Water Temperature, Water Level, and Adult Sockeye Salmon Migration Observations in Auke Creek, Alaska

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WATER TEMPERATURE, WATER LEVEL, AND ADULT SOCKEYE SALMON MIGRATION OBSERVATIONS IN AUKE CREEK, ALASKA

by

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ABSTRACT

Stiff, H. W., K. D. Hyatt, S. C. Vulstek, J. R. Russell, and J. E. Joyce. 2019. Water temperature, water level, and adult Sockeye salmon migration observations in Auke Creek, Alaska. Can. Manuscr. Rep. Fish. Aquat. Sci. 3178: vi + 157 p.

Daily mean water temperature and adult migration data (1980-2016) were assembled for Auke Creek Sockeye in southeast Alaska. Regional air temperature collected at Juneau-area meteorological stations were linearly correlated to generate a continuous mean daily air temperature index, which was used as a predictor for Auke Creek water temperatures to model daily mean water temperatures from 1900-2016. A similar process was used with regional precipitation data in relation to creek water level data (2006-2016) to hind-cast Auke Creek daily water levels back to 1900. Trend and exceedance analyses were applied to reconstructed time-series to review long-term trends in Auke Creek water temperature and level, recent trends in inter-annual migration timing, and within-year daily migration patterns.

The most consistent environmental impacts evident in the historical data were delays in the onset of migration and interruption of active migration due to low water levels in early summer. The majority of adult Sockeye migration activity and volume occurred between 14-17 ºC at water levels of 6.6-6.8 m. While high daily migration rates were occasionally evident at the upper limits (99th percentile) of water temperature (>19 ºC) and water level (>6.85 m), less than 5% of fish migration activity occurred at <6.5 m, and only at low/negligible daily migration rates. The annual median migration timing index was not correlated with mean seasonal water temperature, but was correlated with exceedance indices associated with the 18 ºC temperature threshold. The timing index was also negatively correlated with mean seasonal water levels, as well as ‘low water’ (<6.5 m) threshold indices.

The frequency of ‘low water’ events averaged 11 days per year over the last century, but trended upward, peaking in the 1990s at ~18 days per year, with continuous ‘drought’ events averaging <6 days in length, but occasionally extending 15-17 days. Biological impacts on the population due to migration delays, though currently likely negligible, may become more evident, as Alaskan climatologists project warmer, drier summers, which are likely to reduce Auke Creek water availability during peak Sockeye migration, and exacerbate migration-related stresses for this stock.

RÉSUMÉ

Stiff, H. W., K. D. Hyatt, S. C. Vulstek, J. R. Russell, and J. E. Joyce. 2019. Water temperature, water level, and adult Sockeye salmon migration observations in Auke Creek, Alaska. Can. Manuscr. Rep. Fish. Aquat. Sci. 3178: vi + 157 p.

Des données sur la température quotidienne moyenne de l'eau et sur la migration des adultes (1980-2016) ont été recueillies pour le saumon rouge du ruisseau Auke, dans le sud-est de l'Alaska. La température de l'air régionale recueillie aux stations météorologiques de la région de Juneau a été corrélée de façon linéaire pour générer un indice de température de l'air quotidien moyen continu, qui a servi à prédire la température de l'eau du ruisseau Auke afin de modéliser les températures quotidiennes moyennes de l'eau de 1900 à 2016. Un processus semblable a été utilisé avec les données sur les précipitations régionales par rapport aux données sur les niveaux d'eau du ruisseau (2006-2016) pour déterminer les niveaux d'eau journaliers du ruisseau Auke depuis 1900. Des analyses des tendances et des dépassements ont été appliquées aux séries chronologiques reconstituées pour étudier les tendances à long terme de la température et du niveau de l'eau du ruisseau Auke, les tendances récentes dans la période de migration interannuelle ainsi que les tendances dans la migration quotidienne au cours de l'année.

