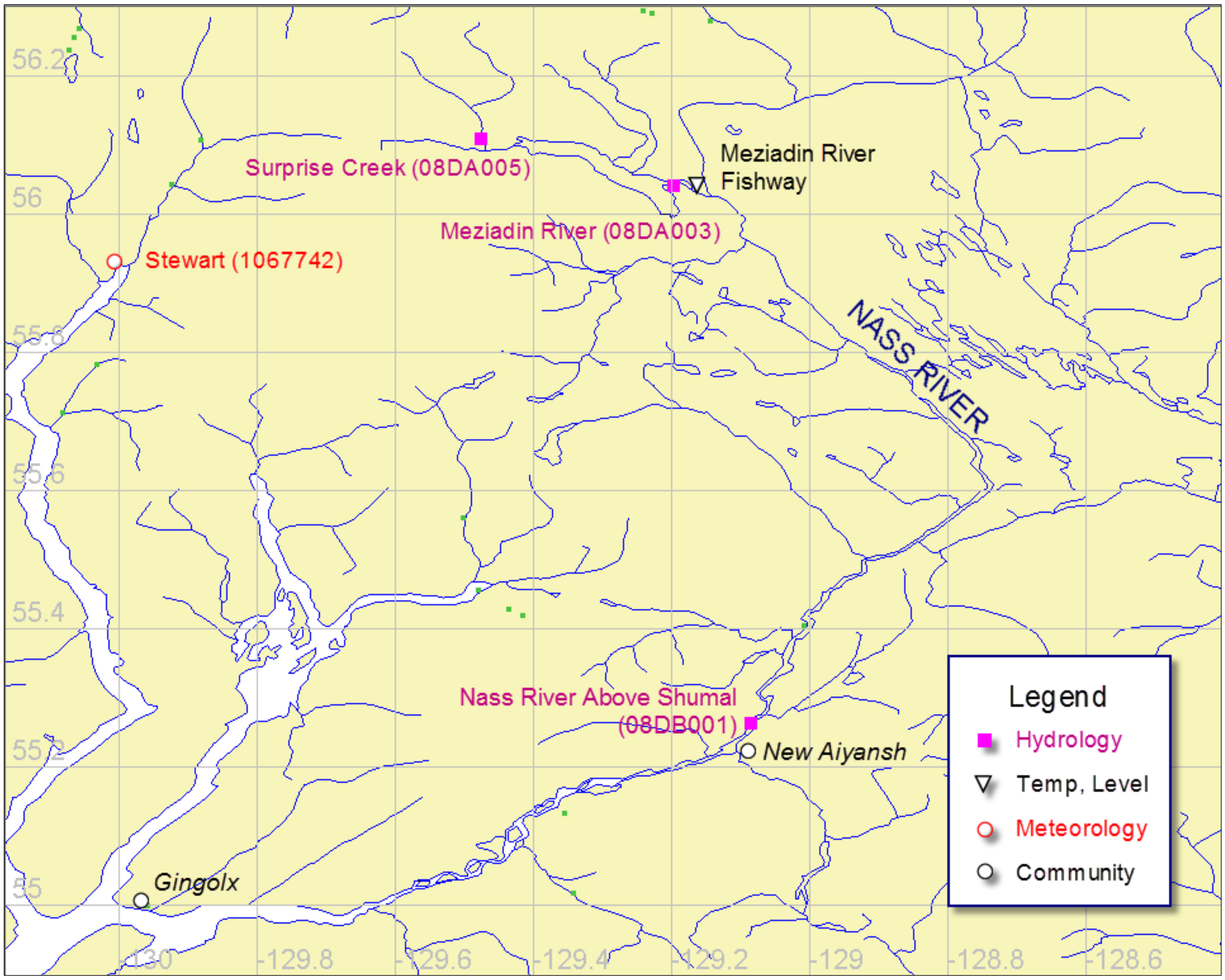


Figure 2. Nass River system with monitoring stations.

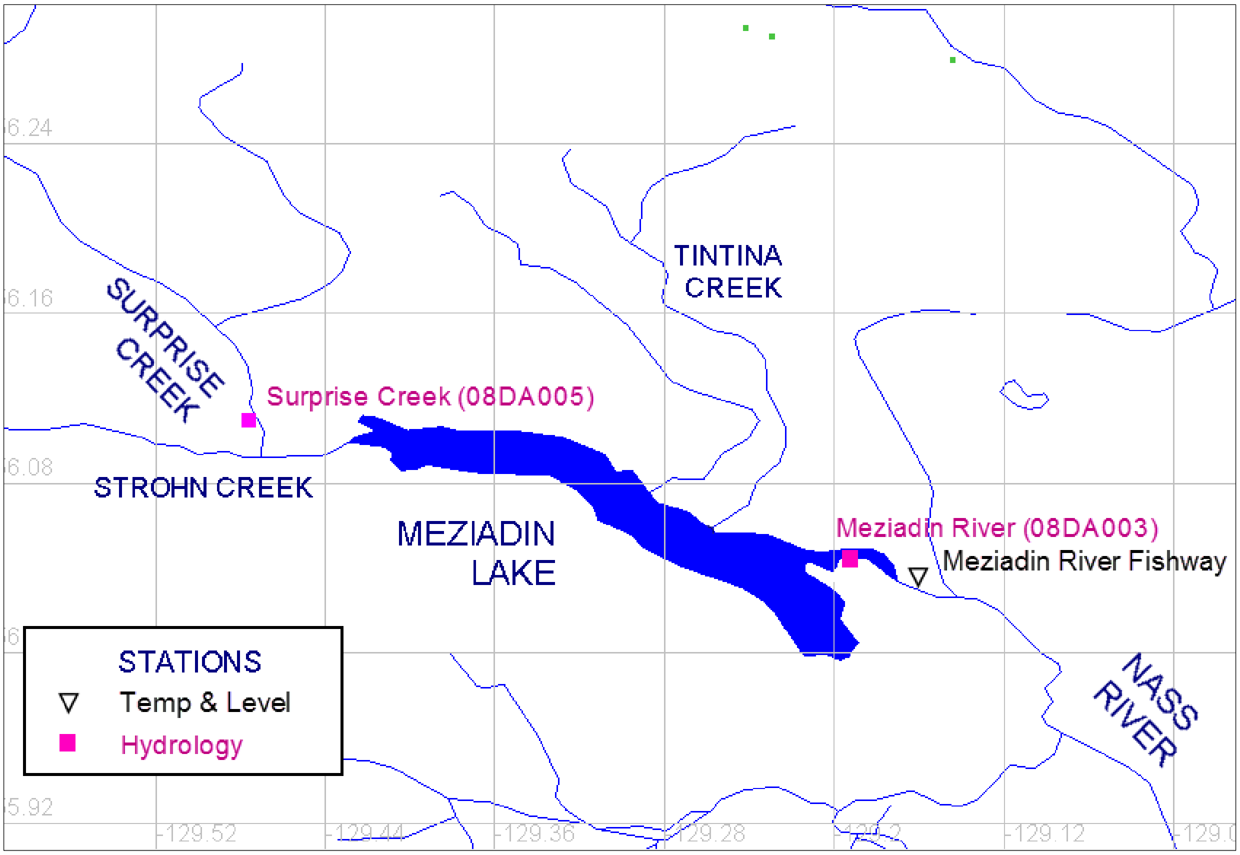
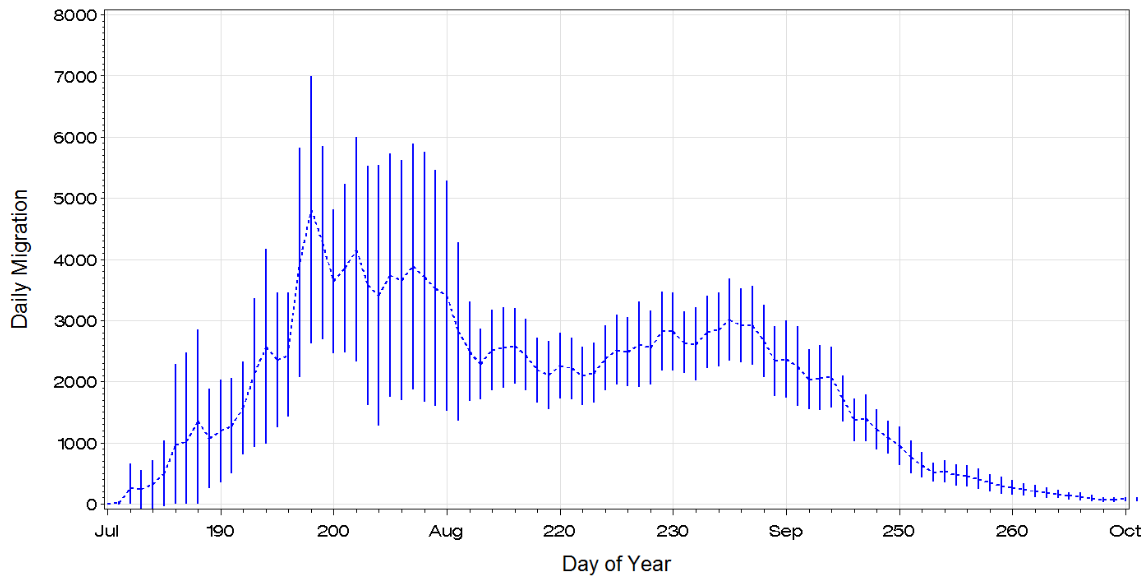


Figure 3. Meziadin watershed with monitoring stations.



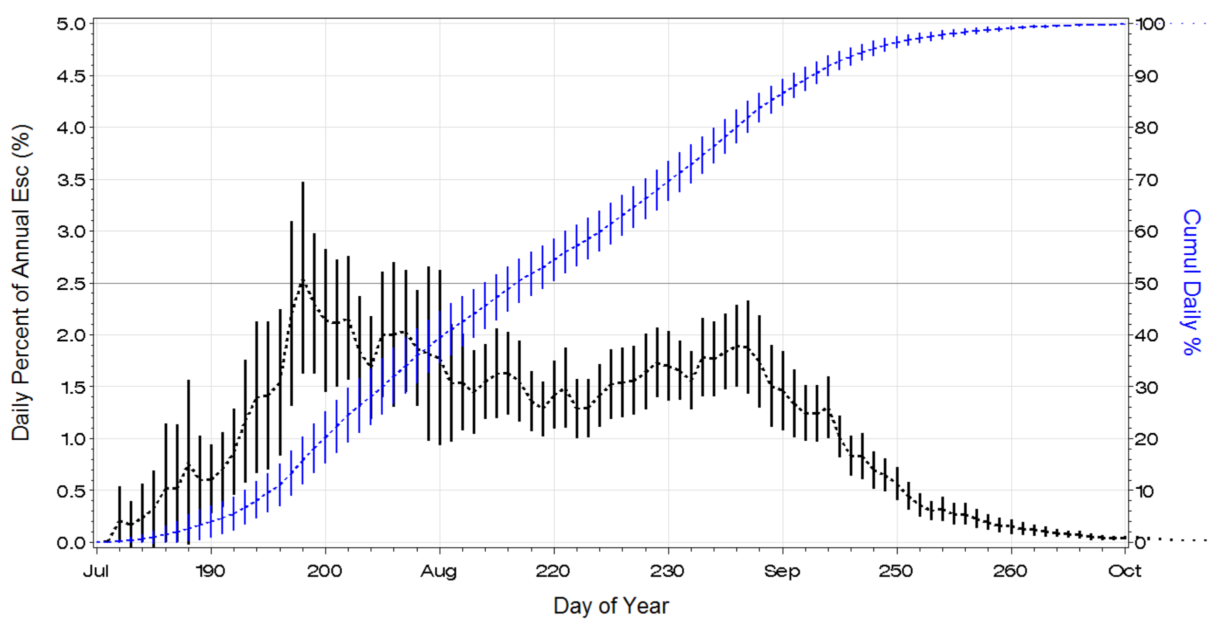


Figure 4. Historical mean daily migration timing. Mean and variance (95% CI) of daily Sockeye migrants (top) and mean daily % and cumulative % of total annual escapement (bottom). Time-to-50% ~ day 217 ~ August 5th (Source: DFO North Coast, unpub. data).

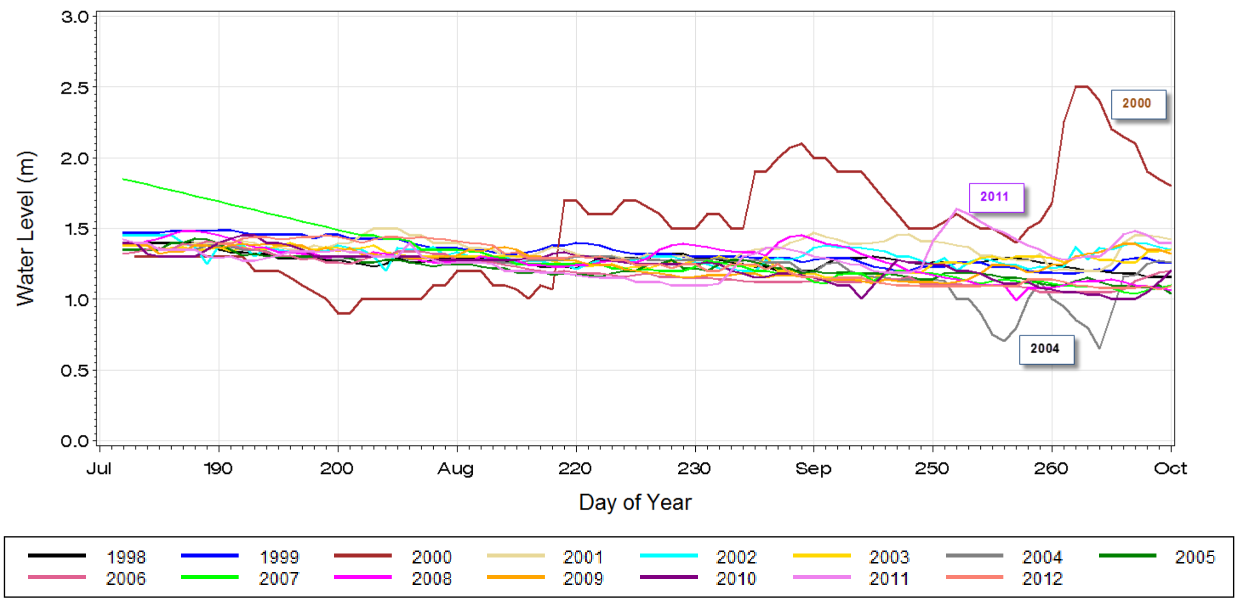


Figure 5. Observed daily mean water level (m) at the Meziadin River fishway, by year (1998-2012). Extreme flows in years 2000, 2004, and 2011. (Source: NTC Fisheries, c/o R Alexander, LGL Ltd.)

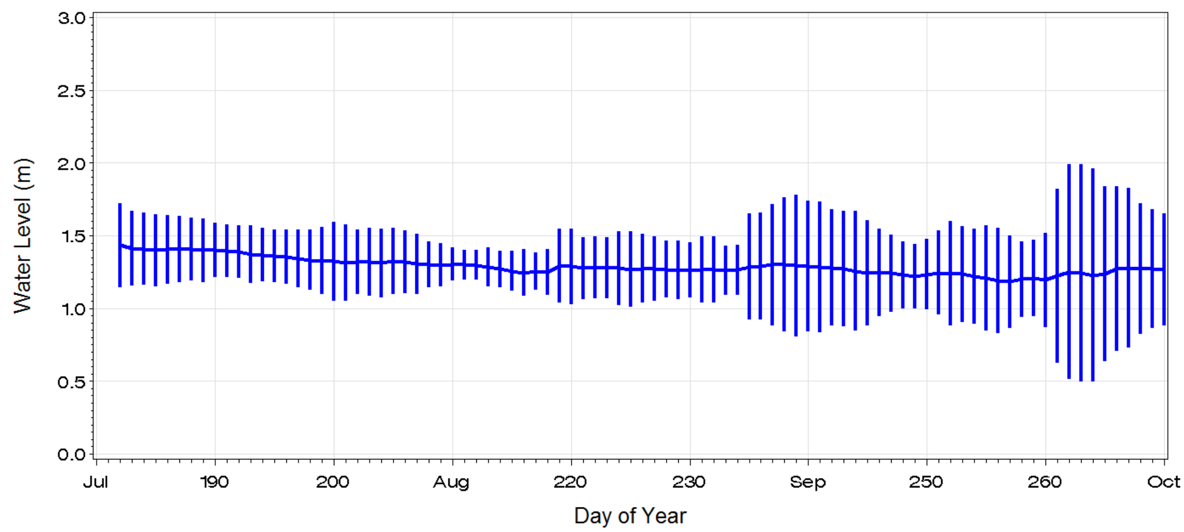


Figure 6. Observed daily mean water level (m) ± two standard deviations at Meziadin River fishway (1998-2012).

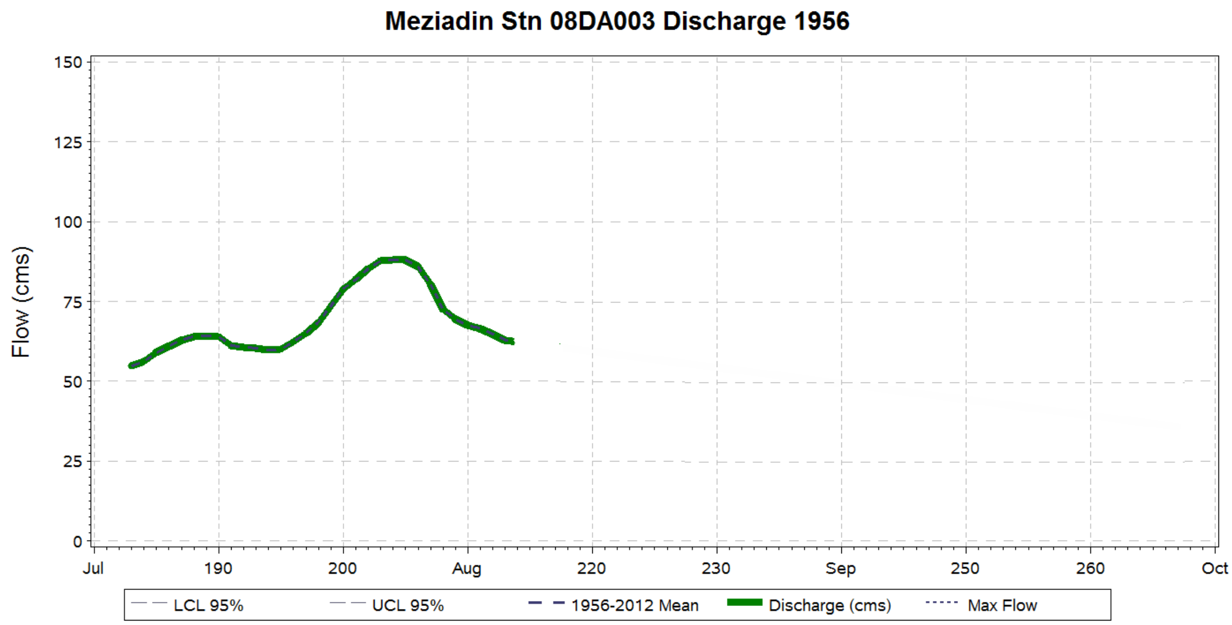


Figure 7. Observed daily mean discharge (cms) for Meziadin River (08DA003), by year (1956). Observations limited to 35 dates between 10-Jun and 23-Sep, 1956. (Source: WSC)

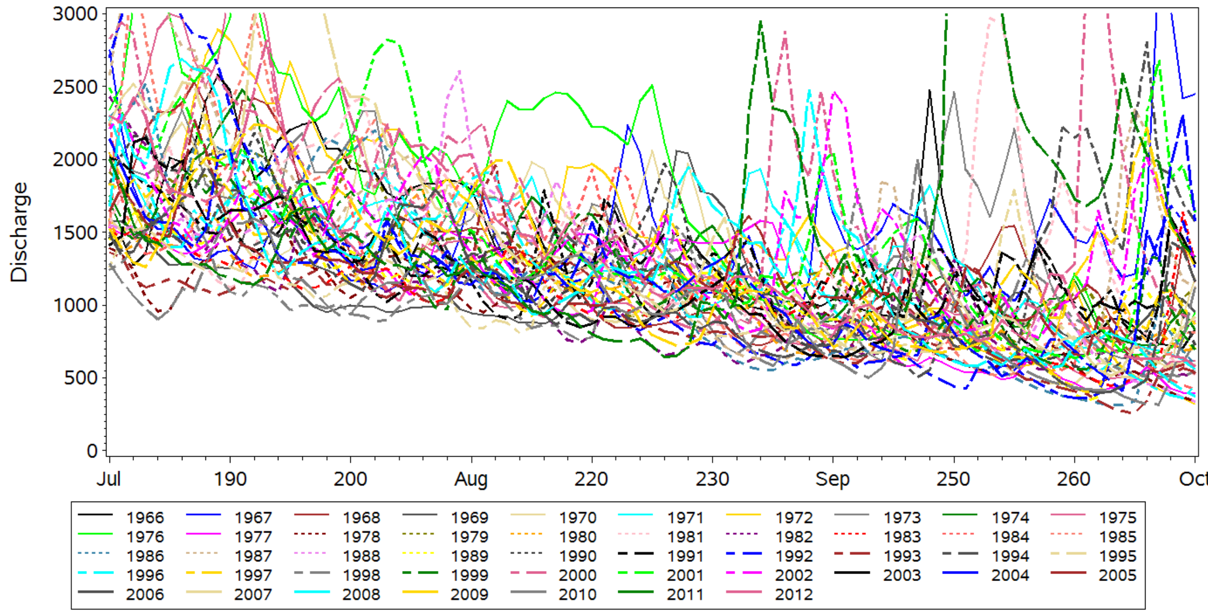


Figure 8. Observed daily mean discharge (cms) for the *Nass River above Shumal* (08DB001), by year (1966-2012). (Source: WSC)

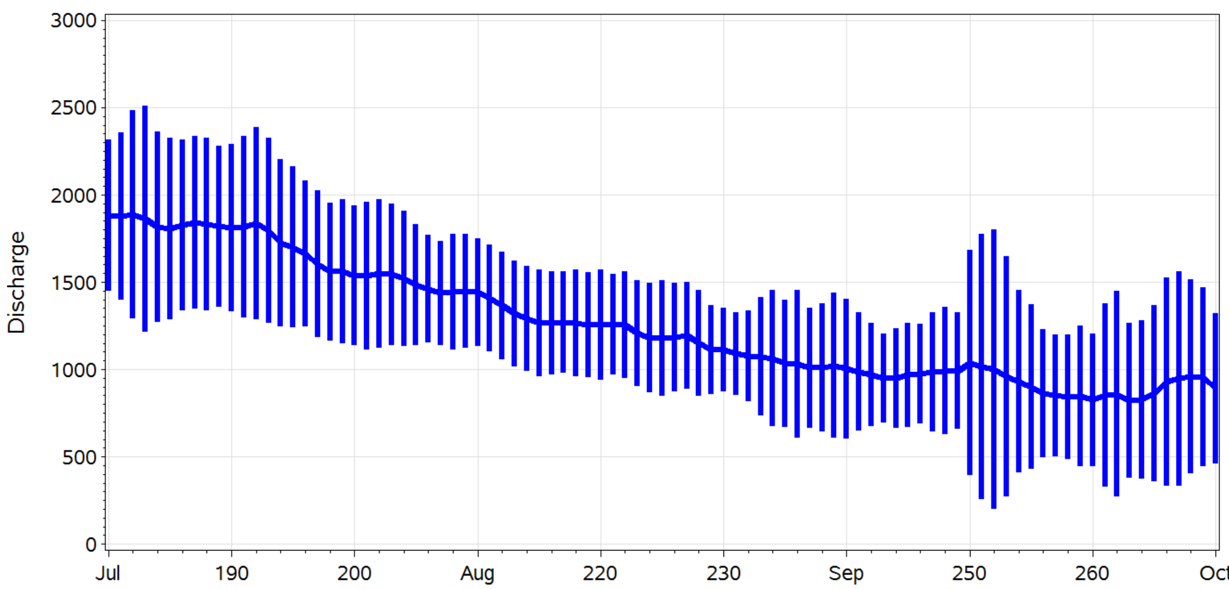


Figure 9. Observed daily mean discharge (cms) ± two standard deviations for the *Nass River above Shumal* (08DB001) (1966-2012).

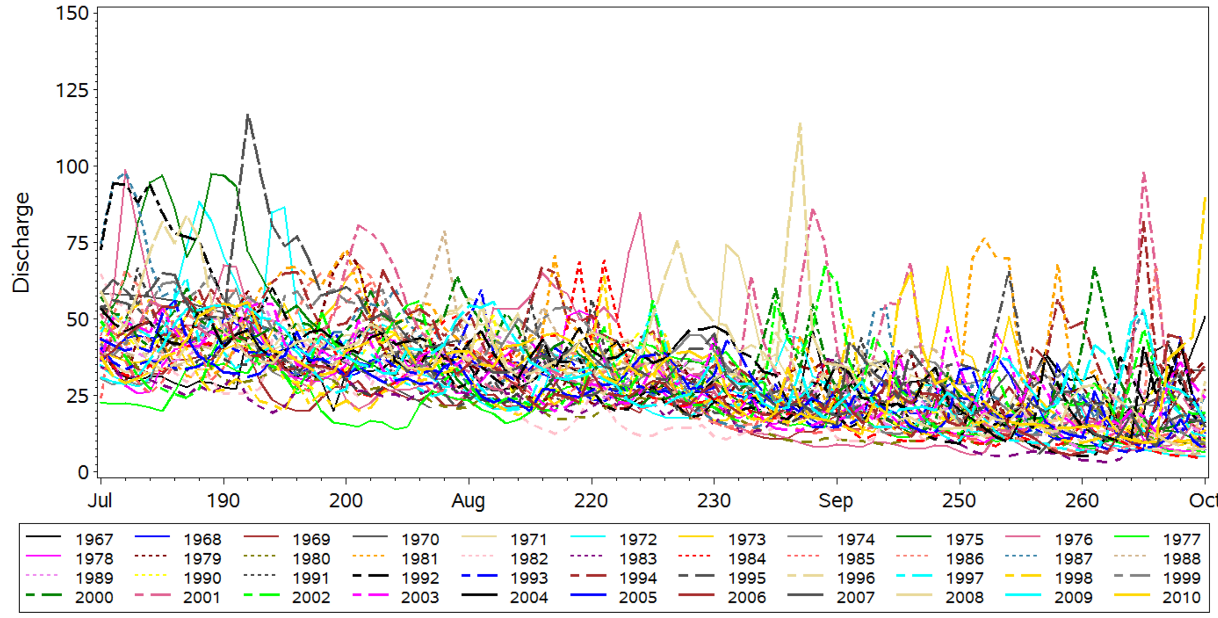


Figure 10. Observed daily mean discharge (cms) for *Surprise Creek* (tributary to Meziadin Lake), by year (1967-2012). (Source: WSC)

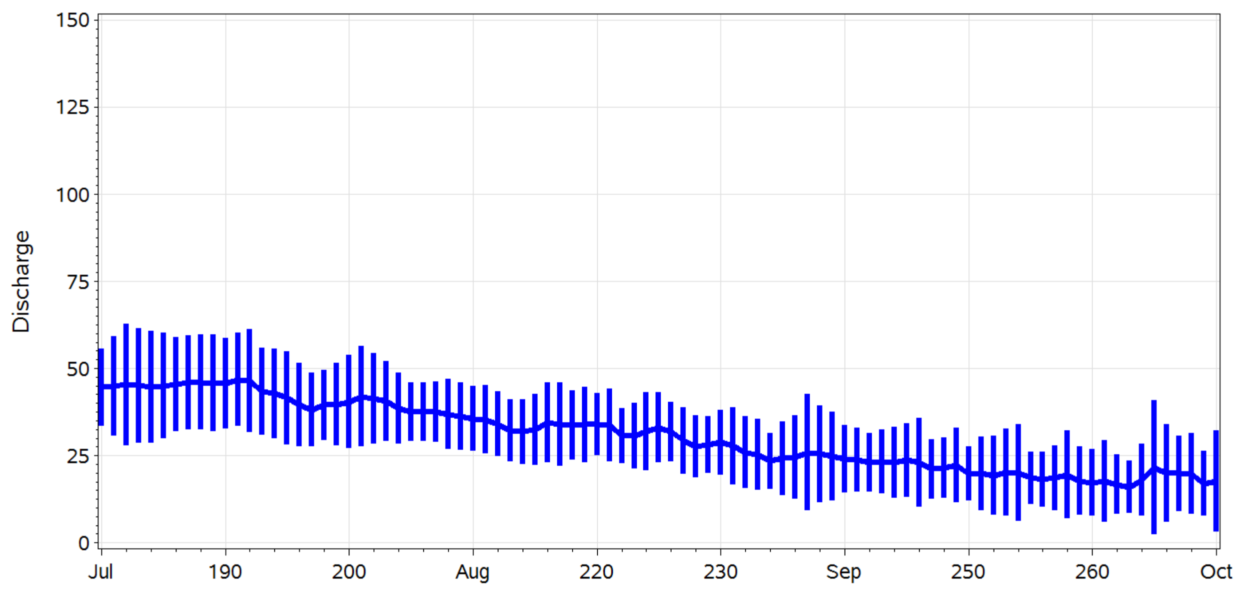
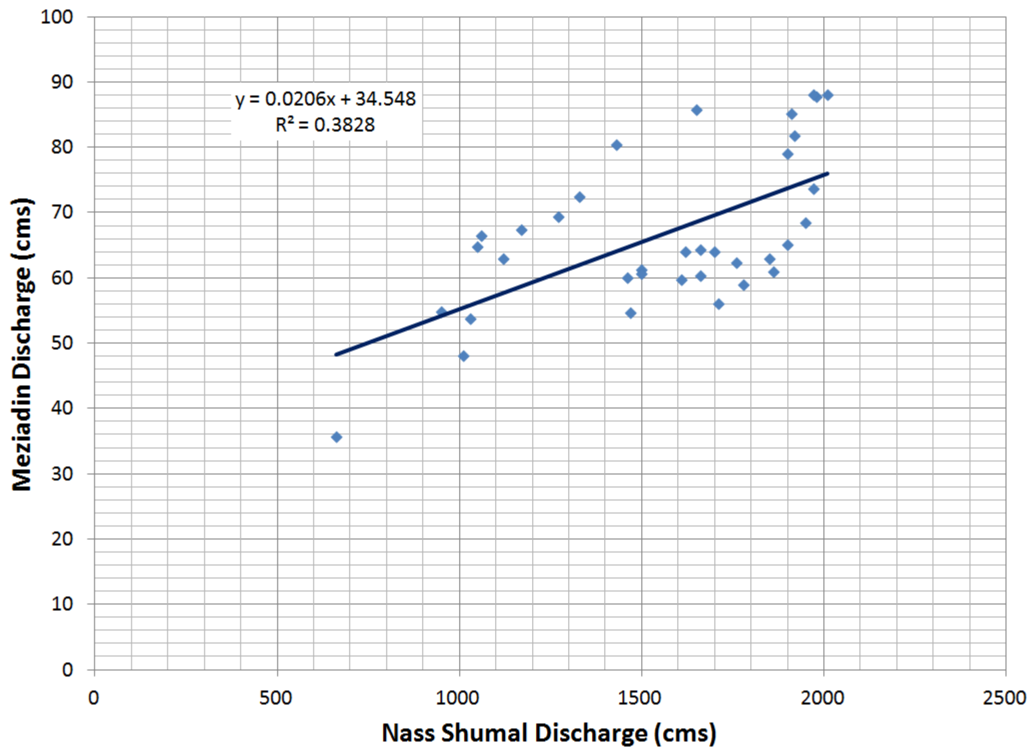


Figure 11. Observed daily mean discharge (cms) ± two standard deviations for *Surprise Creek* (08DA005) (1966-2012).



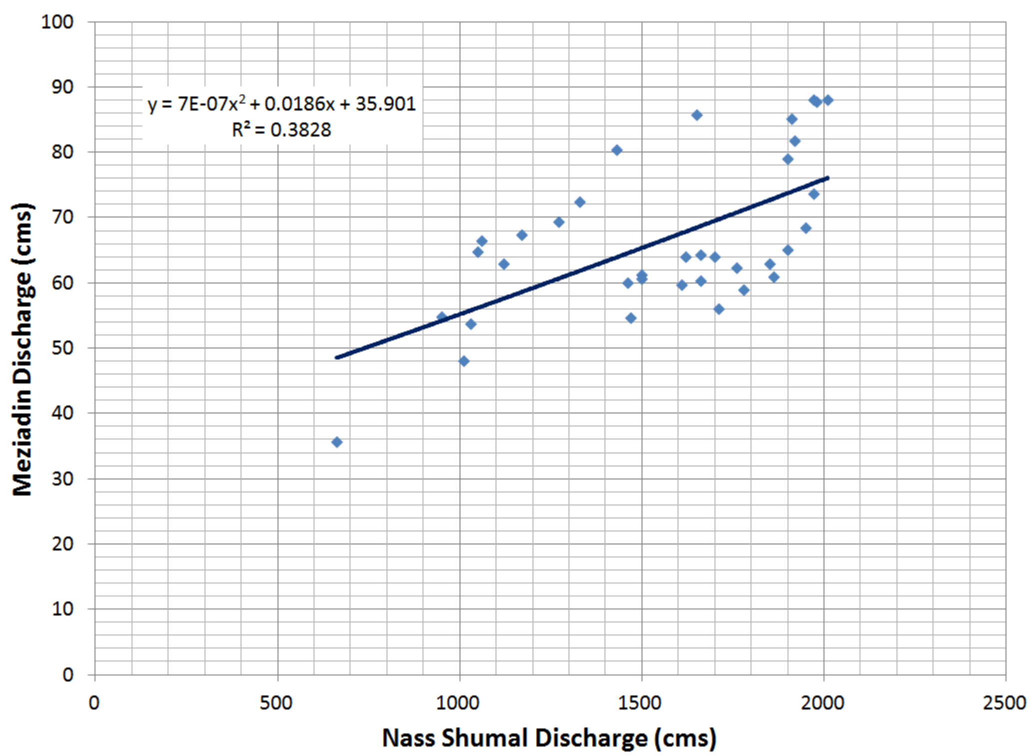


Figure 12. *Meziadin River* discharge (station 08DA003) as a function of *Nass River at Shumal* discharge (station 08DB001), 1956. Models include simple linear (Y=a+bX, r^2 = 0.38, P < .001, n=35; top), and curvilinear (Y=a+bX+cX^2, r^2 = 0.38, P < .001, n=35; bottom).

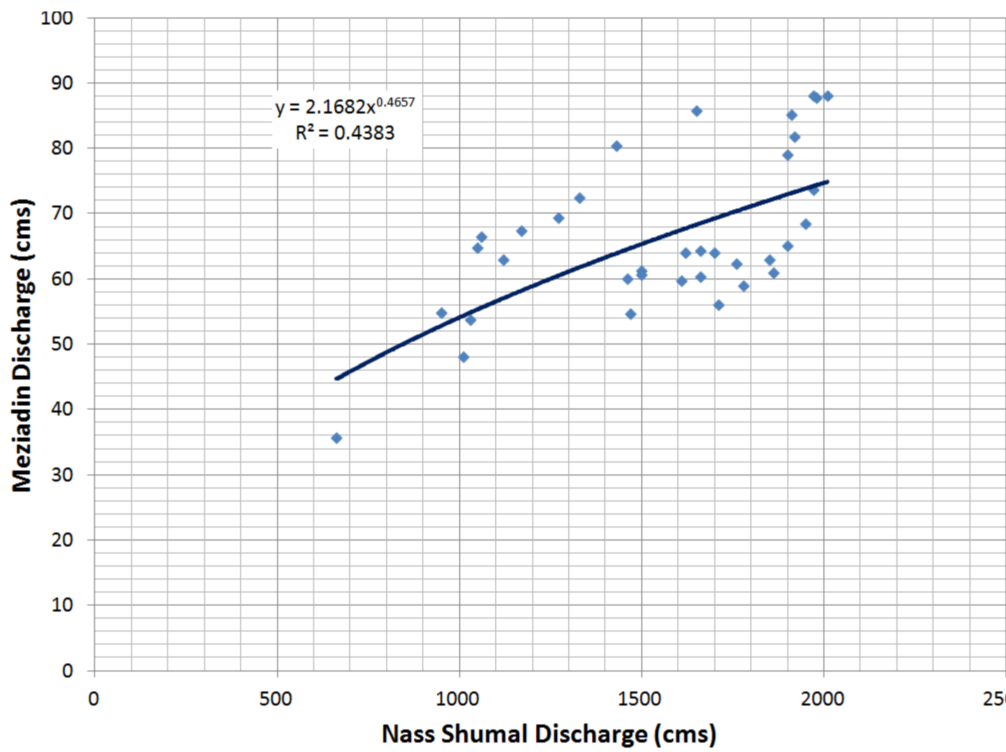


Figure 13. *Meziadin River* discharge (station 08DA003) as a function of *Nass Above Shumal* discharge (station 08DB001), 1956. Models log-linear ($Y=aX^b$; r^2 = 0.48, P < .001, n=35).

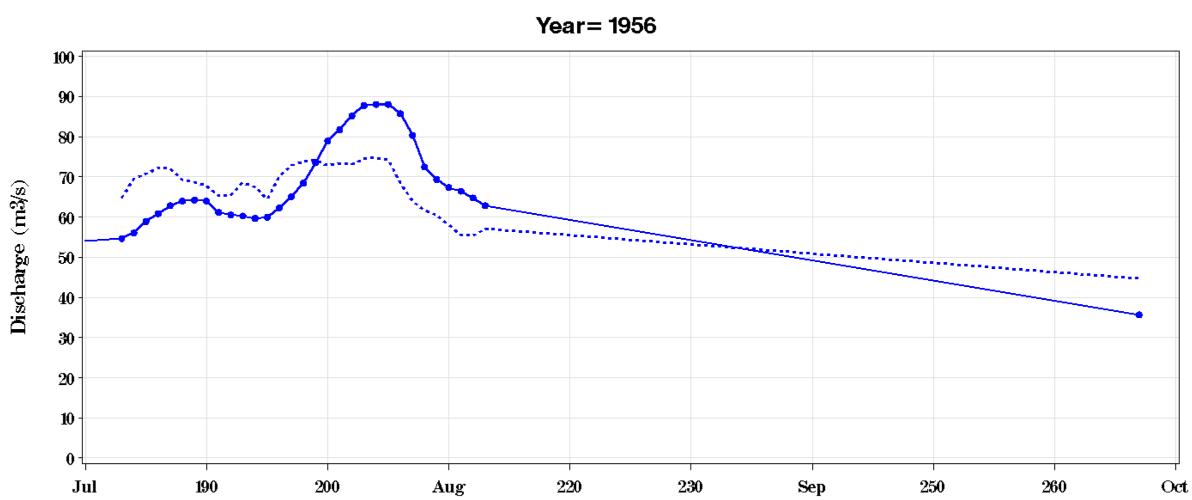
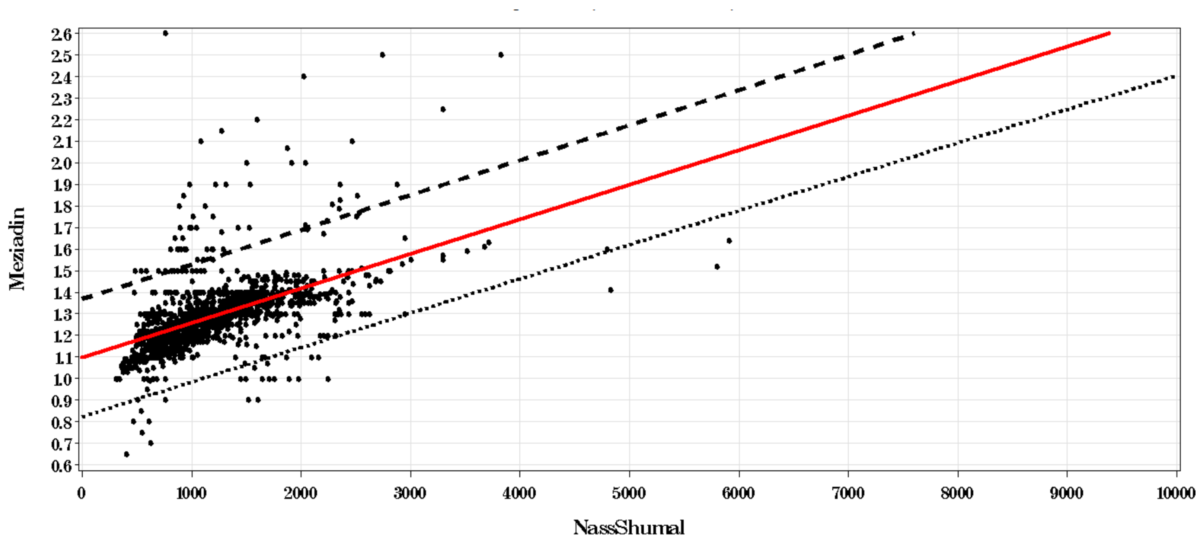


Figure 14. Observed (solid line) and predicted (dashed line) *Meziadin River* discharge (station 08DA003) based on log-linear ($Y=aX^b$) relationship with *Nass River at Shumal* discharge (station 08DB001), 1956 (r^2 = 0.31, P < .001, n=35).



Analysis of Variance

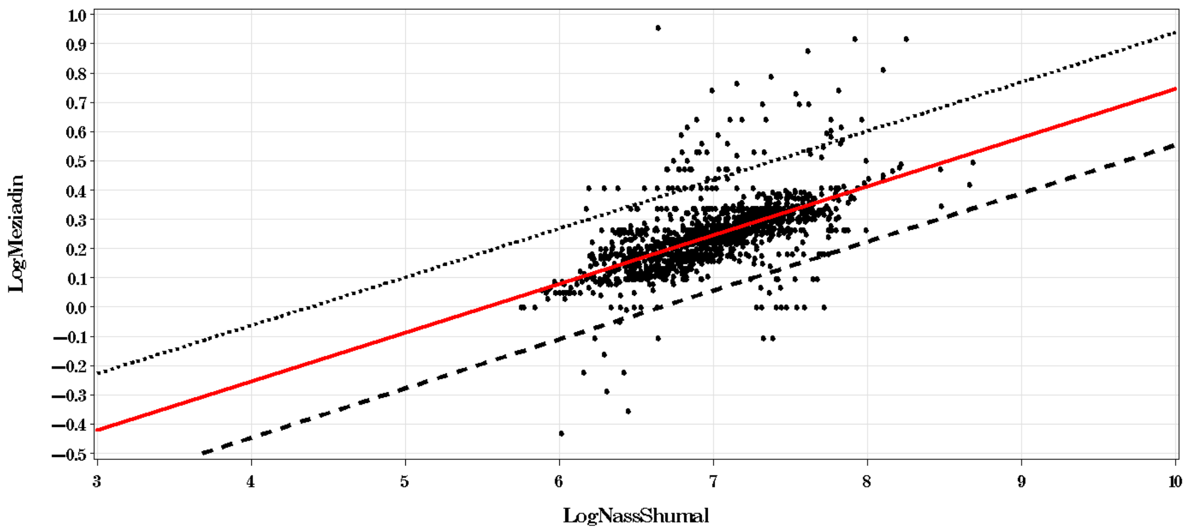
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	11.34777	11.34777	587.33	<.0001
Error	1460	28.20842	0.01932		
Lack of Fit	520	13.69821	0.02634	1.71	<.0001
Pure Error	940	14.51021	0.01544		
Corrected Total	1461	39.55618			

Root MSE	0.13900	R-Square	0.2869
Dependent Mean	1.28940	Adj R-Sq	0.2864
Coeff Var	10.78012		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	1.09577	0.00878	124.83	<.0001
NassShumal	1	0.00016032	0.00000662	24.23	<.0001

Figure 15. Mean daily mean water level (m) at the Meziadin River fishway as a linear function of daily mean discharge in the *Nass River at Shumal* (WSC Station 08DB001) (1998-2012).



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	7.14353	7.14353	773.69	<.0001
Error	1460	13.48031	0.00923		
Lack of Fit	520	6.36293	0.01224	1.62	<.0001
Pure Error	940	7.11738	0.00757		
Corrected Total	1461	20.62384			

Root MSE	0.09609	R-Square	0.3464
Dependent Mean	0.24687	Adj R-Sq	0.3459
Coeff Var	38.92366		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-0.92187	0.04209	-21.90	<.0001
LogNassShumal	1	0.16678	0.00600	27.82	<.0001

Figure 16. Logarithm of mean daily mean water level (m) at the Meziadin River fishway as a function of logarithm of daily mean discharge in the *Nass River at Shumal* (WSC Station 08DB001) (1998-2012).

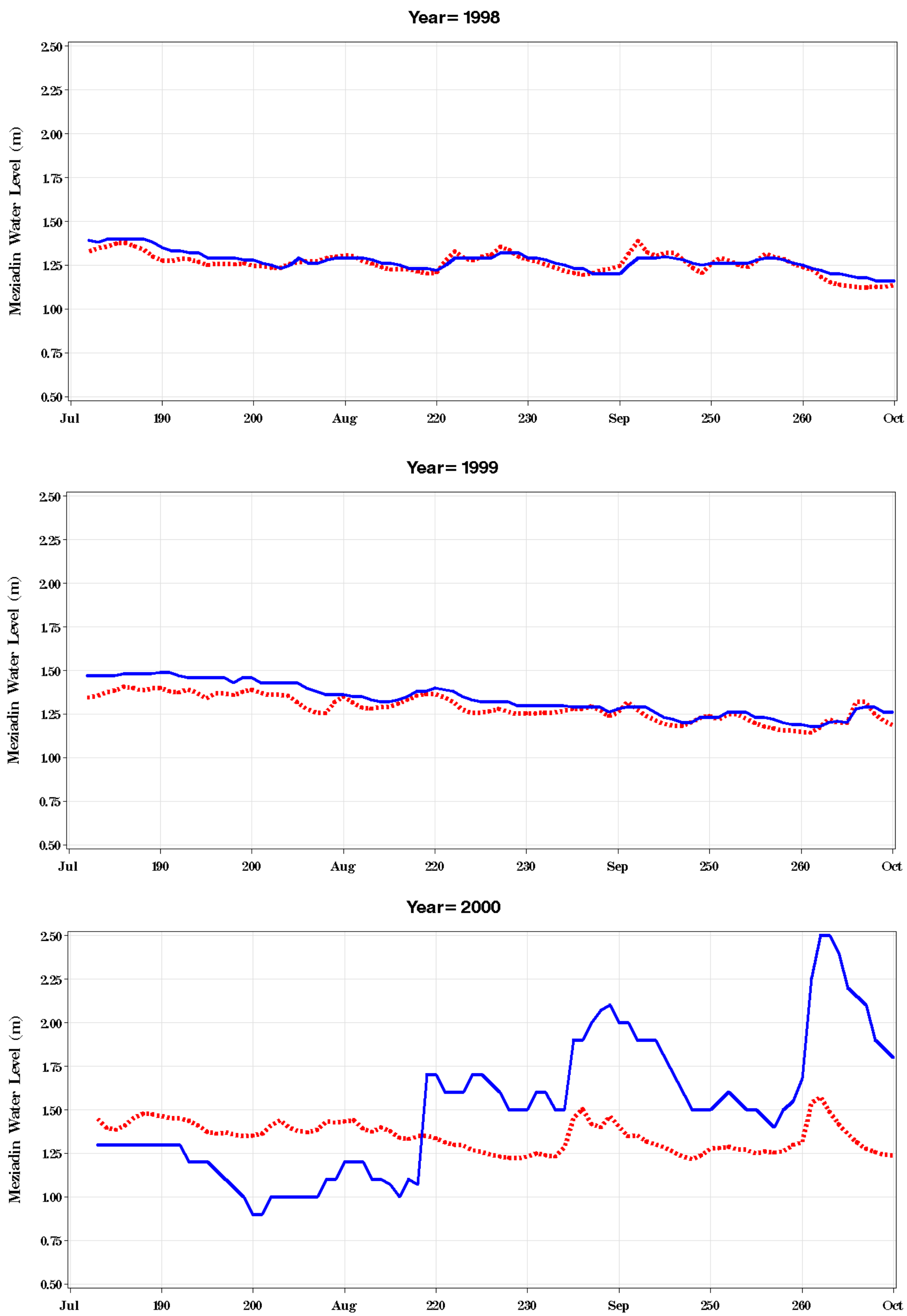


Figure 17. Observed daily mean water level (blue solid line) at the Meziadin River fishway and estimated Meziadin water level (red dashed line) based on log-linear ($Y=aX^b$) relation with daily mean discharge at *Nass River at Shumal* (WSC Station 08DB001). Sample plots: 1998, 1999, 2000.

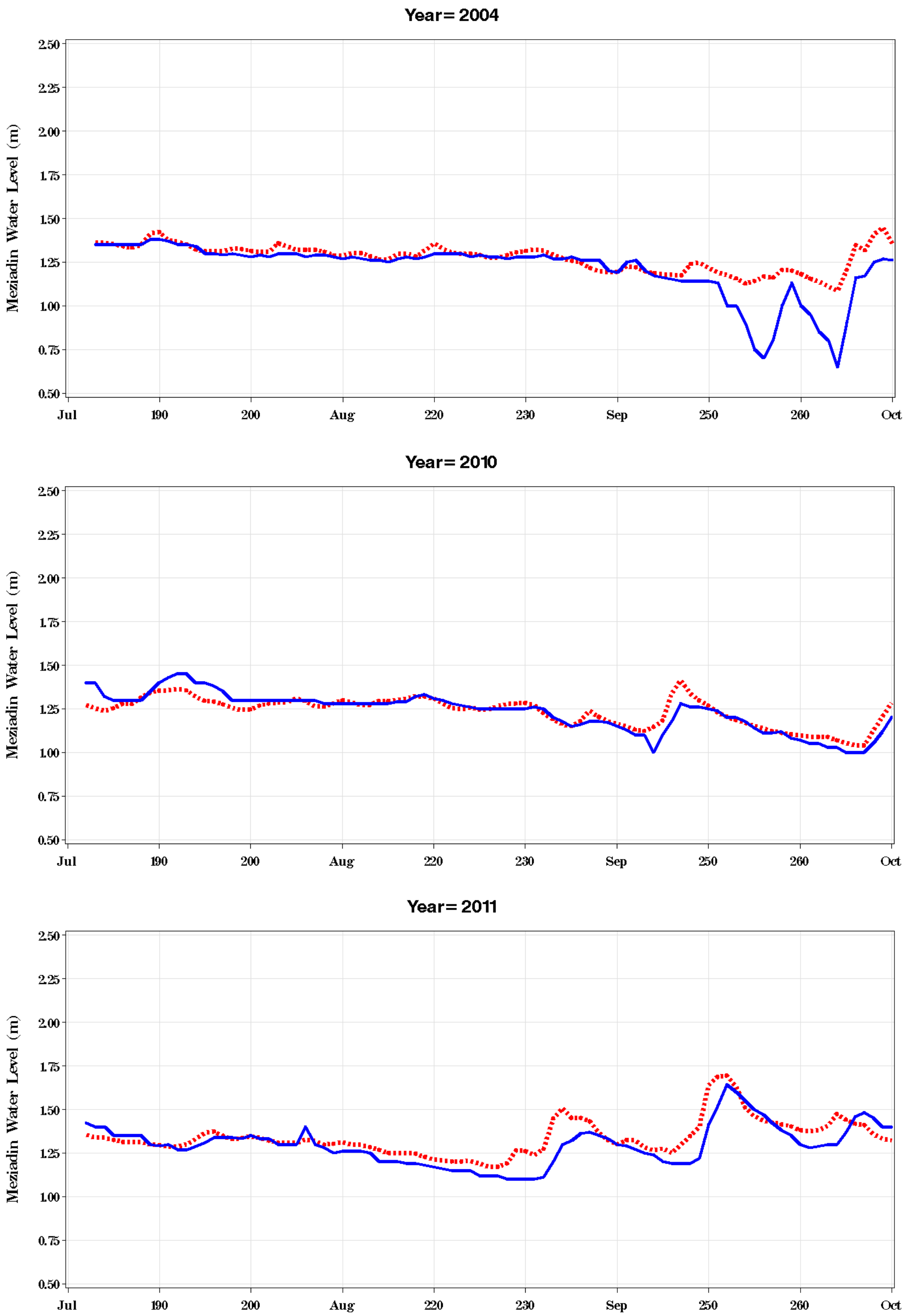
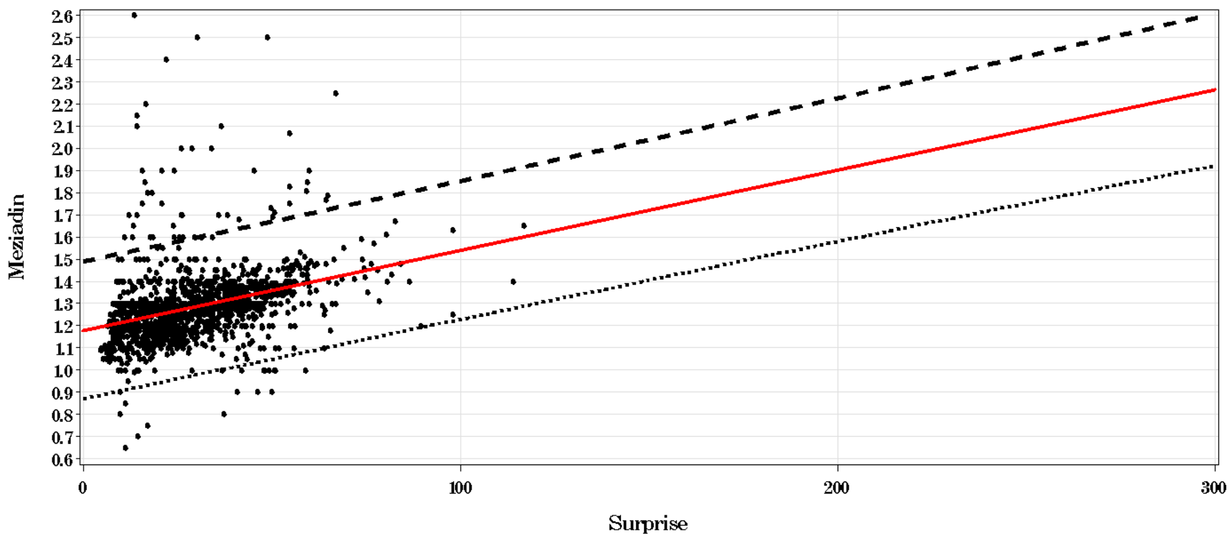


Figure 18. Observed daily mean water level (blue solid line) at the Meziadin River fishway and estimated Meziadin water level (red dashed line) based on log-linear ($Y=aX^b$) relation with daily mean discharge at *Nass River at Shumal* (WSC Station 08DB001). Sample plots: 2004, 2010, 2011.



Analysis of Variance

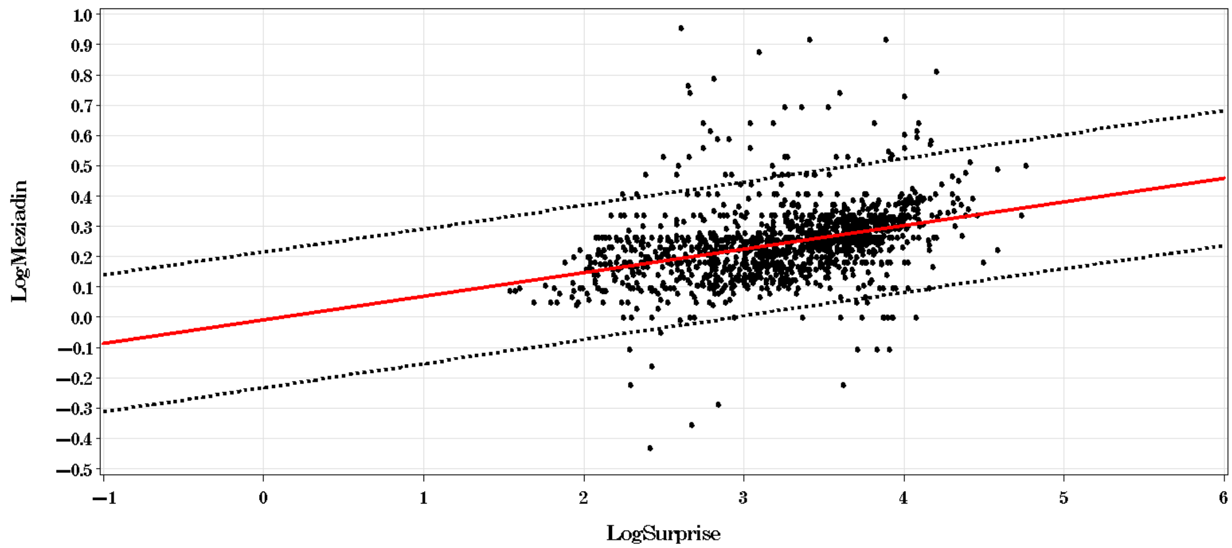
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	4.32168	4.32168	172.76	<.0001
Error	1352	33.82133	0.02502		
Lack of Fit	569	14.52569	0.02553	1.04	0.3237
Pure Error	783	19.29563	0.02464		
Corrected Total	1353	38.14300			

Root MSE	0.15816	R-Square	0.1133
Dependent Mean	1.28758	Adj R-Sq	0.1126
Coeff Var	12.28375		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	1.17859	0.00934	126.18	<.0001
Surprise	1	0.00362	0.00027534	13.14	<.0001

Figure 19. Mean daily mean water level (m) at the Meziadin River fishway as a linear function of daily mean discharge in *Surprise Creek* (WSC Station 08DA005) (1998-2010).



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	2.63129	2.63129	207.39	<.0001
Error	1352	17.15333	0.01269		
Lack of Fit	569	7.45074	0.01309	1.06	0.2379
Pure Error	783	9.70259	0.01239		
Corrected Total	1353	19.78462			

Root MSE	0.11264	R-Square	0.1330
Dependent Mean	0.24517	Adj R-Sq	0.1324
Coeff Var	45.94244		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-0.00969	0.01796	-0.54	0.5894
LogSurprise	1	0.07818	0.00543	14.40	<.0001

Figure 20. Mean daily mean water level (m) at the Meziadin River fishway as a log-linear function of daily mean discharge in *Surprise Creek* (WSC Station 08DA005) (1998-2010).

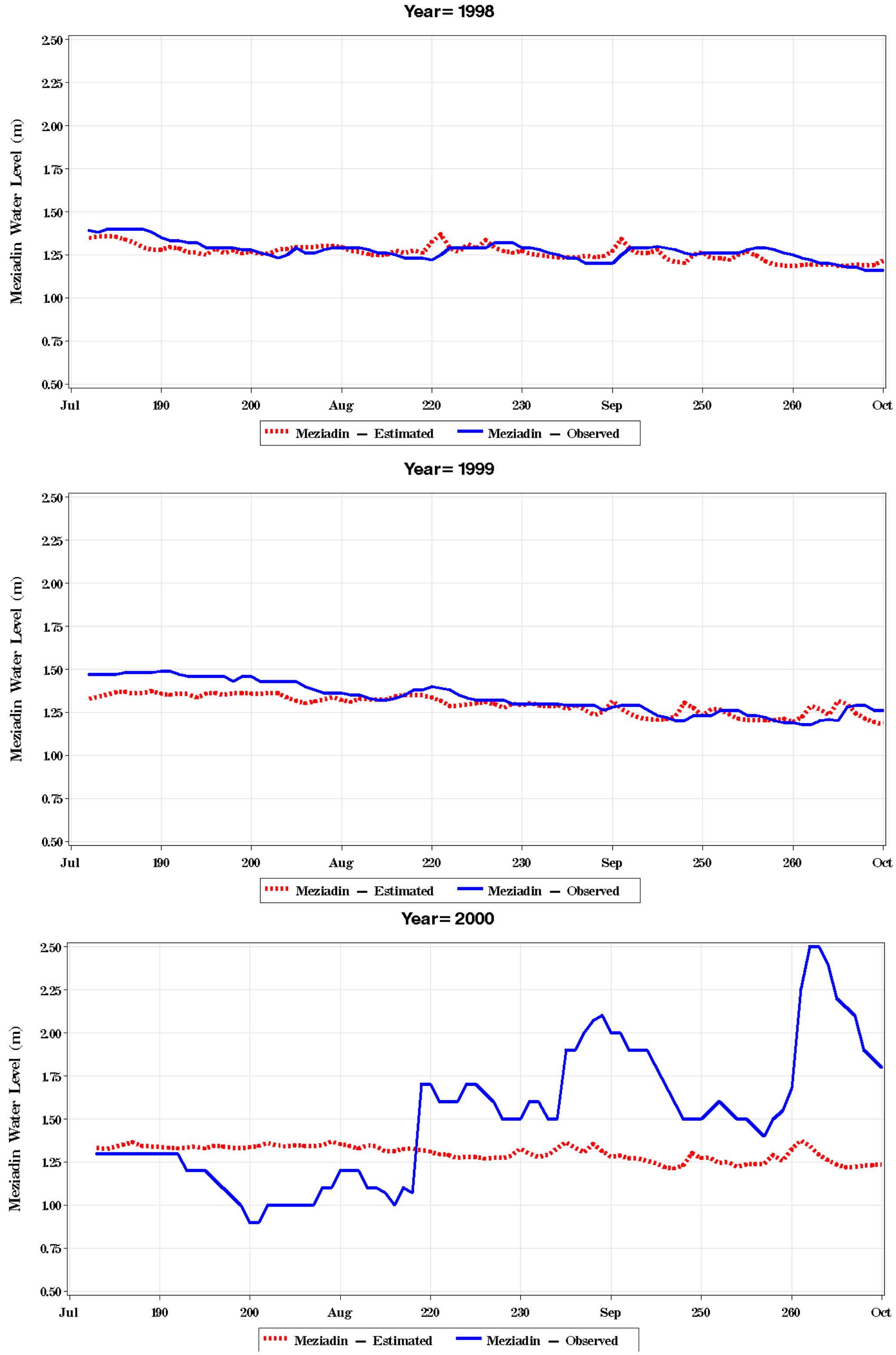


Figure 21. Observed daily mean water level (blue solid line) at the Meziadin River fishway and estimated Meziadin water level (red dashed line) based on log-linear ($Y=aX^b$) relation with daily mean discharge at *Surprise Creek* (WSC Station 08DA005). Sample plots: 1998, 1999, 2000.

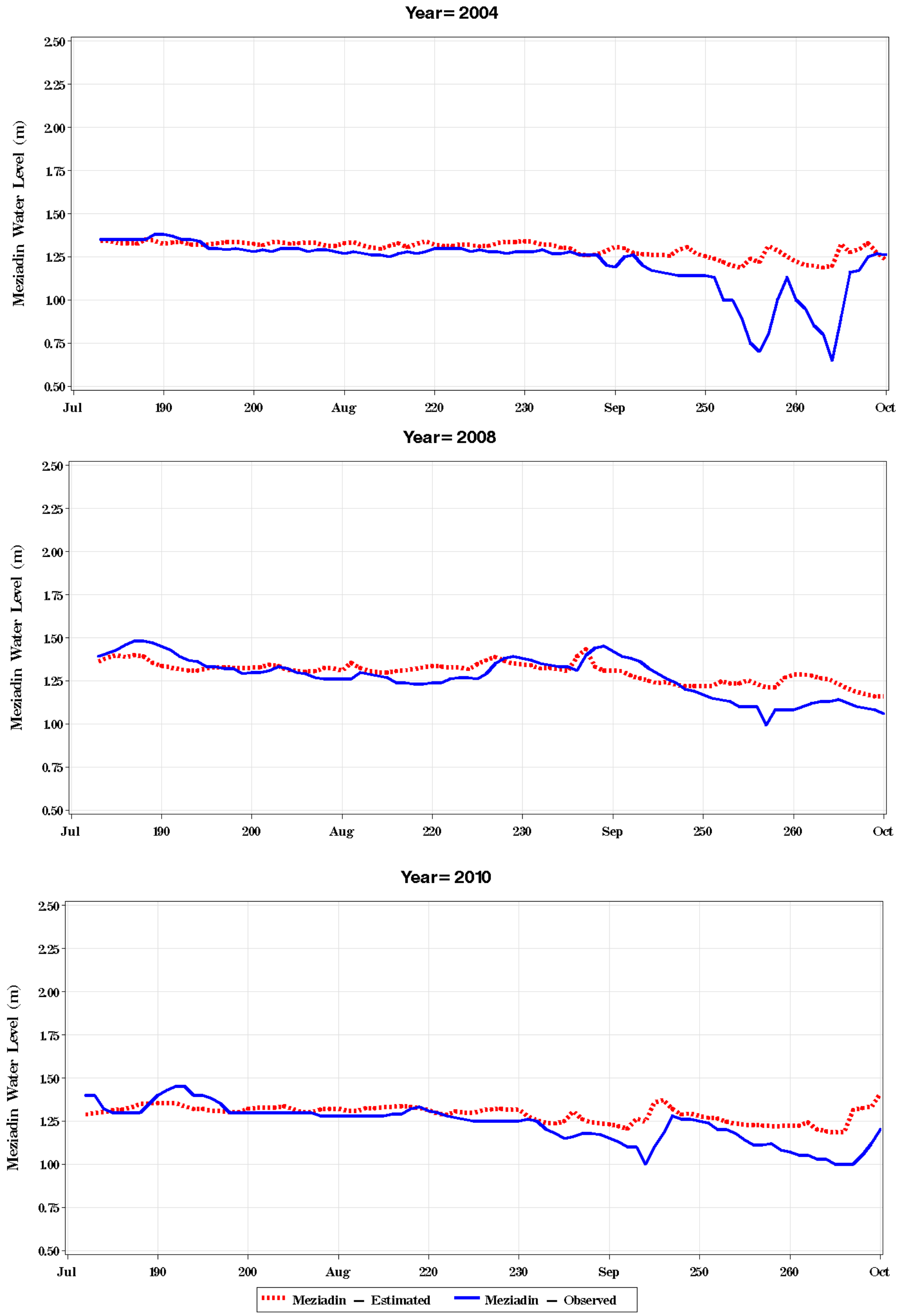


Figure 22. Observed daily mean water level (blue solid line) at the Meziadin River fishway and estimated Meziadin water level (red dashed line) based on log-linear ($Y=aX^b$) relation with daily mean discharge at *Surprise Creek* (WSC Station 08DA005). Sample plots: 2004, 2008, 2010.

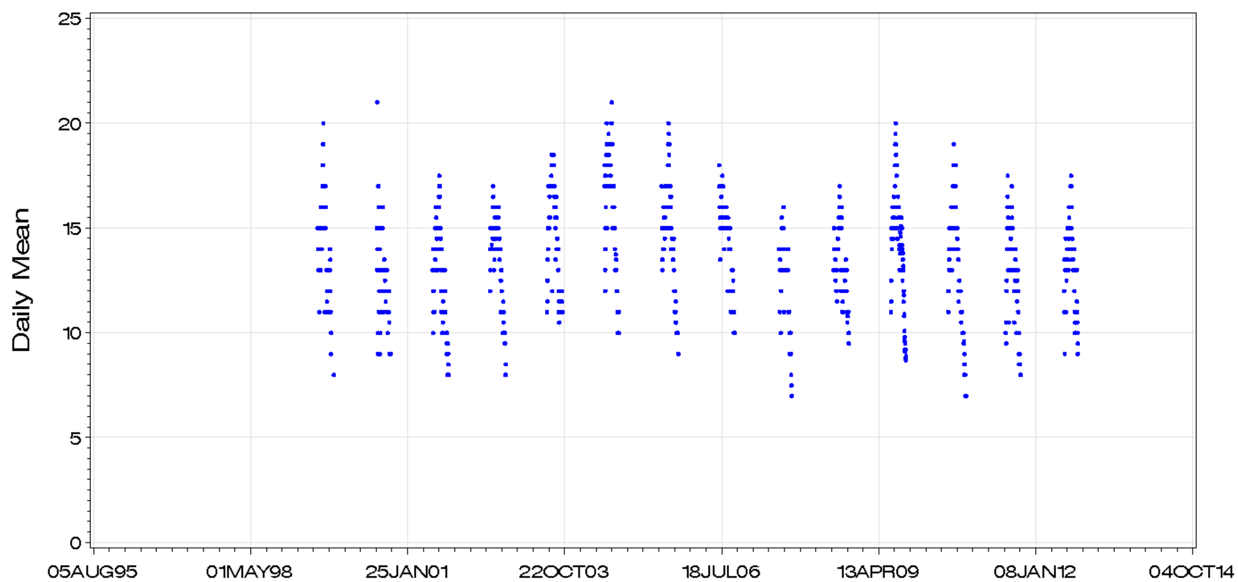


Figure 23. Water temperature data for Meziadin River at the fishway (Source: Nisga'a Fisheries).

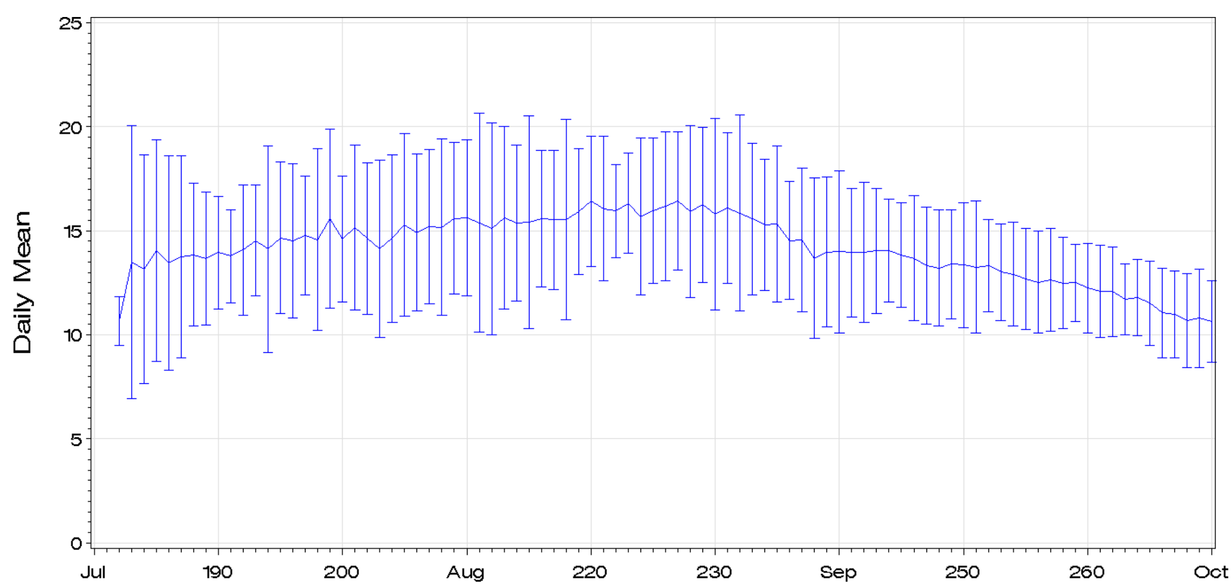


Figure 24. Annual thermograph of water temperature data ± two standard deviations for Meziadin River at the fishway (Source: Nisga'a Tribal Council Fisheries).

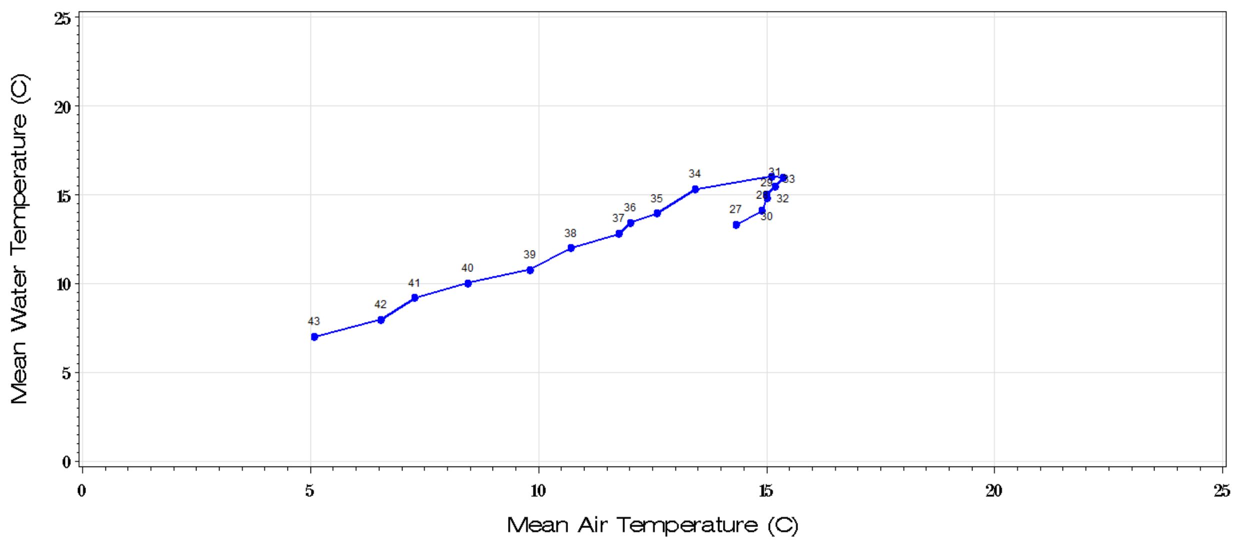


Figure 25. Derivation of seasonal turn-around point for Meziadin River, based on maximum weekly mean air and water temperature data. The seasonal turn-around point is in week 31-32, approximately August 6th. The “warming season” therefore extends from April 1 to August 2nd, followed by the “cooling season” from day 218-329, i.e., August 3rd – November 25th.

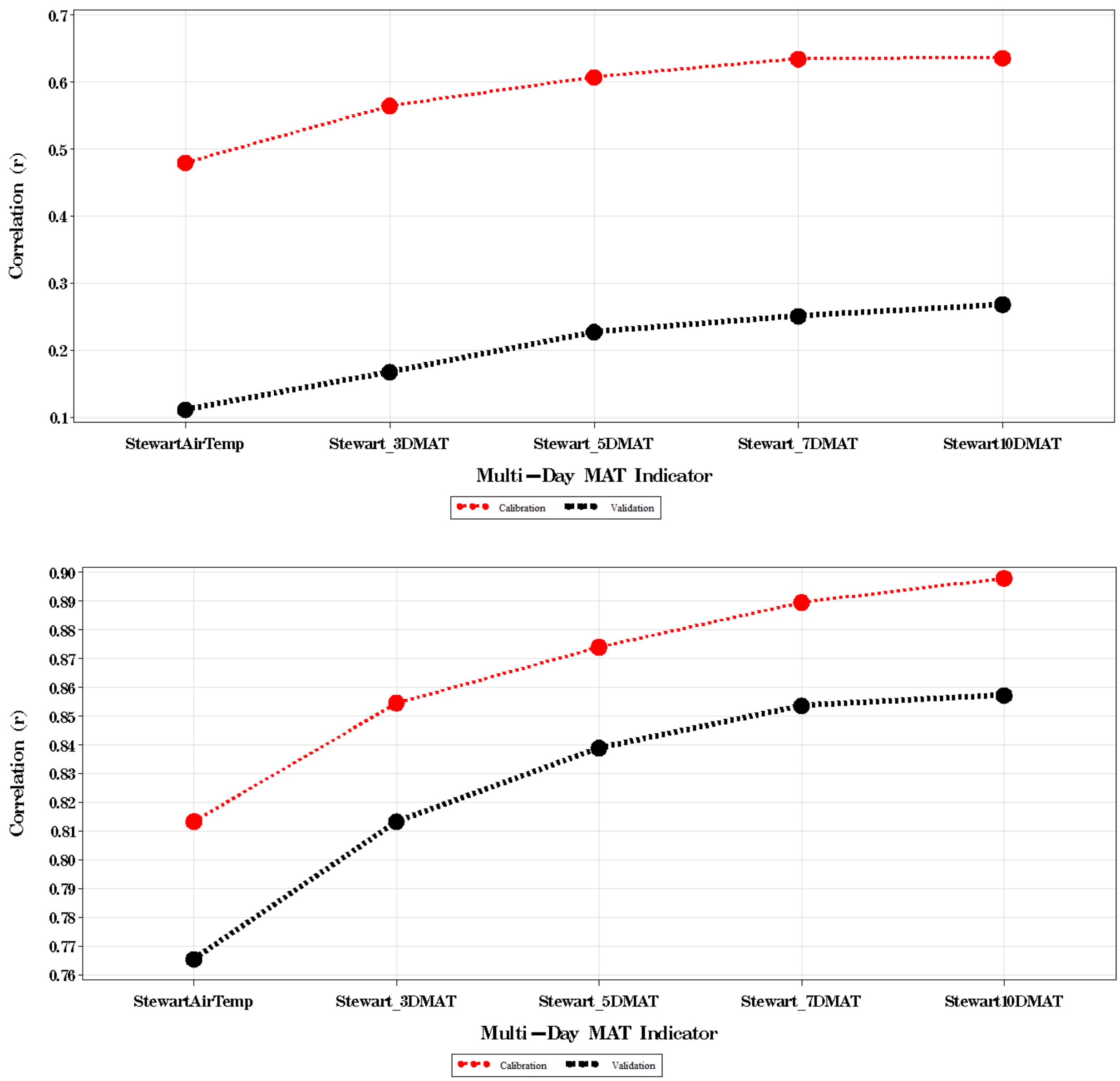


Figure 26. Derivation of optimum regional air temperature index for air/water temperature analyses, based on maximum all-year correlation between various *Stewart* multi-day mean air temperature indicators (MATs) with Meziadin daily mean water temperature (MWT) for calibration (red) and validation (black) data; warming season (top), cooling season (bottom). *Stewart* air temperature indicators include (l-r): Air Temp (same day mean); 3-day centered moving average air temperature (3D-MAT), 5D-MAT, 7D-MAT, and 10-DMAT. Overall, the 7D-MAT provides the best trade-off between correlation and multi-day averaging (which affects predictive power at longer period lengths).

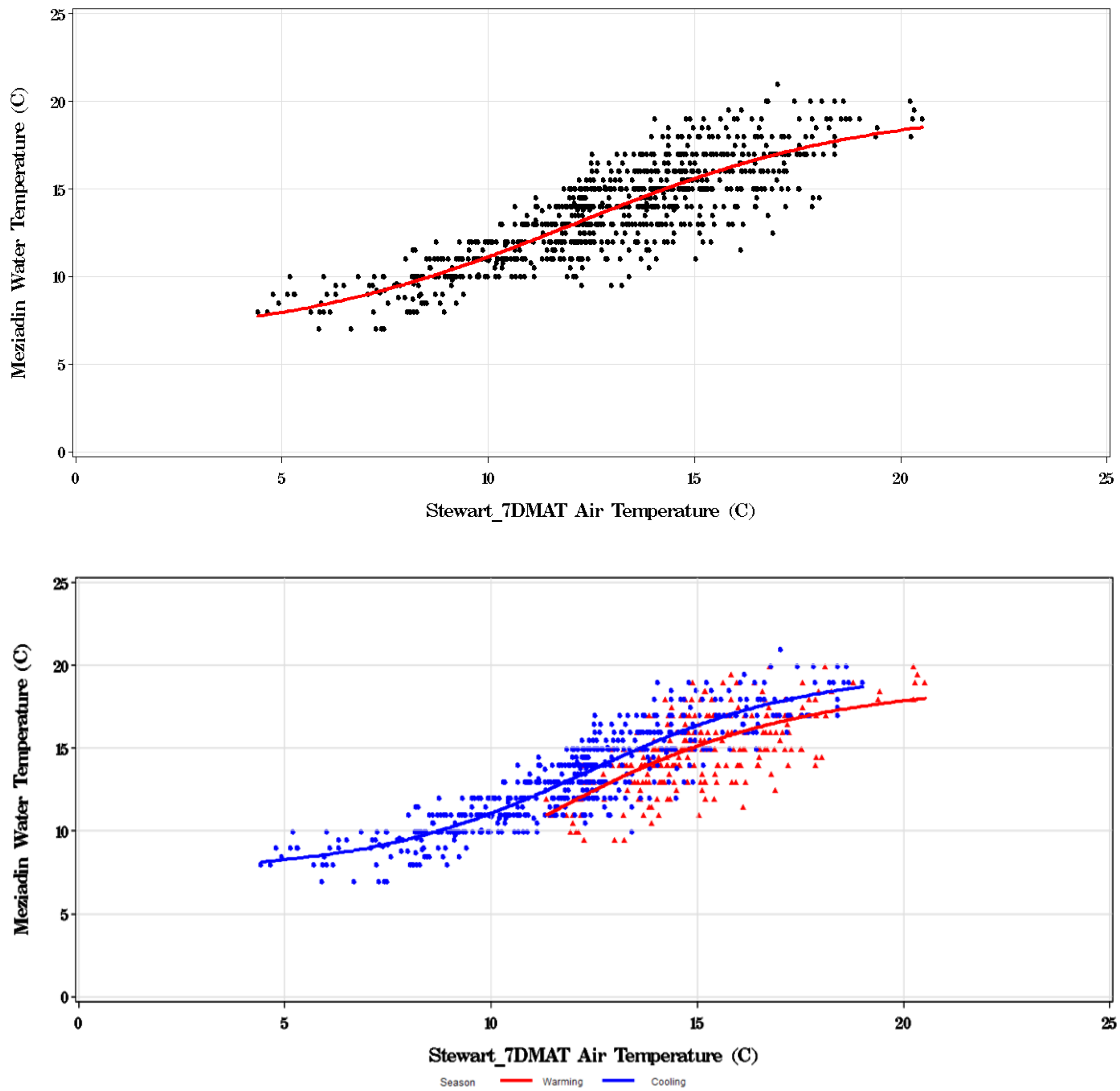


Figure 27. Logistic regression fits for air/water temperature relationship for Meziadin daily mean water temperatures as a function of the STEWART 7d-CMAT (air temperature index): seasons combined (top); separate warming season (red) and cooling seasons (blue)(bottom).

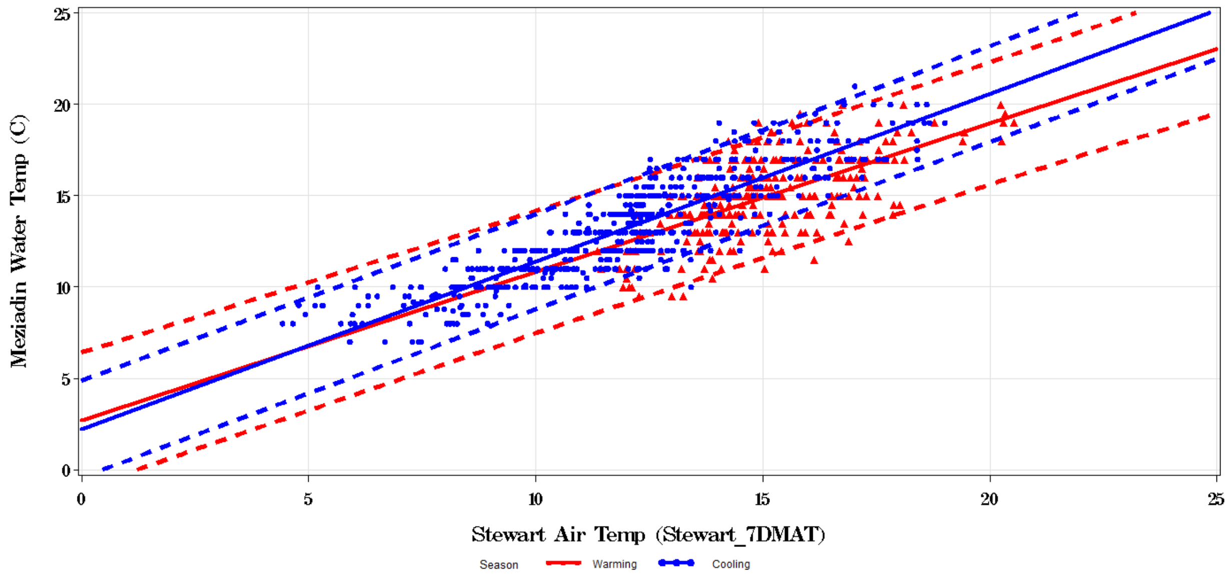


Figure 28. Linear regression fits for air/water temperature relationship for Meziadin daily mean water temperatures as a function of the STEWART 7d-CMAT (air temperature index), by season (warming season (red) and cooling season (blue)).

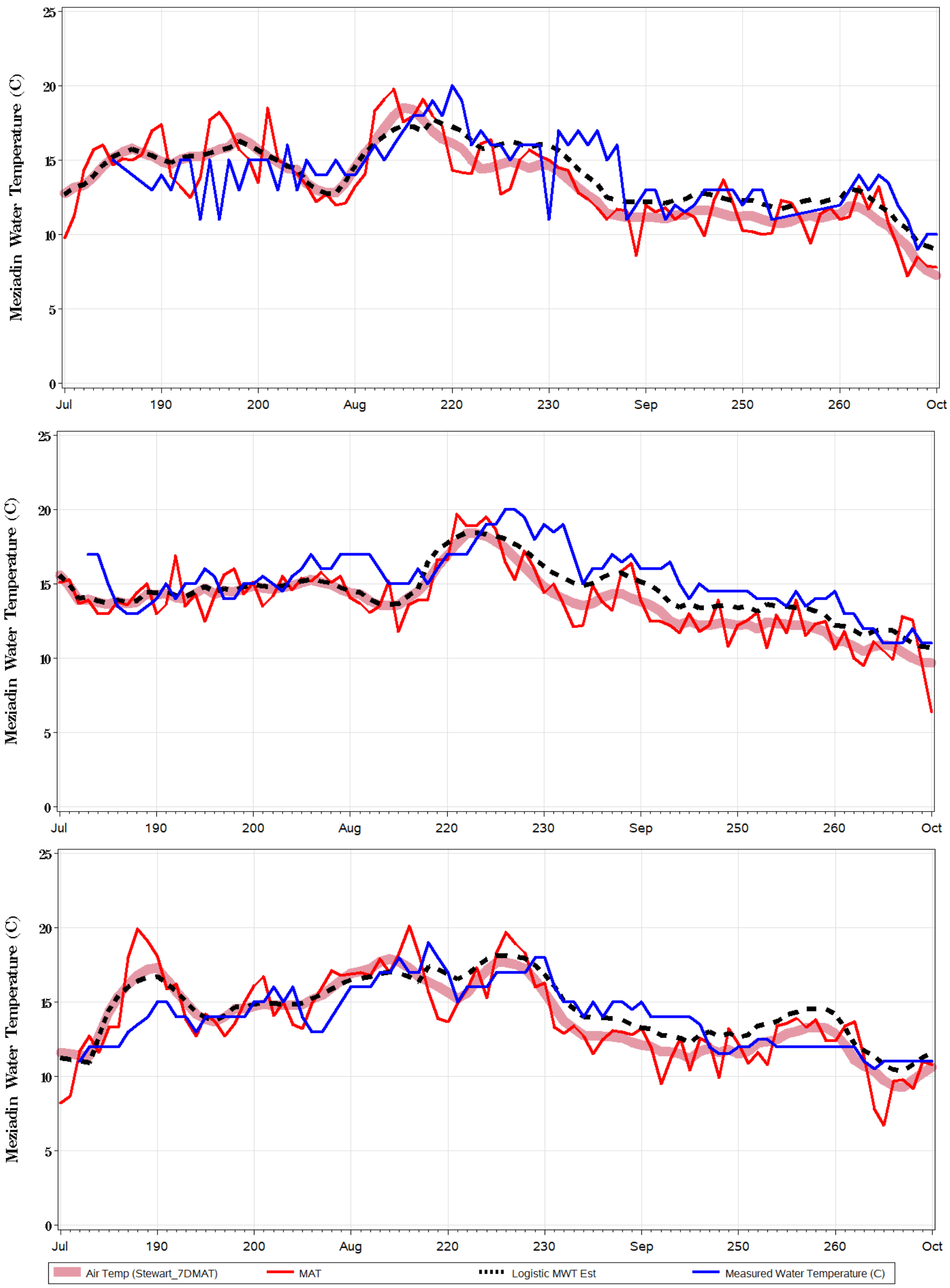


Figure 29. Sample validation plots of daily mean air temperature (red line), 7-day MAT index (broad pink line), observed daily mean water temperature (blue solid line) and estimated MWT (black dashed line; based on seasonal logistic regression models) for Meziadin River, July-September 1999 (top), 2004 (middle), 2010 (bottom).

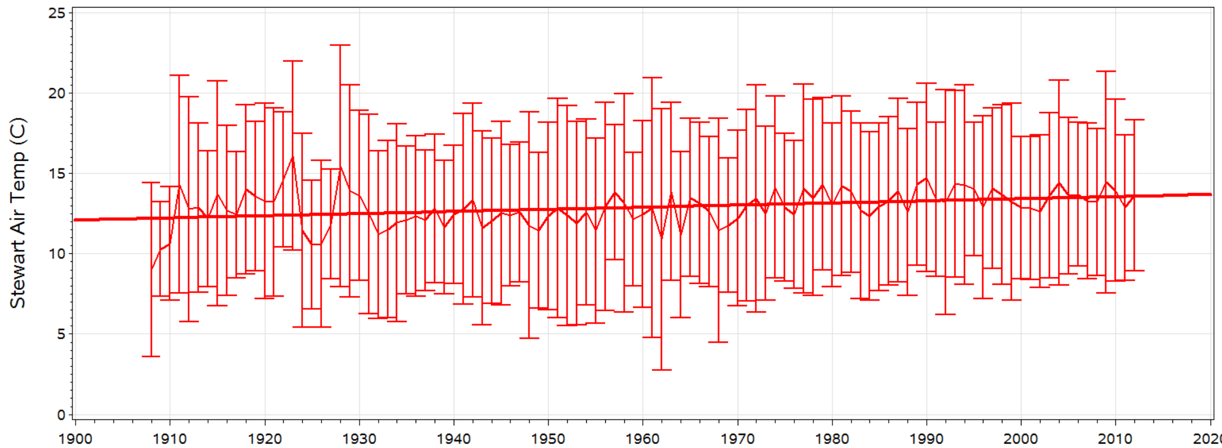


Figure 30. Observed and estimated STEWART mean air temperature ± 2 std deviations, July-September 1908-2012. Long-term warming trend is evident (Y = -13.0 + 0.013 * Year; r = 0.14; P < .0001).

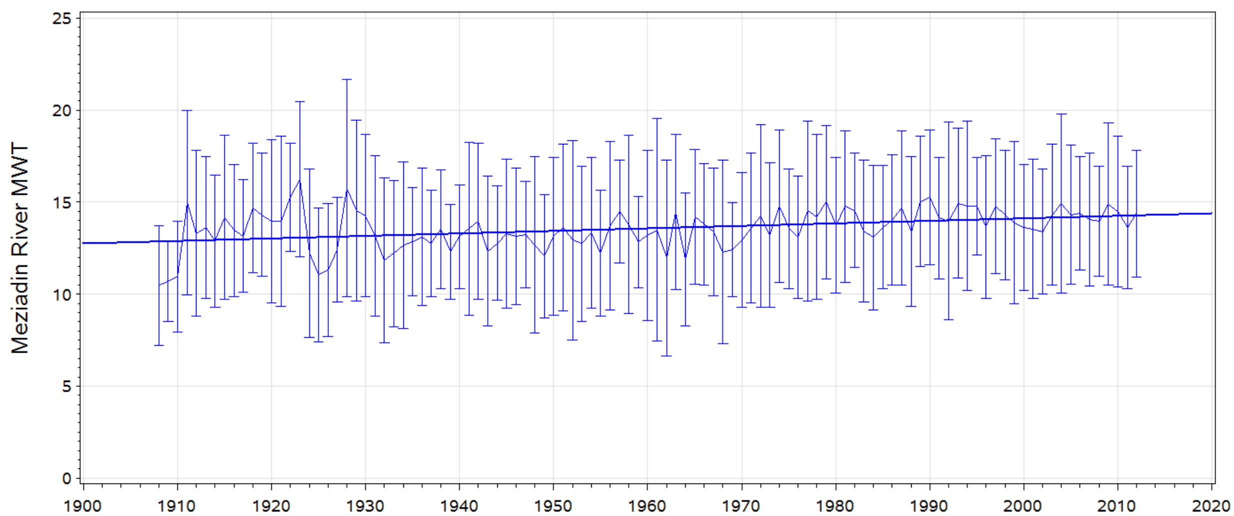


Figure 31. Estimated Meziadin River mean water temperature ± 2 std deviations, July-September 1908-2012, based on seasonal logistic air/water temperature regression models. Significant long-term trend is evident (Y = -13.13 + 0.014 * Year; r = 0.17; P < .0001).

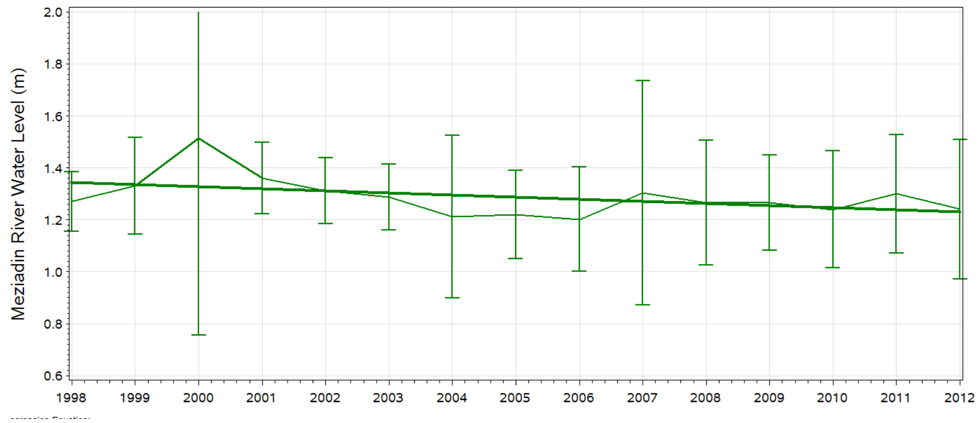


Figure 32. Meziadin River mean water level ± 2 std deviations, July-September 1998-2012, based on observed data from the fishway. Negative trend is evident (Y = 17.5 -.008 * Year; r = 0.20; P < .0001).

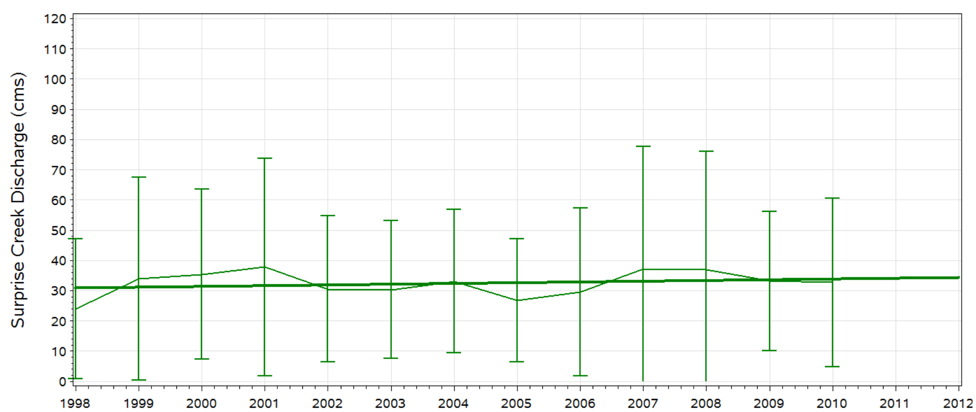


Figure 33. Surprise Creek mean discharge ± 2 std deviations, July-September 1998-2010 for comparison with Meziadin water level. Weak positive trend is evident (Y = -483.1 + .257 * Year; r = 0.06; P < .027).

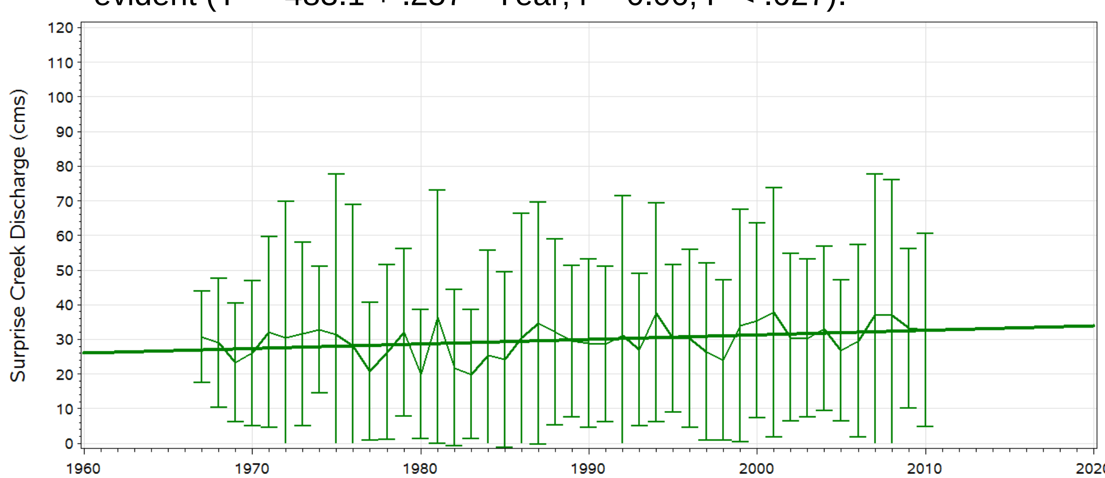
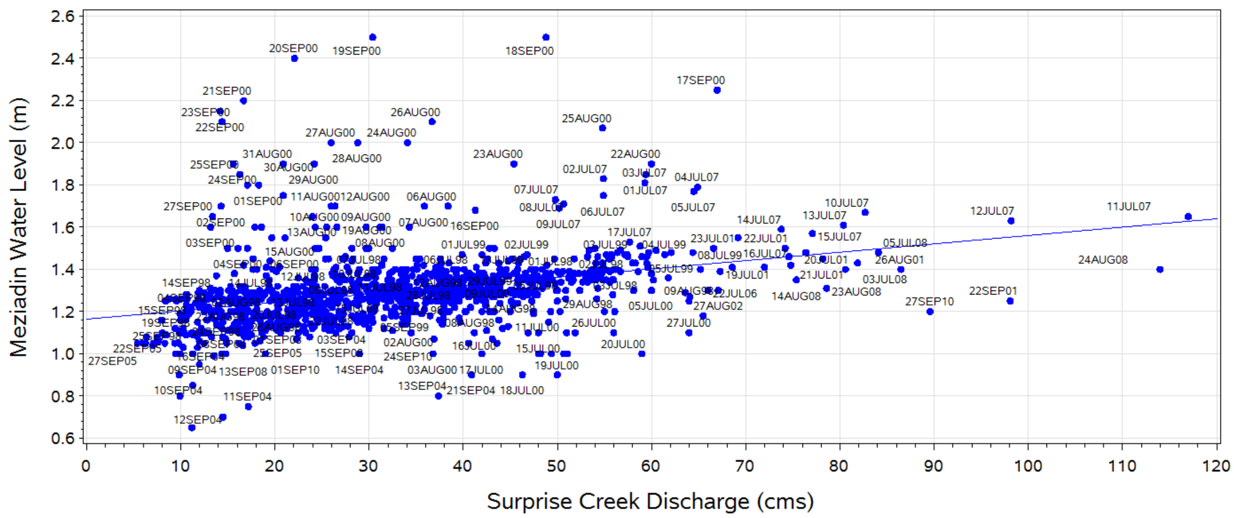


Figure 34. Surprise Creek mean discharge ± 2 std deviations, July-September 1967-2010. Positive trend is evident in time-series (Y = -228.6 + .130 * Year; r = 0.10; P < .0001).



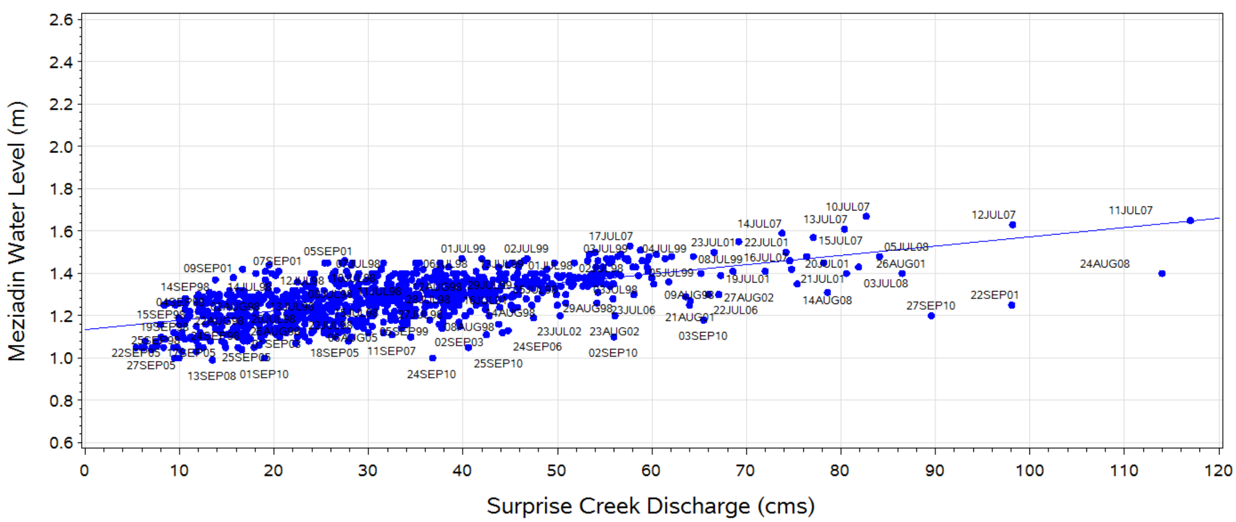


Figure 35. Meziadin River water level as a function of Surprise Creek discharge, July-September 1998-2010 (top; r = .36, P < .0001, n = 1196); outliers (2000, 2004, and July 1-9, 2007) removed (bottom; r = .64, P < .0001, n = 1003).