Les effets environnementaux qui ressortent le plus souvent dans les données historiques sont les retards dans le début de la migration et l'interruption de la migration active en raison des bas niveaux d'eau au début de l'été. La majorité des activités et du volume de migration du saumon rouge adulte s'est produite entre 14 et 17 °C à des niveaux d'eau entre 6,6 et 6,8 m. Bien que des taux de migration quotidiens élevés aient parfois été observés aux limites supérieures (99^{e} centile) de la température (>19 °C) et du niveau d'eau (>6,85 m), moins de 5 % des activités de migration des poissons ont eu lieu à <6,5 m d'eau, et ce, à des taux de migration quotidienne faibles voire négligeables. L'indice médian annuel du moment de la migration n'était pas corrélé avec la température moyenne saisonnière de l'eau, mais il l'était avec les indices de dépassement associés au seuil de température de 18 °C. L'indice du moment de la migration était également corrélé négativement avec les niveaux d'eau saisonniers moyens ainsi qu'avec les indices de seuil de « basses eaux » (<6,5 m).

La fréquence des épisodes de « basses eaux » a été en moyenne de 11 jours par année au cours du siècle dernier, mais elle a eu tendance à augmenter, atteignant un sommet d'environ 18 jours par année dans les années 1990. Les épisodes continus de « sécheresse » ont duré en moyenne <6 jours, mais se sont parfois étendus jusqu'à 15-17 jours. Les effets biologiques sur la population attribuables aux retards de migration, bien qu'ils soient actuellement probablement négligeables, pourraient devenir plus évidents, car les climatologues de l'Alaska prévoient des étés plus chauds et plus secs, ce qui réduira probablement la disponibilité de l'eau dans le ruisseau Auke pendant la période de pointe de migration du saumon rouge et pourrait accroître les stress liés à la migration pour ce stock.

INTRODUCTION

Maintaining healthy and diverse populations of salmon that will support sustainable fisheries in the present and for future generations 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 British Columbia and the Pacific coast 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). Mean annual temperatures in Alaska have increased over the past 60 years twice as much as the rest of the continental U.S.A. (Chapin et al. 2014). Seasonal precipitation has also changed markedly in the recent past (Walker and Sydneysmith 2008), and future projections point to increased annual precipitation levels contributing 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; Chapin et al. 2014). 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; Fleming and Whitfield 2010; Fleming et al. 2016).

Temperature effects on migrating adult Sockeye (*Oncorhynchus nerka*) have been well documented in many river systems in the Pacific Northwest (Hyatt and Stockwell 2003; Nelitz et al. 2007; Salinger and Anderson 2006). Lethal temperatures are reported in the range 21-24°C, and water temperatures in excess of 18°C may affect migration speed, cause timing delays, and alter spatial distribution of Sockeye salmon (Hyatt et al. 2015; Pellett et al. 2015). Increased water temperature also may result in secondary effects such as increased disease, resulting in pre-spawn mortality (Cooke et al. 2004; Hinch and Martins 2011; Hyatt et al. 2016). 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.

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 (Mantua et al. 2010). 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 (Pellett et al. 2015). 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 (Hinch and Bratty 2000).

This report documents the data assembled for derivation of historic water temperature and flows affecting Sockeye salmon on the final leg of their migration to the spawning grounds in the Auke Lake watershed. It is one of a series of manuscripts intended to 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 the eastern Pacific region (Hyatt et al. 2015; Stiff et al. 2013; 2015a; 2015b; 2015c; 2016; 2018; Damborg et al. 2015a; 2015b). 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

Biogeoclimatology

The Auke Lake drainage is located approximately 30 km north of downtown Juneau, in southeast Alaska (Figure 1). The watershed drains an area of approximately 1,000 hectares, with elevations ranging up to ~600 m (Bethers 1995, in: JWP 2009).

Between 10,000 to 12,000 years ago, Auke Lake was part of a marine embayment until post-glacial isostatic rebound raised the landmass approximately 6,500 years ago, slowly transforming the lake from a salt-chuck inundated during high tides, to a freshwater lake at its current elevation of 17 m ASL over the last 6,000 years (Monteith 2007, in: JWP 2007). Tectonic and glacial activity resulted in primarily glacial, glacio-marine, and alluvial deposits overlaying a belt of metamorphosed volcanic and sedimentary bedrock (Brew and Ford 1985, in: JWP 2009). The Mendenhall Glacier, currently retreating, advanced multiple times into the Auke Lake watershed during the neo-glacial period during the last 3,000 years, carving a U-shaped lake basin (JWP 2009).