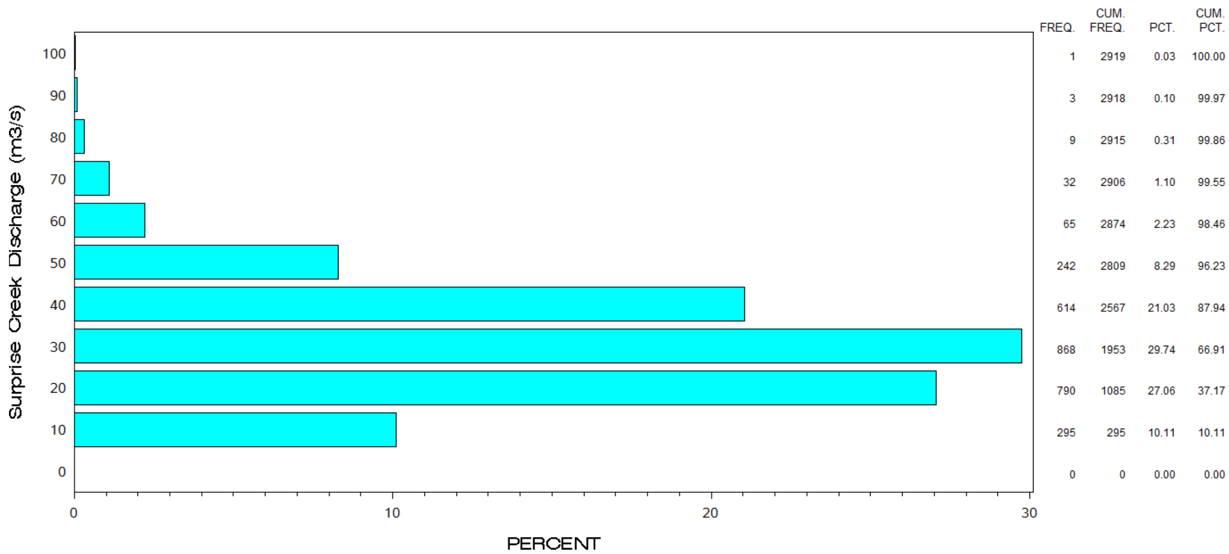


Figure 36. Frequency plot of historical Meziadin Sockeye non-zero migration (un-weighted tally of non-zero migration dates), at varying levels of *Surprise Creek* discharge (as an indicator of Meziadin flow conditions). Most dates (77%) of migration in the Meziadin occur when flows in Surprise Creek are ~20-40 cms.

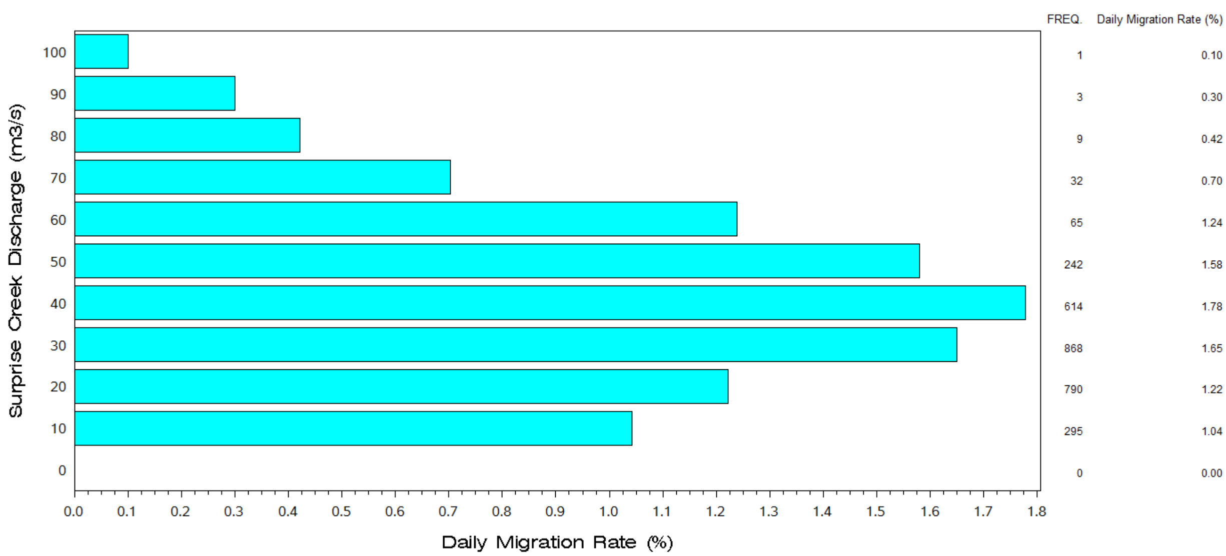
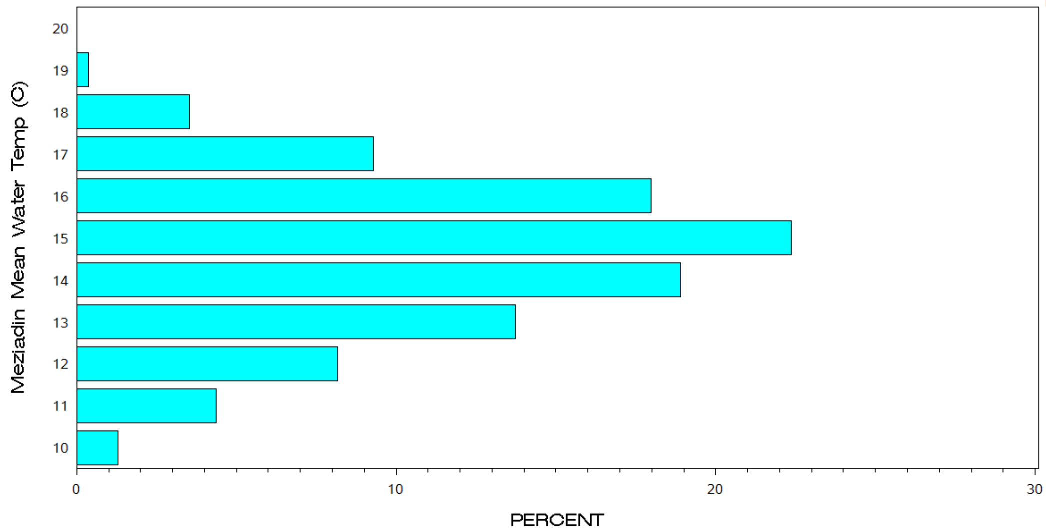
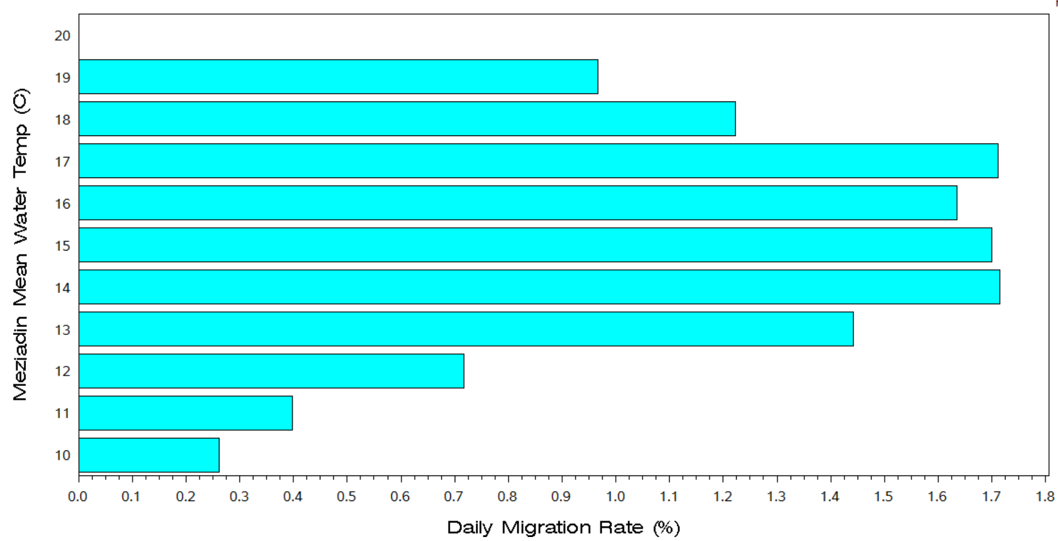


Figure 37. Frequency plot of historical Meziadin Sockeye non-zero migration dates, weighted by daily migration rate, at varying levels of *Surprise Creek* discharge (unlagged). Ignoring low-frequency occurrences (FREQ < 3), the highest daily migration rates (>1.5% per day) at the Meziadin fishway occur when Surprise Creek flows are ~30-50 cms.



Temp (C)	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
20	0	3163	0.00	100.00
19	12	3163	0.38	100.00
18	112	3151	3.54	99.62
17	294	3039	9.29	96.08
16	569	2745	17.99	86.78
15	707	2176	22.35	68.80
14	598	1469	18.91	46.44
13	434	871	13.72	27.54
12	258	437	8.16	13.82
11	138	179	4.36	5.66
10	41	41	1.30	1.30

Figure 38. Frequency plot of historical Meziadin Sockeye migration (un-weighted tally of non-zero migration dates), at varying levels of Meziadin River water temperature. ~72% of migration activity occurs at 13-16°C.



Temp (C)	FREQ.	Daily Migration Rate (%)
20	0	0.00
19	12	0.97
18	112	1.22
17	294	1.71
16	569	1.64
15	707	1.70
14	598	1.72
13	434	1.44
12	258	0.72
11	138	0.40
10	41	0.26

Figure 39. Frequency plot of historical Meziadin Sockeye non-zero migration dates, weighted by daily migration rate, at varying levels of Meziadin River water temperature. Highest migration rates (i.e., > 75^{th} percentile, ~1.66%) are associated with temperatures of 14-17°C.

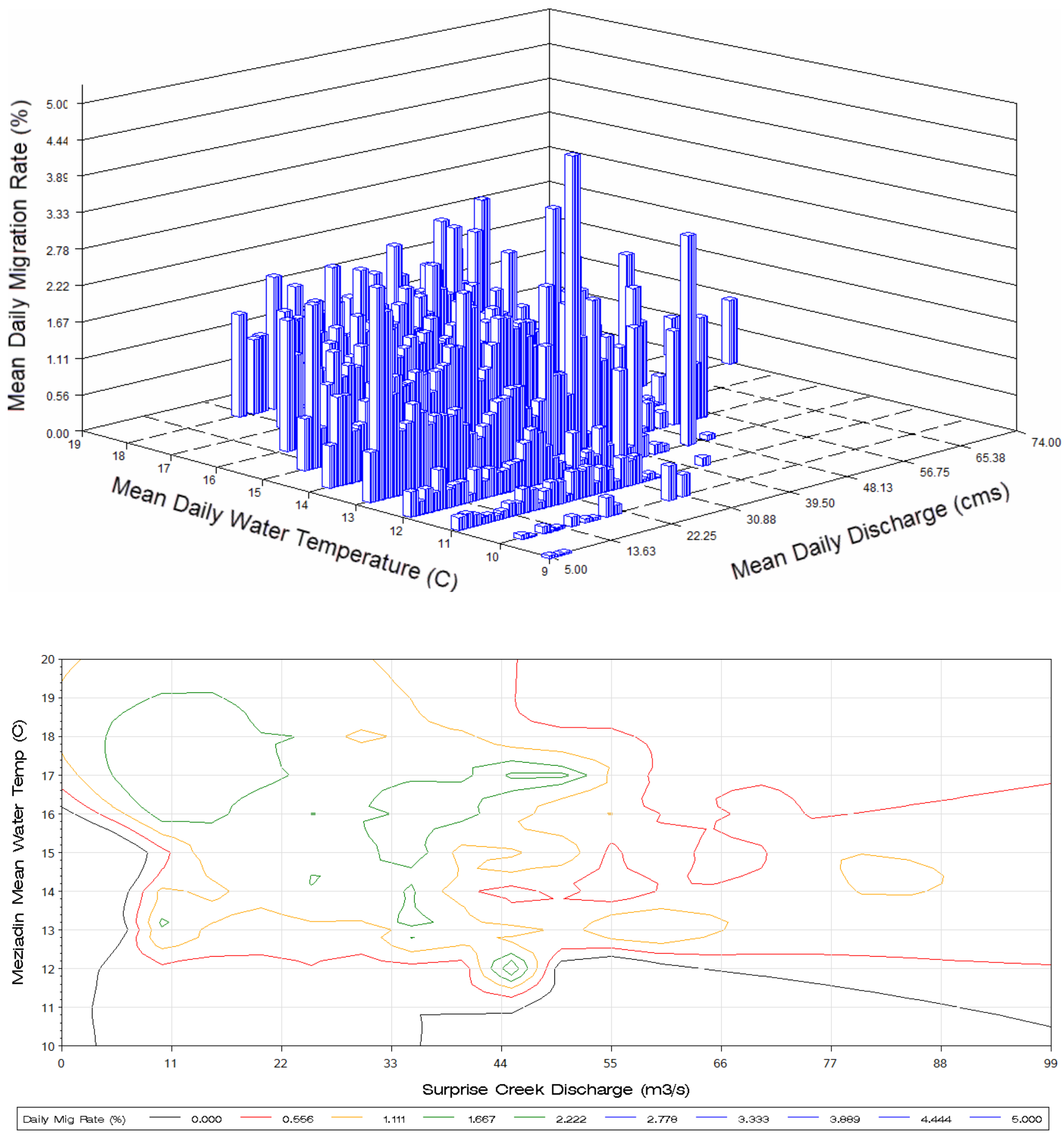
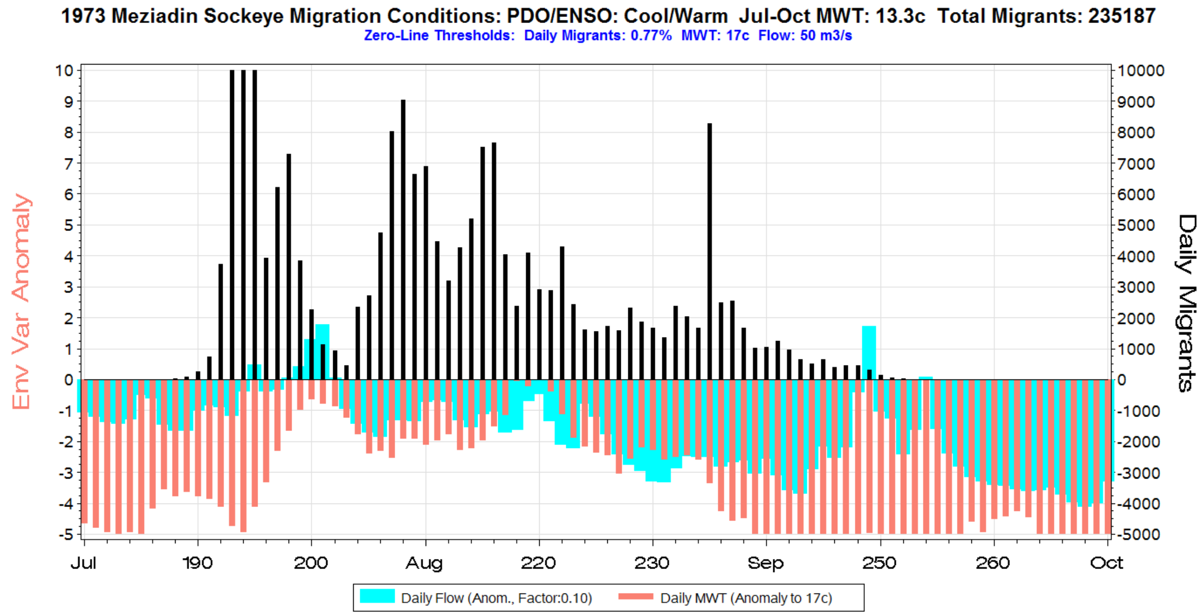


Figure 40. Distribution (top) and smoothed contour (bottom) of historical Meziadin Sockeye migration rates (daily %), at varying levels of Meziadin River water temperature and Surprise Creek discharge (filtered for a minimum of 3 observations at each MWT x flow point). Maximum migration rate found at 17°C or less and 40-50 cms.



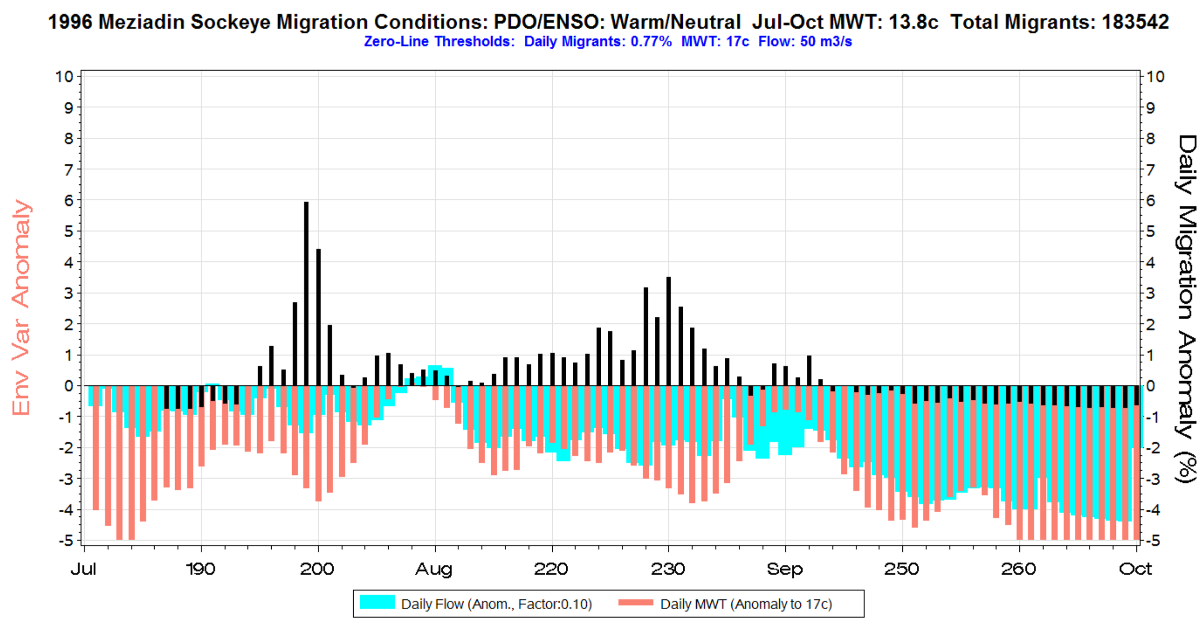
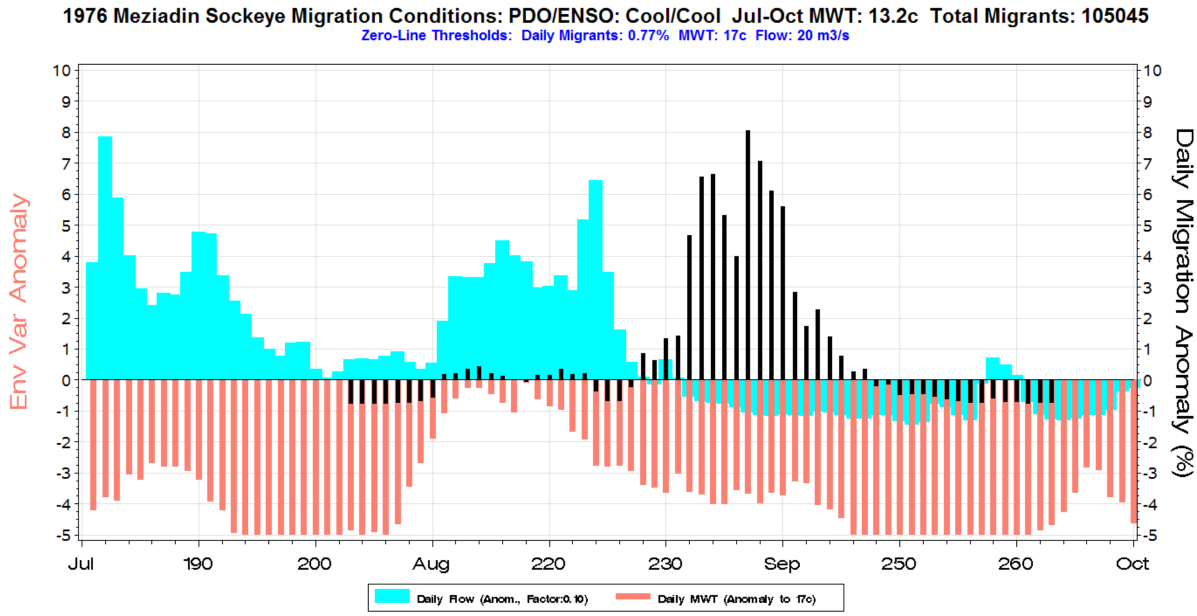


Figure 41. Annual anomaly plot for Meziadin migration, Meziadin River water temperature (estimated), and flow indicator variable *Surprise Creek* discharge (factored by 0.1 to fit on y-axis), 1976 (top), 1980 (bottom). Zero-line thresholds: (a) Daily migration rate = 0.77% (50th percentile of non-zero daily migration rates (1966-2012); (b) water temperature = 17°C; discharge = 50 cms.



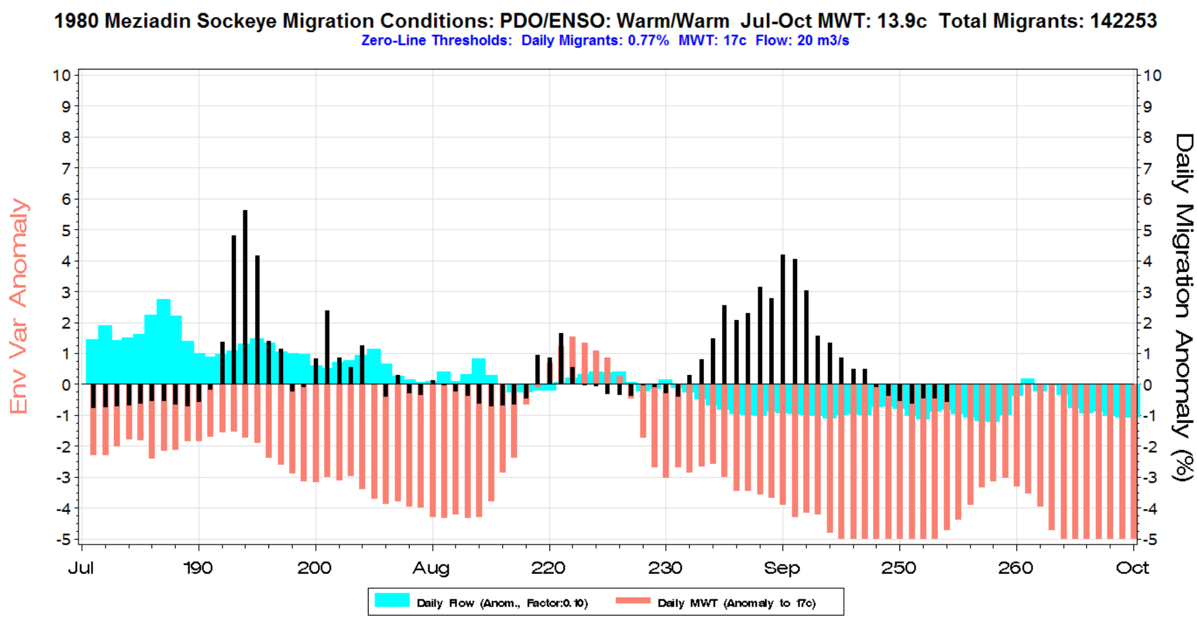


Figure 42. Annual anomaly plot for Meziadin migration, Meziadin River water temperature (estimated), and flow indicator variable *Surprise Creek* discharge (factored by 0.1 to fit on y-axis), 1976 (top), 1980 (bottom). Zero-line thresholds: (a) Daily migration rate = 0.77% (50th percentile of non-zero daily migration rates (1966-2012); (b) water temperature = 17°C; discharge = 20 cms.

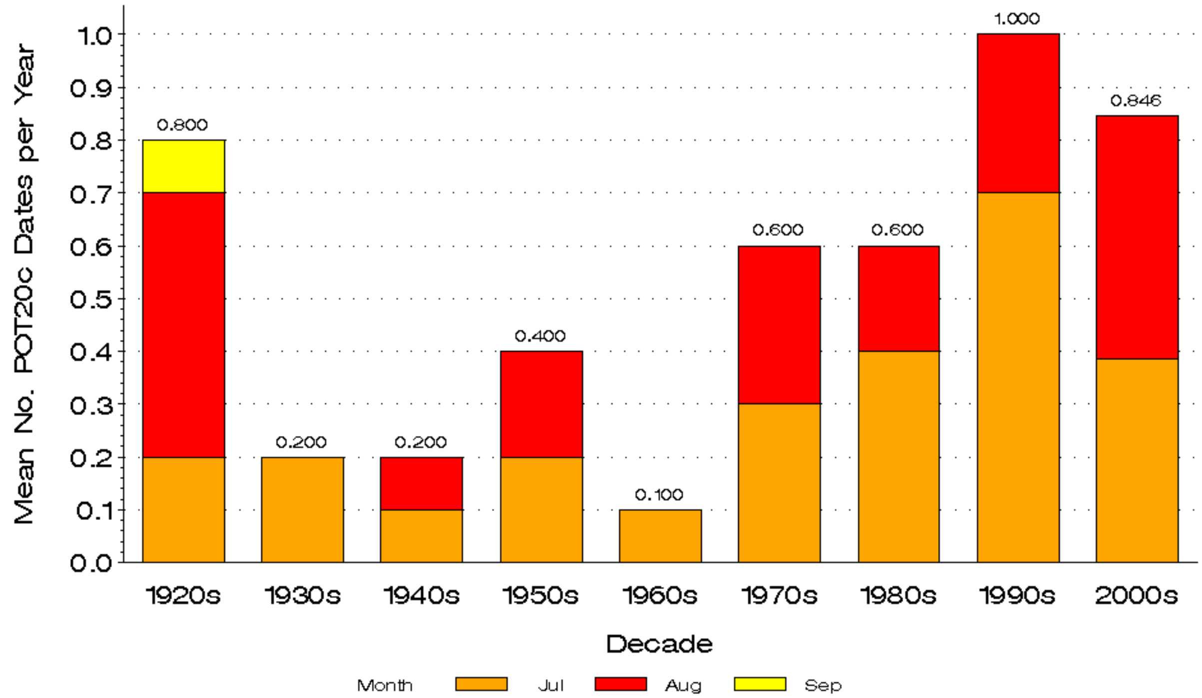


Figure 43. Frequency analysis of decadal mean number of dates per month in which regional daily mean air temperature (at *Stewart*) exceeded 20°C (Jul-Sep).

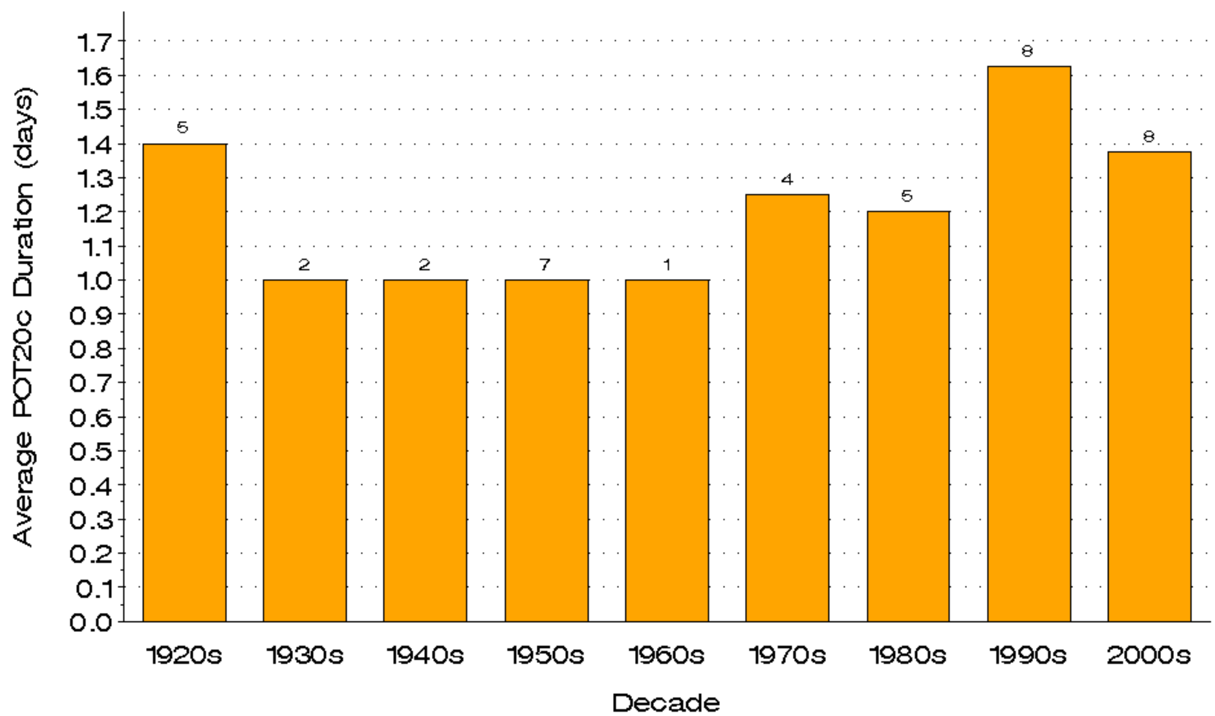


Figure 44. Mean length (days) and total decadal frequency of periods in which regional daily mean air temperature (at *Stewart*) exceeded 20°C during Jul-Sep.

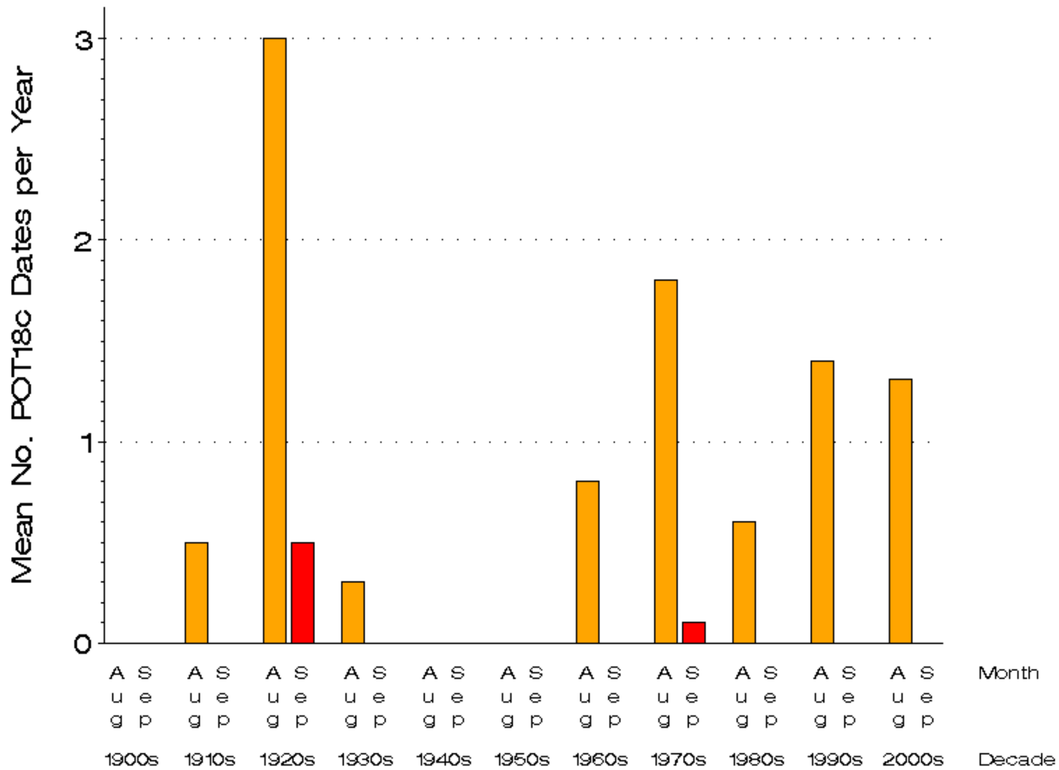


Figure 45. Frequency analysis of decadal mean number of dates per month (Jul-Sep) in which estimated mean water temperature in Meziadin River exceeded 18°C.

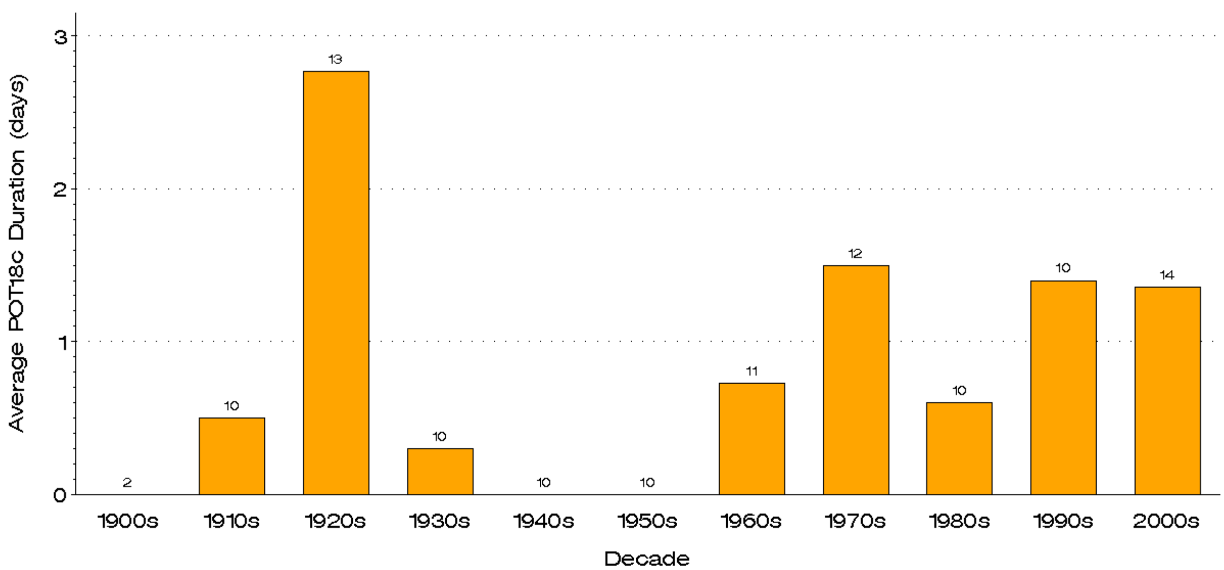


Figure 46. Mean length (days) and total decadal frequency of periods in which estimated daily mean water temperature (Jul-Sep) in Meziadin River continuously exceeded 18°C, by decade.

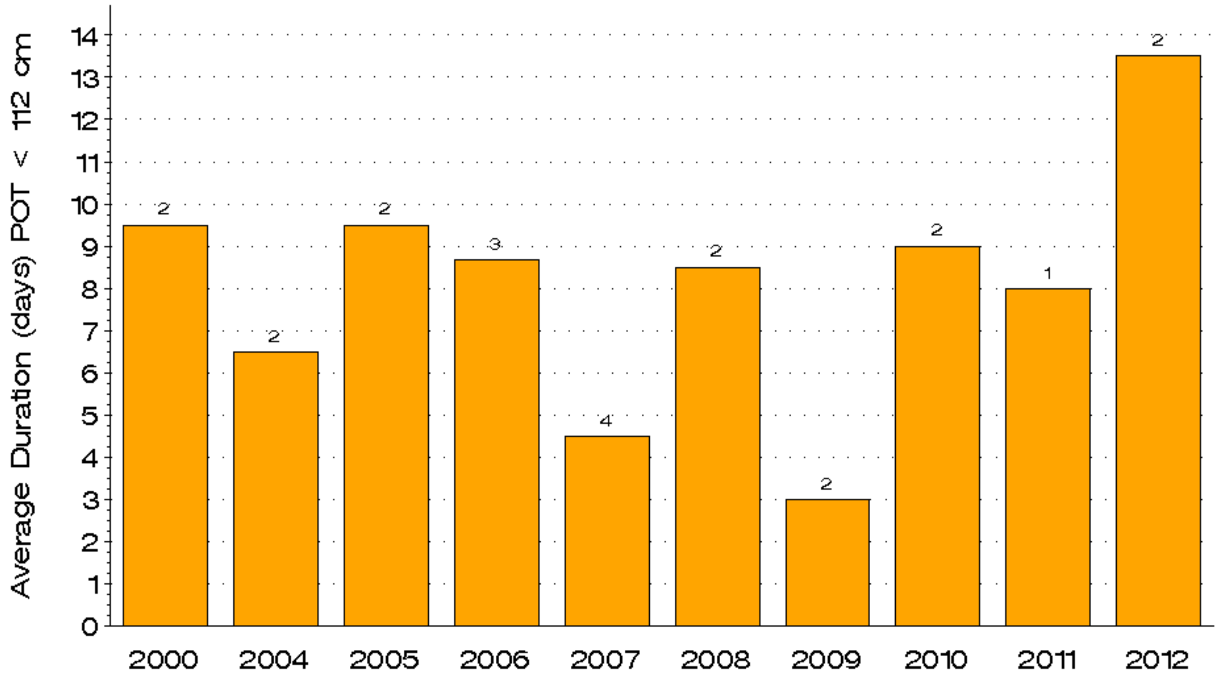


Figure 47. Mean length (days) and frequency of “low water level” periods in which Meziadin River water level continuously remained below 1.12 meters (i.e., 10th percentile of July-September levels).

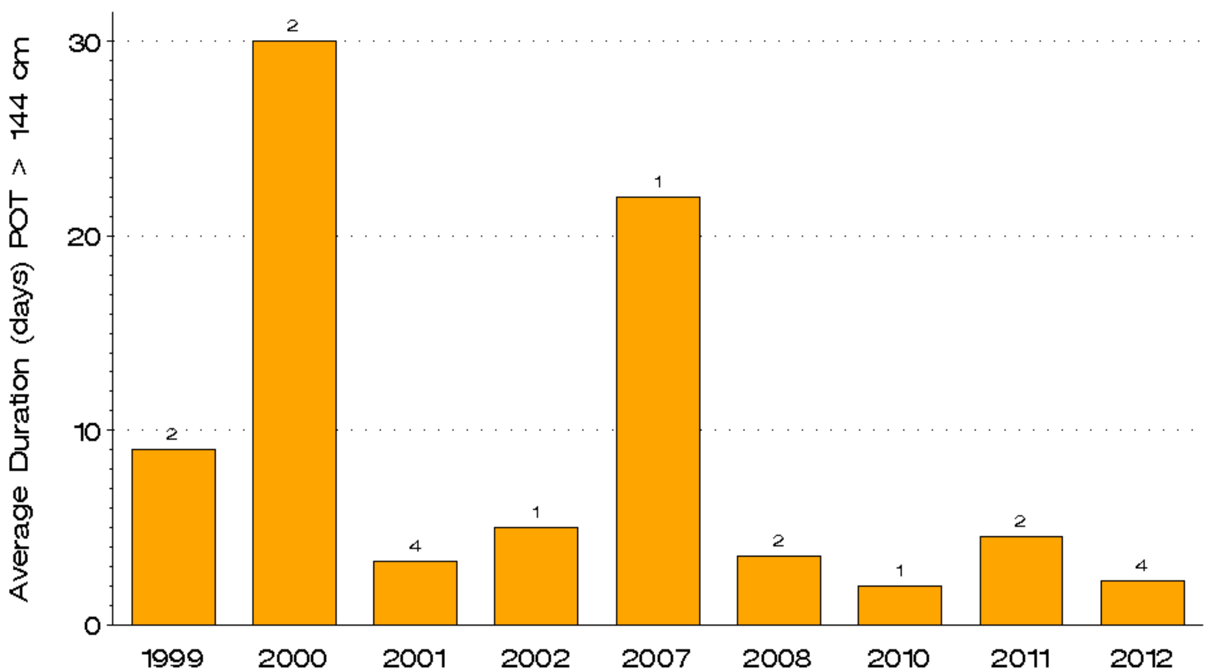


Figure 48. Mean length (days) and frequency of “high water level” periods in which Meziadin River water level continuously remained above 1.44 meters (i.e., 90th percentile of July-September levels).

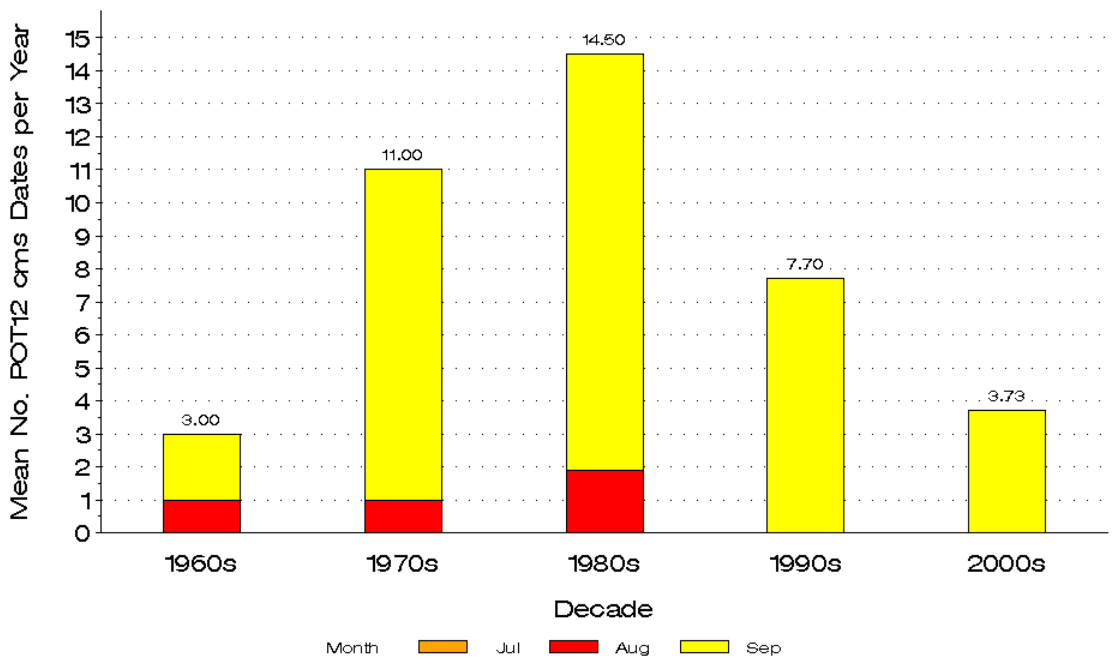


Figure 49. Frequency analysis of decadal mean number of “low water level” dates (i.e., < 10th percentile of July-September flows, ~12 cms) per month at *Surprise Creek* (as an indicator of Meziadin water levels). Note: “1960s” contains only three years of data (1967-1969) and may not be directly comparable to other decades.

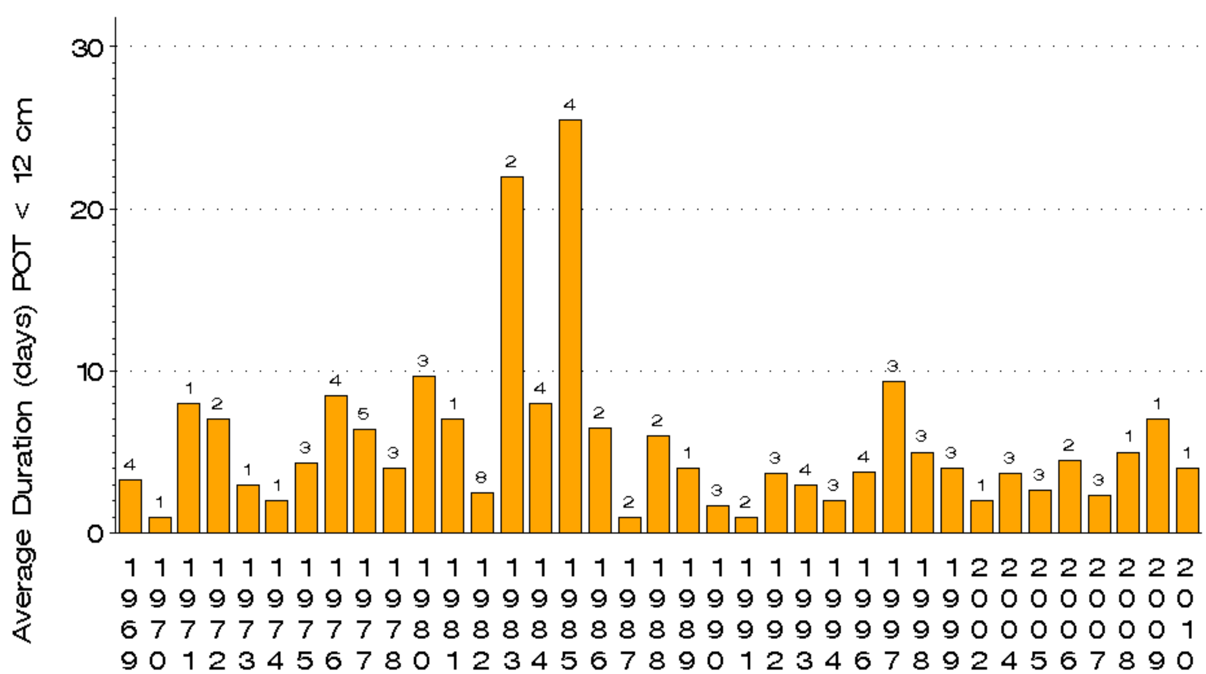


Figure 50. Mean length (days) and frequency of “low water level” periods in which *Surprise Creek* discharge continuously remained below the 10th percentile of July-September flows (~12 cms).

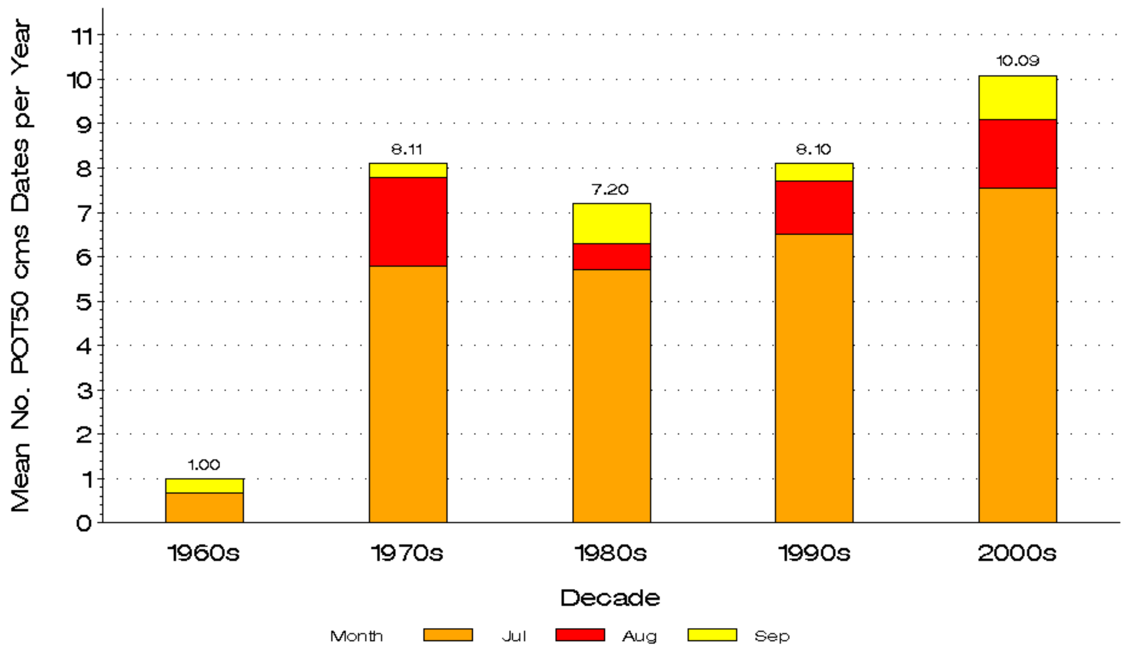


Figure 51. Frequency analysis of decadal mean number of “high water level” dates (i.e., > 90th percentile of July-September flows, ~50 cms) per month at *Surprise Creek* (as an indicator of Meziadin flows). Note: “1960s” contains only three years of data (1967-1969) and may not be directly comparable to other decades.

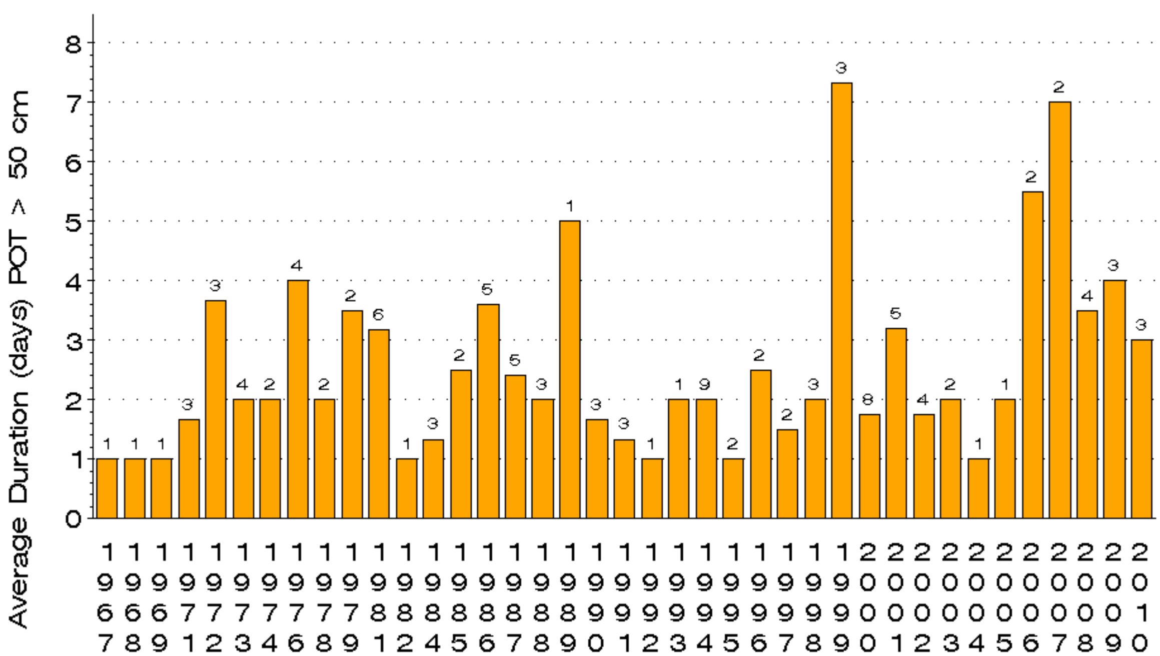


Figure 52. Mean length (days) and frequency of “high water level” periods in which *Surprise Creek* discharge continuously remained above the 90th percentile of July-September flows (~50 cms).

APPENDICES

Appendix A. DFO STOCK ASSESSMENT DIVISION environmental variable datasets documented in the FRESHWATER ENVIRONMENTAL VARIABLES DATABASE. Where DATA = YES, raw data are included in the database. Where DATA = NO, raw data may be available from the CONTACT NAME.

Government of Canada Gouvernement du Canada

Environmental Monitoring Datasets

Agency Projects

Research Projects & Field Studies

DFO Mgmt Area: **North Coast** Major Drainage: **Nass** Joint Adaptive Zone: **Nass | Nass-Skeena Estuary**

Watershed Group	Waterbody	Location	Contact Name	Type	Start	End	Years	Resolution	Status	Data
KINSKUCH	Meziadin River	Fishway	DFO - Kim Hyatt	Water Temperature	1908	2012	105	Daily	C	Yes
	Meziadin River	Fishway	DFO - Kim Hyatt	Water Temperature	1908	2012	105	Daily	C	Yes
	Meziadin River	Meziadin Fence	LGL - Richard Alexander	Water Level	1998	2012	15	Spot	A	Yes
	Meziadin River	Meziadin Fence	LGL - Richard Alexander	Water Temperature	1999	2012	14	Spot	A	Yes

DFO Mgmt Area: **North Coast** Major Drainage: **Nass** Joint Adaptive Zone: **Lower Nass - Portland | Nass-Skeena Estua**

Watershed Group	Waterbody	Location	Contact Name	Type	Start	End	Years	Resolution	Status	Data
LOWER NASS	Nass River	Gitwinkshlkw Fish-Wheel	LGL Consultants - Richard Alexander / Anita Blakley	Water Temperature	1994	1998	5	Daily	U	No
	Nass River	Gitwinkshlkw Fish-Wheel	LGL Consultants - Richard Alexander / Anita Blakley	Water Temperature	1999	2011	13	Daily	U	No

DFO Mgmt Area: **North Coast** Major Drainage: **Nass** Joint Adaptive Zone: **Lower Nass - Portland | Nass-Skeena Estua**

Watershed Group	Waterbody	Location	Contact Name	Type	Start	End	Years	Resolution	Status	Data
LOWER NASS	Kincolith RIver	Kincolith RIver Hatchery	Nisga'a Lisims Government - Cheryl Stephens/Blair Stewart, CEDP Mgrs	Water Temperature	1980s	Current	34	Unknown	A	No

Appendix B. Reference climate station environmental variable datasets documented in the FRESHWATER ENVIRONMENTAL VARIABLES DATABASE. Where DATA = YES, raw data are included in the database. Where DATA = NO, raw data are available online or from the CONTACT NAME.

Government of Canada / Gouvernement du Canada

Environmental Monitoring Datasets

Climate Reference Meta-Data — Adjusted and Homogenized Canadian Climate Data (AHCCD)

DFO Mgmt Area: **North Coast** Major Drainage: **Skeena** Joint Adaptive Zone: **Hecate Lowlands | Nass-Skeena Estuary**

Watershed Group	Waterbody	Location	Contact Name	Type	Start	End	Years	Resolution	Status	Data
	Unspecified	PRINCE RUPERT	Climate Research Division - Lucie Vincent	Air Temperature	1908	2010	103	Daily	A	No
	Unspecified	PRINCE RUPERT A	Climate Research Division - Lucie Vincent	Precipitation	1909	2006	98	Daily	D	No
	Unspecified	PRINCE RUPERT A	-	Barometric Pressure	1961	2005	45	Daily	D	No
	Unspecified	STEWART	Climate Research Division - Lucie Vincent	Air Temperature	1910	2012	103	Daily	A	No
	Unspecified	STEWART A	Climate Research Division - Lucie Vincent	Precipitation	1911	2010	100	Daily	A	No
	Unspecified	STEWART A	-	Barometric Pressure	1975	2008	34	Daily	D	No

DFO Mgmt Area: **North Coast** Major Drainage: **Nass** Joint Adaptive Zone: **Unspecified**

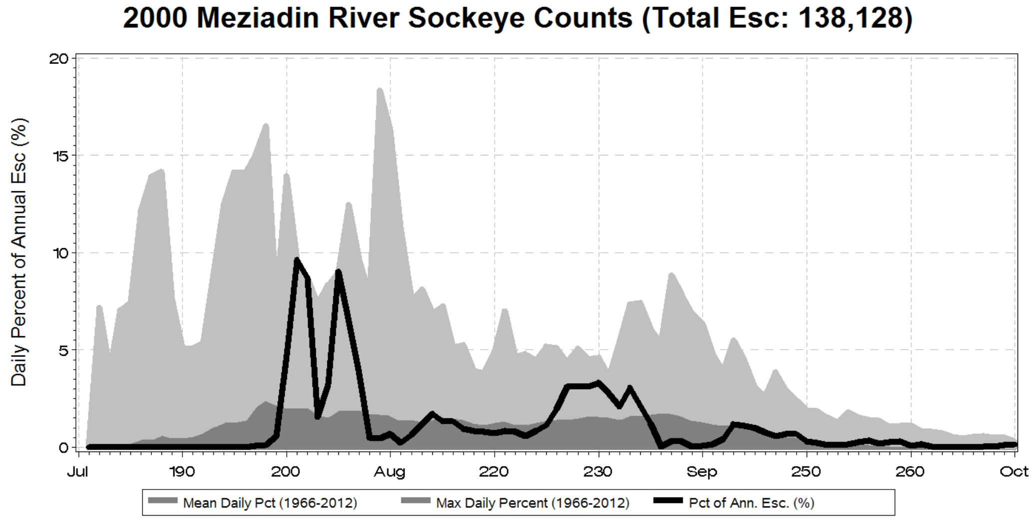
Watershed Group	Waterbody	Location	Contact Name	Type	Start	End	Years	Resolution	Status	Data
NASS	Nass River	NASS CAMP	Climate Research Division - Lucie Vincent	Precipitation	1924	2010	87	Daily	A	No

DFO Mgmt Area: **Yukon Transboundary** Major Drainage: **MacKenzie** Joint Adaptive Zone: **Upper Liard | Arctic Ocean**

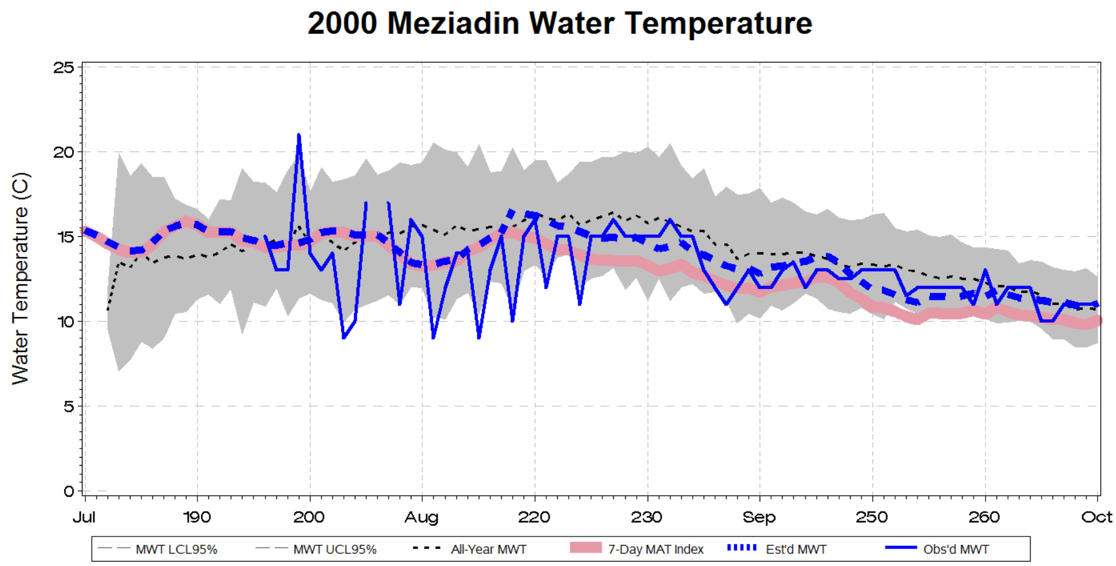
Watershed Group	Waterbody	Location	Contact Name	Type	Start	End	Years	Resolution	Status	Data
DEASE LAKE	Dease Lake	DEASE LAKE	Climate Research Division - Lucie Vincent	Air Temperature	1944	2010	67	Daily	A	No
	Dease Lake	DEASE LAKE	Climate Research Division - Lucie Vincent	Precipitation	1945	2008	64	Daily	D	No
	Dease Lake	DEASE LAKE	-	Barometric Pressure	1953	2008	56	Daily	D	No
	Dease Lake	DEASE LAKE (AUT)	-	Barometric Pressure	1993	2008	16	Daily	D	No

Appendix C. Multi-panel plots of daily Meziadin Sockeye migration in relation to environmental variables, by year, 1966-2012.

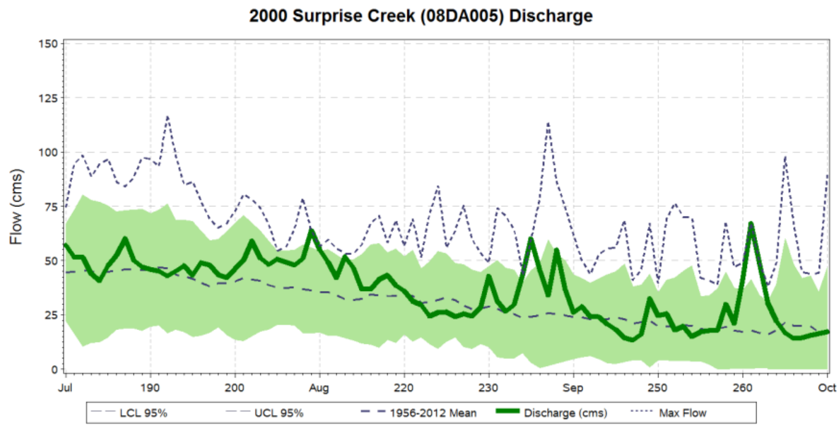
Sample plots for the year 2000 (below) display legend with vertical axis variates and horizontal axis with day of year (month label is *approximate* start of each month). Annual plots (following pages) are organized in a multi-panel format for comparison of the following variates:



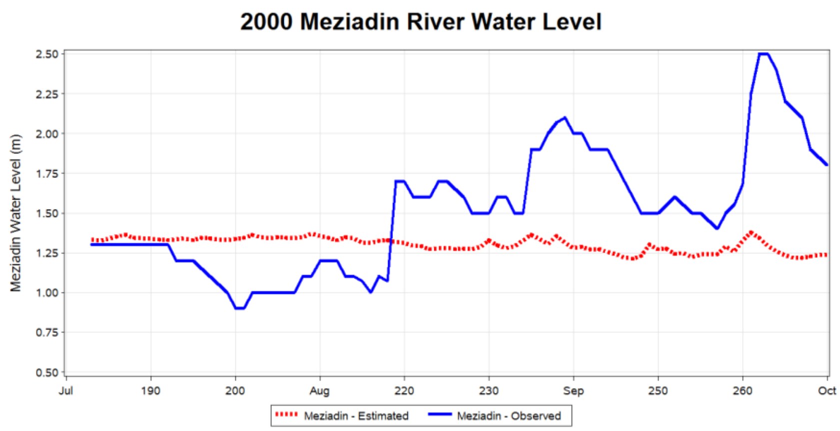
1. Daily migration rates as a percent (%) of annual stock escapement (black line), from daily Sockeye (adult + jack) migrants counted at the Meziadin fishway. Historical mean daily migration rate (dark gray area) and maximum daily migration rate (light gray area) for years 1966-2012.



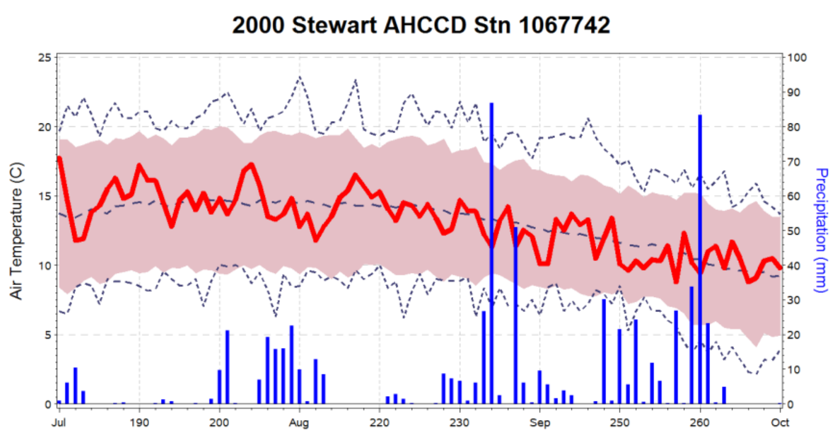
2. Observed (solid blue line) and estimated (dashed blue line) daily mean water temperature at the Meziadin fishway, with historical daily MWT and variance (dashed line and gray area), 1998-2012, and daily air temperature index (pink).



3. Daily mean discharge (cms) at WSC station *Surprise Creek* (green line), with historical daily mean and variance (dashed line and green area), 1967-2010.

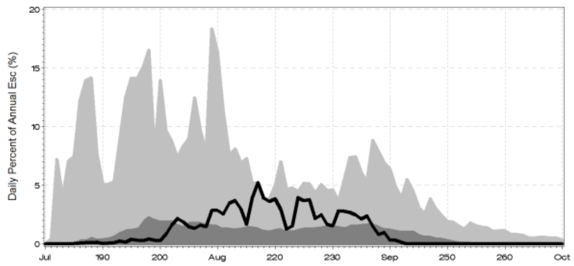


4. Daily mean water level recorded at the Meziadin fishway (in meters, blue line), and estimated Meziadin water level as a function of Surprise Creek discharge.

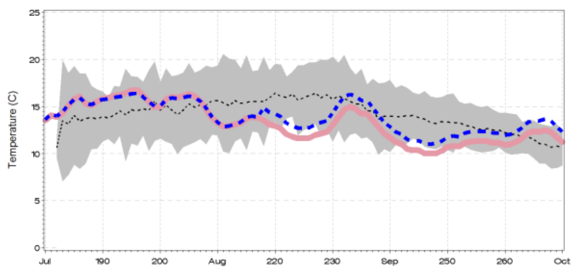


5. Precipitation (mm, blue bars) and daily mean air temperature (°C, red line) at EC meteorological station *Stewart*, with historical daily mean and variance (dashed line and red area), 1911-2012.

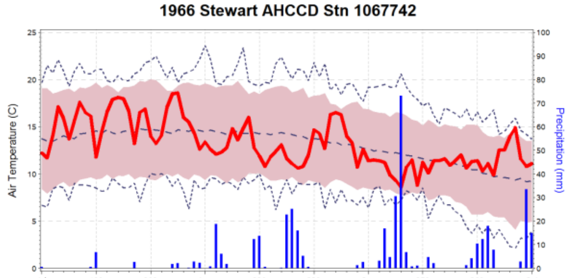
1966 Meziadin River Sockeye Counts (Total Esc: 64,884)



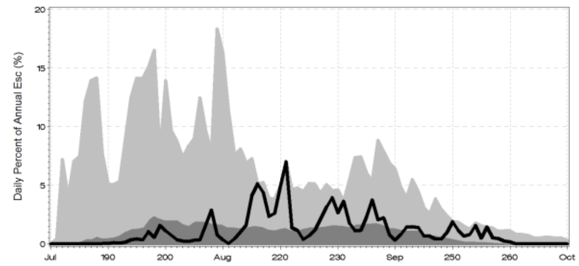
1966 Meziadin Water Temperature



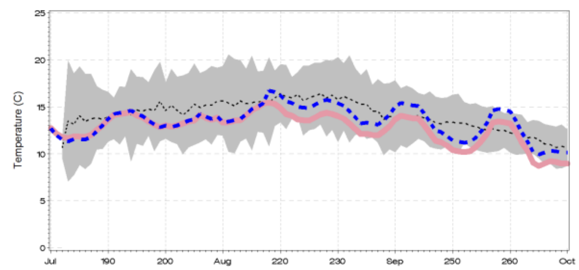
1966 Stewart AHCCD Stn 1067742



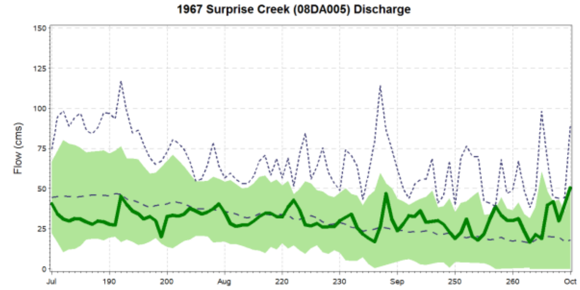
1967 Meziadin River Sockeye Counts (Total Esc: 41,842)



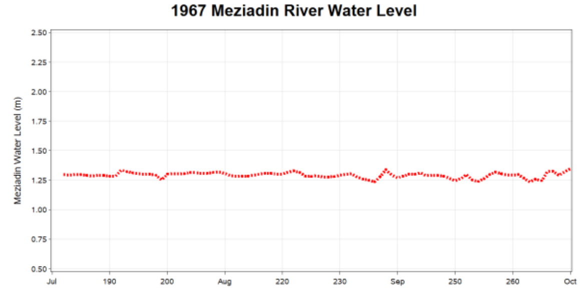
1967 Meziadin Water Temperature



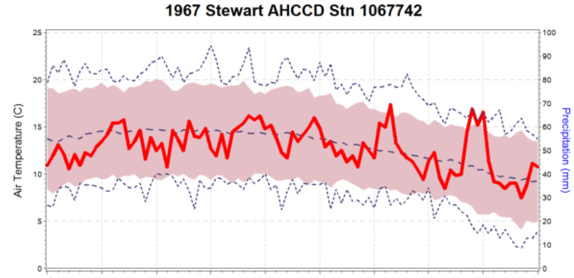
1967 Surprise Creek (08DA005) Discharge



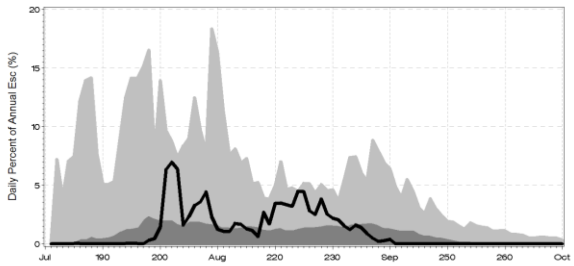
1967 Meziadin River Water Level



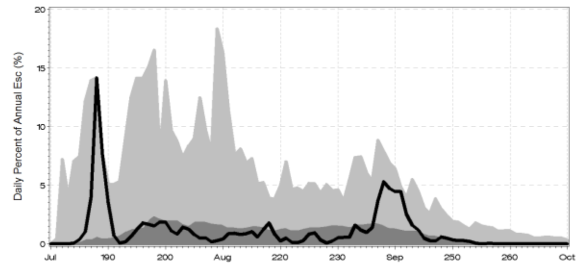
1967 Stewart AHCCD Stn 1067742



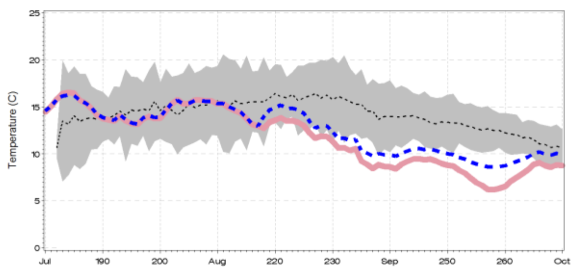
1968 Meziadin River Sockeye Counts (Total Esc: 72,087)



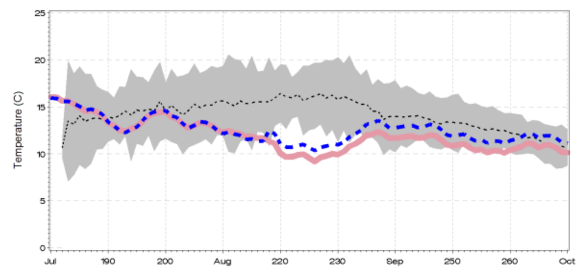
1969 Meziadin River Sockeye Counts (Total Esc: 135,798)



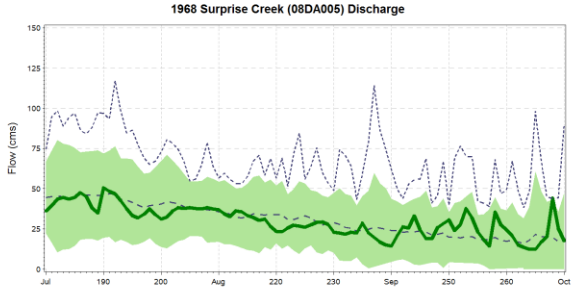
1968 Meziadin Water Temperature



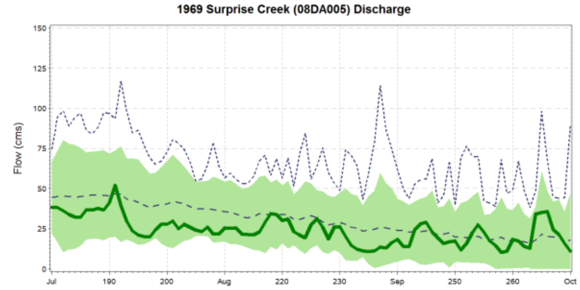
1969 Meziadin Water Temperature



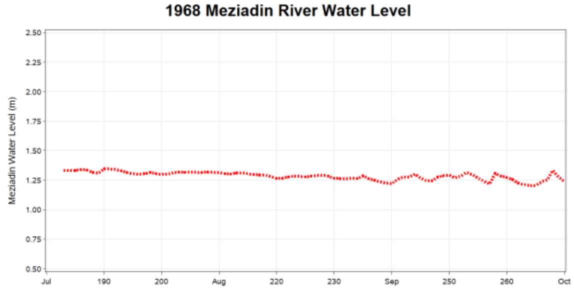
1968 Surprise Creek (08DA005) Discharge



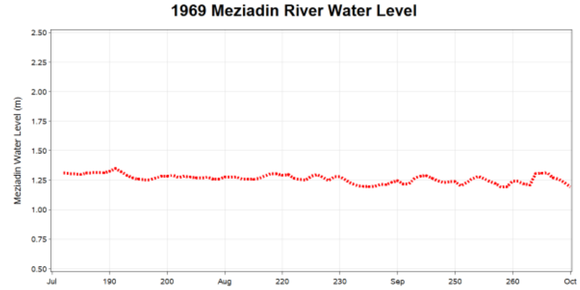
1969 Surprise Creek (08DA005) Discharge



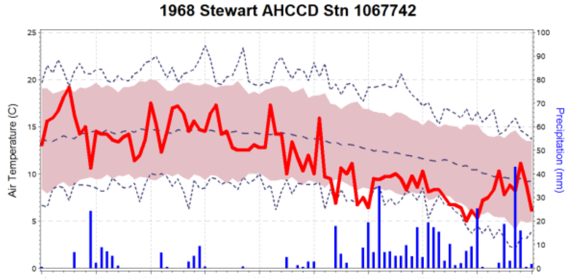
1968 Meziadin River Water Level



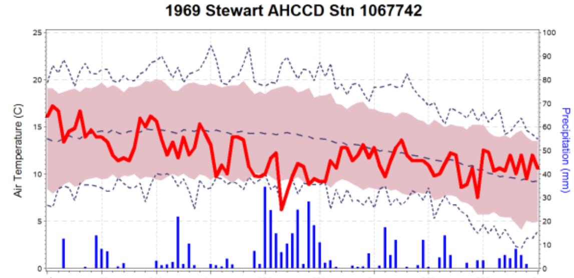
1969 Meziadin River Water Level



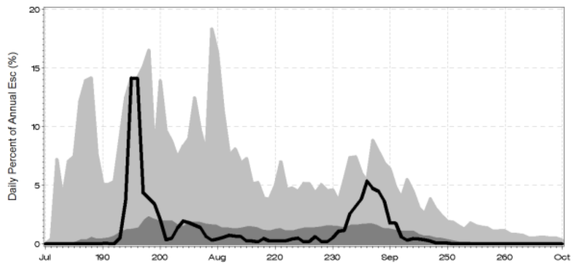
1968 Stewart AHCCD Stn 1067742



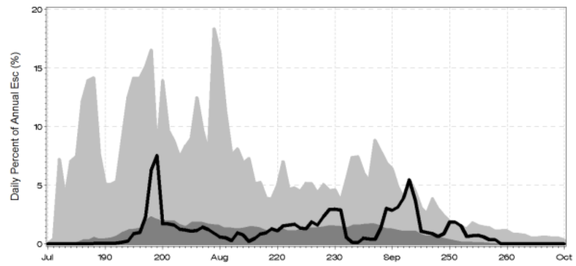
1969 Stewart AHCCD Stn 1067742



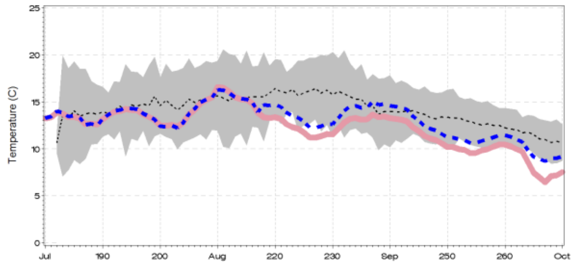
1970 Meziadin River Sockeye Counts (Total Esc: 77,990)



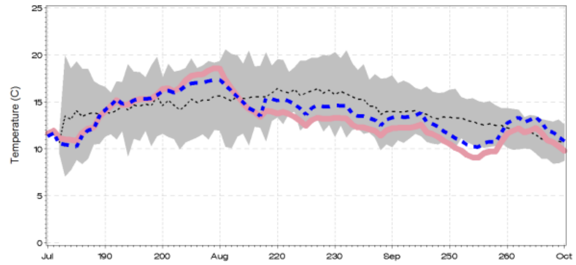
1971 Meziadin River Sockeye Counts (Total Esc: 193,823)



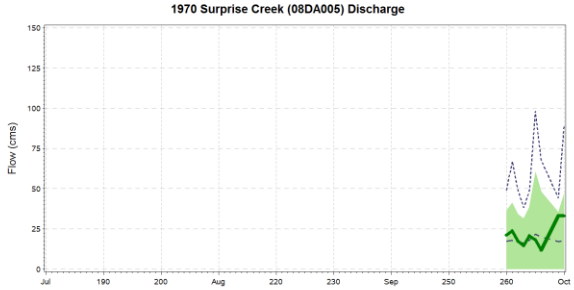
1970 Meziadin Water Temperature



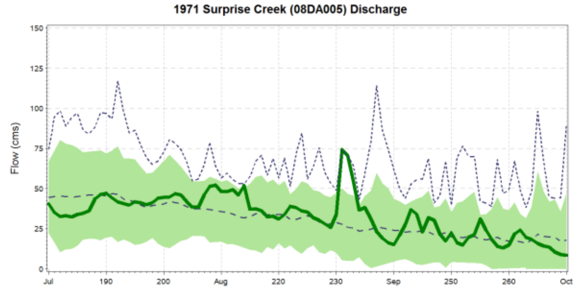
1971 Meziadin Water Temperature



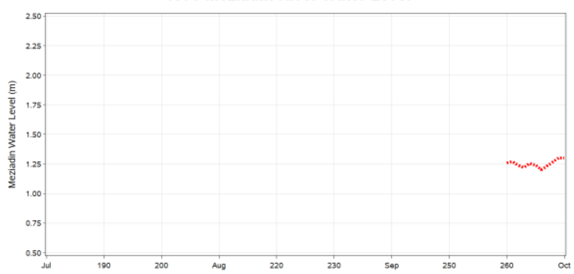
1970 Surprise Creek (08DA005) Discharge



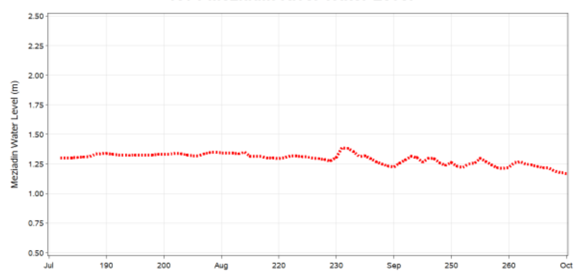
1971 Surprise Creek (08DA005) Discharge



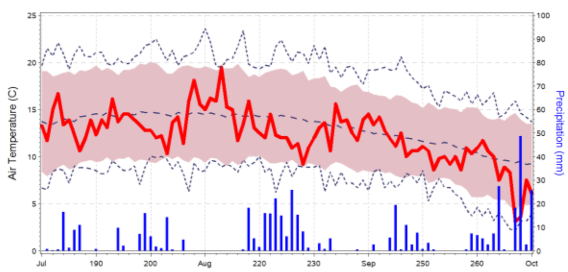
1970 Meziadin River Water Level



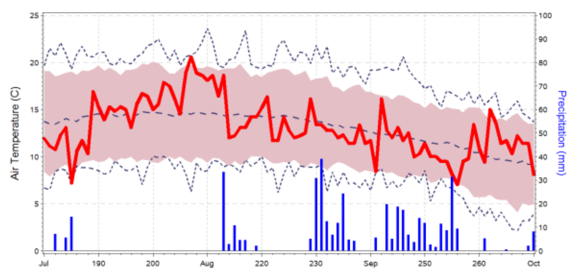
1971 Meziadin River Water Level



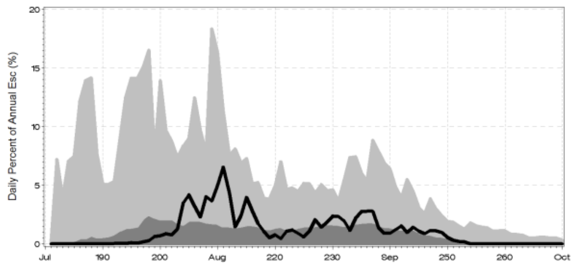
1970 Stewart AHCCD Stn 1067742



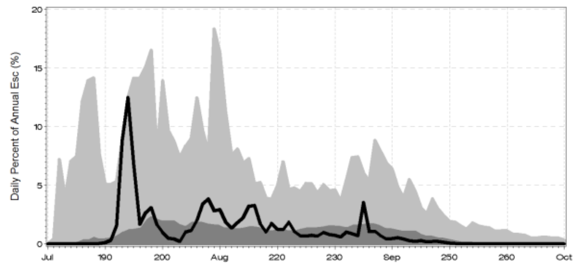
1971 Stewart AHCCD Stn 1067742



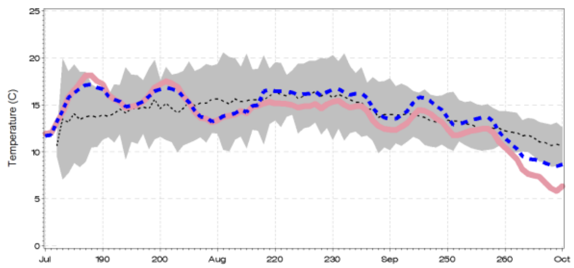
1972 Meziadin River Sockeye Counts (Total Esc: 131,076)



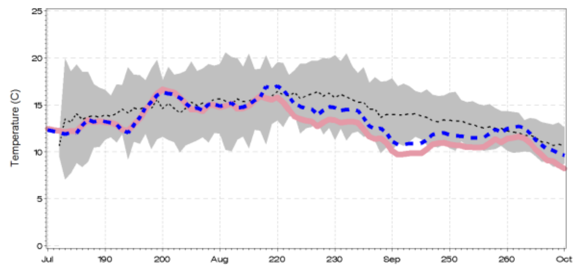
1973 Meziadin River Sockeye Counts (Total Esc: 235,187)



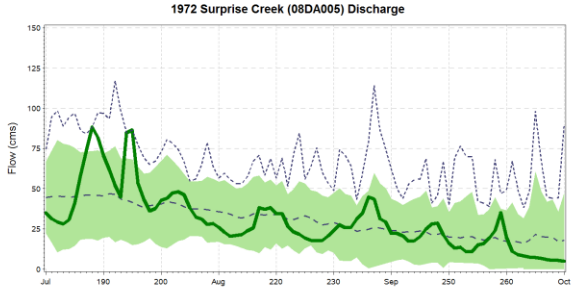
1972 Meziadin Water Temperature



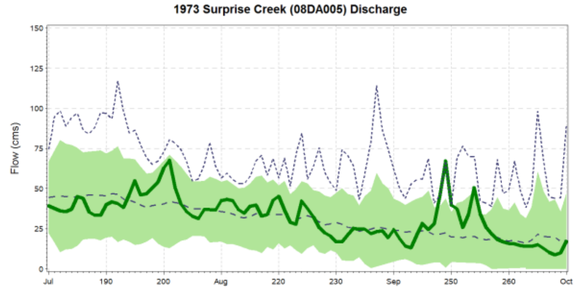
1973 Meziadin Water Temperature



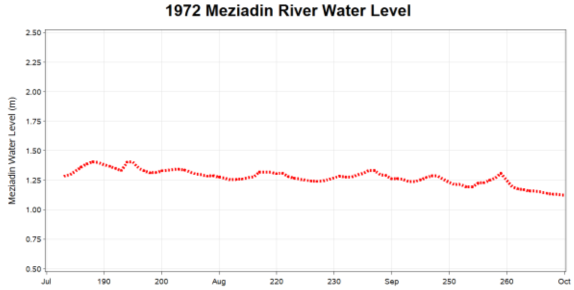
1972 Surprise Creek (08DA005) Discharge



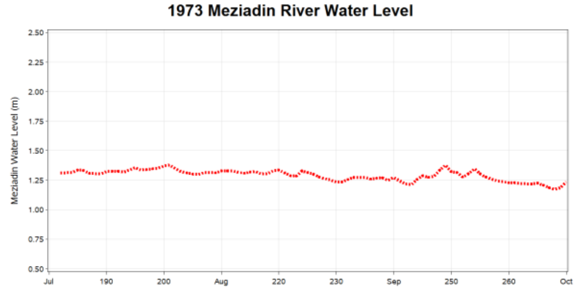
1973 Surprise Creek (08DA005) Discharge



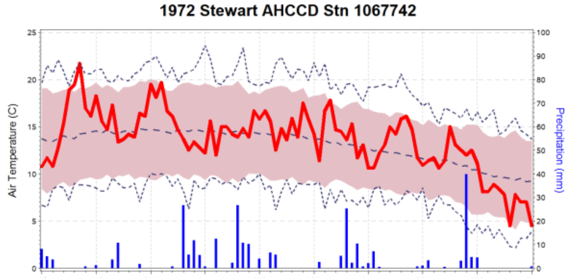
1972 Meziadin River Water Level



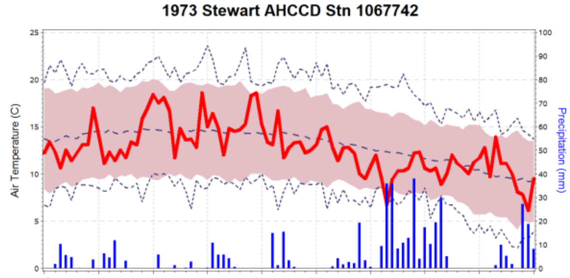
1973 Meziadin River Water Level



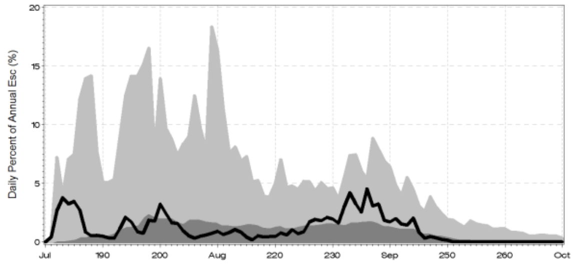
1972 Stewart AHCCD Stn 1067742



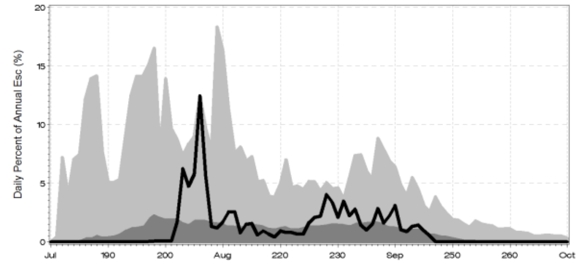
1973 Stewart AHCCD Stn 1067742



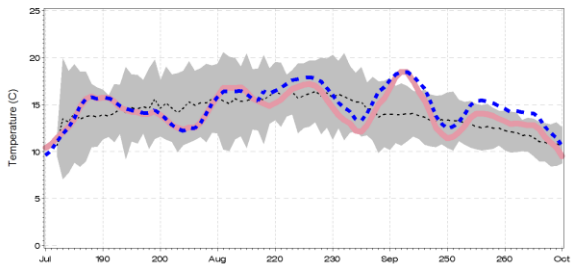
1974 Meziadin River Sockeye Counts (Total Esc: 166,014)



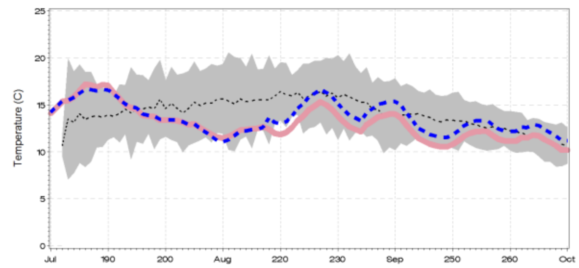
1975 Meziadin River Sockeye Counts (Total Esc: 55,170)



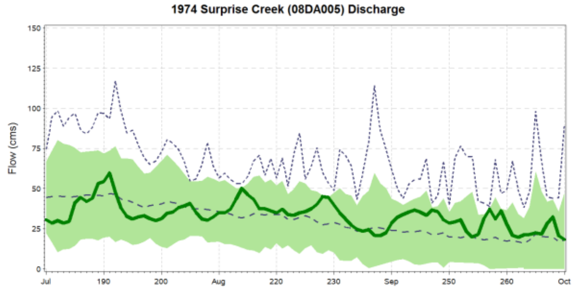
1974 Meziadin Water Temperature



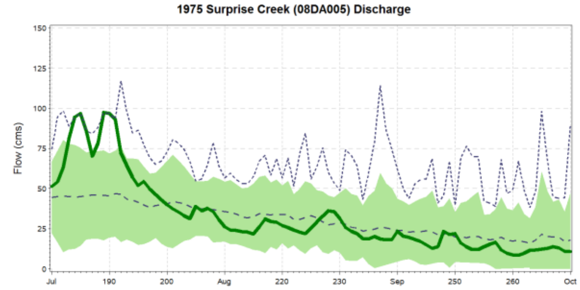
1975 Meziadin Water Temperature



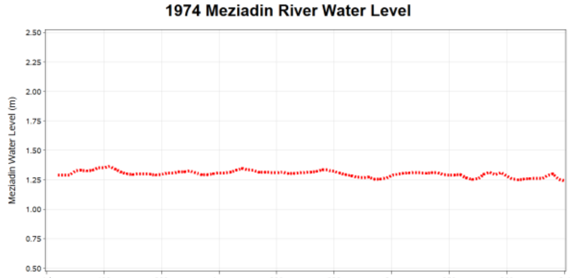
1974 Surprise Creek (08DA005) Discharge



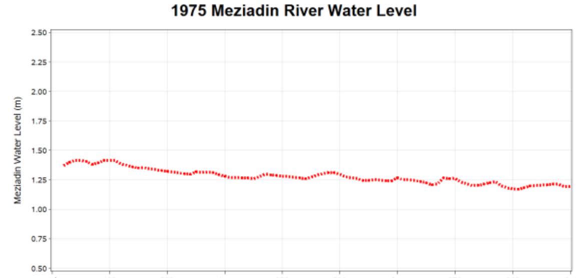
1975 Surprise Creek (08DA005) Discharge



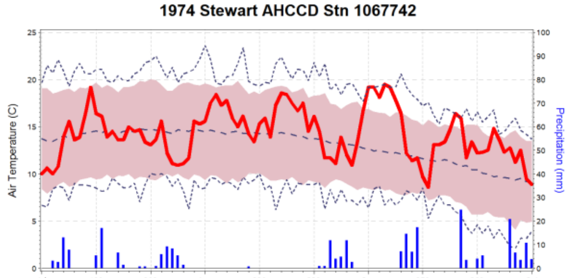
1974 Meziadin River Water Level



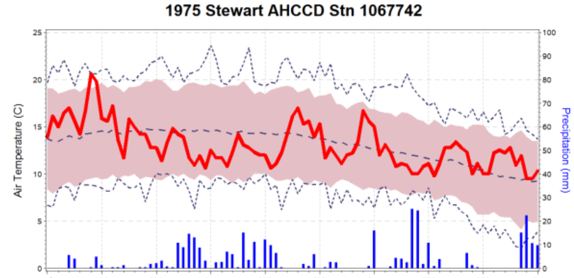
1975 Meziadin River Water Level



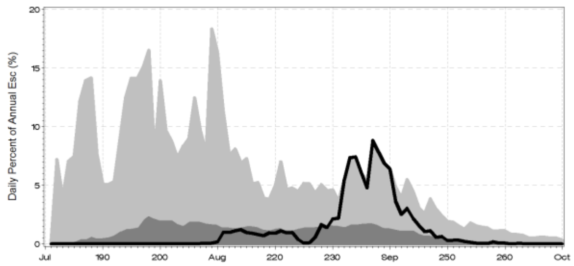
1974 Stewart AHCCD Stn 1067742



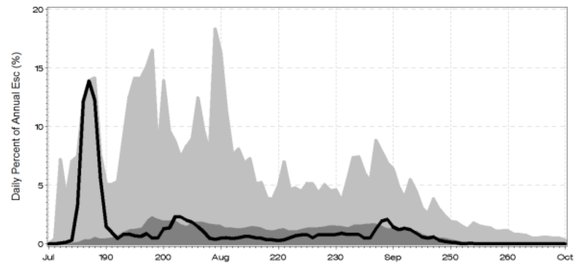
1975 Stewart AHCCD Stn 1067742



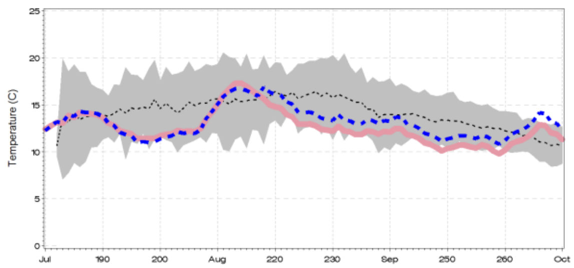
1976 Meziadin River Sockeye Counts (Total Esc: 105,045)



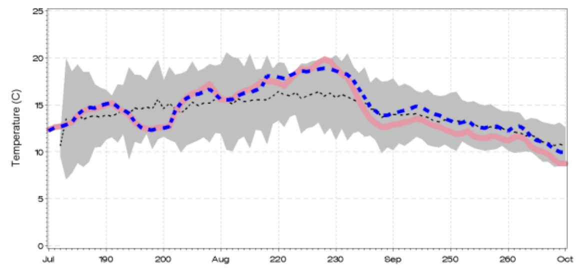
1977 Meziadin River Sockeye Counts (Total Esc: 242,640)



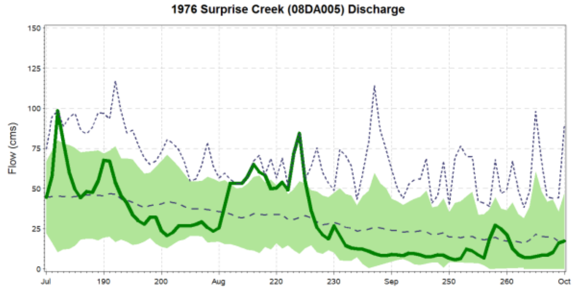
1976 Meziadin Water Temperature



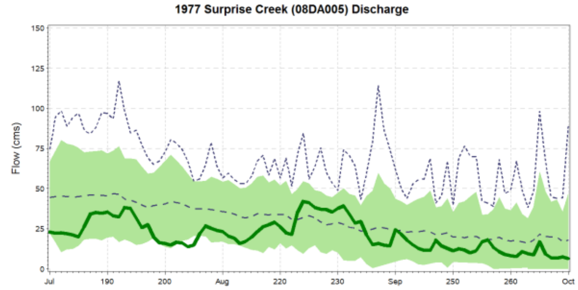
1977 Meziadin Water Temperature



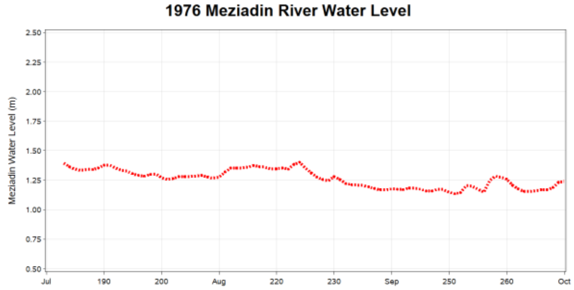
1976 Surprise Creek (08DA005) Discharge



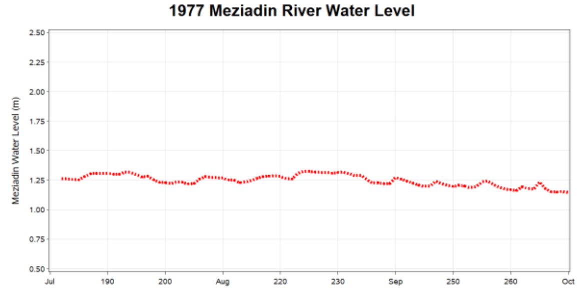
1977 Surprise Creek (08DA005) Discharge



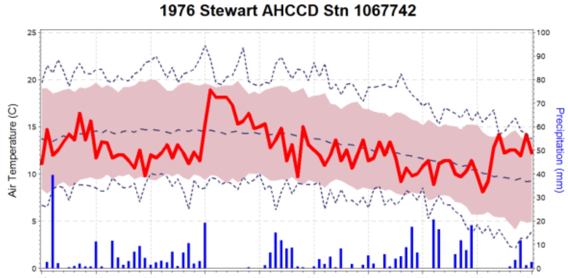
1976 Meziadin River Water Level



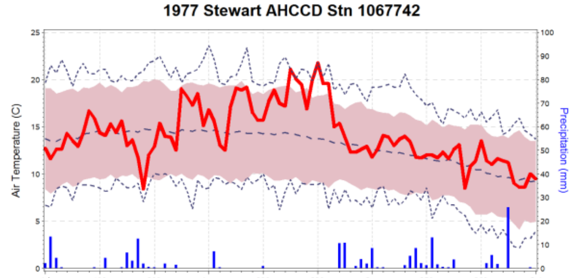
1977 Meziadin River Water Level



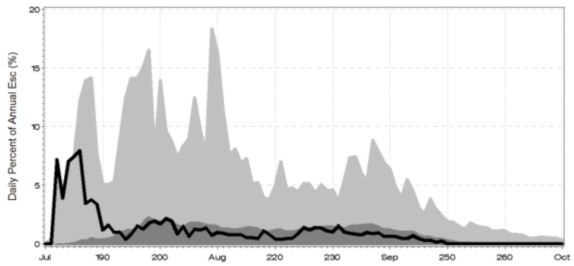
1976 Stewart AHCCD Stn 1067742



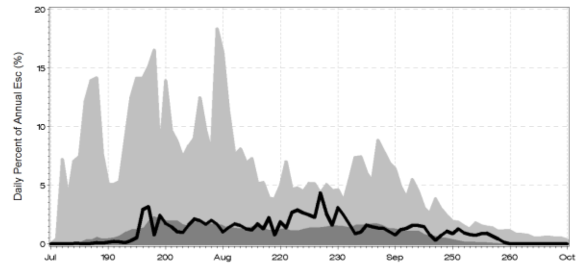
1977 Stewart AHCCD Stn 1067742



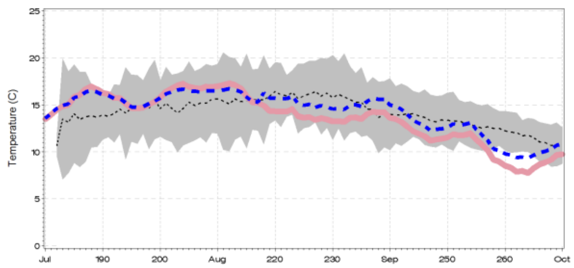
1978 Meziadin River Sockeye Counts (Total Esc: 111,731)



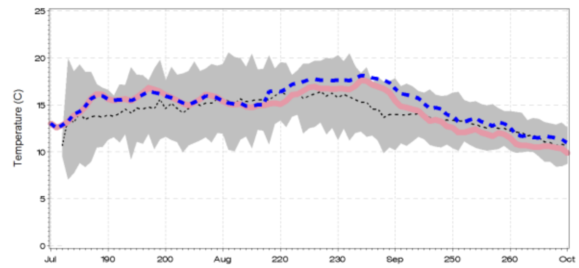
1979 Meziadin River Sockeye Counts (Total Esc: 195,850)