Climatologically, the region exists in a transition zone between *continental* (Köppen *Dfb/Dfc*) and *oceanic* (Köppen *Cfb/Cfc*) climates. Winters are long and moist, but mild by Alaskan standards due to the influence of the Pacific Ocean. The average low is −5°C in January, and winter highs are frequently above freezing (1981-2010 normals). Summer highs typically peak in July at 18.3°C. Maximum temperatures, however, can reach 32°C in July, and 31°C in June or August (Table 1).

Precipitation falls an average 230 days per year, averaging a total of 62 inches (1,580 mm) at Juneau International Airport (1981-2010 normals), but ranging from 55 - 92 inches (1,400 to 2,340 mm), depending on location (Figure 2, Figure 3, Figure 4). The spring months are the driest while September and October are the wettest. Snowfall averages 87.4 inches (222 cm) and occurs chiefly from November to March.

Sitka Spruce and Western and Mountain Hemlock forests typical of northern temperate rainforests dominate the island archipelago and lower altitudes between the ocean and the icy alpine zone.

Hydrology

Auke Lake is a low-altitude, non-glacial lake with a surface area of approximately 70 hectares (175 acres), a mean depth of 19 m, and a maximum depth of 31 m (Ray et al. 2014). The lake is currently 17 m above sea level (ASL) (Lum and Taylor 2006, in: JWP 2009). Dark, tannic lake water overlays the muddy bottom and gravelly areas located at the stream inlets (Bethers 1995, in: JWP 2009).

The lake freezes over each winter and has both autumn and spring turnover events. Observations of lake freezing and thawing since 1961 show a general trend toward earlier ice-out, though not at a statistically-significant rate (Kovach et al. 2014).

Lake Creek is the largest of six inlet streams that enter the lake on the north and west shores of Auke Lake (Figure 1). Smaller streams include Lake Two Creek (also known as Little Auke Creek), and the unofficially named UAJ, MB and Hanna Creeks (JWP 2009). Discharge for Lake Creek and Auke Creek are correlated with rainfall in late summer and early fall, while the spring peak discharges in May are mainly a response to snowmelt (Figure 2, 3 in: JWP 2009).[1]

Auke Creek is a 323 m freshwater body that flows from Auke Lake to the estuarine wetland in Auke Bay (Manhard et al. 2017)[2]. Water flowing into Auke Creek passes through a shallow lagoon into a stable narrow channel with a bedrock sill. The creek substrate is primarily bedrock and small boulders or cobbles.[3] Spawning gravels (used by non-Sockeye) now occur in patches separated by bedrock or boulder substrate (JWP 2009). Water depth is often less than 20 cm at the sill (Wing et al. 2006) and infrequently as low as 3 cm (JWP 2009). Historical stream discharge

[1] Based on USGS data for Auke Creek (1947-1975) and Lake Creek (1963-1973) (JWP 2009).

[2] Total stream length from lake to zero tide-line in Auke Bay is ~0.65 km with a steep 26 m/km gradient (Wing et al. 2006).

[3] In 1963 Auke Creek was modified when NMFS installed a spawning channel in the upper portion of the creek. The channel was created with stacked timbers buttressed with concrete-filled sandbags, and filled with cobbles 5-10 cm in size. Since 1963 floods have washed large amounts of the cobble downstream and the upper portion is reverting to bedrock (JWP 2009).

levels (1963-1973) ranged from “no measurable surface flow during hard winter freezes and summer dry periods, to maximum instantaneous flows up to 9.85 m^3/s following late summer and fall rain storms” (Wing and Pella 1998, p. 15).

Sockeye Population

The watershed supports seven anadromous fish species, including: Sockeye, Coho, Pink and Chum salmon, and Cutthroat Trout, Steelhead Trout and Dolly Varden char.[4] Peak upstream migration for Sockeye occurs in late June and July. Sockeye do not reproduce immediately after ascending Auke Creek, but mature in Auke Lake for up to a month before spawning in August, principally in tributaries (Kovach et al. 2014; Taylor 2008a). In 2012, 98% of tagged fish spawned in Lake Creek and Lake Two Creek, and about 2% around creek deltas and submerged lakeshore springs (Ray et al. 2014)[5] (Figure 1). Eggs hatch in spring, and fry rear in the lake for 1-3 years before heading to sea as smolts in May (Kovach et al. 2014).

Sockeye returns to Auke Creek are considered to be relatively stable, with an average return of 2,754 wild adults and jacks since 1980 (Kovach et al. 2013; 2014). However, between 1963 and 1981, Sockeye adults returning to Auke Lake averaged 7,312 fish (Vulstek et al. 2016). The cause of the reduced average returns of Sockeye is unknown, but may be associated with development-driven declines in freshwater productivity[6,7,8], variations in remote mixed-stock commercial harvests[9], or changes in migrant estimation methods[10].

Median date of upstream migration timing appeared to be trending earlier between 1980 and 2015 (Vulstek et al. 2016). However, this may be age-specific: Kovach et al. (2013) estimated that adult Sockeye were moving into freshwater later (0.2 days per year), while jack Sockeye were trending earlier (0.3 days per year). The range of

[4] Auke Creek is the site of one of the four index runs in southeast Alaska that the ADF&G uses to determine Coho salmon abundance (Taylor and Wing 2008; in: JWP 2009).

[5] In 2012, 87% of tagged Sockeye spawned in the “spatially-limited habitat” of the lower reaches of Lake Creek, within 1.1 km of the lake, suggesting that population sustainability may be at risk due to natural flooding and drought events, as well as anthropogenic development impacts (Ray et al. 2014).

[6] The 1980-2015 average annual smolt abundance was 17,032 wild smolts, less than half the 1964-1979 average of 39,839 wild smolts (Vulstek et al. 2016). Peak estimate: 90,816 in 1961 (JWP 2009).

[7] Approximately 50% of the shoreline of Auke Lake is developed, including state, private, and municipal land owners (JWP 2009).

[8] The lower section of the primary spawning tributary (Lake Creek) has been channelized for flood control. Gravel aggradation in the lower reaches, resulting in subsurface low flows, may be limiting upstream migration and spawning (Taylor and Wing 2008; in: JWP 2009).

[9] Sockeye harvest has been closed in Auke Bay since 1980, and no aboriginal fisheries occur in-river, but commercial fisheries occur on mixed stocks migrating through distant purse seine, drift gillnet, and trolling fisheries (Kovach et al. 2013). Therefore annual Auke Sockeye harvest rates are unknown but are unlikely to incur directional selection on migration timing for Auke Sockeye (*ibid*).

[10] Different adult fish estimation methods before and after permanent weir installation in 1980 may be a factor. However, adult salmon pre-1980 were similarly captured via a semi-permanent gated picket-type weir (Vulstek et al. 2016), thus enumeration methods are not a likely source of error.

dates of upstream migration has decreased for all Auke salmon species (*ibid*).

Auke Lake Fisheries Research

The Auke Lake watershed has been an important contributor to tribal, commercial and sport fisheries in the area, until all fisheries were closed in 1980. The protected marine waters were a favorite fishing ground for the Auke (A'akw Kwáan) and Taku tribes, which had inhabited the Auke watershed and surrounding area for thousands of years (JWP 2009). By the late 1800s, the U.S. Fish Commission assumed responsibility for natural resource conservation, and in 1911, the Alaska Fisheries Service was established to manage marine resources. A hatchery and dam was built by residents on Auke Creek in 1902, and a cannery was added in 1919, which operated until 1921. In 1954, a fish hatchery was built on Auke Creek to support sport fisheries (Mobley 1992, in: JWP 2009).

Marine and freshwater research facilities continued to develop over the following decades, with the establishment of the Auke Bay Laboratory (ABL) in 1960. The National Marine Fisheries Service (NMFS) installed a fish weir in Auke Creek in 1961 to augment anadromous fisheries research (Lum and Taylor 2006, in: JWP 2009); annual Sockeye escapements became available as of 1963. The NMFS became part of NOAA in 1970. In 1976, the ABL became a part of what was later called the Northwest and Alaska Fisheries Center (NWAFC). By 1990, a division of the NWAFC agency, the Alaska Fisheries Science Center (AFSC), was facilitating operations at the Auke Creek Research Station (ACRS) through the ABL salmon research program.[11] The ACRS hatchery, established originally in 1971, was used to enhance Sockeye smolt production in various years in response to population declines since the 1970s. Hatchery-reared sockeye juveniles stocked in Auke Lake contributed to adult returns in 1977-1982 and 1990-1995 (Taylor et al. 1992; Vulstek et al. 2016)[12].