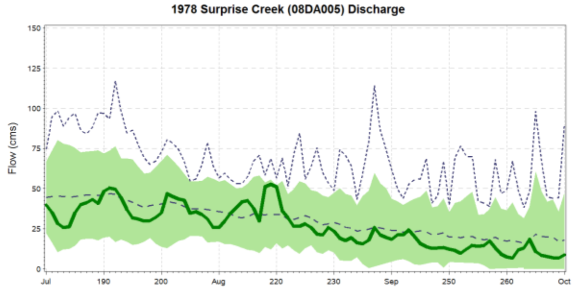
1978 Meziadin Water Temperature



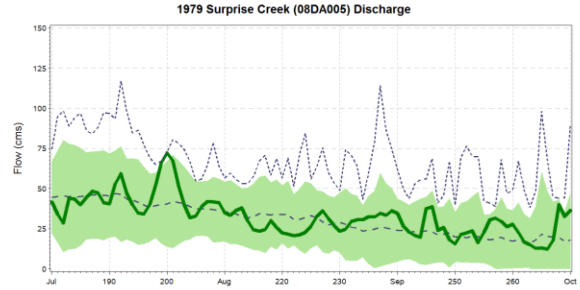
1979 Meziadin Water Temperature



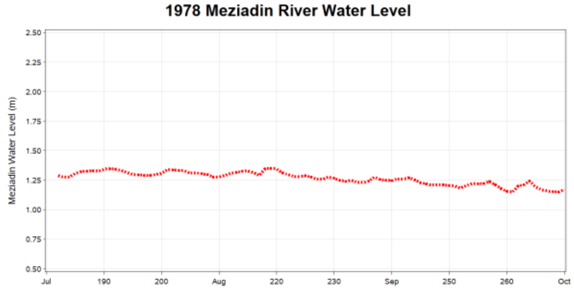
1978 Surprise Creek (08DA005) Discharge



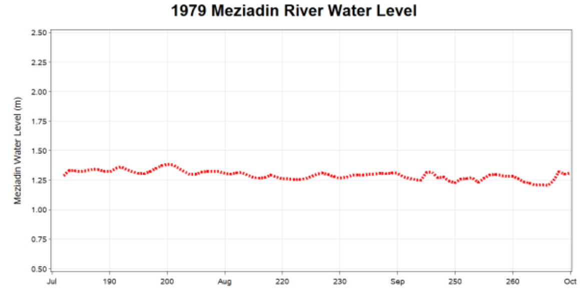
1979 Surprise Creek (08DA005) Discharge



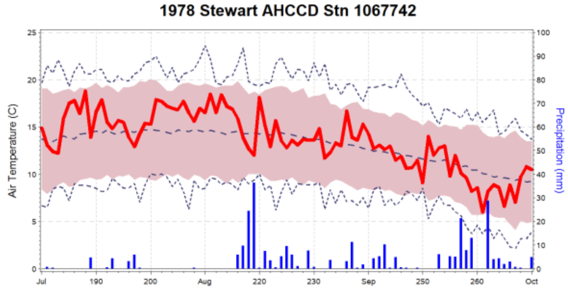
1978 Meziadin River Water Level



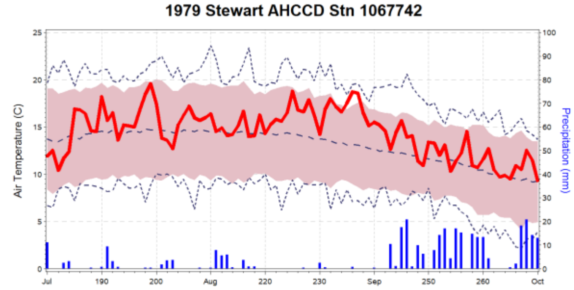
1979 Meziadin River Water Level

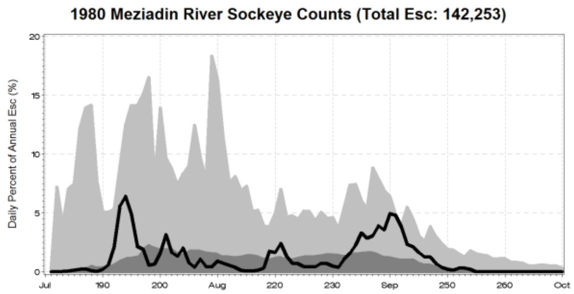


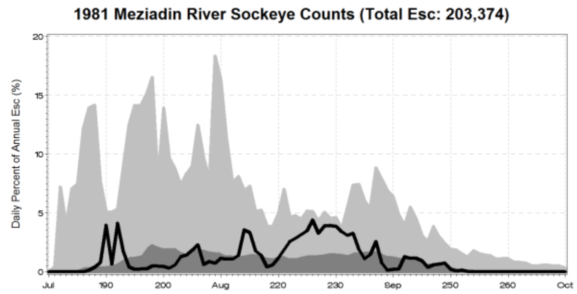
1978 Stewart AHCCD Stn 1067742

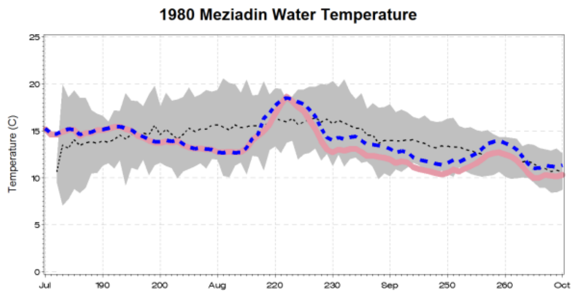


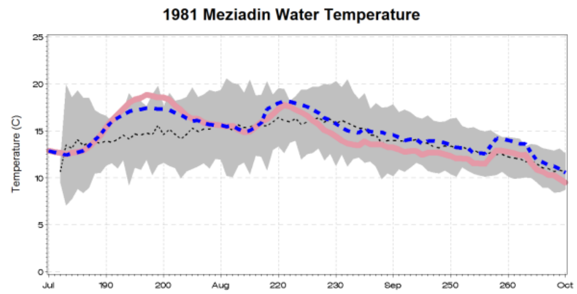
1979 Stewart AHCCD Stn 1067742

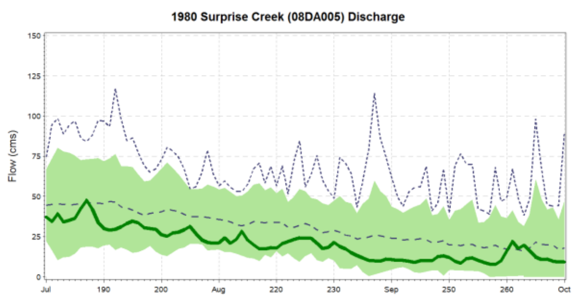


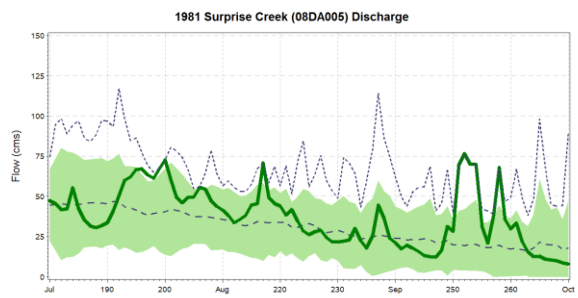

1980 Meziadin River Sockeye Counts (Total Esc: 142,253)
Daily Percent of Annual Esc (%)

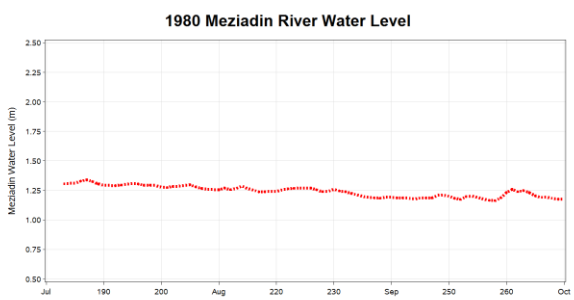

1981 Meziadin River Sockeye Counts (Total Esc: 203,374)
Daily Percent of Annual Esc (%)

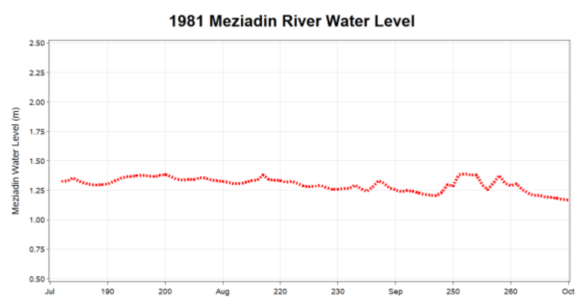

1980 Meziadin Water Temperature
Temperature (C)

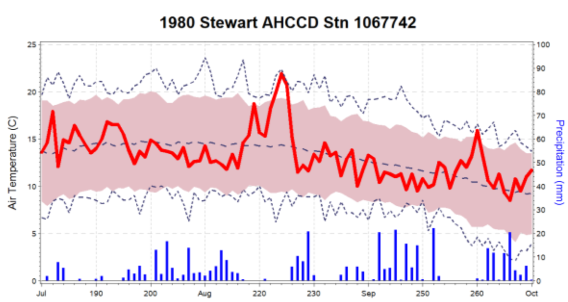

1981 Meziadin Water Temperature
Temperature (C)

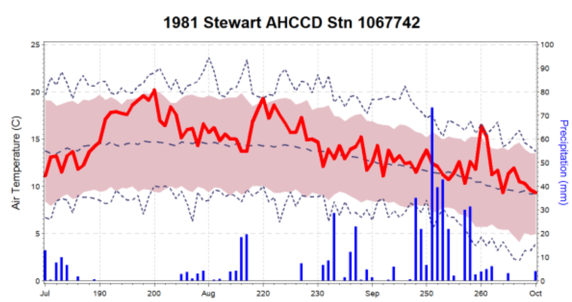

1980 Surprise Creek (08DA005) Discharge
Flow (cms)


1981 Surprise Creek (08DA005) Discharge
Flow (cms)

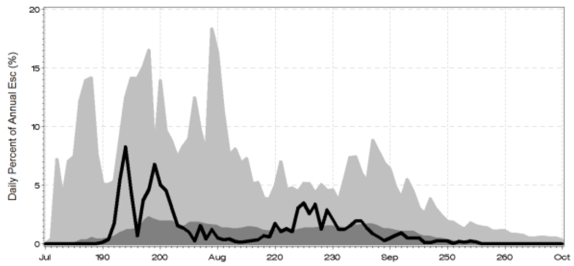

1980 Meziadin River Water Level
Meziadin Water Level (m)


1981 Meziadin River Water Level
Meziadin Water Level (m)

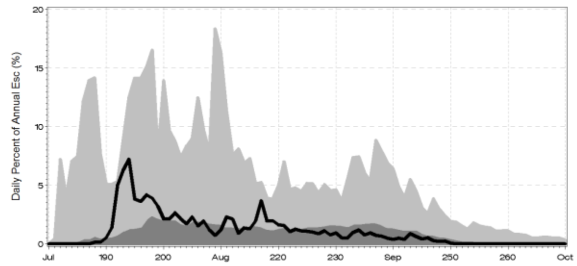

1980 Stewart AHCCD Stn 1067742
Air Temperature (C)
Precipitation (mm)


1981 Stewart AHCCD Stn 1067742
Air Temperature (C)
Precipitation (mm)

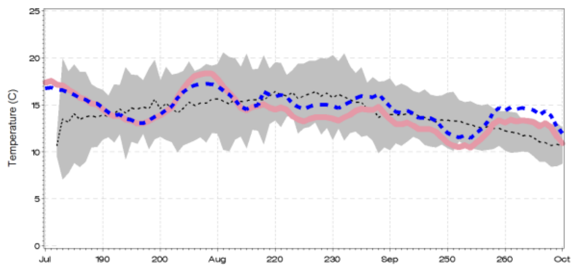
1982 Meziadin River Sockeye Counts (Total Esc: 245,646)



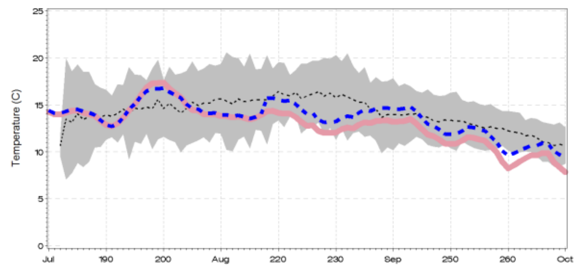
1983 Meziadin River Sockeye Counts (Total Esc: 168,552)



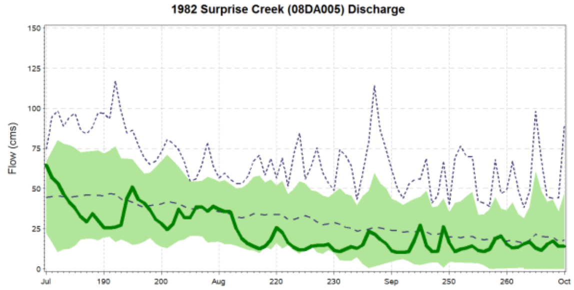
1982 Meziadin Water Temperature



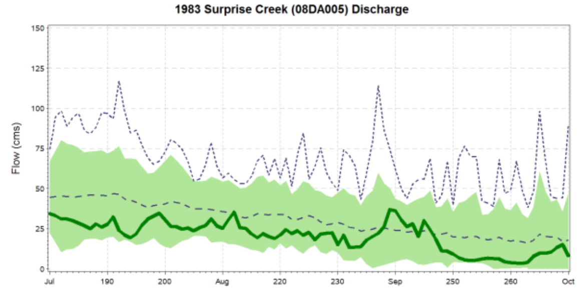
1983 Meziadin Water Temperature



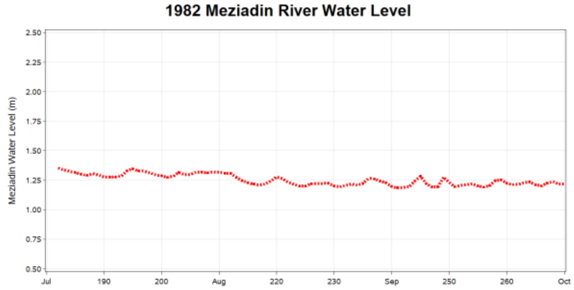
1982 Surprise Creek (08DA005) Discharge



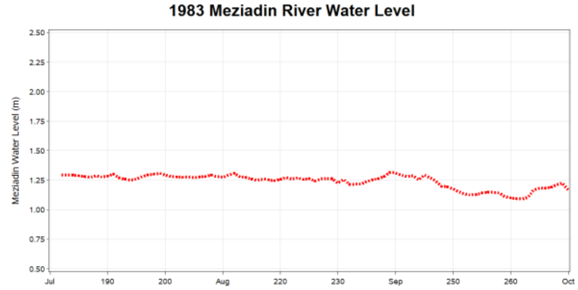
1983 Surprise Creek (08DA005) Discharge



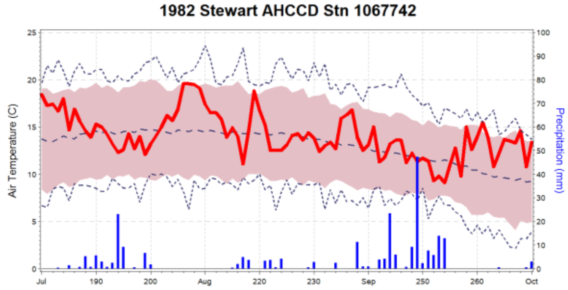
1982 Meziadin River Water Level



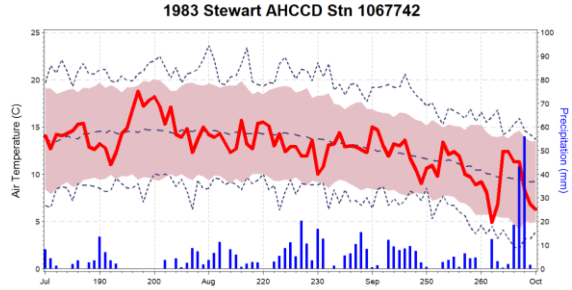
1983 Meziadin River Water Level



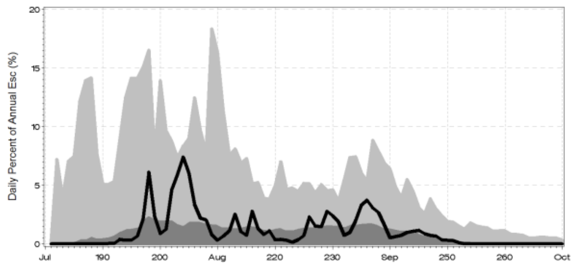
1982 Stewart AHCCD Stn 1067742



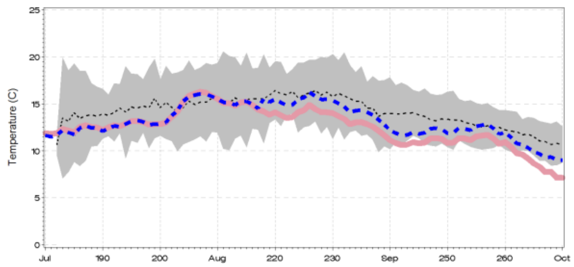
1983 Stewart AHCCD Stn 1067742



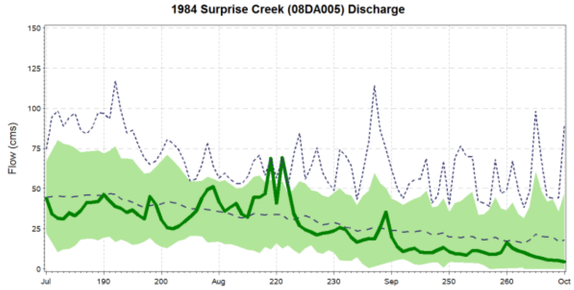
1984 Meziadin River Sockeye Counts (Total Esc: 141,366)



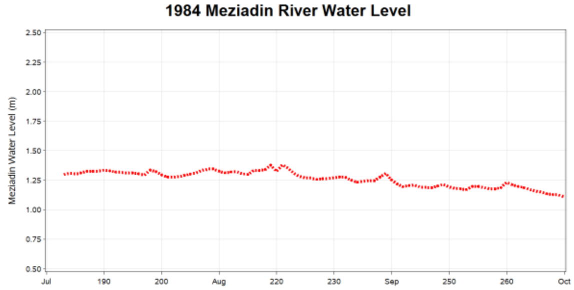
1984 Meziadin Water Temperature



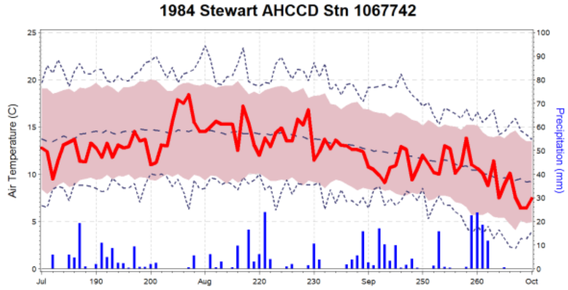
1984 Surprise Creek (08DA005) Discharge



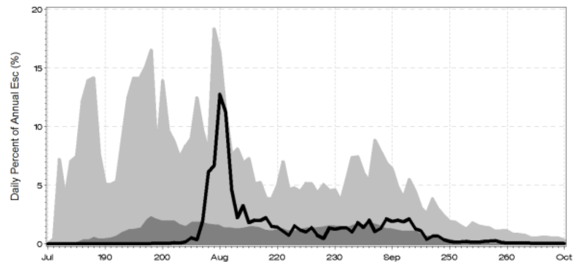
1984 Meziadin River Water Level



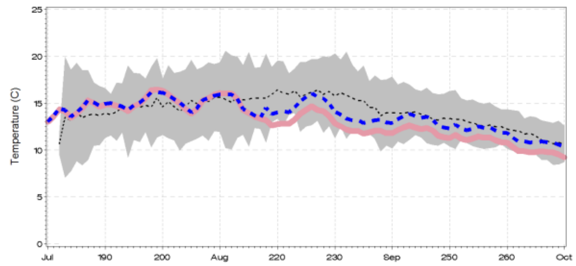
1984 Stewart AHCCD Stn 1067742



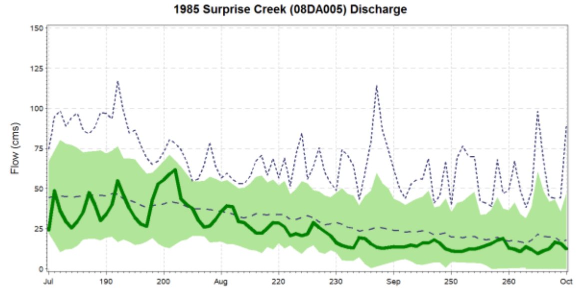
1985 Meziadin River Sockeye Counts (Total Esc: 289,772)



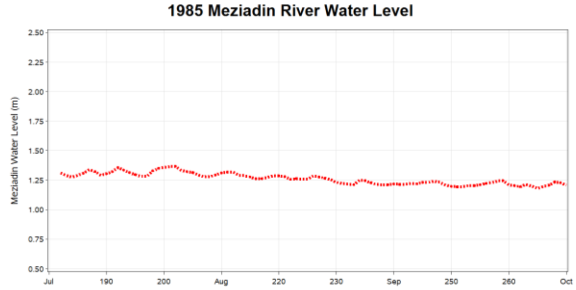
1985 Meziadin Water Temperature



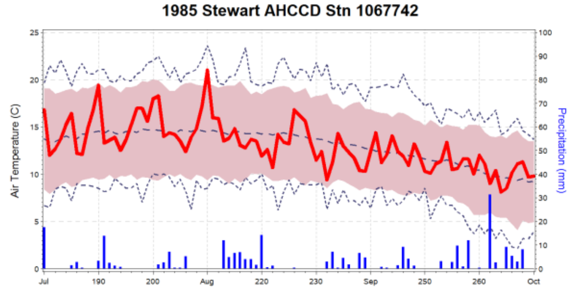
1985 Surprise Creek (08DA005) Discharge



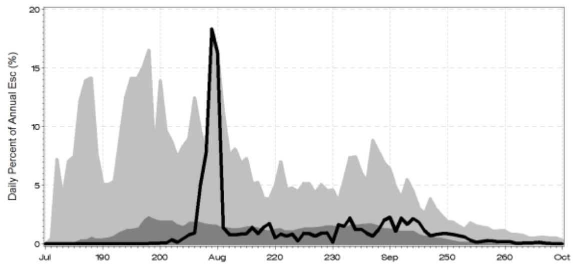
1985 Meziadin River Water Level



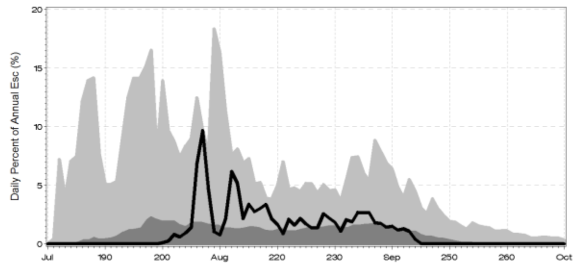
1985 Stewart AHCCD Stn 1067742



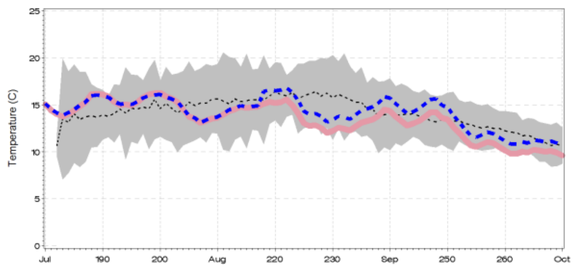
1986 Meziadin River Sockeye Counts (Total Esc: 116,281)



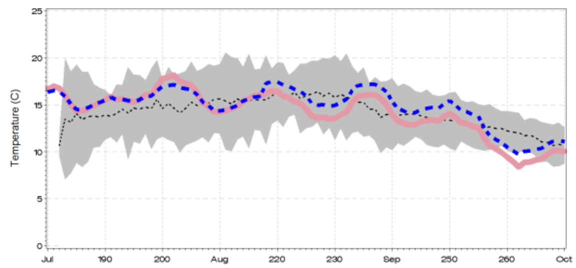
1987 Meziadin River Sockeye Counts (Total Esc: 147,264)



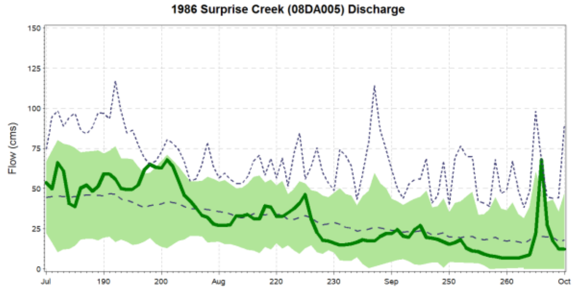
1986 Meziadin Water Temperature



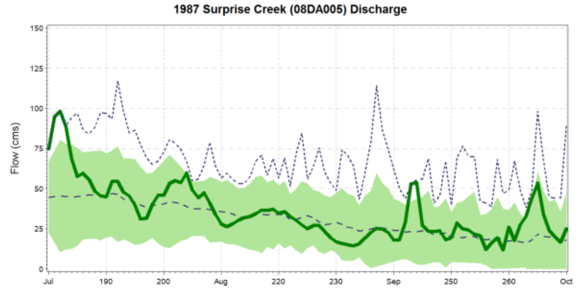
1987 Meziadin Water Temperature



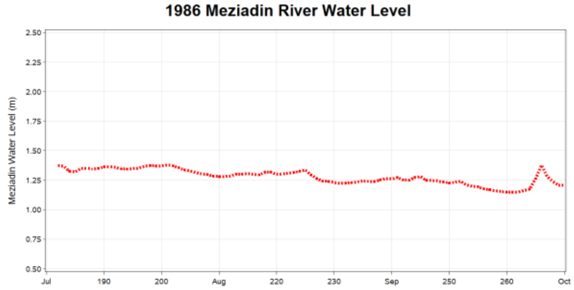
1986 Surprise Creek (08DA005) Discharge



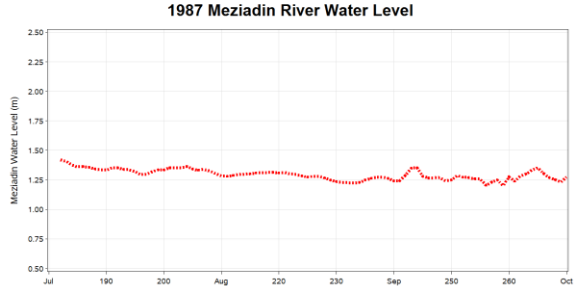
1987 Surprise Creek (08DA005) Discharge



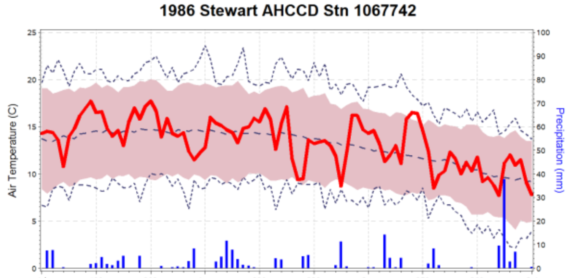
1986 Meziadin River Water Level



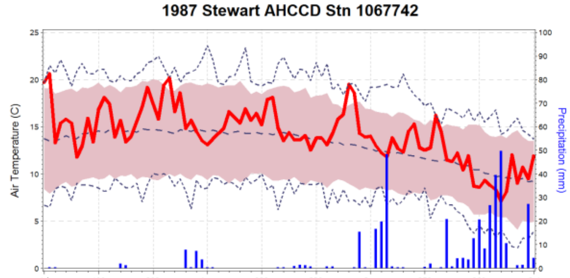
1987 Meziadin River Water Level

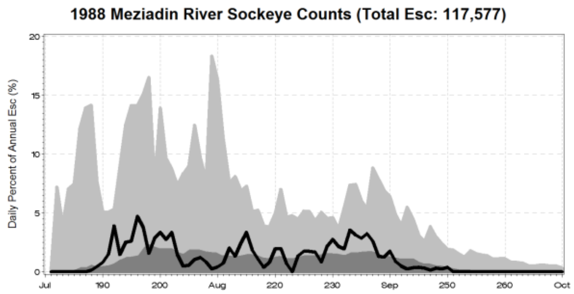


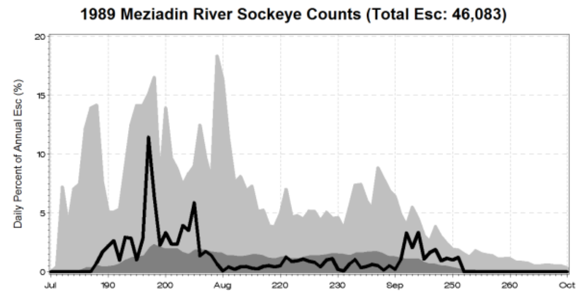
1986 Stewart AHCCD Stn 1067742

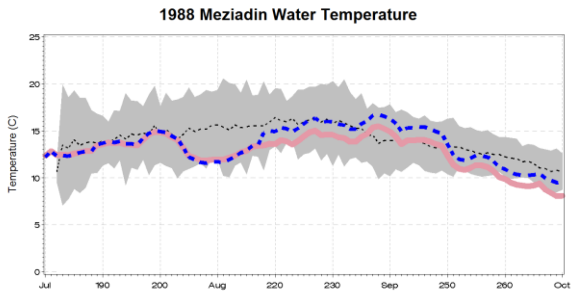


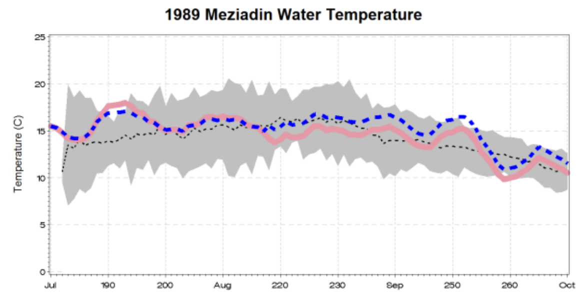
1987 Stewart AHCCD Stn 1067742

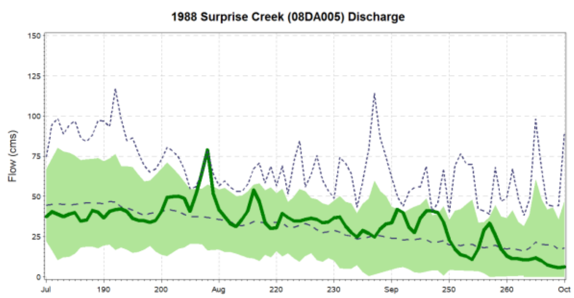


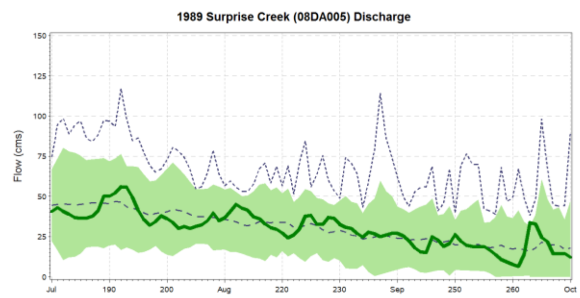

1988 Meziadin River Sockeye Counts (Total Esc: 117,577)
Daily Percent of Annual Esc (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct

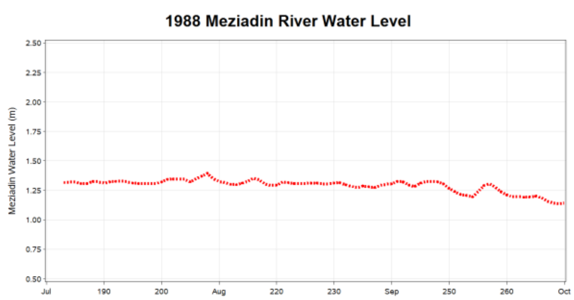

1989 Meziadin River Sockeye Counts (Total Esc: 46,083)
Daily Percent of Annual Esc (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct

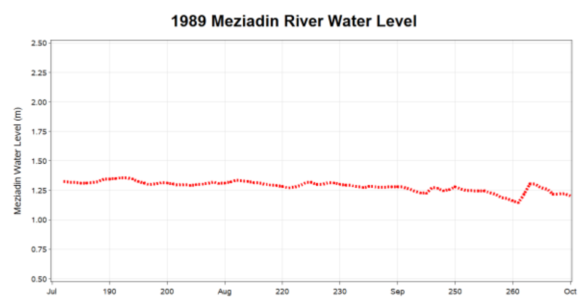

1988 Meziadin Water Temperature
Temperature (C)

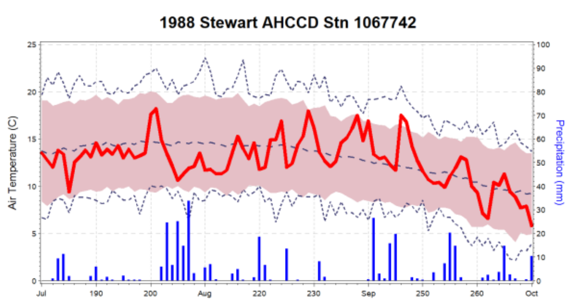

1989 Meziadin Water Temperature
Temperature (C)

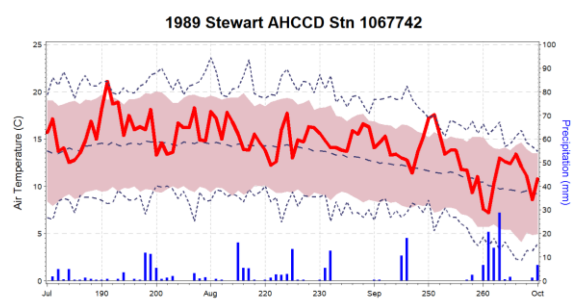

1988 Surprise Creek (08DA005) Discharge
Flow (cms)


1989 Surprise Creek (08DA005) Discharge
Flow (cms)

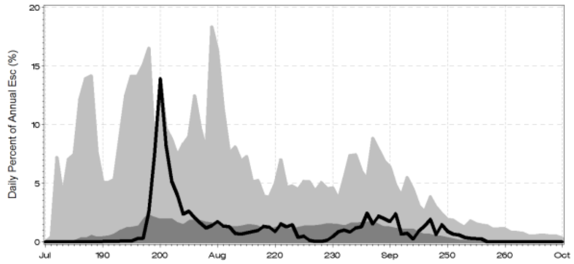

1988 Meziadin River Water Level
Meziadin Water Level (m)


1989 Meziadin River Water Level
Meziadin Water Level (m)

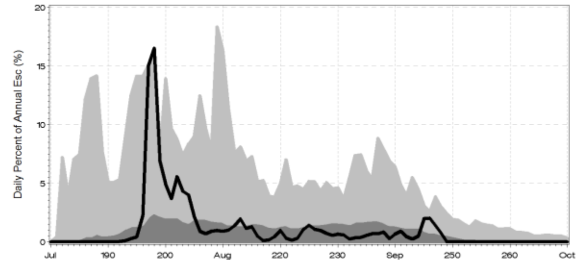

1988 Stewart AHCCD Stn 1067742
Air Temperature (C)
Precipitation (mm)


1989 Stewart AHCCD Stn 1067742
Air Temperature (C)
Precipitation (mm)

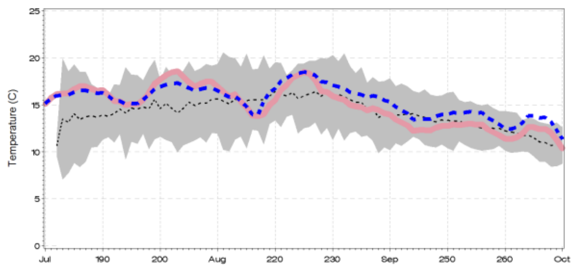
1990 Meziadin River Sockeye Counts (Total Esc: 123,958)



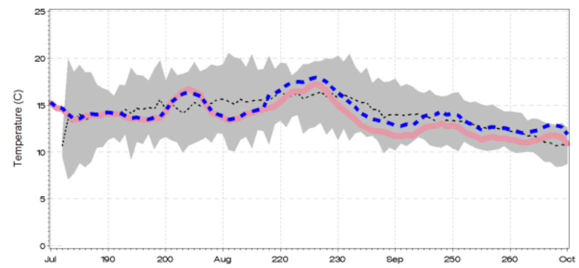
1991 Meziadin River Sockeye Counts (Total Esc: 232,557)



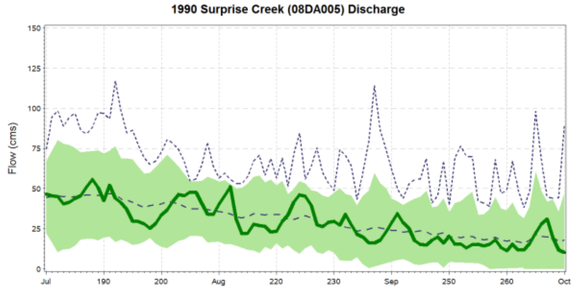
1990 Meziadin Water Temperature



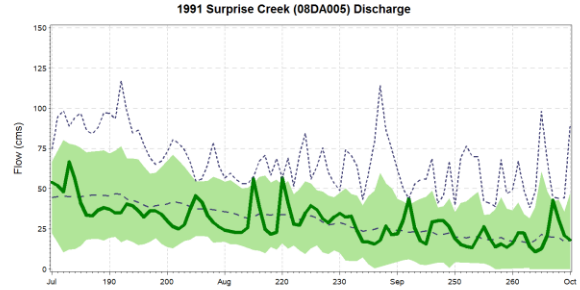
1991 Meziadin Water Temperature



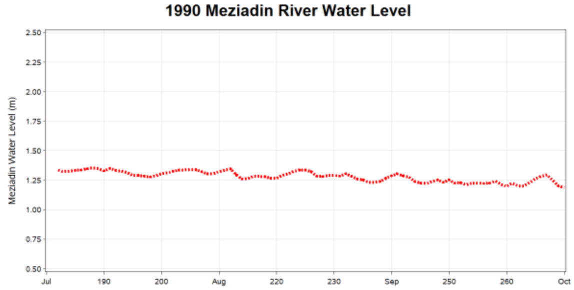
1990 Surprise Creek (08DA005) Discharge



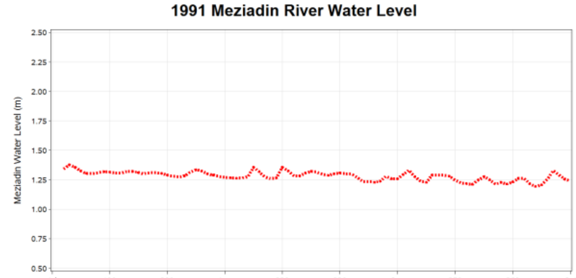
1991 Surprise Creek (08DA005) Discharge



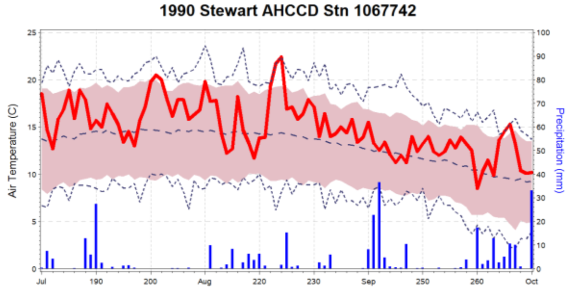
1990 Meziadin River Water Level



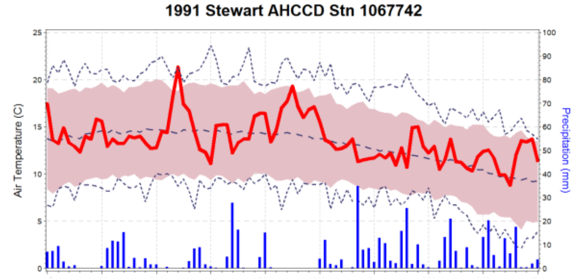
1991 Meziadin River Water Level



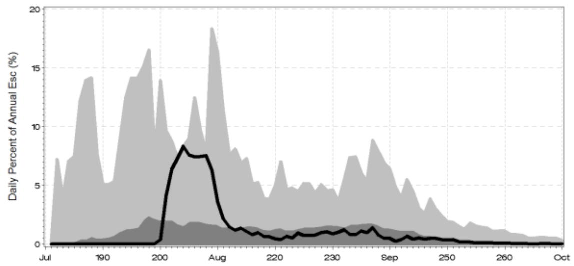
1990 Stewart AHCCD Stn 1067742



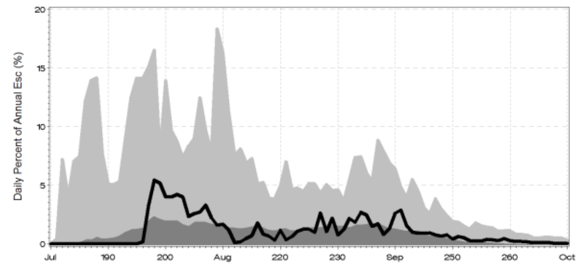
1991 Stewart AHCCD Stn 1067742



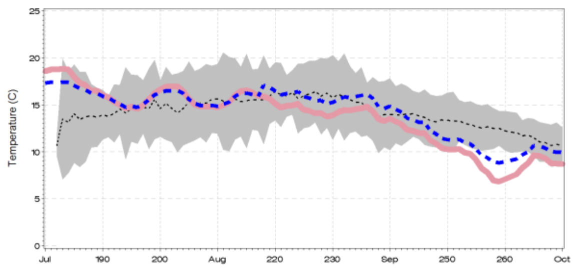
1992 Meziadin River Sockeye Counts (Total Esc: 600,743)



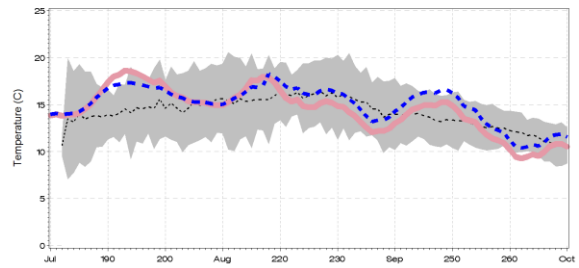
1993 Meziadin River Sockeye Counts (Total Esc: 393,532)



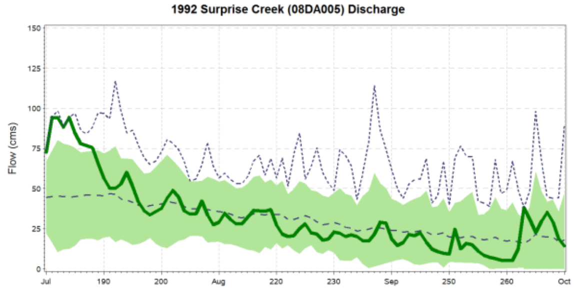
1992 Meziadin Water Temperature



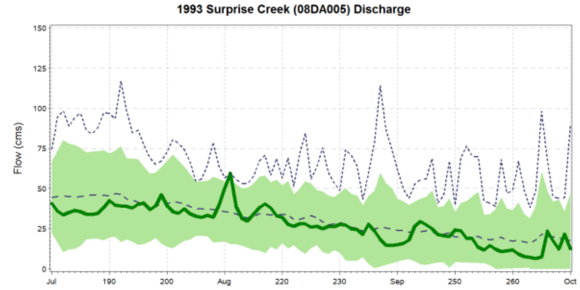
1993 Meziadin Water Temperature



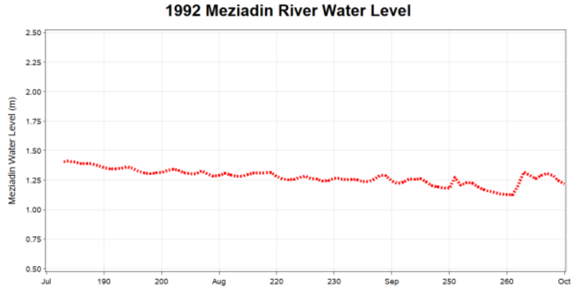
1992 Surprise Creek (08DA005) Discharge



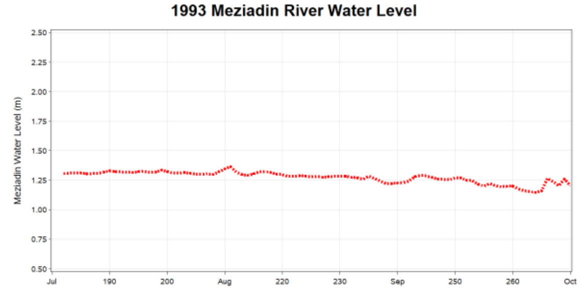
1993 Surprise Creek (08DA005) Discharge



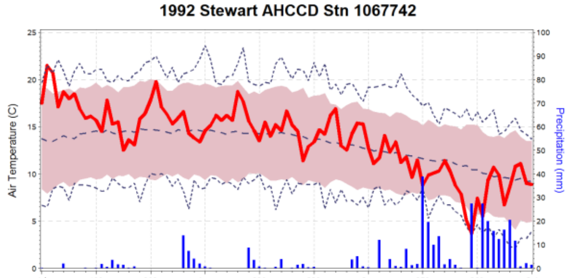
1992 Meziadin River Water Level



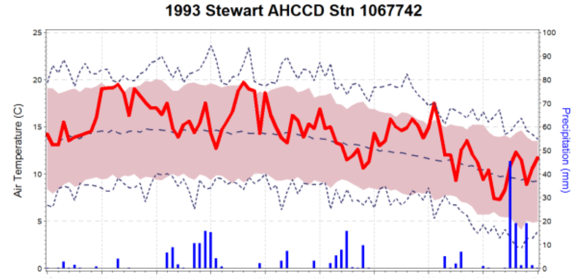
1993 Meziadin River Water Level



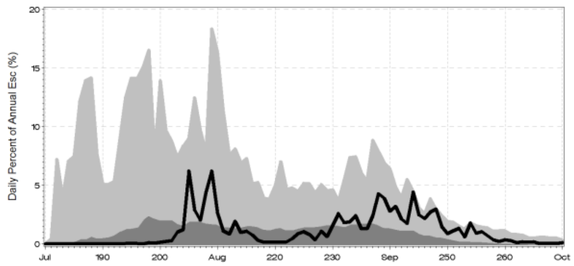
1992 Stewart AHCCD Stn 1067742



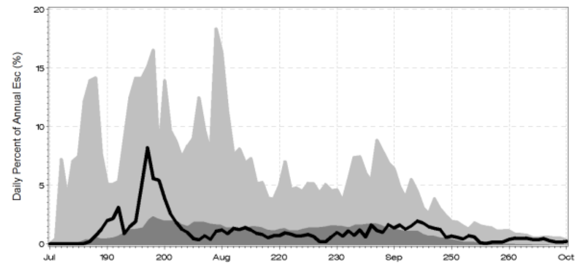
1993 Stewart AHCCD Stn 1067742



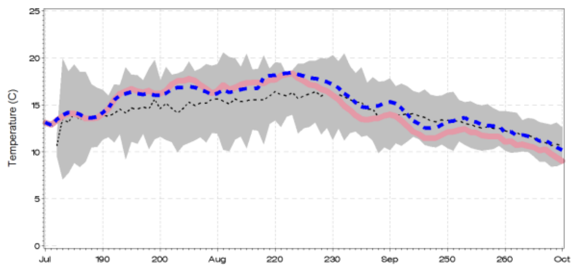
1994 Meziadin River Sockeye Counts (Total Esc: 164,462)



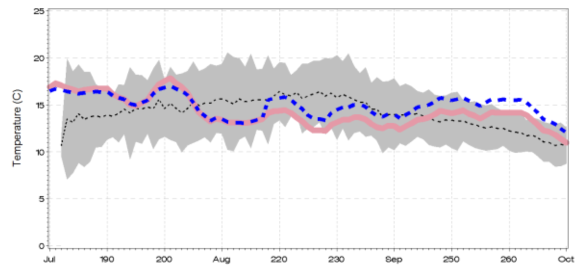
1995 Meziadin River Sockeye Counts (Total Esc: 212,192)



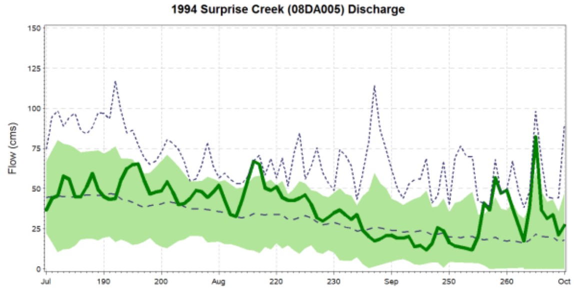
1994 Meziadin Water Temperature



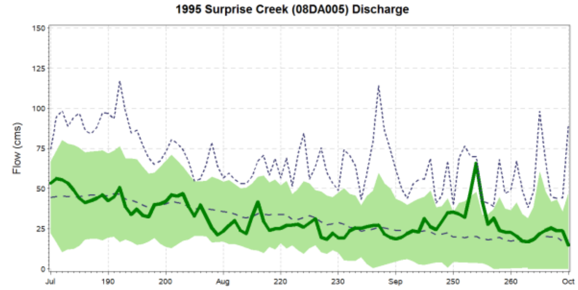
1995 Meziadin Water Temperature



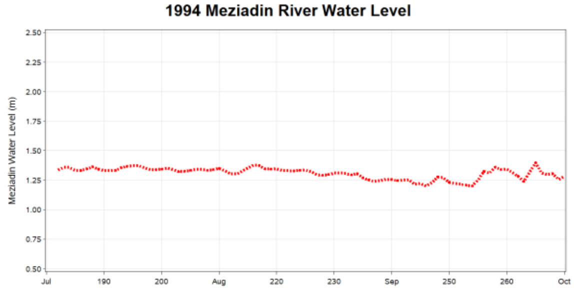
1994 Surprise Creek (08DA005) Discharge



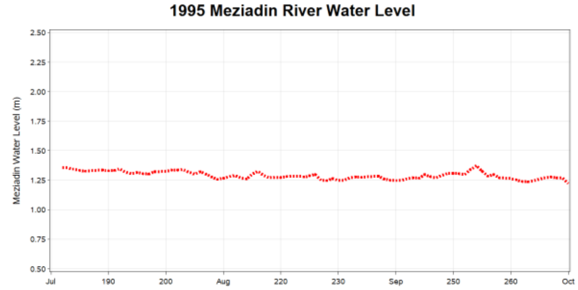
1995 Surprise Creek (08DA005) Discharge



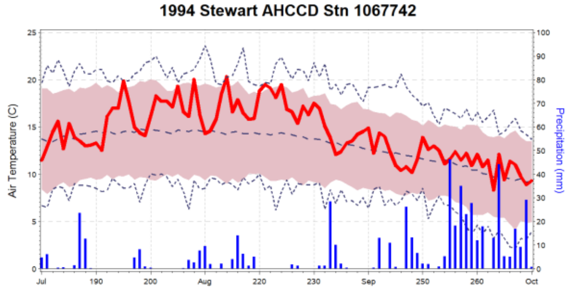
1994 Meziadin River Water Level



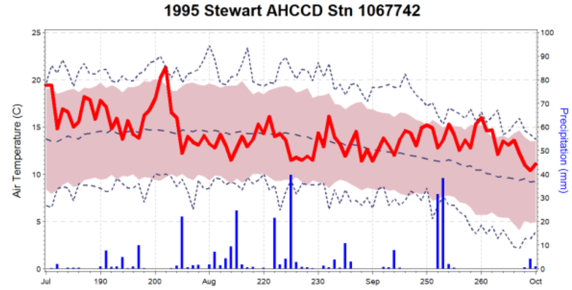
1995 Meziadin River Water Level



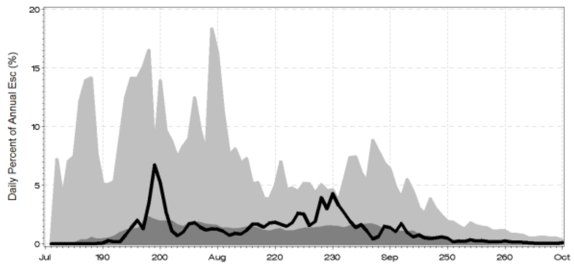
1994 Stewart AHCCD Stn 1067742



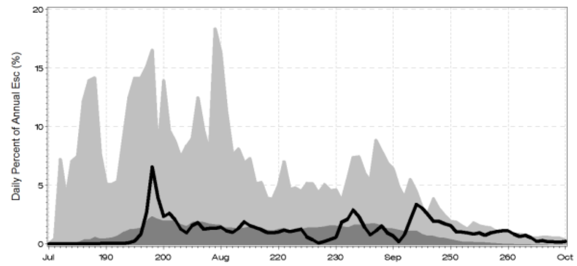
1995 Stewart AHCCD Stn 1067742



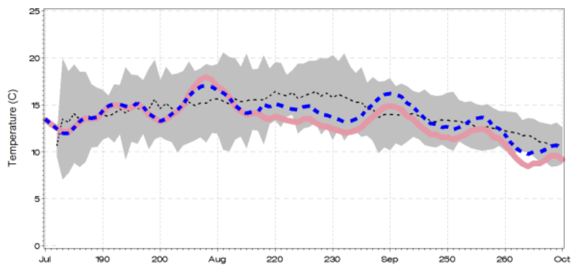
1996 Meziadin River Sockeye Counts (Total Esc: 183,542)