The Auke Creek fish weir currently in operation was constructed in 1980, about 50 m above the high tide line and 400 m downstream from Auke Lake (Hoover 2007; 2008; Echave 2009). The weir permits biologists to census all downstream and upstream migratory fish. The weir operates on a daily basis between late February and mid-to-late June to tally juvenile emigrants, and then operates in reverse until October for a complete census of adult immigrants (JWP 2009). The extensive observational time series for anadromous fish species made at the ACRS counting weir has enabled research on the response of fish populations to climate change.

[11] Auke Creek Research Station is operated by the ABL Salmon Ocean Ecology study program on a cooperative basis with University of Alaska Fairbanks (UAF), the Alaska Department of Fish and Game (ADF&G), and the University of Alaska Southeast (UAS).

[12] The contribution of hatchery-produced Sockeye to subsequent adult returns has not been fully studied. Adult returns in affected years ranged from ~1,300 – 4,600 fish (Table 2).

METHODS

DAILY SOCKEYE COUNTS

Daily adult Sockeye migrant estimates were obtained from NOAA personnel based on visual counts at the NMFS Auke Creek Weir, near the outlet of Auke Lake, for the years 1980 to 2016[13]. Adult Sockeye migrants were enumerated visually by an observer stationed on the weir between June and September.

Annual plots of daily and cumulative migration rate (i.e. percent 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 multi-year stock migration data (number of observations, central tendency (mean, median, mode), scale (range, variance, extreme values and outliers), and shape (skewness, kurtosis)). Median (50th percentile) and 75th percentile values of the historical datasets were calculated to establish categories of “insignificant” or “negligible” daily migration rates (0-50th percentile) versus “significant-but-moderate” (50-75th percentile) and “significant-and-high” (75-100th percentile) migration activity.

The day of the year (Julian date) when 50% of the total annual Sockeye escapement was tallied determined the annual time-to-50% (TT50%), and was used to calculate the multi-year historical mean TT50% (1980-2016). Trend analyses were applied to the TT50% time-series, with and without years potentially influenced by hatchery returns (1980-1982, 1990-1995; Vulstek et al. 2016) to review changes in annual migration timing.

ENVIRONMENTAL DATA

Meteorological, hydrographic, and water temperature data necessary for derivation of long-term (30+ years) time-series of water temperature and flow conditions were assembled from online databases, published documents, unpublished reports, and personal records from government agencies (e.g. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA); NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION (NCEI); ALASKA CLIMATE RESEARCH CENTER (ACRC); and AUKE BAY LABORATORY (ABL)).

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 variates where suitable to infill missing observations. STATISTICAL ANALYSIS SOFTWARE (SAS® Version 9.4) was used to assemble and analyze data from CSV file downloads and/or supplied MICROSOFT EXCEL® spreadsheets. The resulting datasets were stored in a relational FRESHWATER ENVIRONMENTAL VARIABLES DATABASE (Hyatt and Stiff, DFO; unpublished data) and are available from DFO

[13] Daily Sockeye migrant data for 2016 were not available at the time of analysis, but have been incorporated into tabular output and plots where feasible. The inclusion of 2016 migration data had no significant effect on multi-year migration statistics (i.e. mean, quartiles, TT50%, etc.).

upon request.[14] Trend analysis software programs were used to identify long-term trends (Kundzewicz and Robson 2000) and 'regime shifts' (Rodionov 2004; 2005; 2015) in the mean and variance of air temperature and precipitation – summarized across Sockeye migration months – via parametric and non-parametric statistics such as the Mann-Kendall (MK) and rank sum tests.[15,16]

Air Temperature

Various studies have demonstrated that regional air temperature variation is generally sufficient to explain as much as 80% of the variation in local daily mean water temperature (Mohseni and Stefan 1999; Stefan and Preud'homme 1993; Webb and Nobilis 1997). Linear and nonlinear regression models have been shown 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 modelled water temperature 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 for comparison with other watersheds, and summarized to examine trends and shifts in water temperature regimes at longer time-scales (e.g. decadal).

NOAA provides public access to an archive of comprehensive meteorological and climatological data gathered from both active and inactive stations distributed throughout the world via the NCEI data portal.[17] Daily meteorological data accessible via the NCEI portal are part of the GHCN (GLOBAL HISTORICAL CLIMATOLOGY NETWORK) database, a composite of climate records from various sources (e.g. WORLD METEOROLOGICAL ORGANIZATION). NCEI collects and merges the data and applies a suite of quality assurance reviews, including removal of biases associated with factors such as urbanization and changes in instrumentation through time (Menne et al. 2012a; 2012b).

The NCEI data portal was accessed to identify potential sites of air temperature data within the area of interest (Figure 2)[18]. AUKE BAY weather station (USC00500464) was selected for daily meteorological data retrieval for the Auke watershed on the basis of:

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[14] Contact Howard.Stiff@dfo-mpo.gc.ca or Kim.Hyatt@dfo-mpo.gc.ca for information on the MICROSOFT ACCESS® database.

[15] TREND / CHANGE DETECTION SOFTWARE Version 1.0.2 from https://toolkit.ewater.org.au. TREND is designed to facilitate statistical testing for trend, change and randomness in time series data. Statistical methods are based on the WMO/UNESCO WCP Expert Workshop on Trend/Change Detection, and on CRCCH Hydrological Recipes (Cooperative Research Centre for Catchment Hydrology's Climate Variability Program) (Kundzewicz and Robson 2000).

[16] SEQUENTIAL REGIME SHIFT DETECTOR SRSD Version 6, downloaded from https://sites.google.com/site/climatelogic/home (Rodionov 2004; 2005; 2015).

[17] NOAA NCEI online climate data portal: https://www.ncdc.noaa.gov/cdo-web/datatools/findstation

[18] https://gis.ncdc.noaa.gov/maps/ncei/cdo/daily

(i) the quantity and quality of data available (1963-2016; 97% complete)[19];

(ii) proximity (<5 km) to Auke Creek water temperature monitoring site; and

(iii) the potential to routinely update the time-series from an “active” high-quality climate station.

The AUKE BAY weather station is located on the northeast shoreline of Auke Bay, with open water to the west and low hills rising to the east. Minor shifts in met station elevation (between 11 and 13 m) and geographical location (approximately 0.8 km) occurred over the years.[20] Statistical comparisons (analysis of means and variance) indicated significant differences in the mean air temperatures between installation periods, with a slight rise in mean annual temperature (~0.8°C) and mean summer temperature (~0.4°C) between the first 20 years and the next 30 years of monitoring (Appendix A), however, no overlapping data were available to control for likely temporal effects due to climate change over the 50-year time period. As NCEI applies a suite of quality assurance reviews, including removal of biases associated with factors such as urbanization and changes in instrumentation over time (GHCN undated)[21], it is assumed that any differences in temperature between installations at this GHCN location are most likely attributable to regional climatological changes (Stafford, Wendler & Curtis 2000) and oceanic regime changes in 1996 (Hartmann and Wendler 2005). Thus, the AUKE BAY air temperature datasets were treated as a continuous time-series with homogeneous statistical properties.

Auke Bay “Air Temperature Standard”, 1900-2016

The Auke Bay daily mean “air temperature standard” was derived as a synthetic variable consisting of observed Auke Bay daily mean air temperatures, infilled where missing with estimates based on interpolation or statistical relations with nearby meteorological stations, as follows.

Minor data gaps (1-3 days) during the adult Sockeye migration period (June-September) were found throughout the AUKE BAY daily air temperature record, with more extensive data gaps (12-30 days) in June-August 1966 and September 1999. To address these gaps, and to extend the daily air temperature time-series back to the year 1900, linear statistical relations were established for AUKE BAY minimum and maximum air temperature time-series as a function of air temperature variates downloaded for NOAA NCEI meteorological stations (Figure 2) at:

[19] Weather observations have been taken daily since February 1963 at AUKE BAY LABORATORIES (58°22'N, 134°38'W), as part of the NATIONAL WEATHER SERVICE COOPERATIVE OBSERVER PROGRAM. Daily air temperatures and precipitation were recorded at approximately 1630 hours local time according to procedures in the WEATHER BUREAU OBSERVING HANDBOOK (Wing et al. 2006).