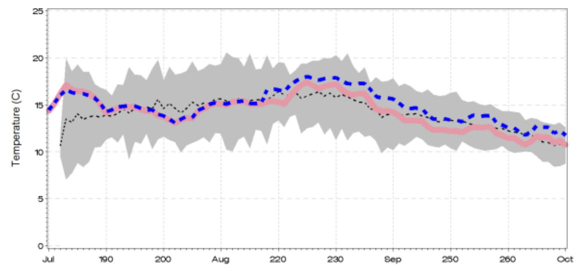
1997 Meziadin River Sockeye Counts (Total Esc: 160,220)



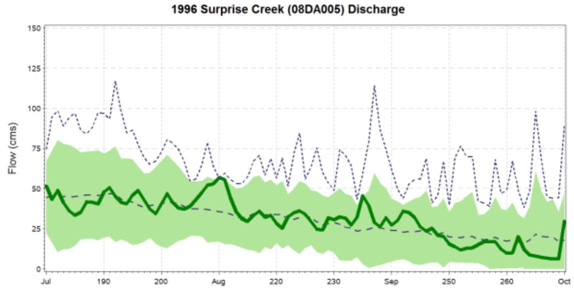
1996 Meziadin Water Temperature



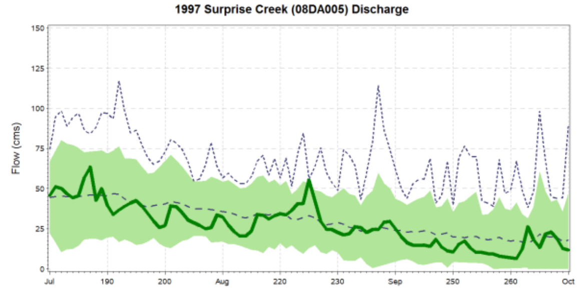
1997 Meziadin Water Temperature



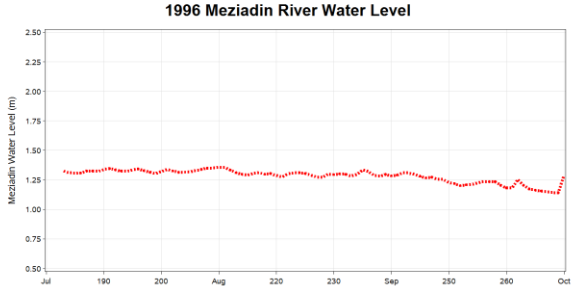
1996 Surprise Creek (08DA005) Discharge



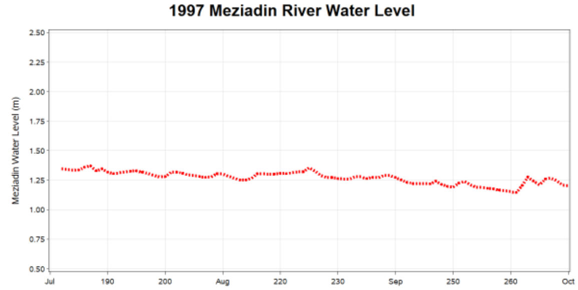
1997 Surprise Creek (08DA005) Discharge



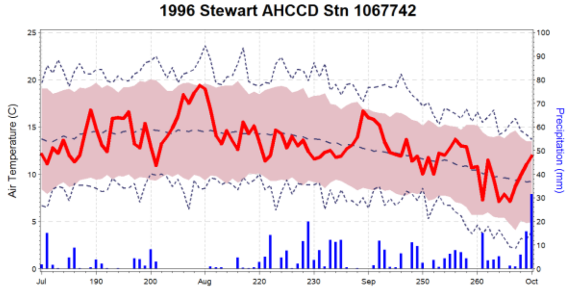
1996 Meziadin River Water Level



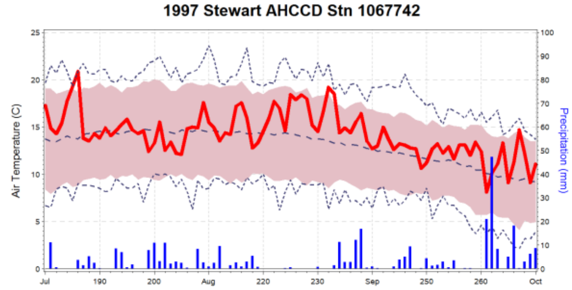
1997 Meziadin River Water Level



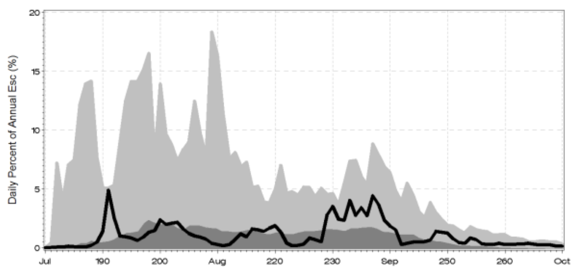
1996 Stewart AHCCD Stn 1067742



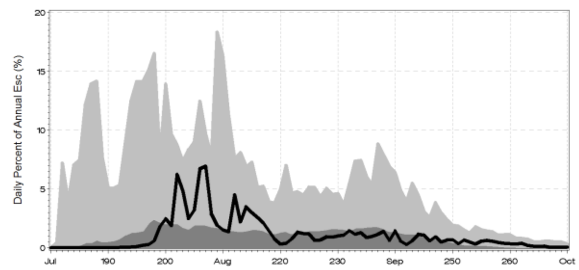
1997 Stewart AHCCD Stn 1067742



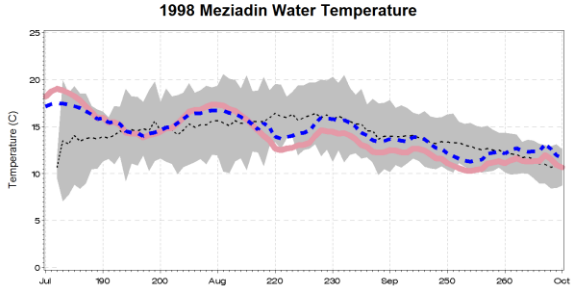
1998 Meziadin River Sockeye Counts (Total Esc: 170,177)



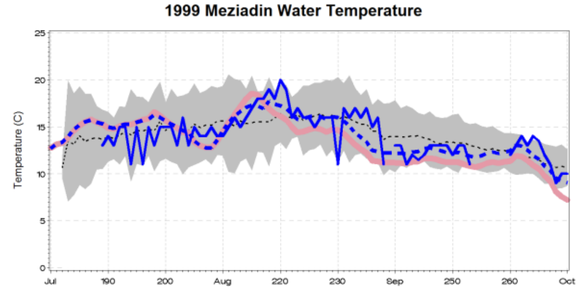
1999 Meziadin River Sockeye Counts (Total Esc: 184,677)



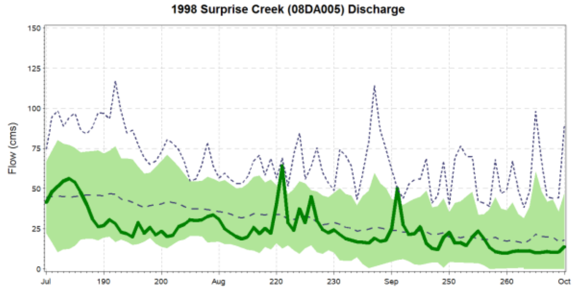
1998 Meziadin Water Temperature



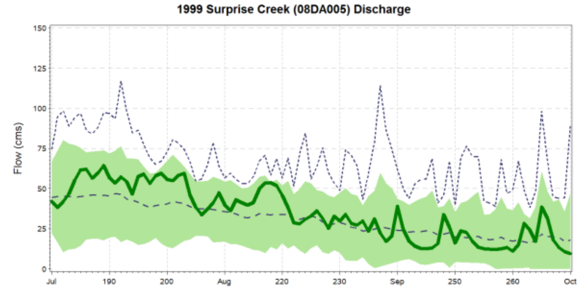
1999 Meziadin Water Temperature



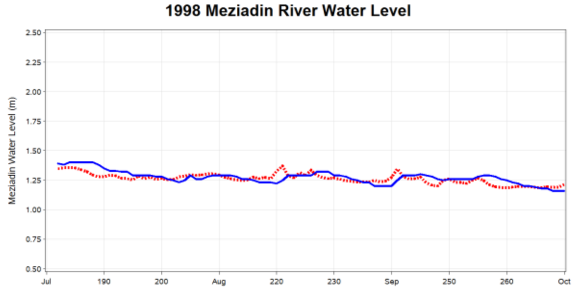
1998 Surprise Creek (08DA005) Discharge



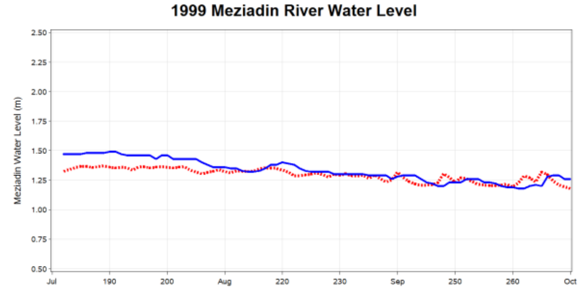
1999 Surprise Creek (08DA005) Discharge



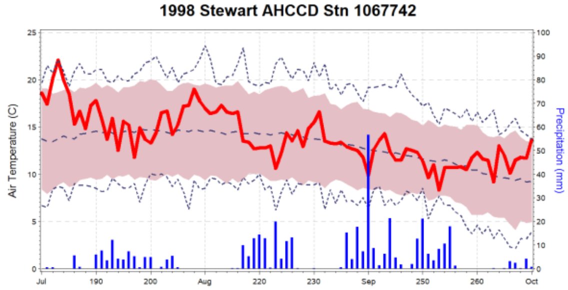
1998 Meziadin River Water Level



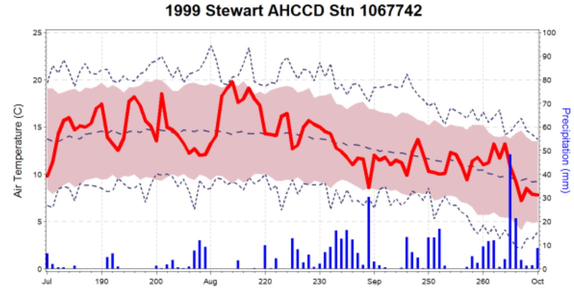
1999 Meziadin River Water Level



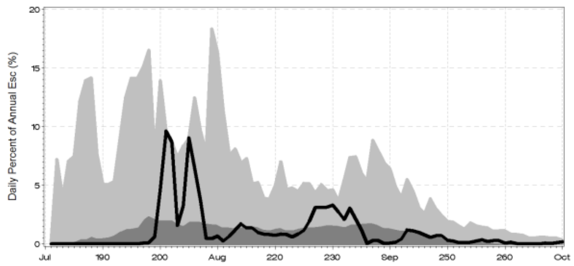
1998 Stewart AHCCD Stn 1067742



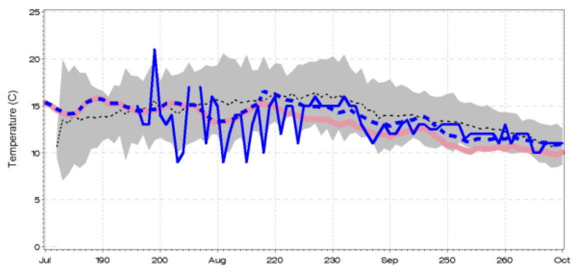
1999 Stewart AHCCD Stn 1067742



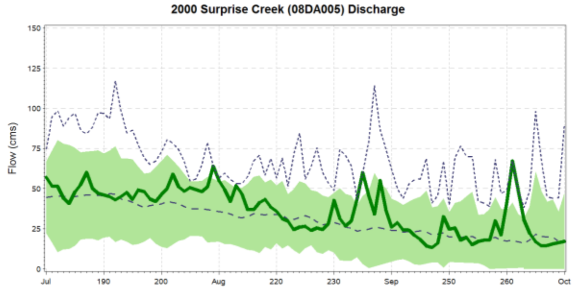
2000 Meziadin River Sockeye Counts (Total Esc: 138,128)



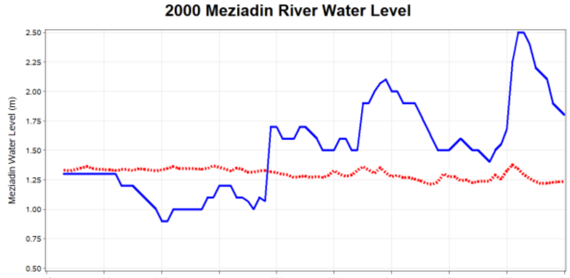
2000 Meziadin Water Temperature



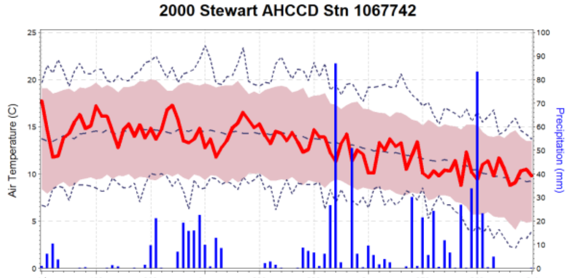
2000 Surprise Creek (08DA005) Discharge



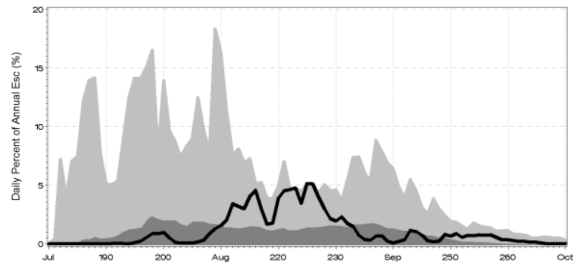
2000 Meziadin River Water Level



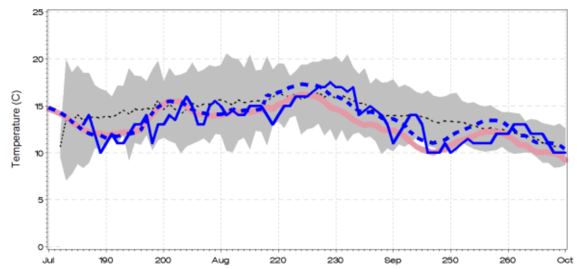
2000 Stewart AHCCD Stn 1067742



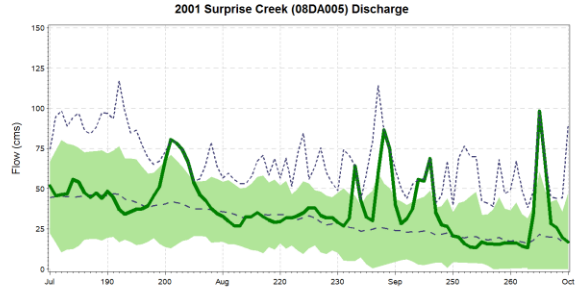
2001 Meziadin River Sockeye Counts (Total Esc: 133,865)



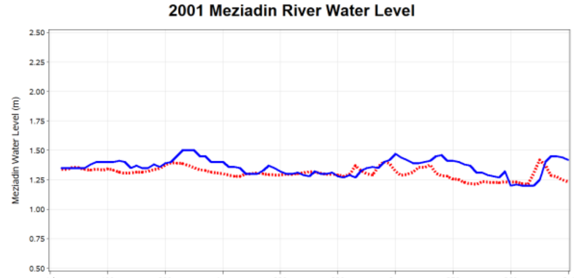
2001 Meziadin Water Temperature



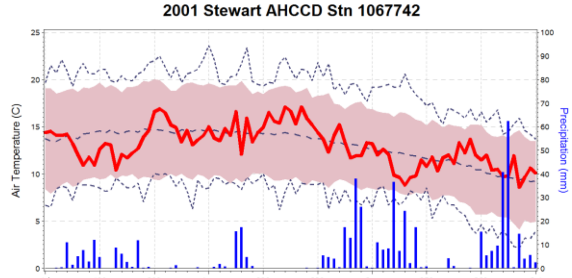
2001 Surprise Creek (08DA005) Discharge



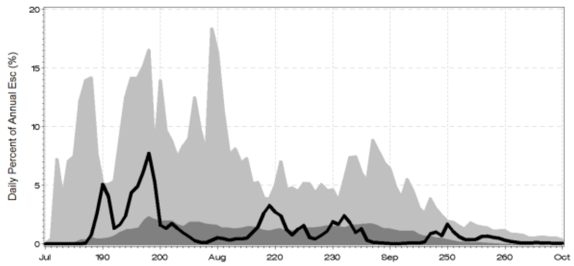
2001 Meziadin River Water Level



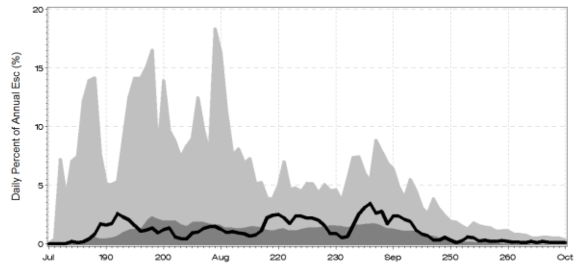
2001 Stewart AHCCD Stn 1067742



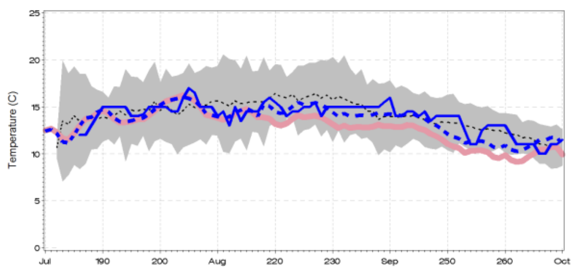
2002 Meziadin River Sockeye Counts (Total Esc: 336,067)



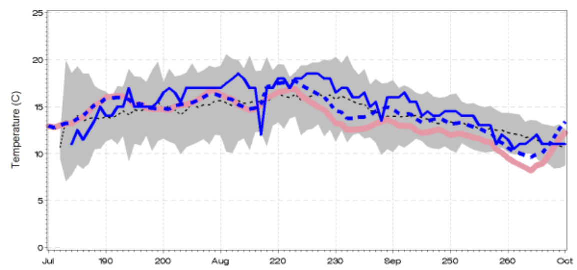
2003 Meziadin River Sockeye Counts (Total Esc: 204,574)



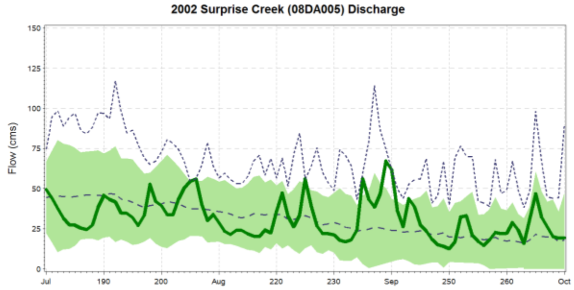
2002 Meziadin Water Temperature



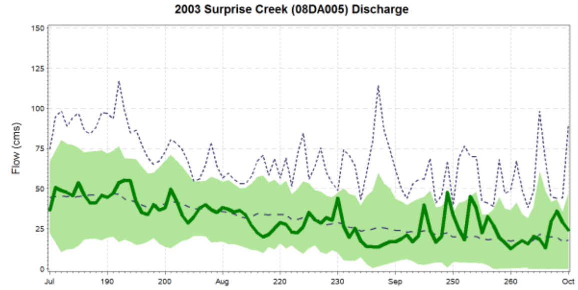
2003 Meziadin Water Temperature



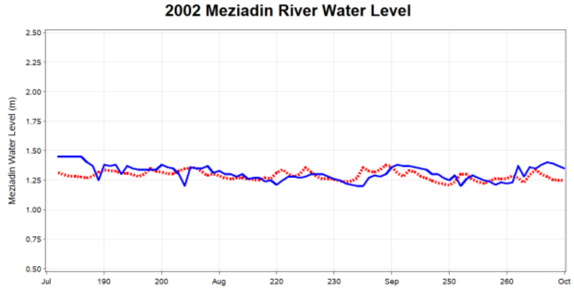
2002 Surprise Creek (08DA005) Discharge



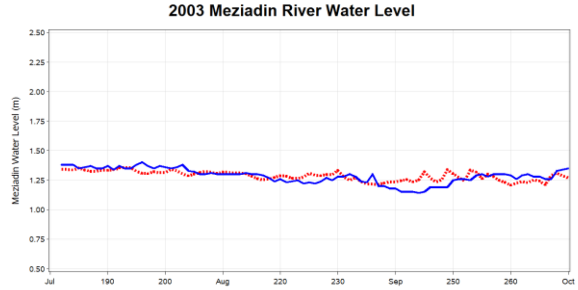
2003 Surprise Creek (08DA005) Discharge



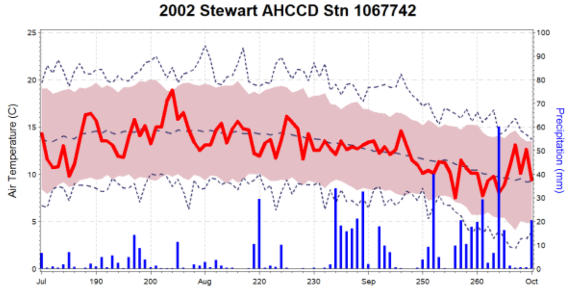
2002 Meziadin River Water Level



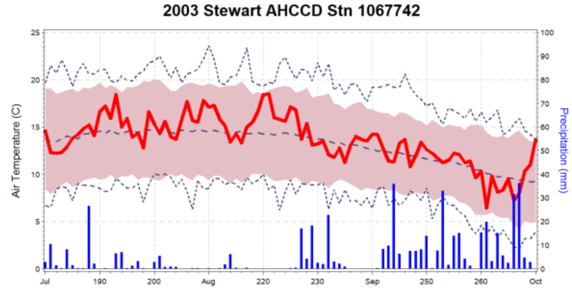
2003 Meziadin River Water Level



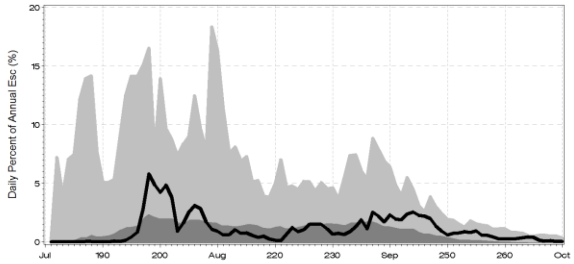
2002 Stewart AHCCD Stn 1067742



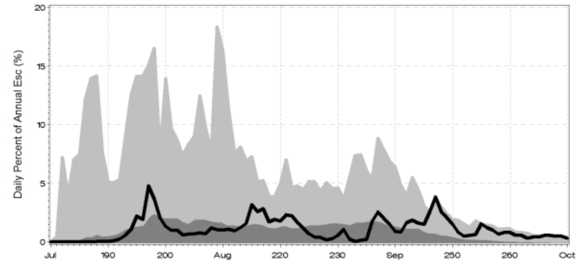
2003 Stewart AHCCD Stn 1067742



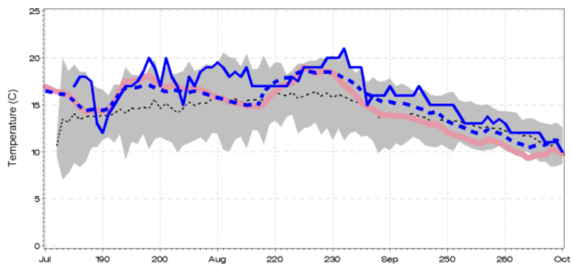
2004 Meziadin River Sockeye Counts (Total Esc: 143,783)



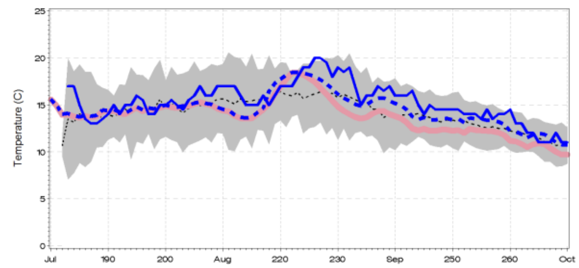
2005 Meziadin River Sockeye Counts (Total Esc: 155,416)



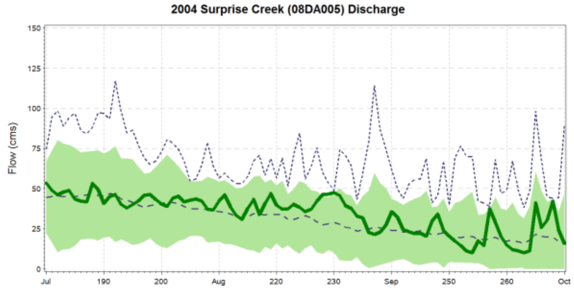
2004 Meziadin Water Temperature



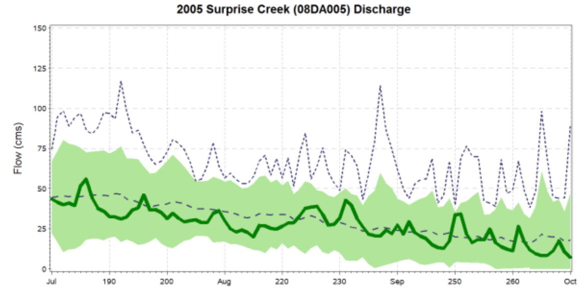
2005 Meziadin Water Temperature



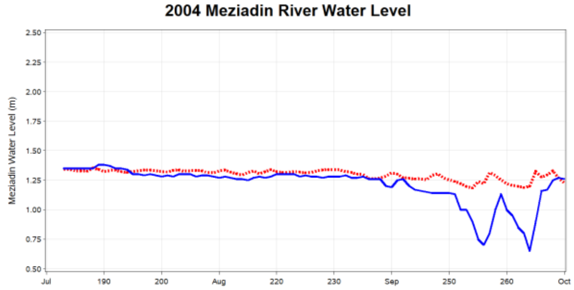
2004 Surprise Creek (08DA005) Discharge



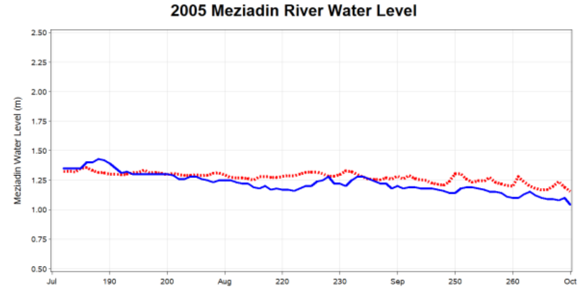
2005 Surprise Creek (08DA005) Discharge



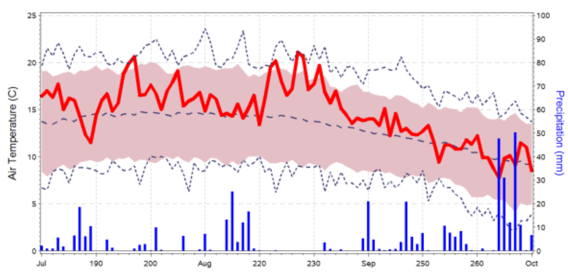
2004 Meziadin River Water Level



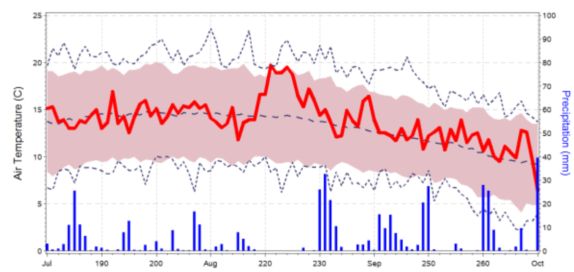
2005 Meziadin River Water Level



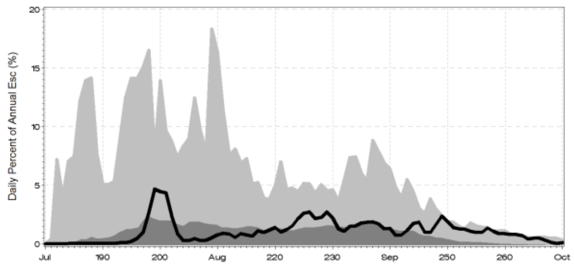
2004 Stewart AHCCD Stn 1067742



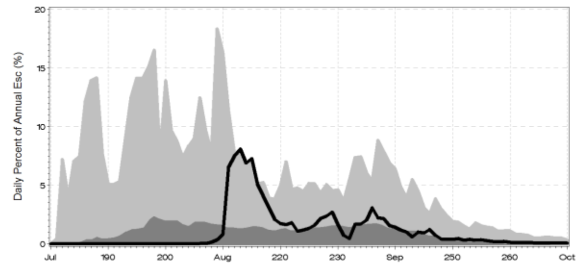
2005 Stewart AHCCD Stn 1067742



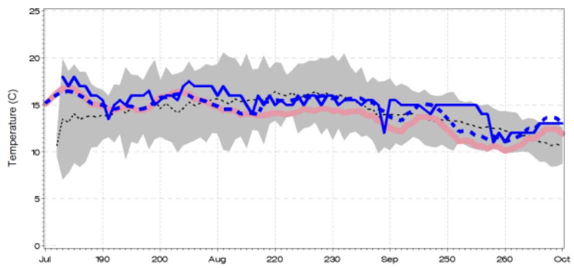
2006 Meziadin River Sockeye Counts (Total Esc: 147,610)



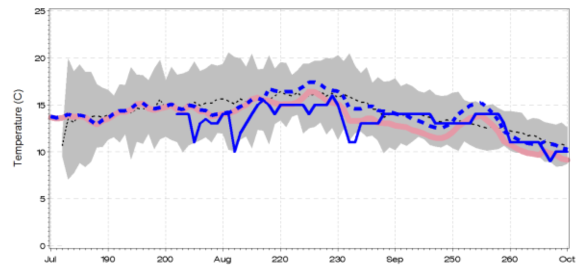
2007 Meziadin River Sockeye Counts (Total Esc: 108,329)



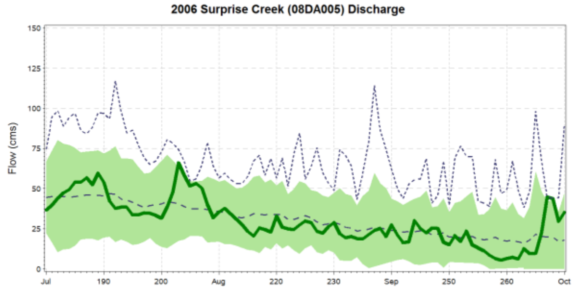
2006 Meziadin Water Temperature



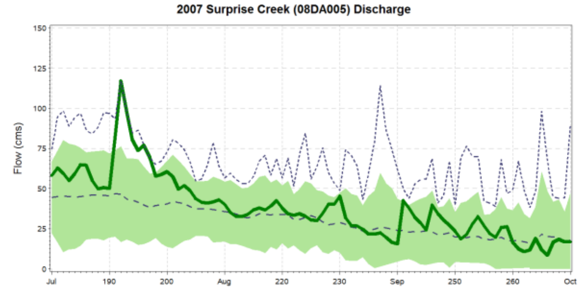
2007 Meziadin Water Temperature



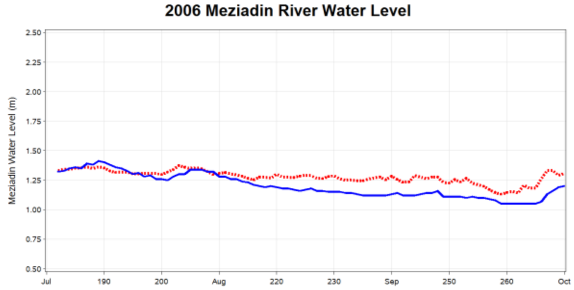
2006 Surprise Creek (08DA005) Discharge



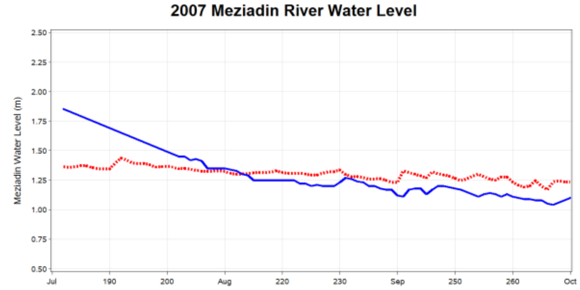
2007 Surprise Creek (08DA005) Discharge



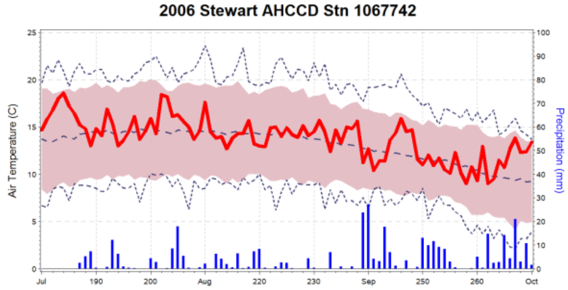
2006 Meziadin River Water Level



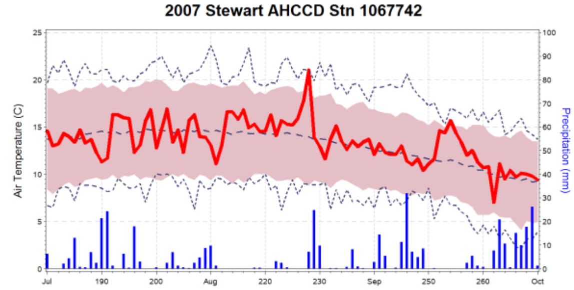
2007 Meziadin River Water Level



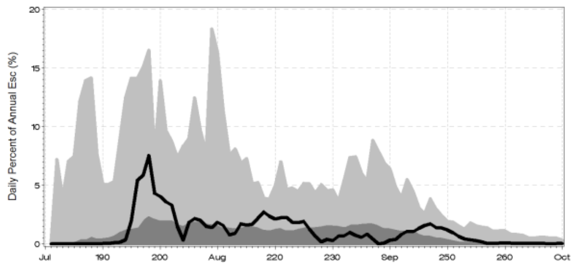
2006 Stewart AHCCD Stn 1067742



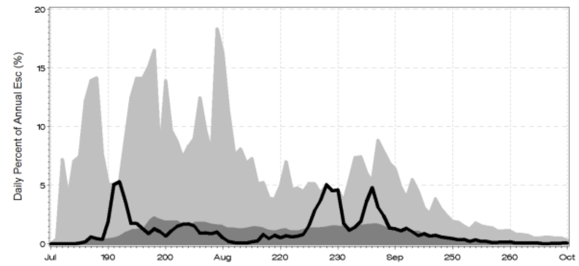
2007 Stewart AHCCD Stn 1067742



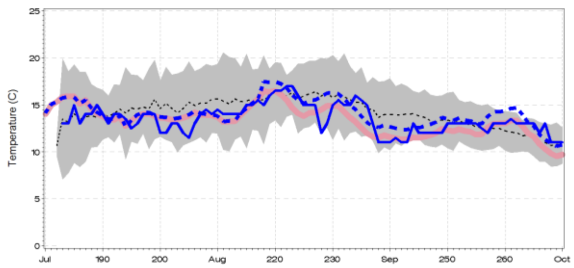
2008 Meziadin River Sockeye Counts (Total Esc: 153,342)



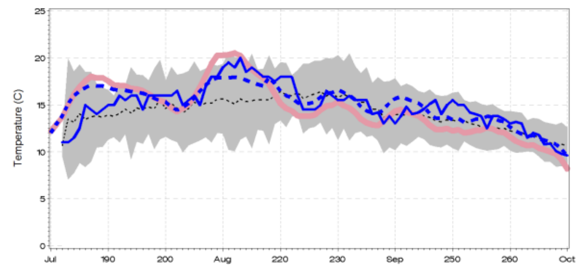
2009 Meziadin River Sockeye Counts (Total Esc: 180,356)



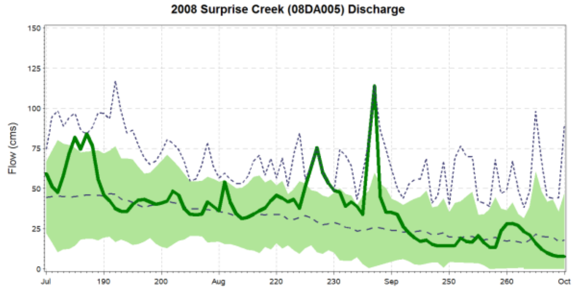
2008 Meziadin Water Temperature



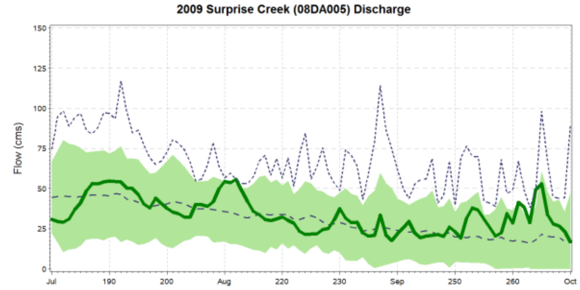
2009 Meziadin Water Temperature



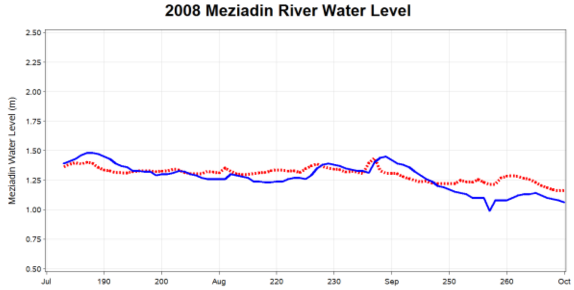
2008 Surprise Creek (08DA005) Discharge



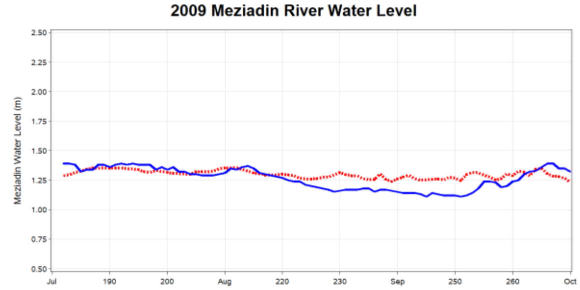
2009 Surprise Creek (08DA005) Discharge



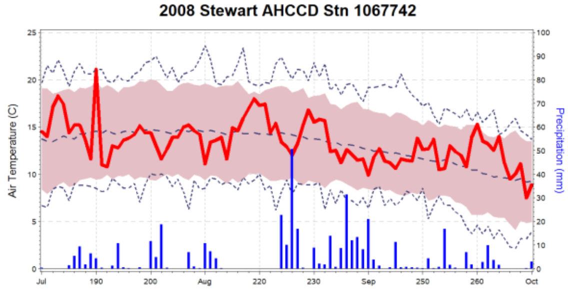
2008 Meziadin River Water Level



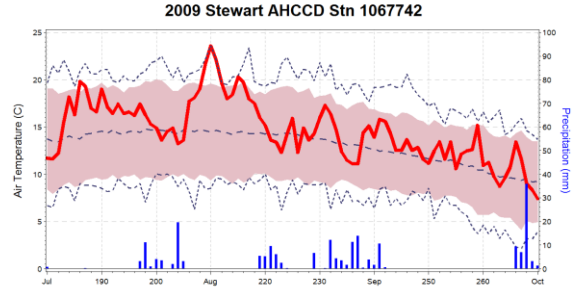
2009 Meziadin River Water Level



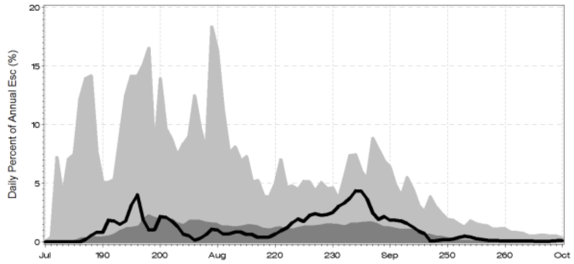
2008 Stewart AHCCD Stn 1067742



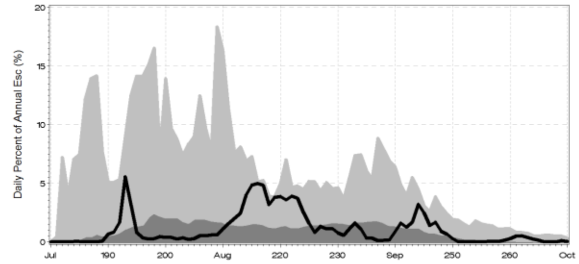
2009 Stewart AHCCD Stn 1067742



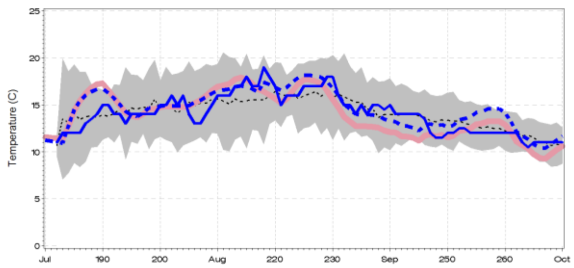
2010 Meziadin River Sockeye Counts (Total Esc: 163,688)



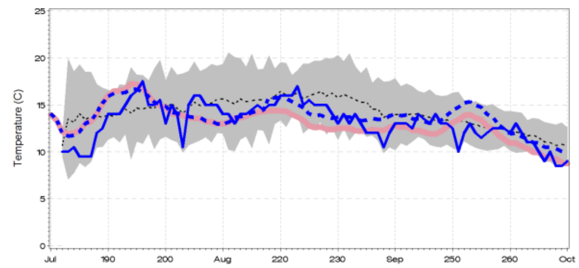
2011 Meziadin River Sockeye Counts (Total Esc: 172,354)



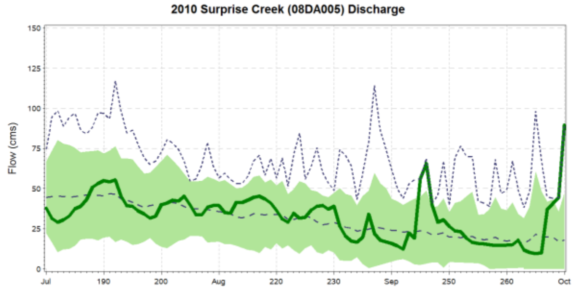
2010 Meziadin Water Temperature



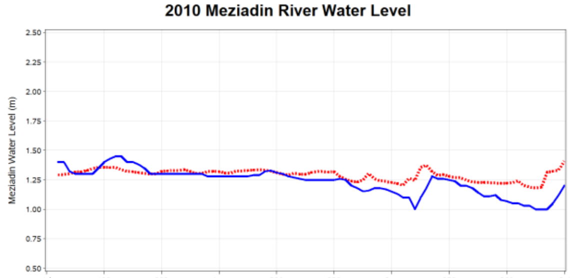
2011 Meziadin Water Temperature



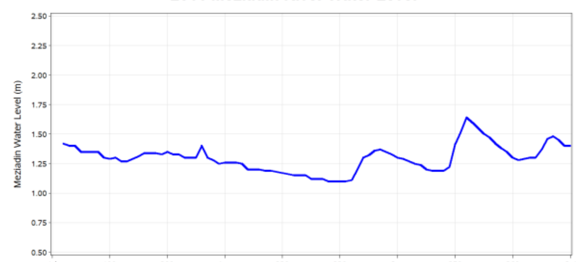
2010 Surprise Creek (08DA005) Discharge



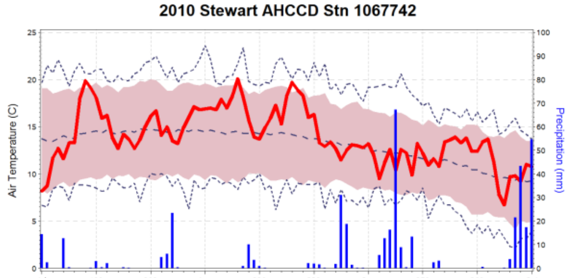
2010 Meziadin River Water Level



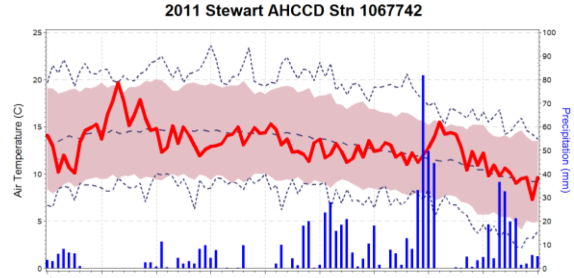
2011 Meziadin River Water Level



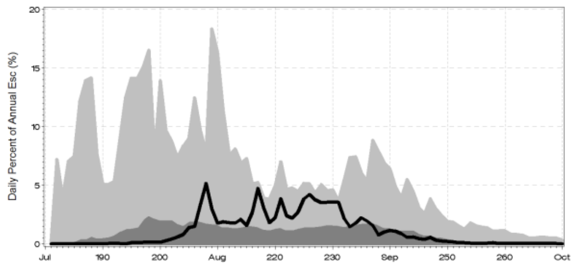
2010 Stewart AHCCD Stn 1067742



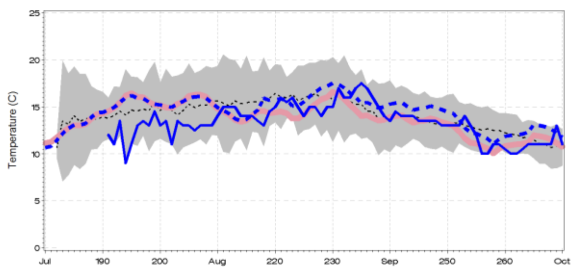
2011 Stewart AHCCD Stn 1067742



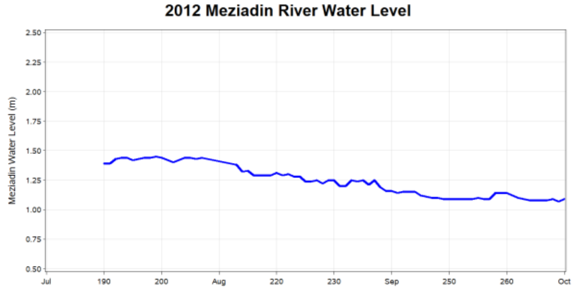
2012 Meziadin River Sockeye Counts (Total Esc: 146,668)



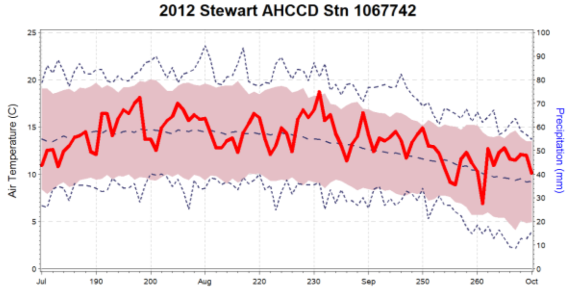
2012 Meziadin Water Temperature



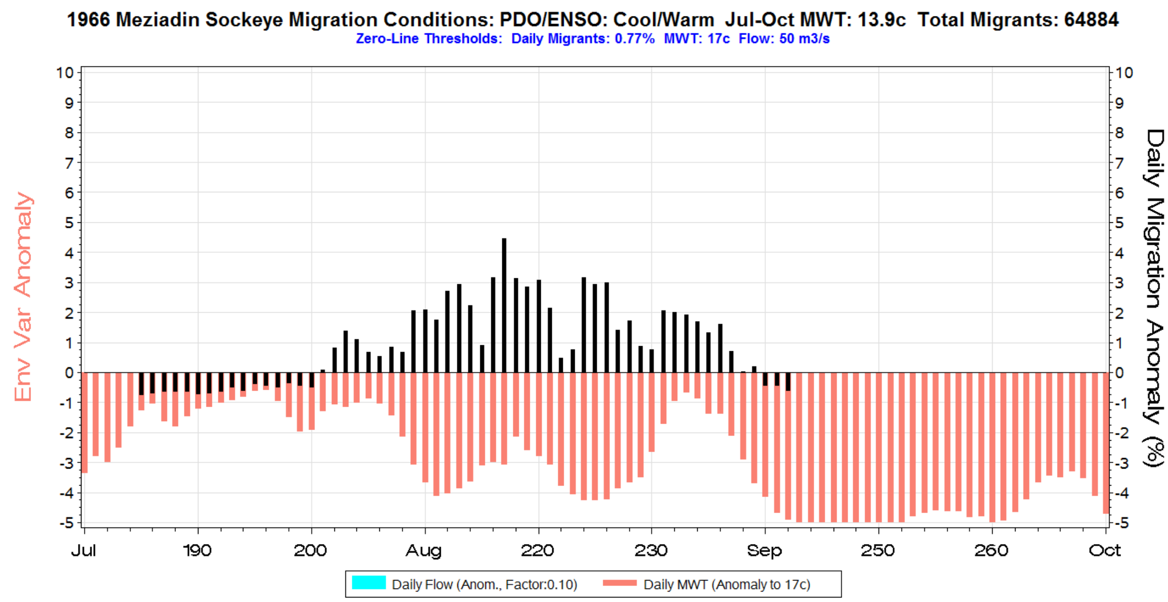
2012 Meziadin River Water Level

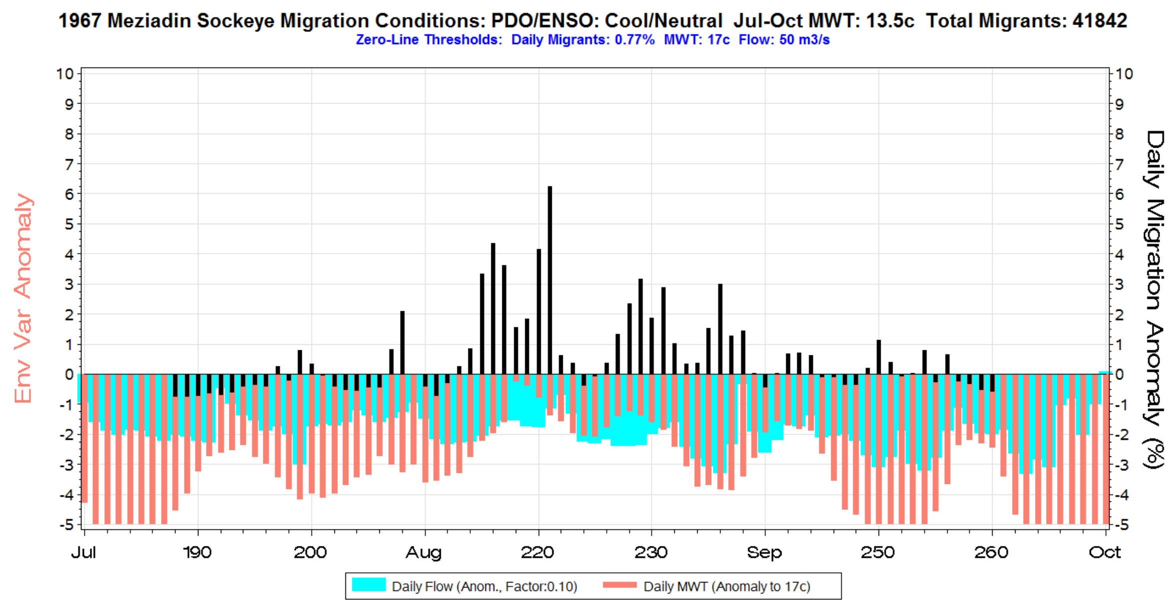


2012 Stewart AHCCD Stn 1067742



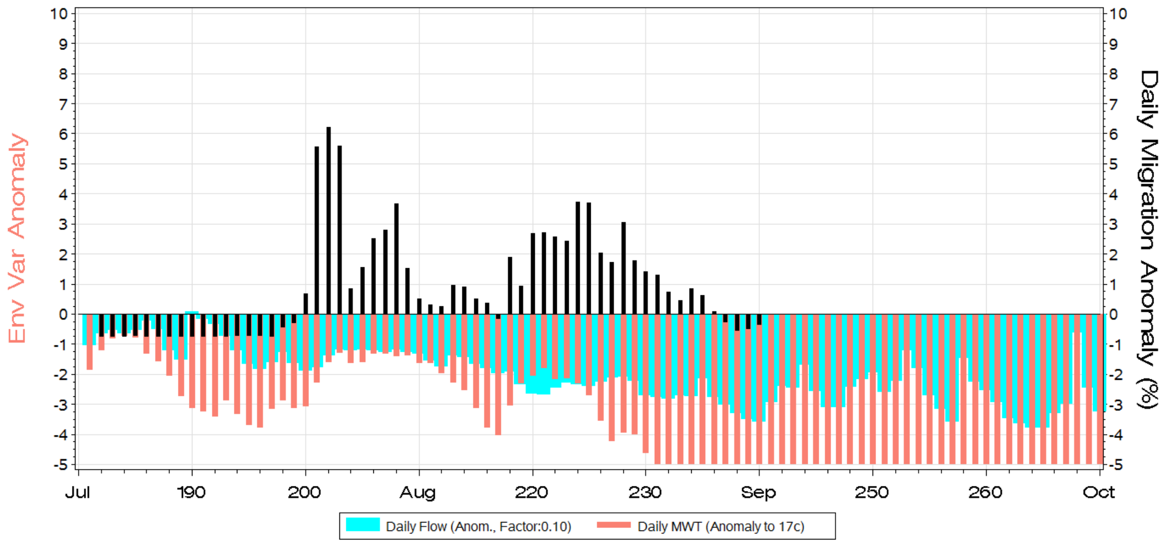
Appendix D. Annual anomaly plot for Meziadin migration, Meziadin River water temperature (estimated), and flow indicator variable *Surprise Creek* discharge (factored by 0.1 to fit on y-axis), 1976 (top), 1980 (bottom). Zero-line thresholds: (a) Daily migration rate = 0.77% (50th percentile of non-zero daily migration rates (1966-2012); (b) water temperature = 17°C (~90th percentile); discharge = 50 cms (~90th percentile).





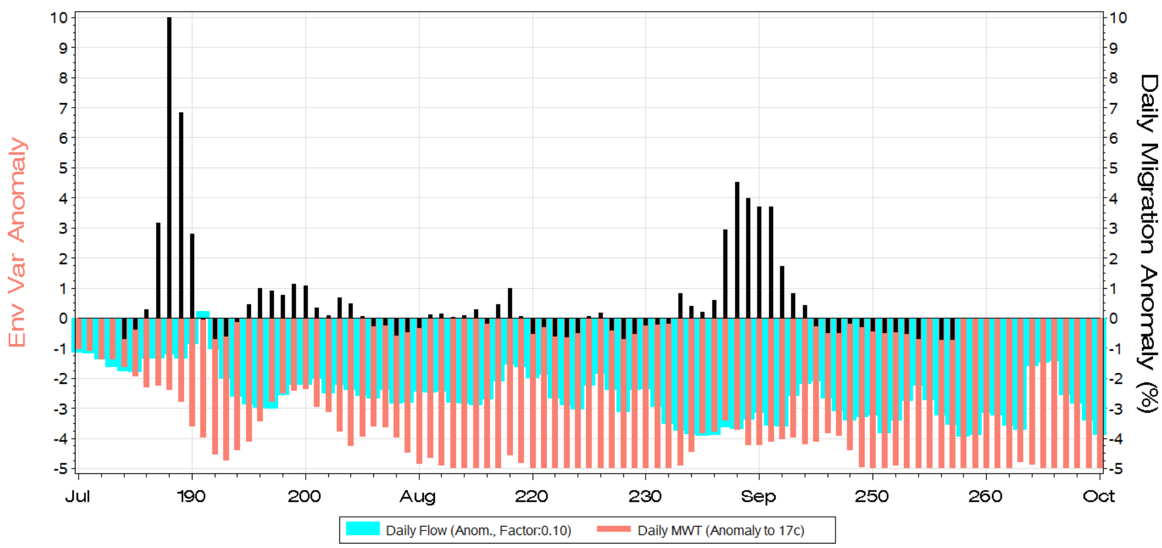
1968 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Oct MWT: 12.5c Total Migrants: 72087

Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s

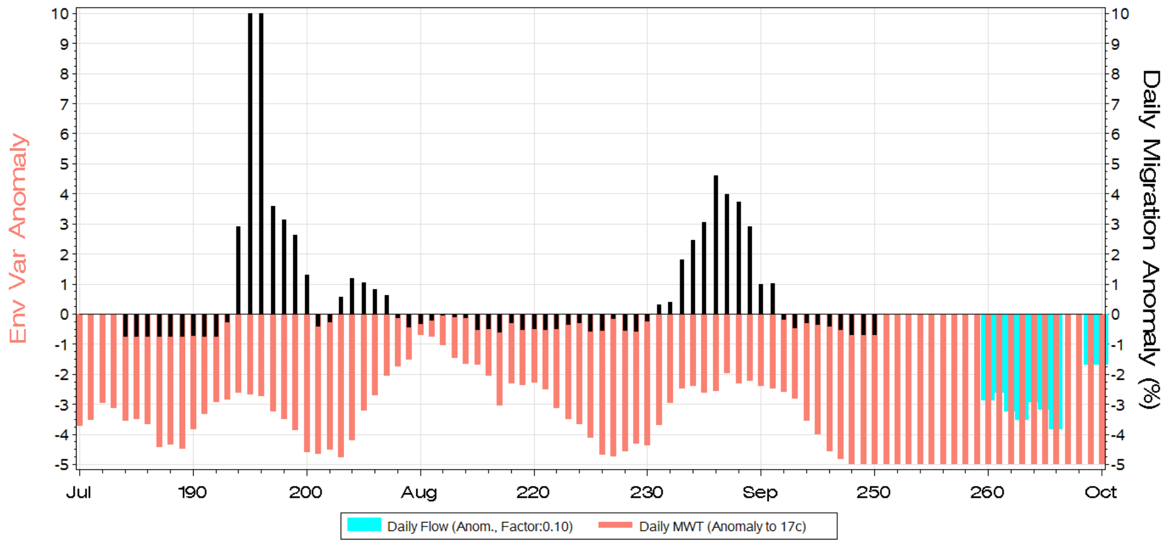


1969 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Oct MWT: 12.6c Total Migrants: 135798

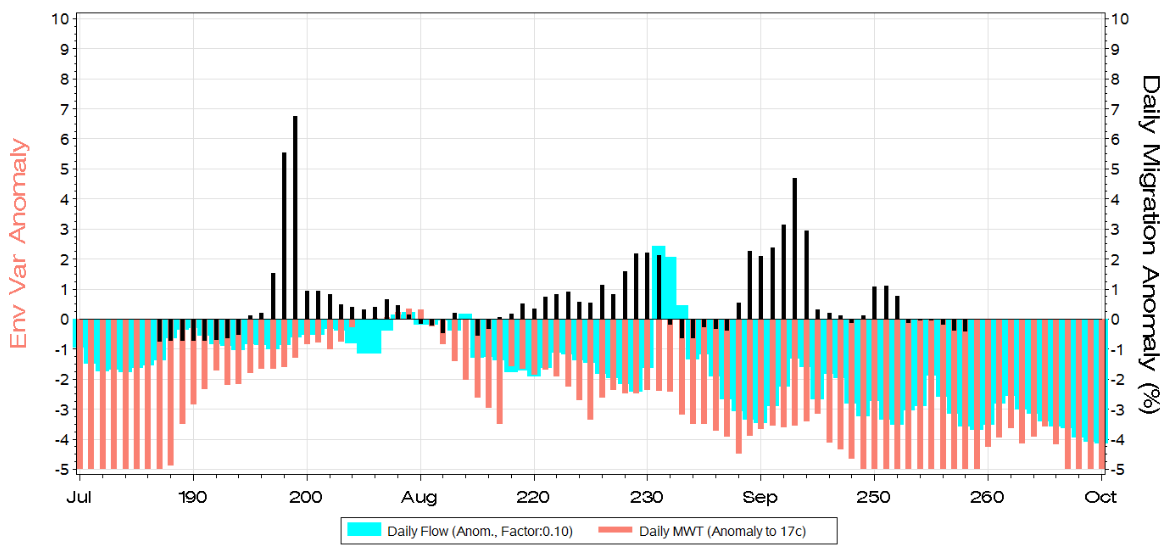
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s

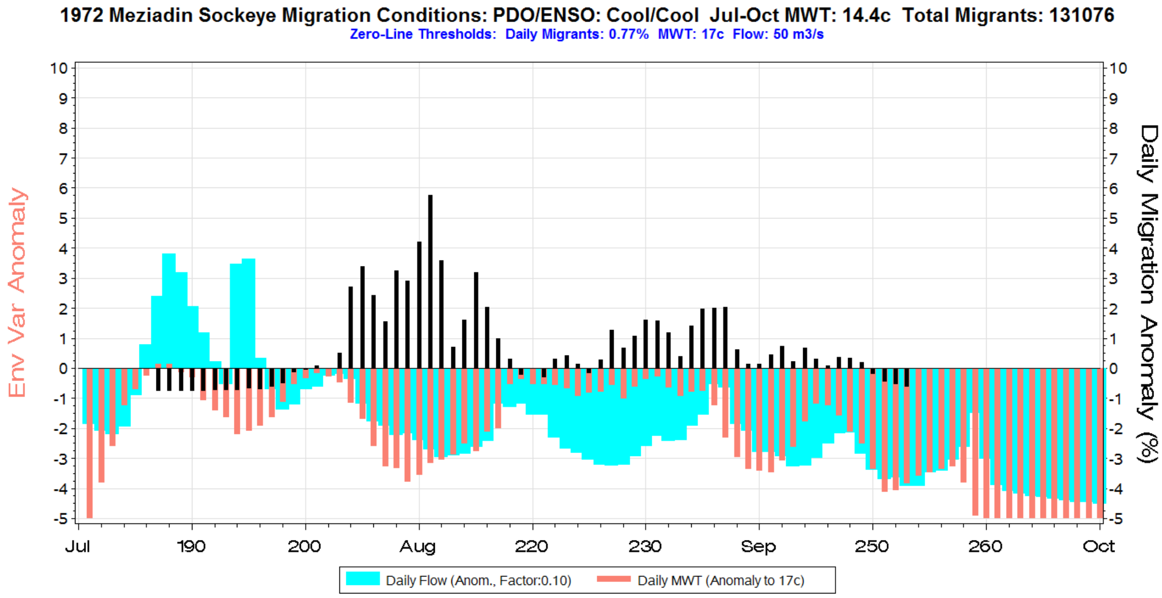


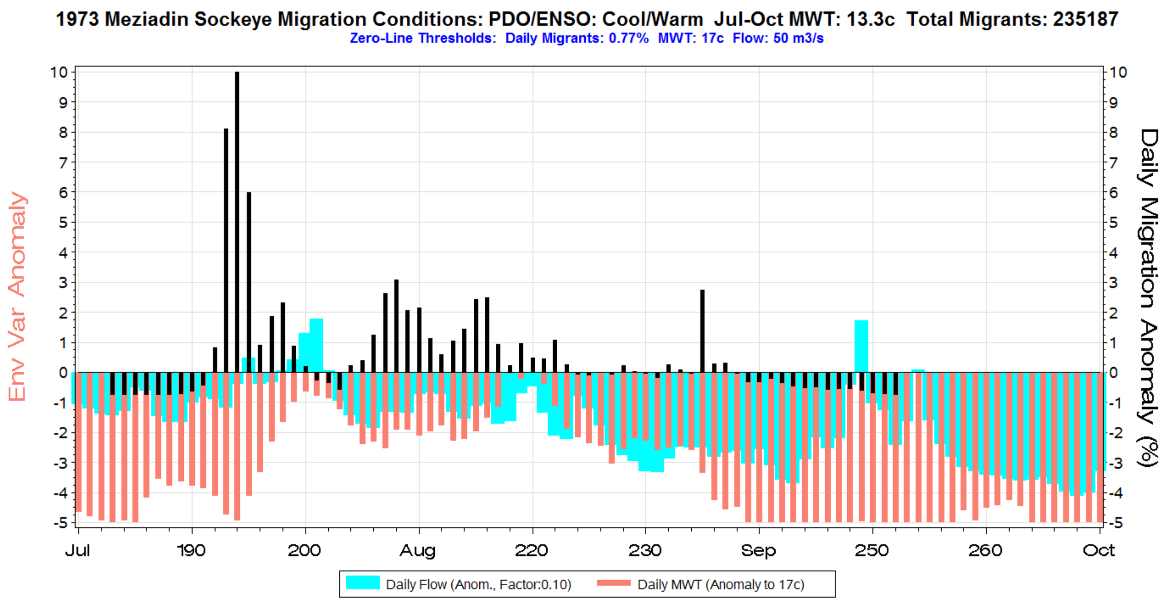
1970 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Oct MWT: 13.0c Total Migrants: 77990
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



1971 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Oct MWT: 13.7c Total Migrants: 193823
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s

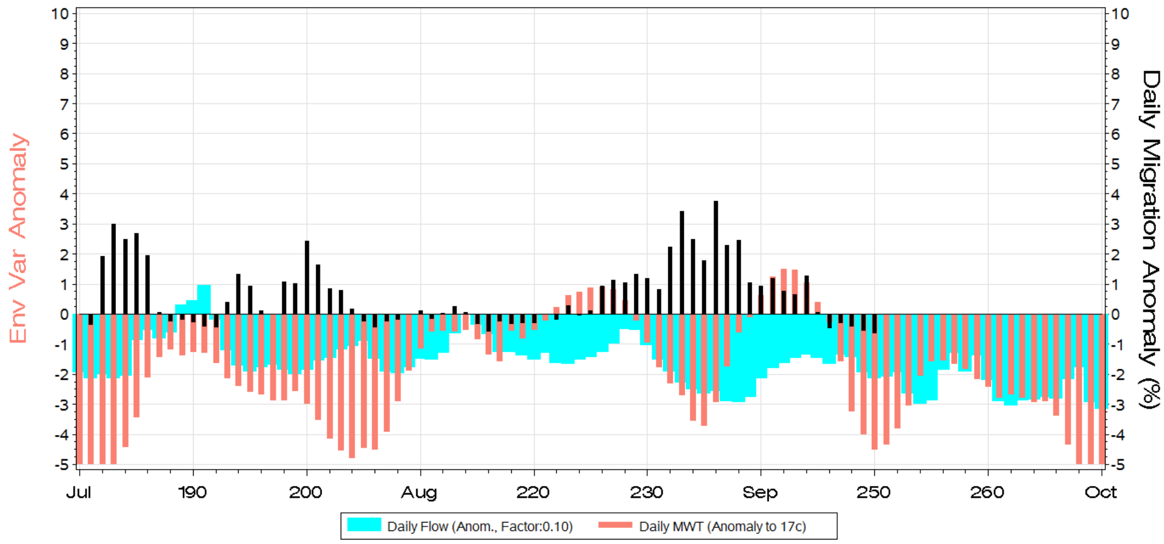



1972 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Oct MWT: 14.4c Total Migrants: 131076
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)


1973 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Oct MWT: 13.3c Total Migrants: 235187
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

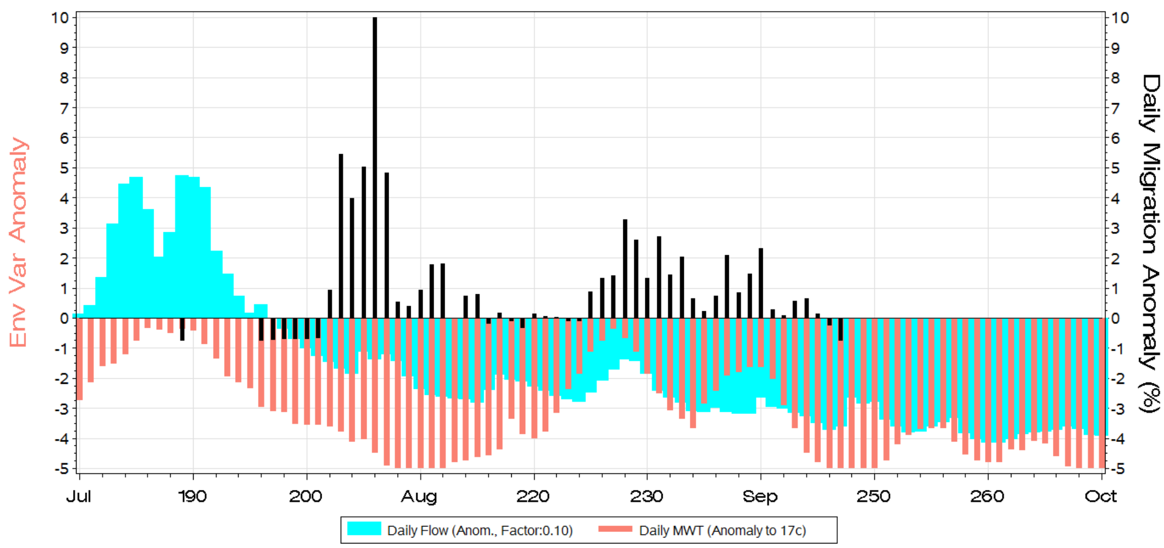
1974 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Oct MWT: 14.8c Total Migrants: 166014

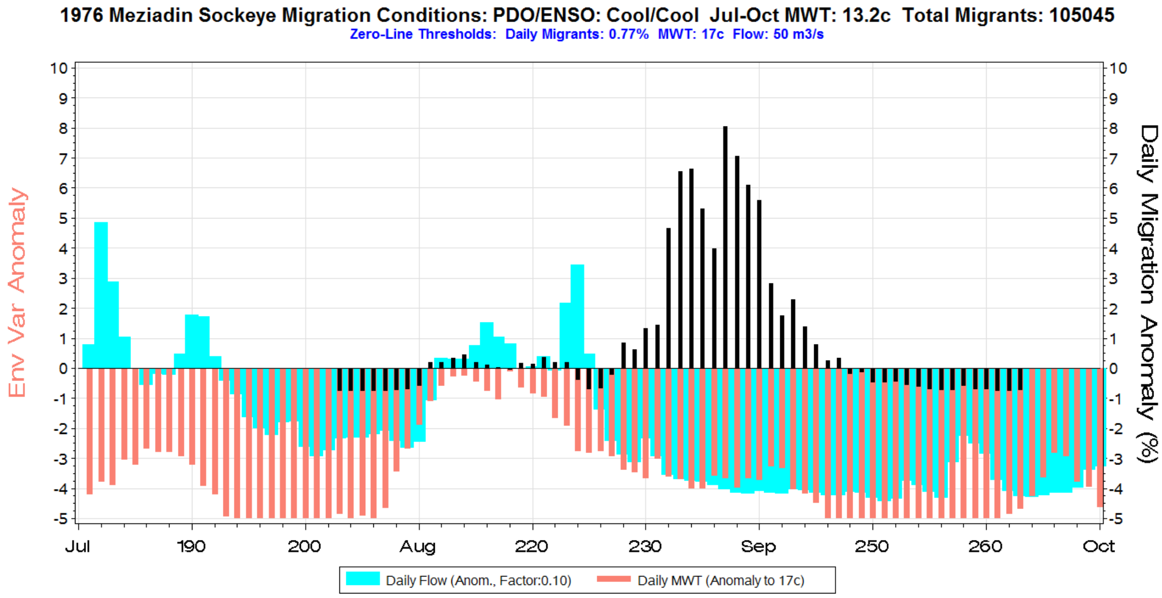
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



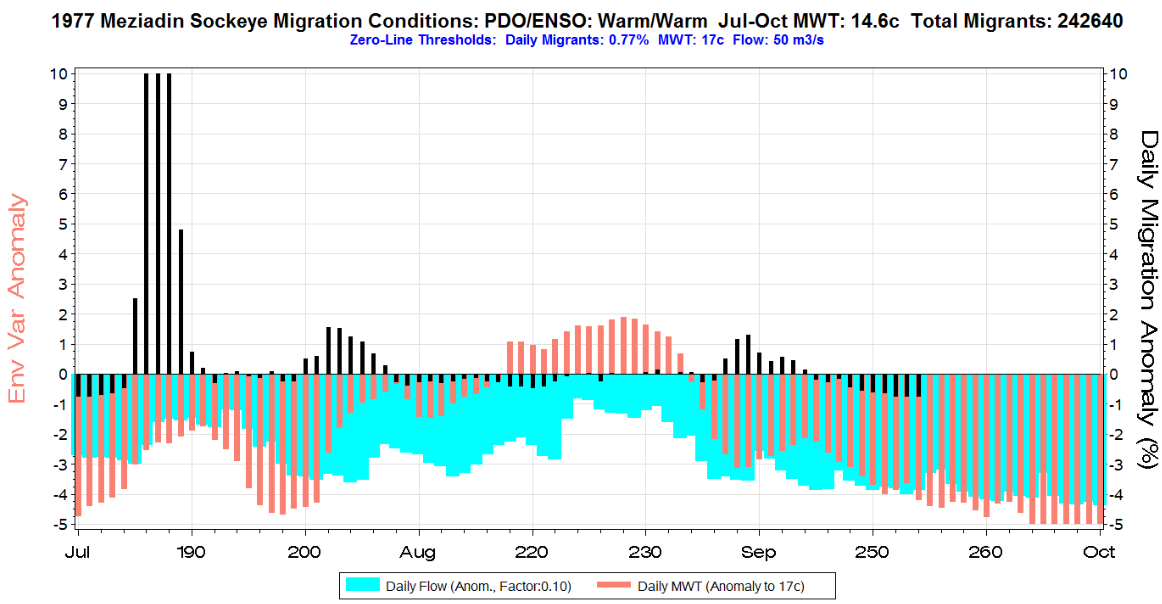
1975 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Oct MWT: 13.6c Total Migrants: 55170

Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s

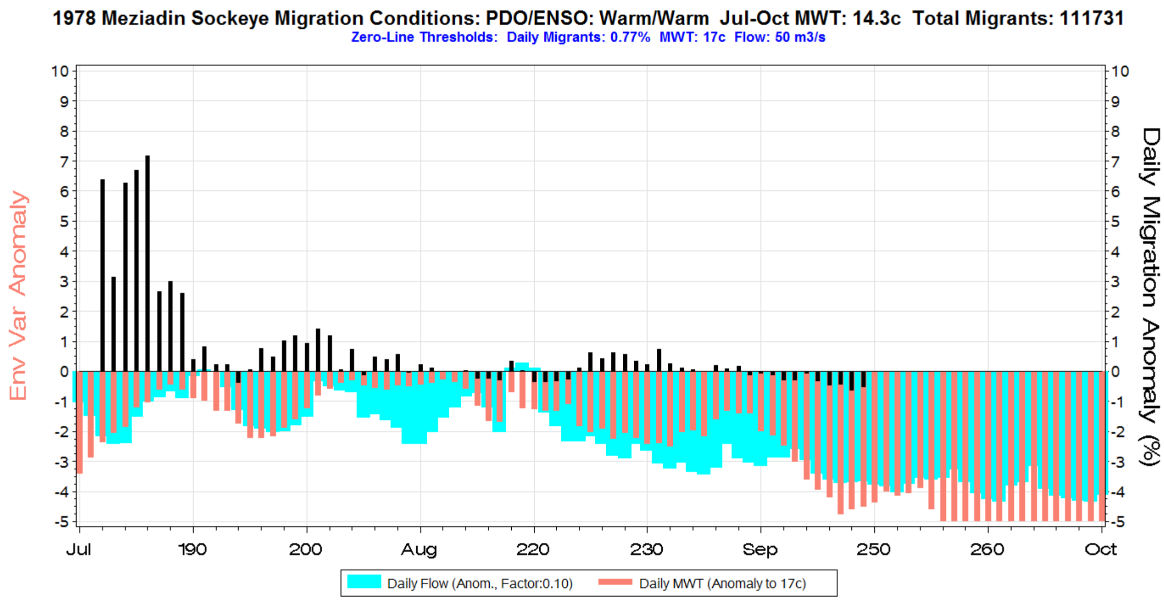


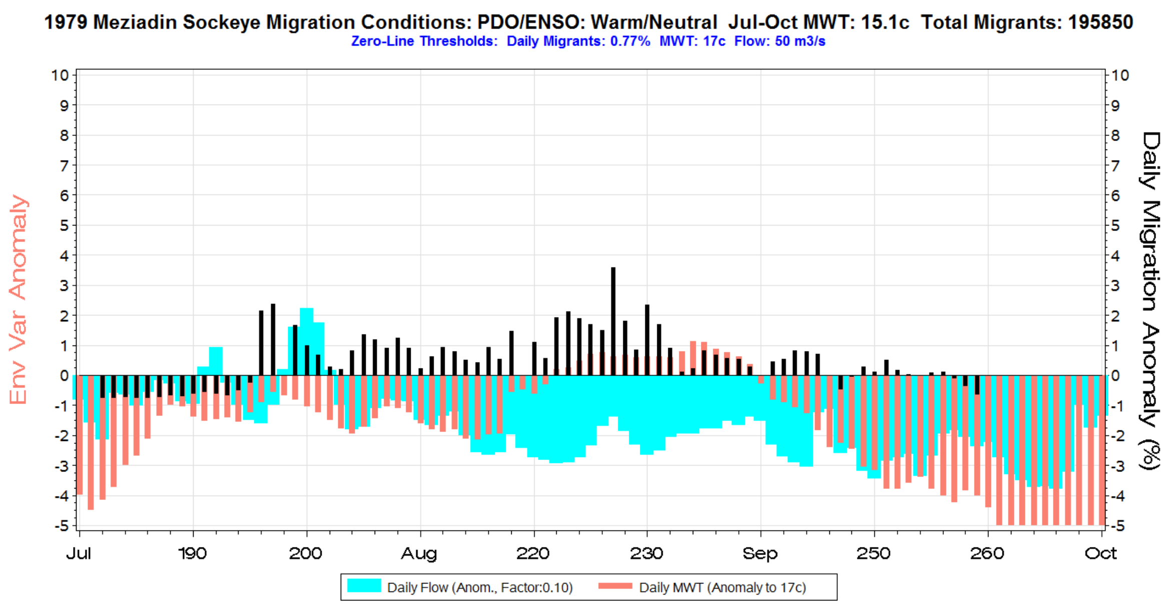


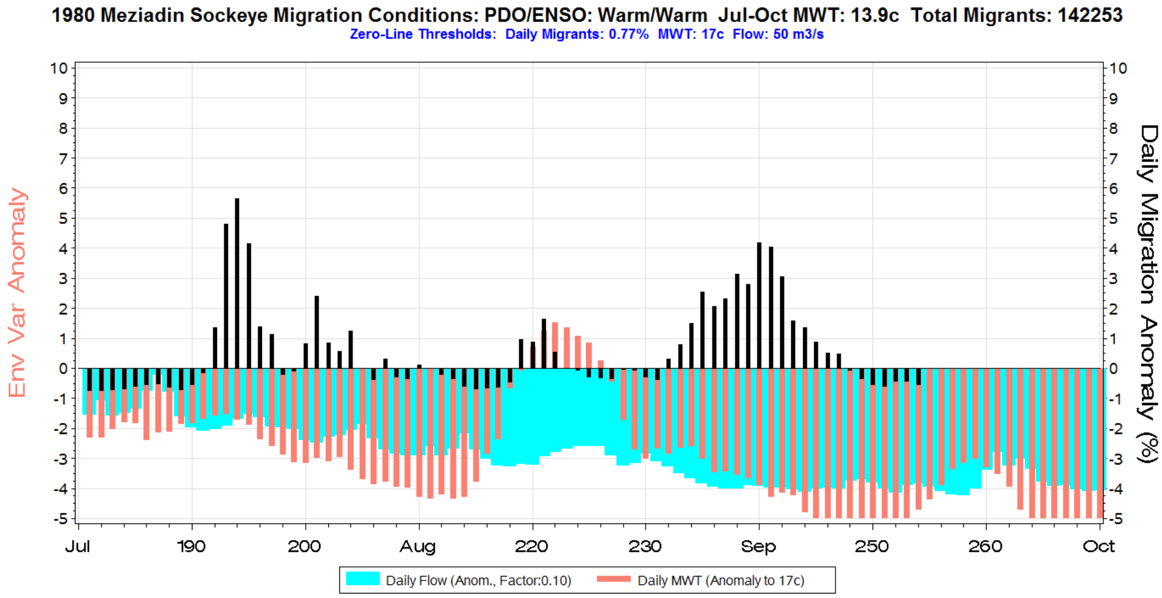
1976 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Oct MWT: 13.2c Total Migrants: 105045
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

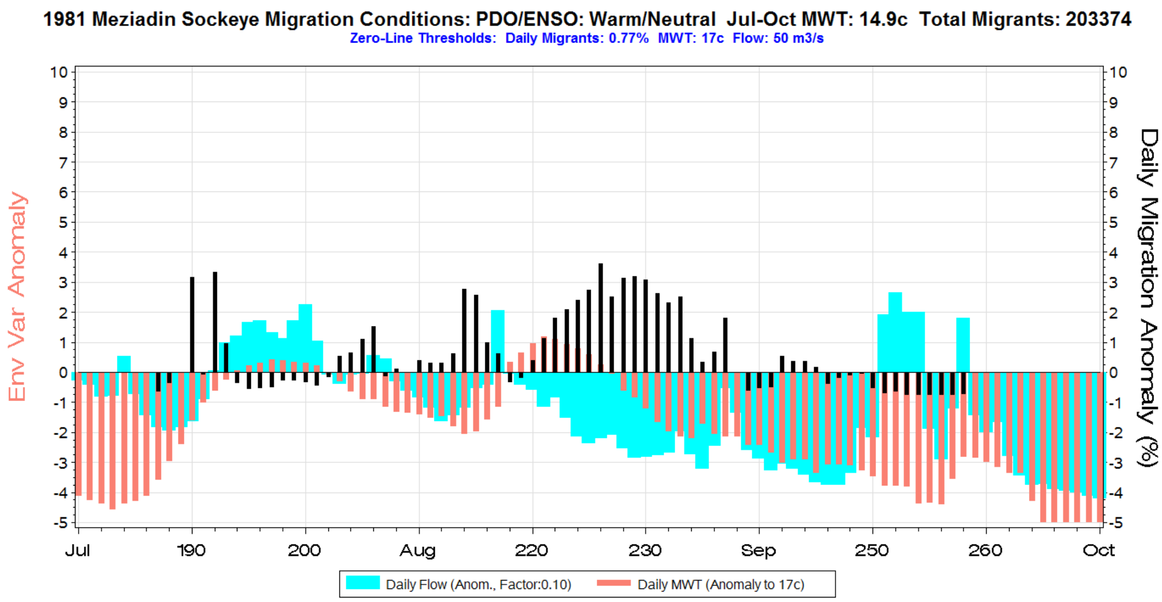


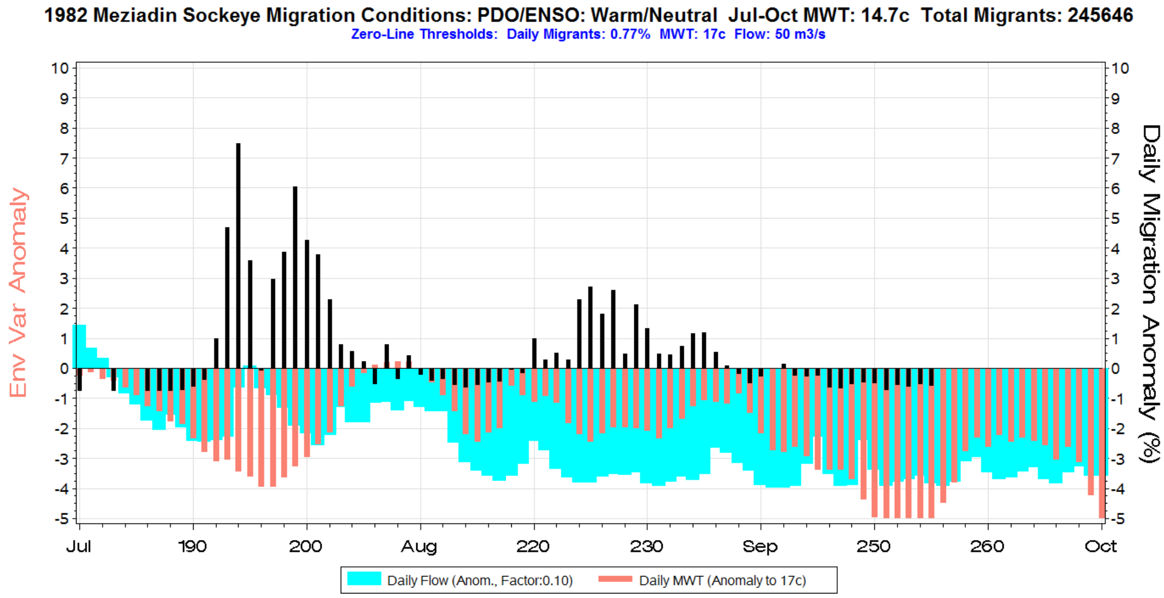
1977 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.6c Total Migrants: 242640
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

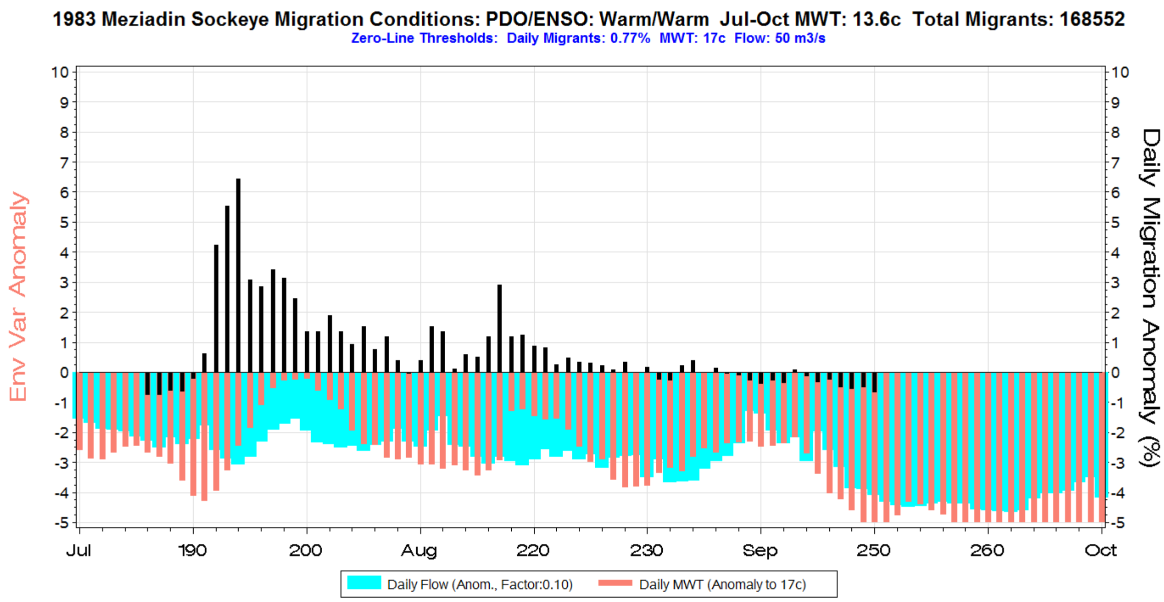

1978 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.3c Total Migrants: 111731
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

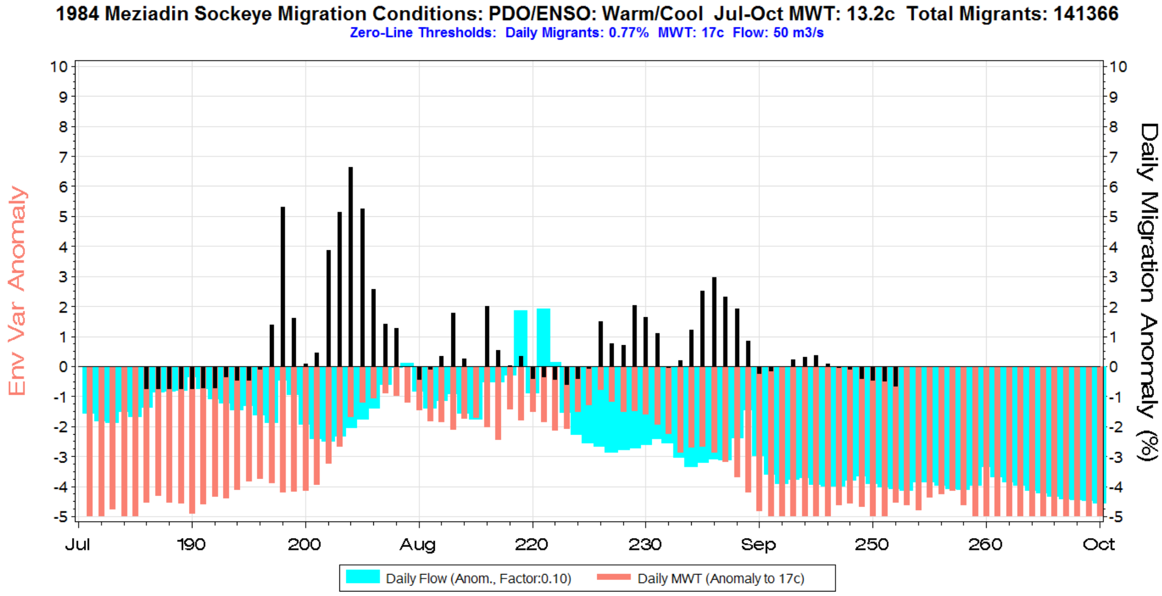

1979 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Oct MWT: 15.1c Total Migrants: 195850
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

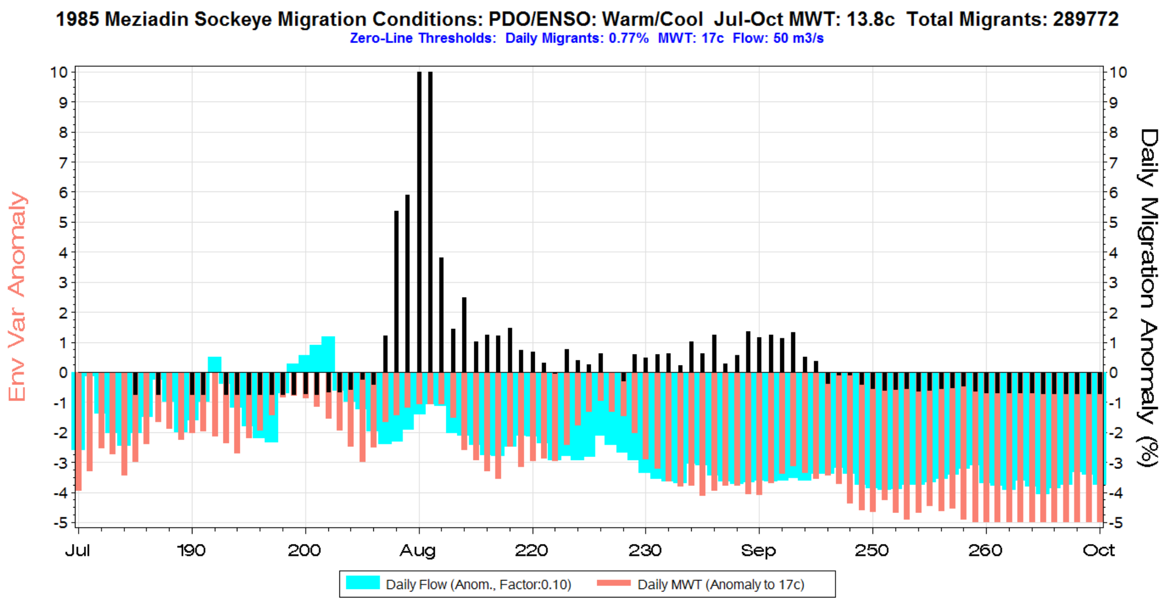

1980 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 13.9c Total Migrants: 142253
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)


1981 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Oct MWT: 14.9c Total Migrants: 203374
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)


1982 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Oct MWT: 14.7c Total Migrants: 245646
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

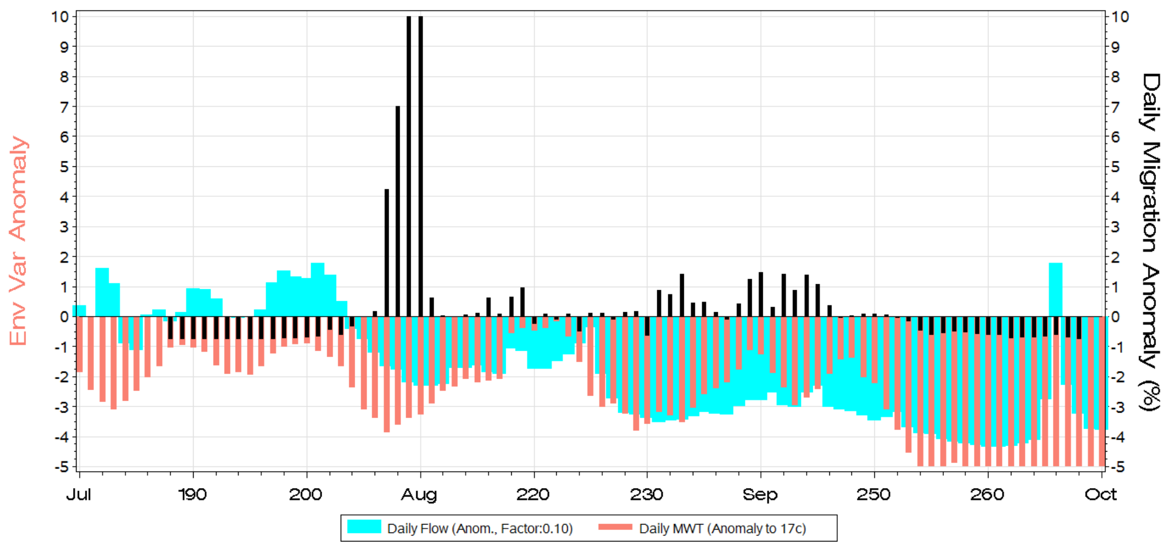

1983 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 13.6c Total Migrants: 168552
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)


1984 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Cool Jul-Oct MWT: 13.2c Total Migrants: 141366
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)


1985 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Cool Jul-Oct MWT: 13.8c Total Migrants: 289772
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

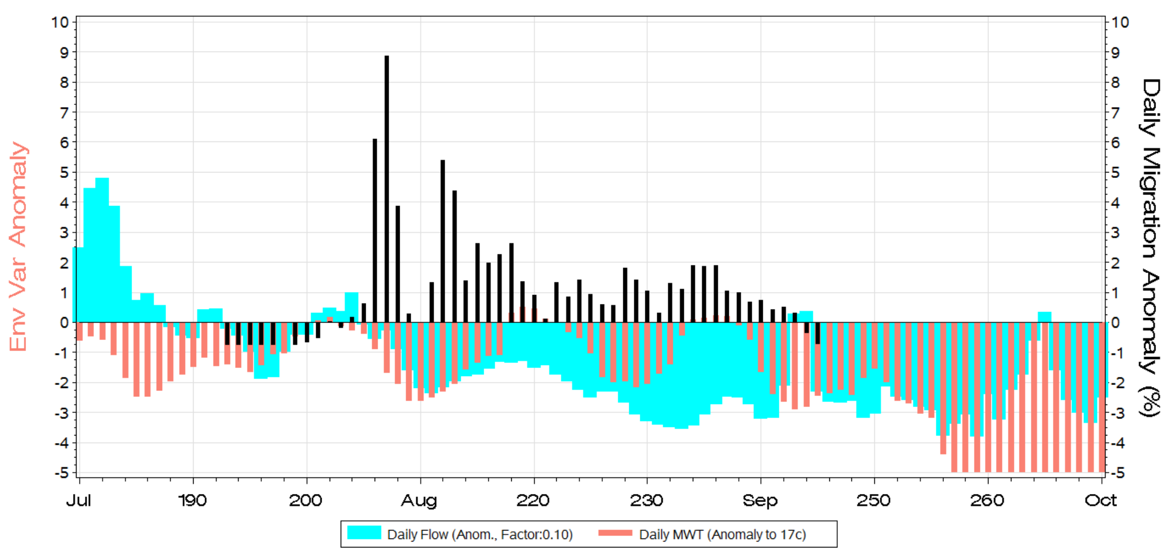
1986 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Oct MWT: 14.2c Total Migrants: 116281

Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



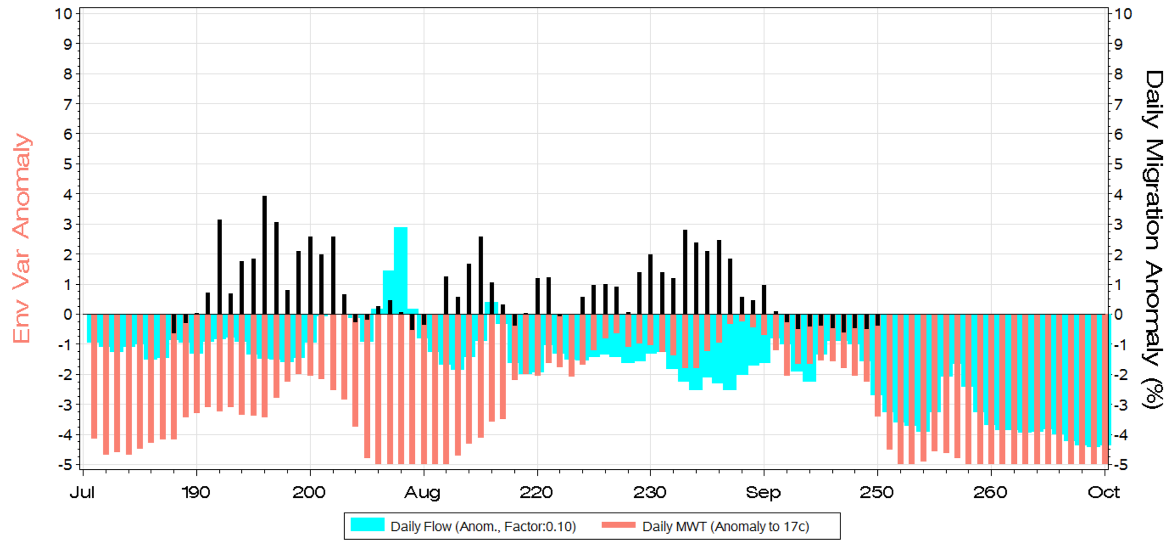
1987 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.8c Total Migrants: 147264

Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



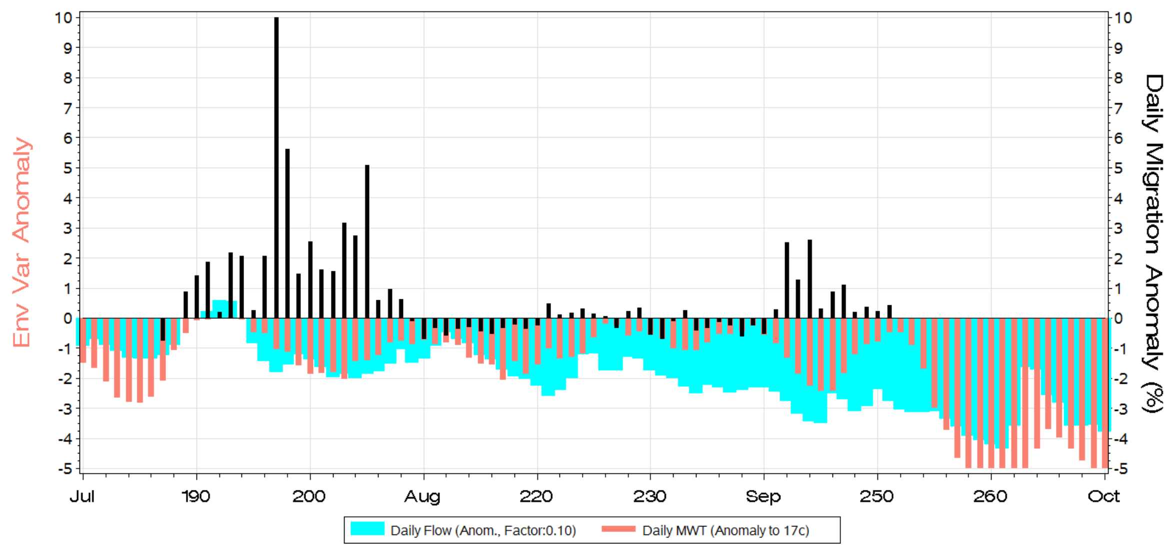
1988 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 13.5c Total Migrants: 117577

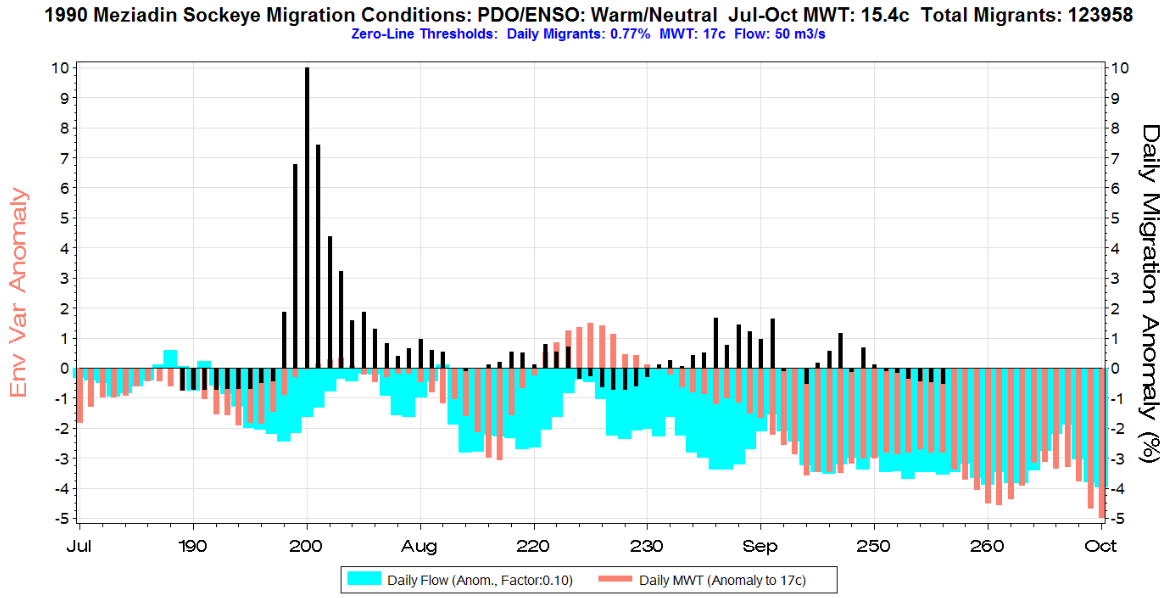
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



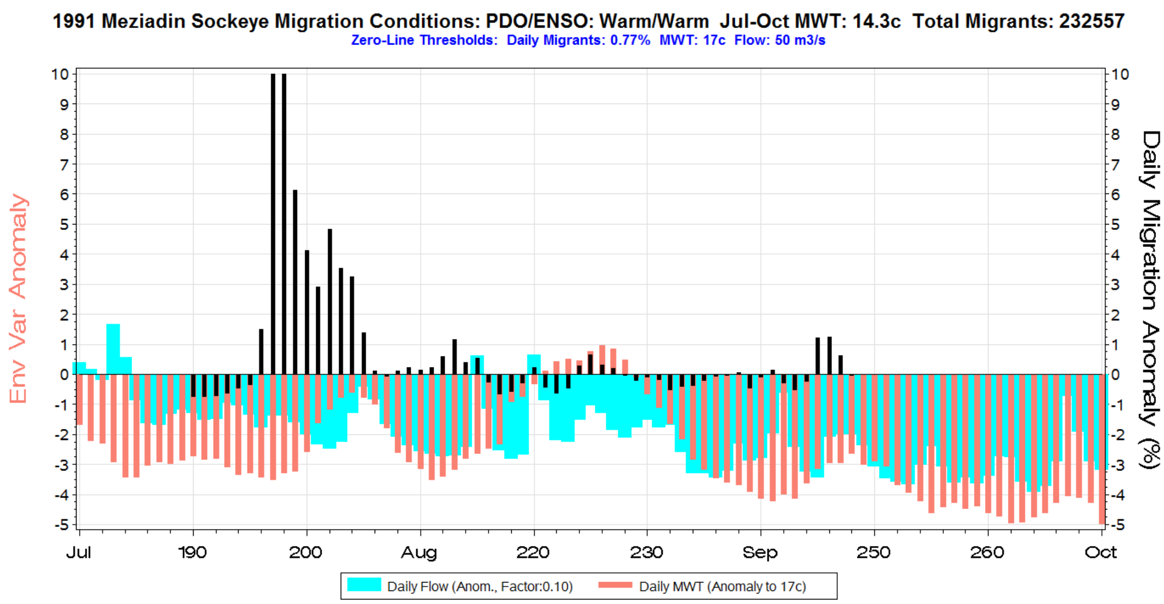
1989 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Cool Jul-Oct MWT: 15.2c Total Migrants: 46083

Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s

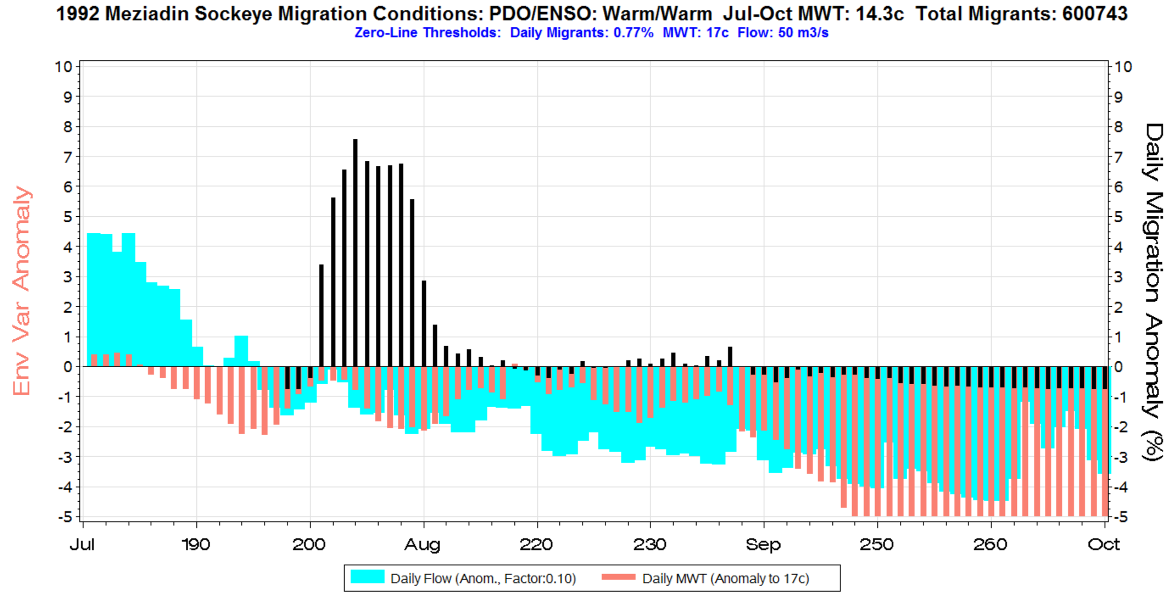


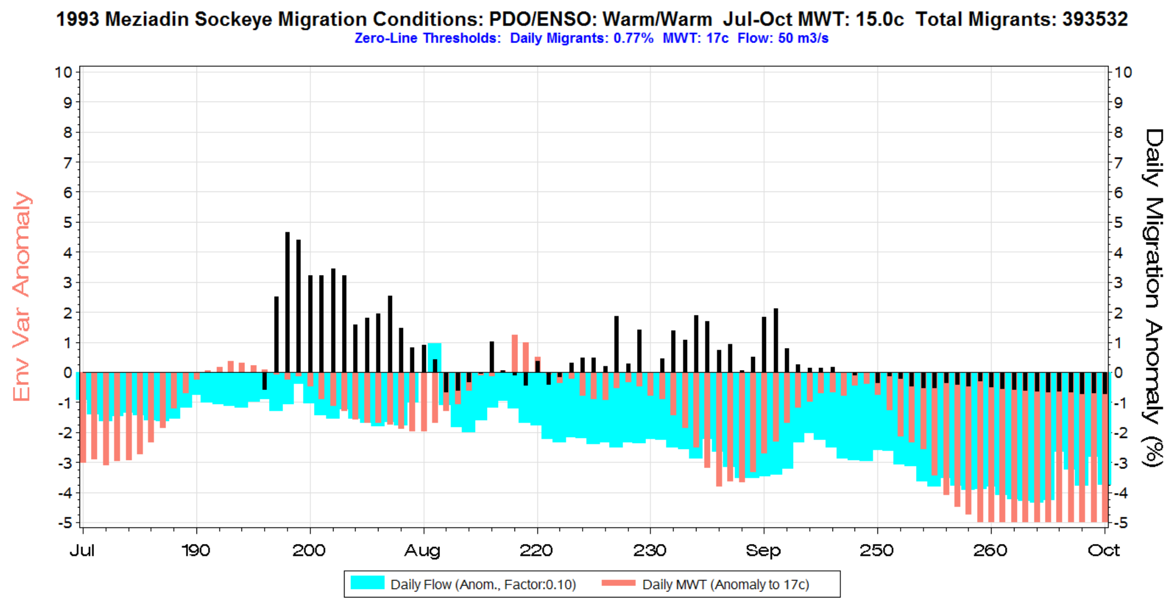


1990 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Oct MWT: 15.4c Total Migrants: 123958
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

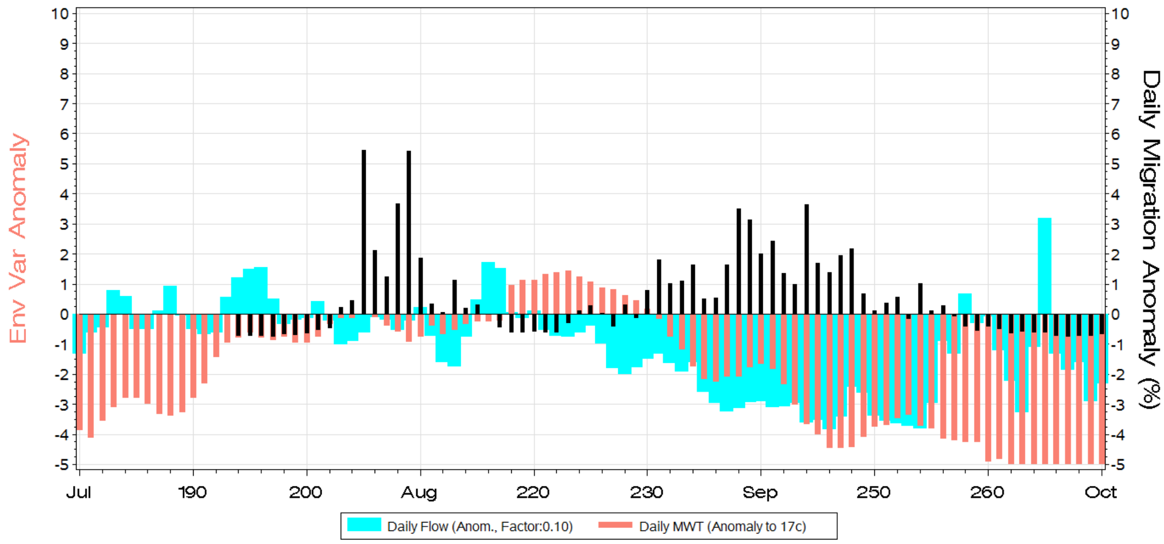


1991 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.3c Total Migrants: 232557
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

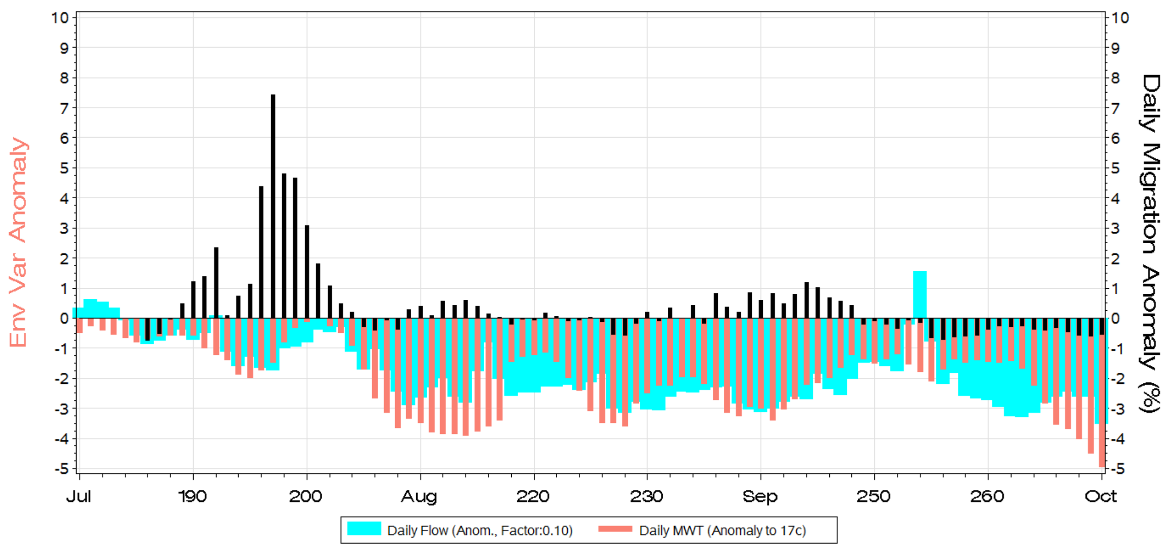

1992 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.3c Total Migrants: 600743
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

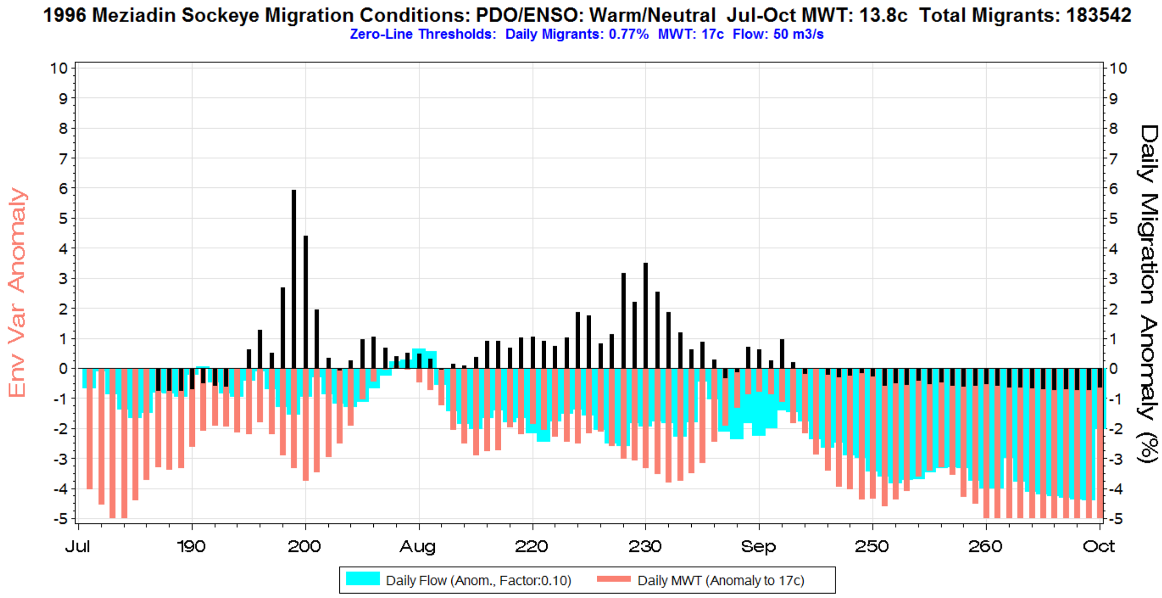

1993 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 15.0c Total Migrants: 393532
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

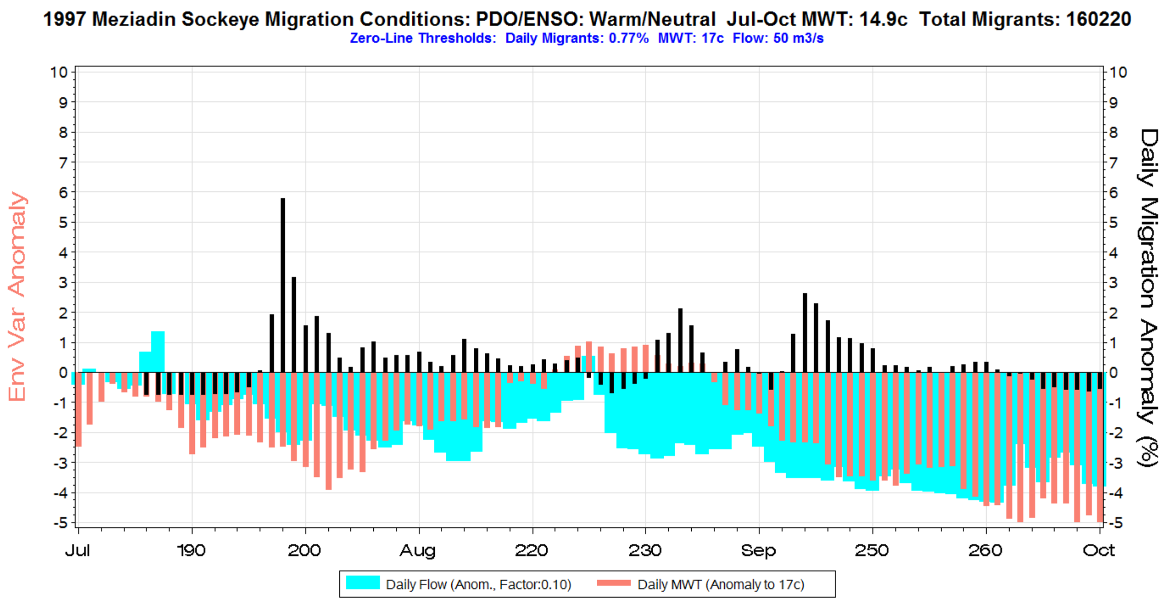
1994 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Oct MWT: 14.9c Total Migrants: 164462
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s

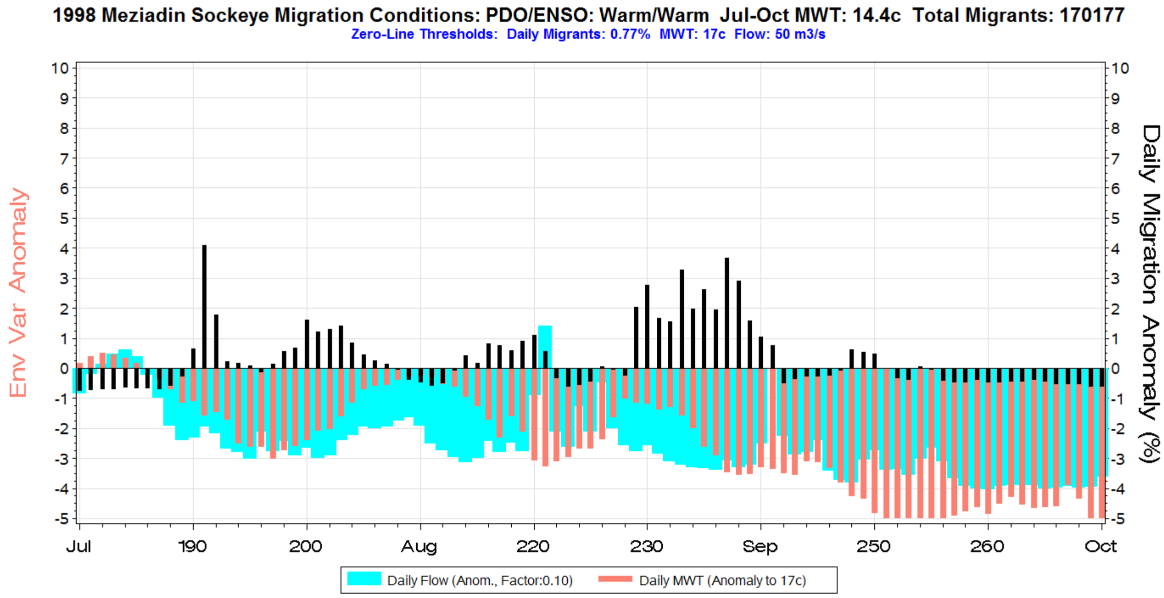


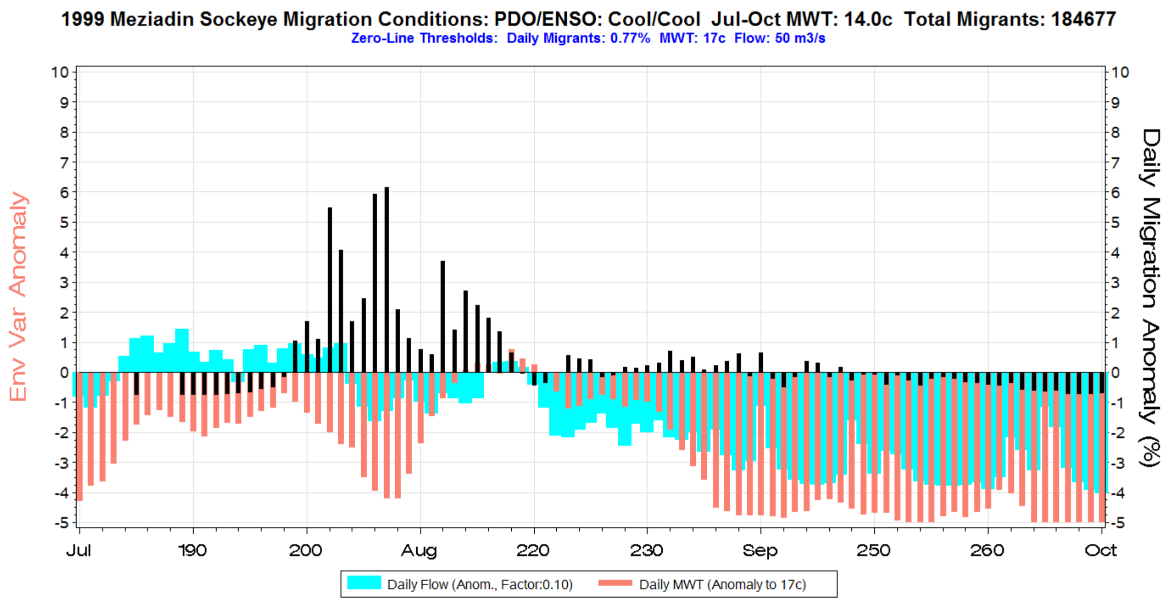
1995 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.9c Total Migrants: 212192
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s

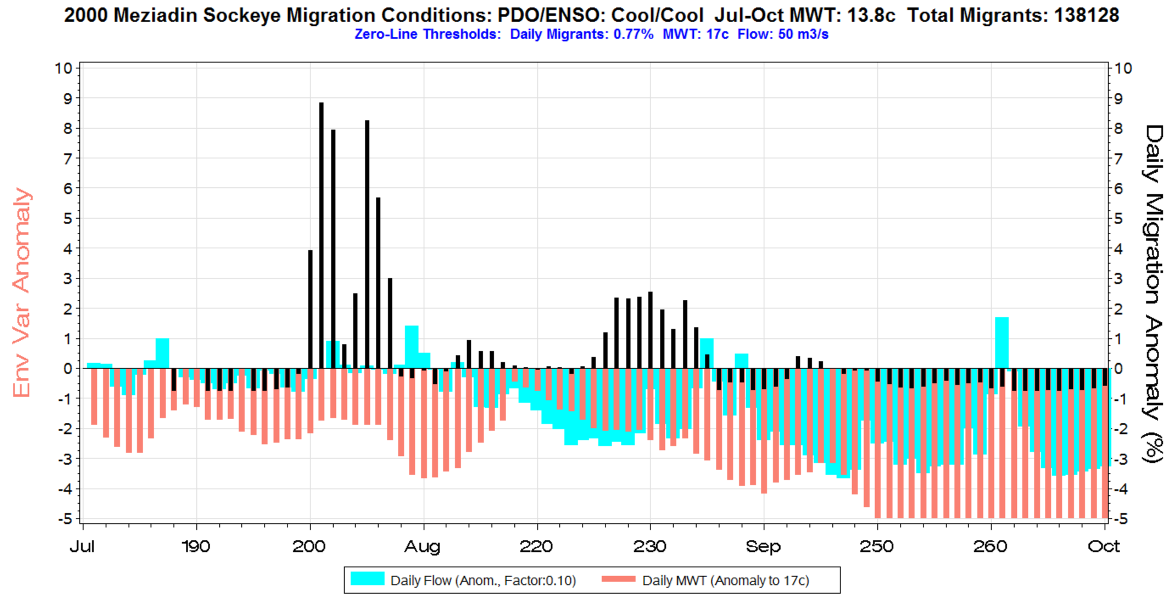


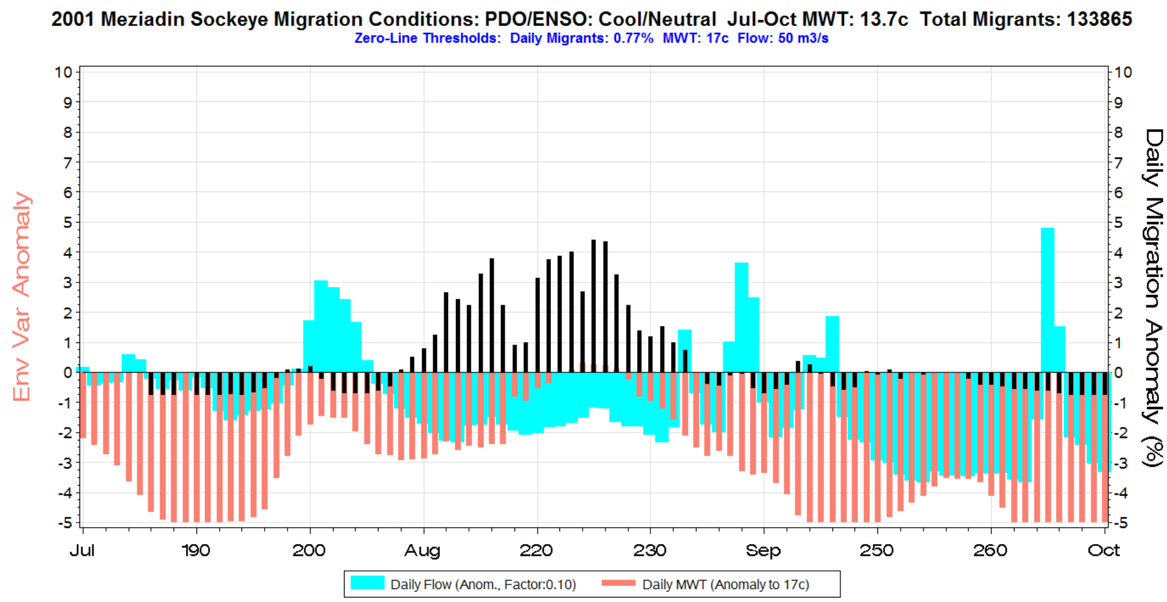

1996 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Oct MWT: 13.8c Total Migrants: 183542
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

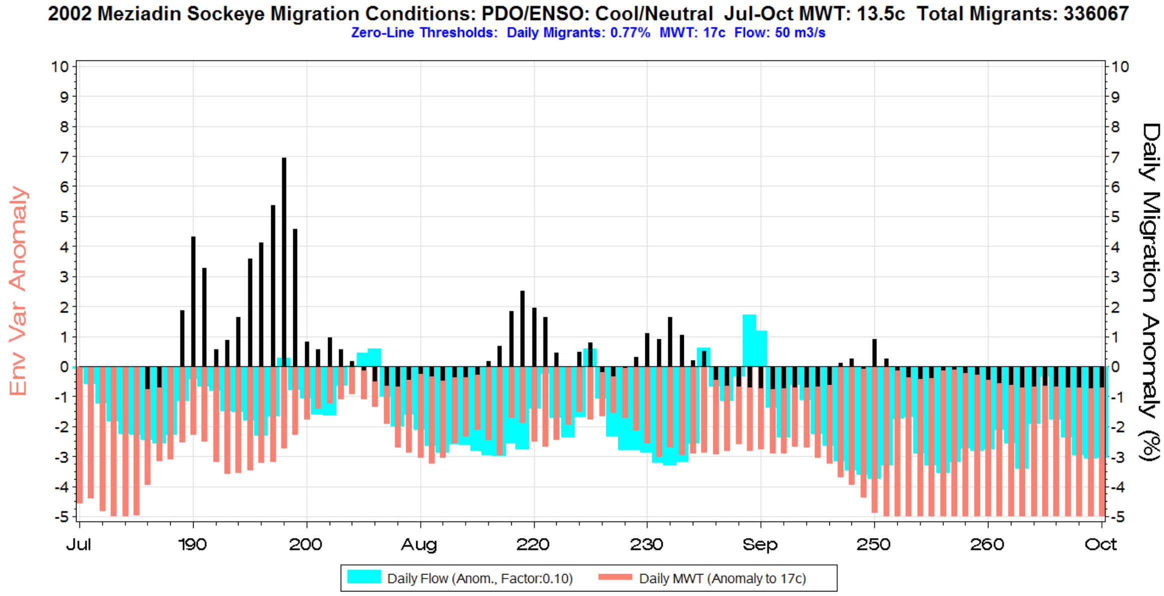

1997 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jul-Oct MWT: 14.9c Total Migrants: 160220
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

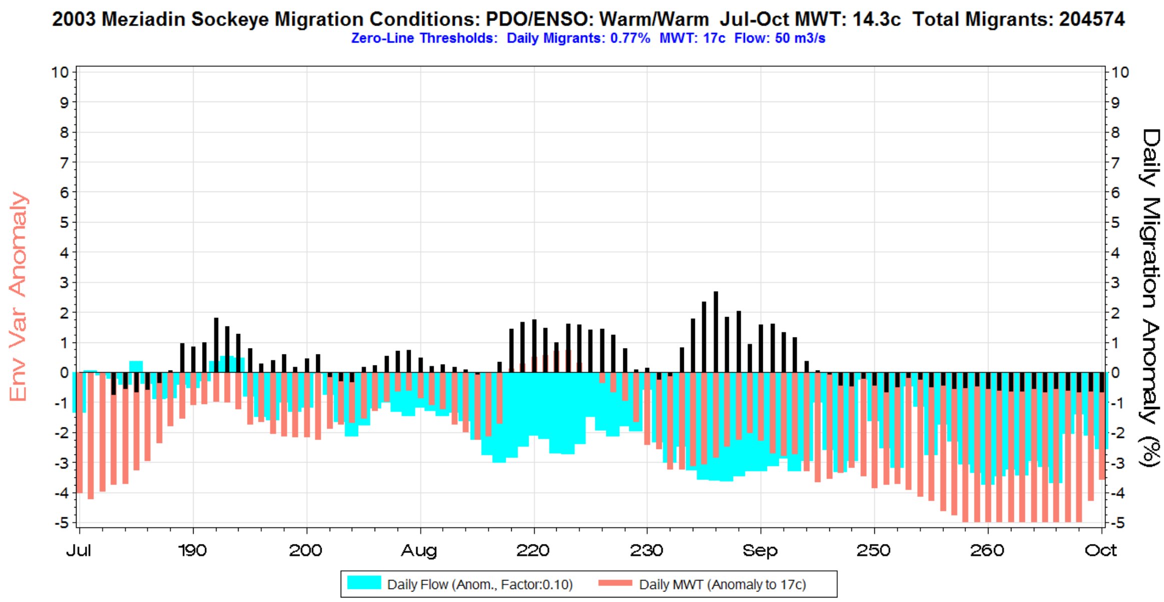

1998 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.4c Total Migrants: 170177
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

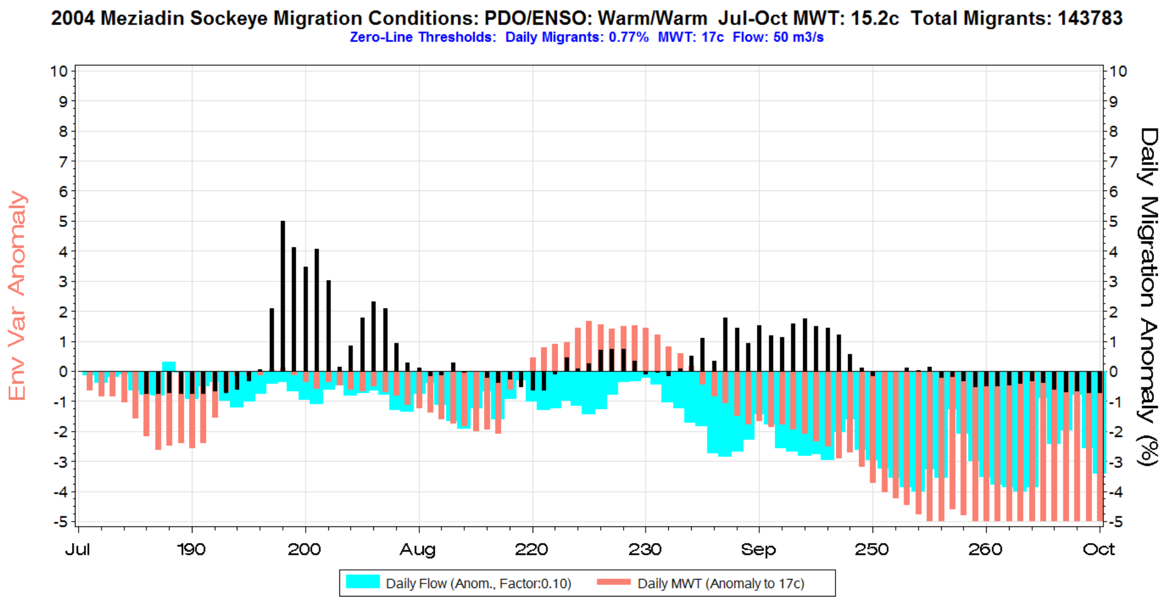

1999 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Oct MWT: 14.0c Total Migrants: 184677
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

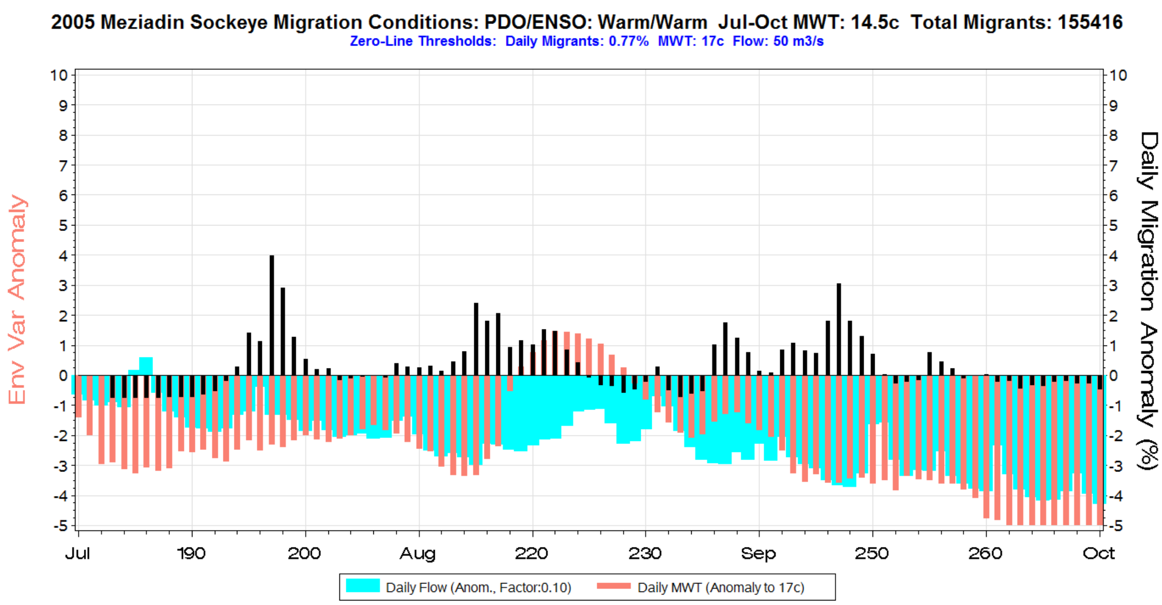

2000 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Oct MWT: 13.8c Total Migrants: 138128
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

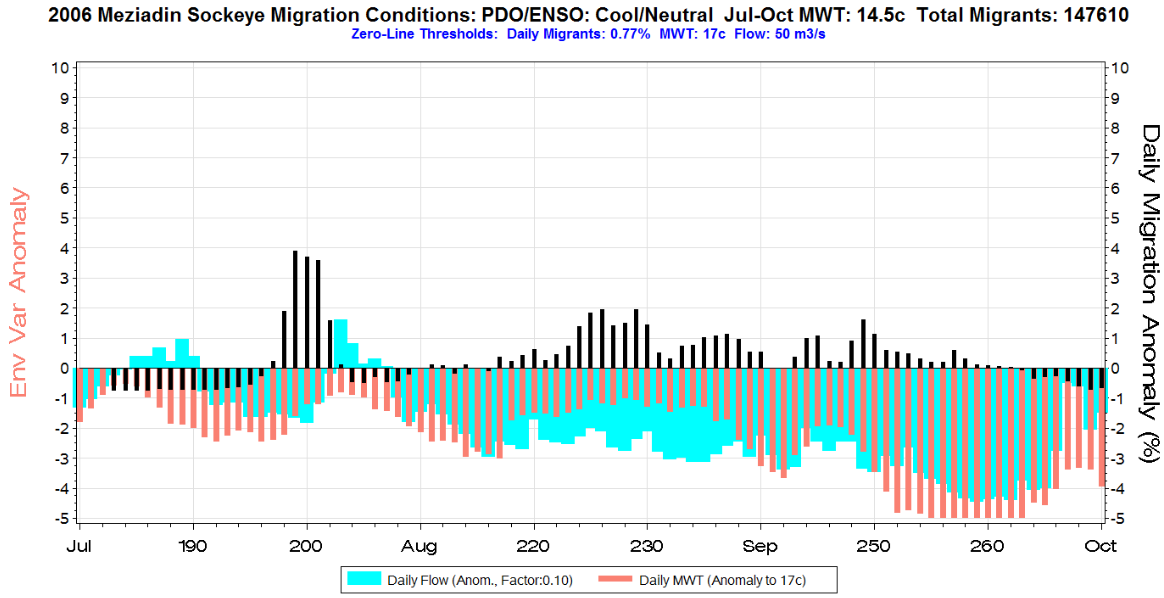

2001 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Oct MWT: 13.7c Total Migrants: 133865
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

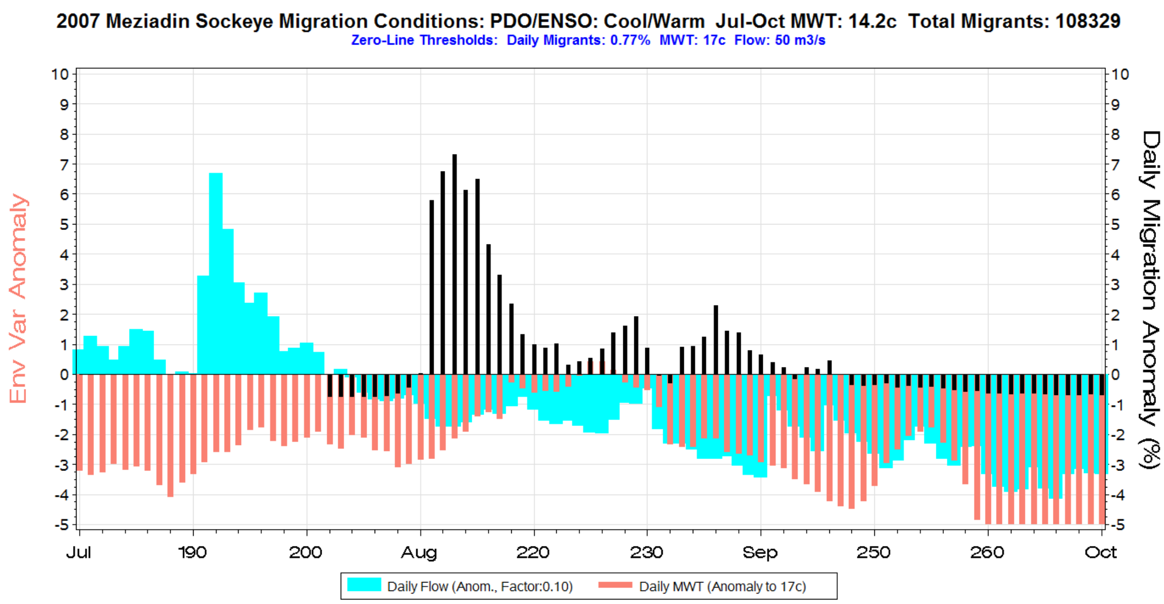

2002 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Oct MWT: 13.5c Total Migrants: 336067
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)


2003 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.3c Total Migrants: 204574
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

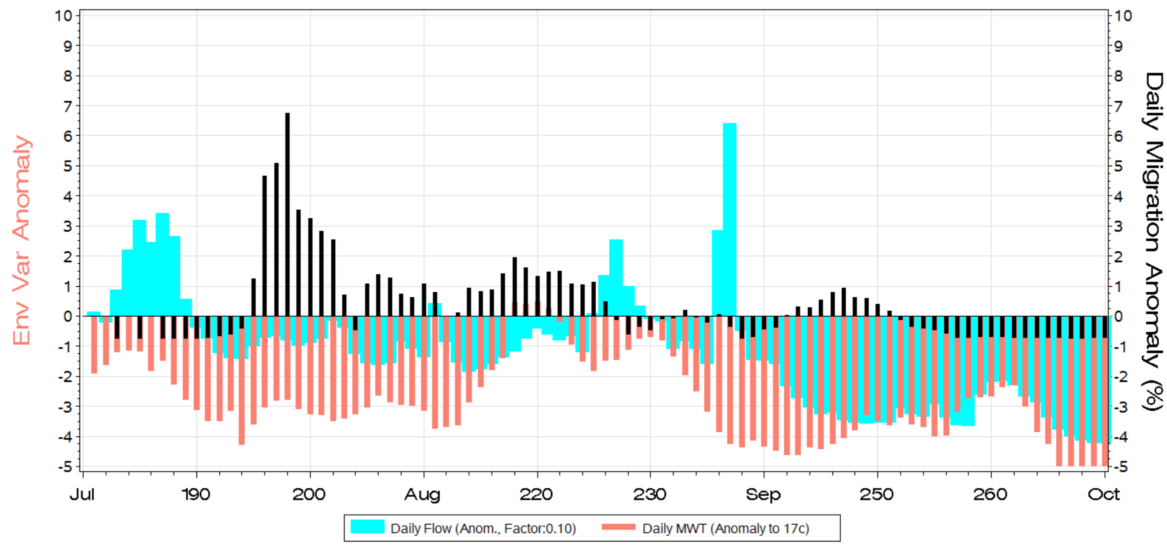

2004 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 15.2c Total Migrants: 143783
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)


2005 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.5c Total Migrants: 155416
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

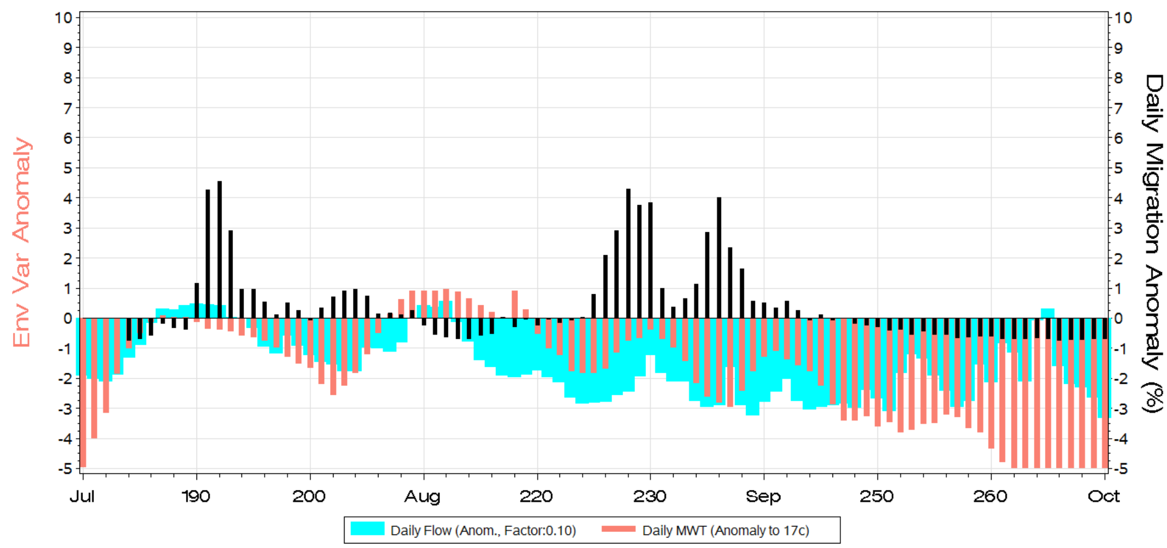

2006 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Oct MWT: 14.5c Total Migrants: 147610
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)


2007 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jul-Oct MWT: 14.2c Total Migrants: 108329
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s
Env Var Anomaly
Daily Migration Anomaly (%)
Jul
190
200
Aug
220
230
Sep
250
260
Oct
Daily Flow (Anom., Factor:0.10)
Daily MWT (Anomaly to 17c)

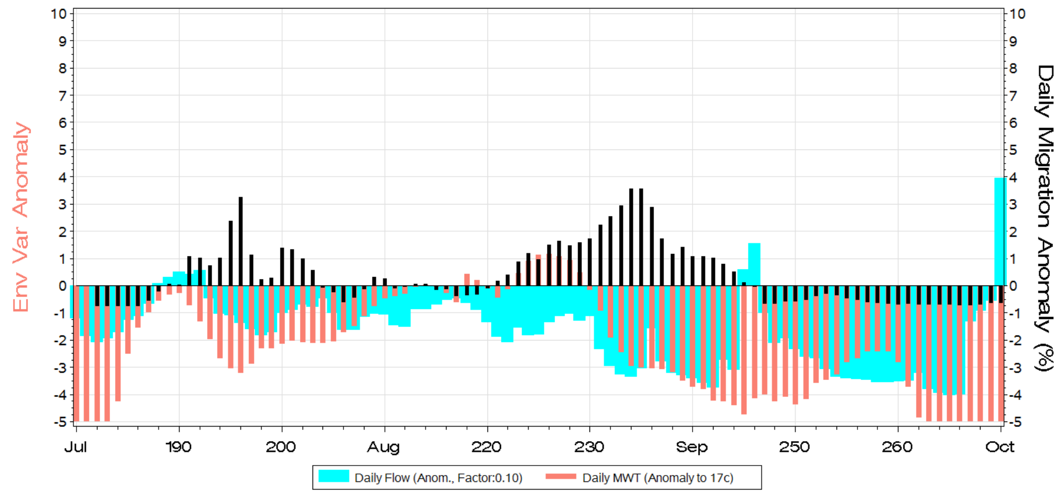
2008 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jul-Oct MWT: 14.1c Total Migrants: 153342
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



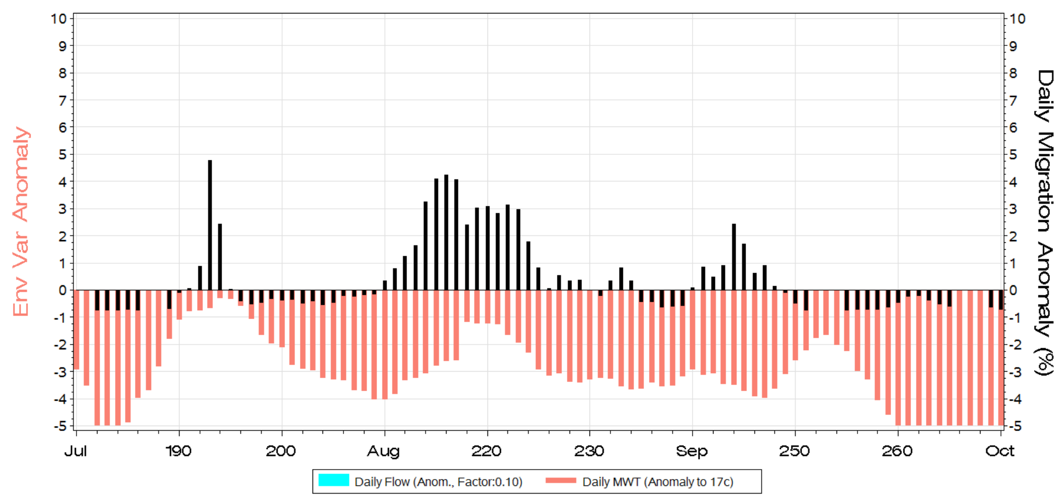
2009 Meziadin Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jul-Oct MWT: 15.0c Total Migrants: 180356
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



2010 Meziadin Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jul-Oct MWT: 14.5c Total Migrants: 163688
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



2011 Meziadin Sockeye Migration Conditions: PDO/ENSO: 2011/Unknown Jul-Oct MWT: 13.7c Total Migrants: 172354
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s



2012 Meziadin Sockeye Migration Conditions: PDO/ENSO: 2012/Unknown Jul-Oct MWT: 14.4c Total Migrants: 146668
Zero-Line Thresholds: Daily Migrants: 0.77% MWT: 17c Flow: 50 m3/s