[20] From 53.38°N x 134.63°W and elev. 11.9 m (1963-1981) to elev. 12.8 m (1982-2011), to 53.38°N x 134.64°W, elev. 13.4 m (2011-2016) https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00500464/detail

[21] GHCN-Daily – online documentation: https://www1.ncdc.noaa.gov/pub/data/cdo/documentation/GHCND_documentation.pdf

1. JUNEAU INTERNATIONAL AIRPORT (1936-2016; 89% complete)[22], approximately 10 km southeast of AUKE BAY, and
2. JUNEAU DOWNTOWN (1900-2016)[23], a more protected, and slightly warmer urban location atop the Juneau Federal Building approximately 31 km southeast of the AUKE BAY station. Data completeness ranged from 54% (1900-1965) to 72% (1965-2016).

Missing data from the GHCN data for JUNEAU DOWNTOWN were first infilled from the ALASKA CLIMATE RESEARCH CENTER for secondary station JUNEAU DWTN (1900-1999), which are based on the same GHCN JUNEAU DOWNTOWN data, where available, but utilize secondary observations from a priority list of federal, regional, state, and local weather and climate networks for missing GHCN data blocks of one month or more (e.g. 1917-1942).[24] [25]

As daily minimum and maximum temperatures were more frequently available than daily mean temperatures in these time-series, linear relationships based on ordinary least squares were established for AUKE BAY station minimum and maximum variables as a function of the same for Juneau stations. Statistical analyses were based on 'summer months' only (June-September) to maximize linearity in the relations. Missing AUKE BAY minima and maxima for these months were then estimated based on corresponding regression coefficients for (1) JUNEAU AIRPORT, where available, and (2) JUNEAU DOWNTOWN, in decreasing order of correlation. Missing values after this process accounted for 1.5% of the AUKE BAY air temperature standard spanning 1900-2016.

Remaining blocks of missing data greater than two consecutive days in the early 1900s and 1966[26] were infilled with normally-distributed random values (seeded) based on day-of-year mean and standard deviation for the periods 1900-1920, and 1960-1970, respectively. Intermittent remaining missing dates of two consecutive days or less were interpolated between adjacent temperature values. This process resulted in a continuous time-series of observed and estimated Auke Bay daily mean air temperatures spanning June 1st - September 30th, 1900-2016. The resulting observed + estimated daily mean air temperature (MAT) dataset is referred to here as the AUKE BAY AIR TEMPERATURE STANDARD. This extended time-series was summarized for the Sockeye migration months and tested for trends and 'regime shifts' using parametric and non-parametric trend statistics (Kundzewicz and Robson 2000; Rodionov 2005).

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[22] JUNEAU INTERNATIONAL AIRPORT station: USW00025309 (53.36°N x 134.56°W and elev. 4.9 m)

[23] JUNEAU DOWNTOWN station: USC00504092 (58.3°N x 134.4°W, elev: 22-54 m): 1900-1965; and USC00504094 (58.3°N x 134.4°W, elev: 7.6 - 15.2 m): 1965-2016. Complete years were limited to: 1900-1916, 1943-1972, 1976-1993, 1998, 2003-2016.

[24] JUNEAU DNTN station (ALASKA CLIMATE RESEARCH CENTER): http://climate.gi.alaska.edu/acis_data

[25] ACRS APPLIED CLIMATE INFORMATION SYSTEM documentation: http://www.rcc-acis.org/docs_datasets.html

[26] e.g. June-August 1903 and 1910, July 1912, Aug-Sep 1915, and June-August 1966.

Multi-day Mean Air Temperature Index

The best predictive air-to-water relationships exist for associations between daily mean water temperature and a multi-day mean air temperature index (Hyatt and Stockwell 2003; Webb and Nobilis 1997). Centered moving averages (i.e. mean air 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).

Using the AUKE BAY AIR TEMPERATURE STANDARD dataset, 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)[27] while retaining a high Pearson correlation coefficient, for a representative subset of data from the associated daily mean water temperature site. The multi-day CMAT index with the lowest adjusted AKAIKE INFORMATION CRITERION (AICc) and the highest Pearson correlation coefficient (r_P) for the calibration dataset was used for subsequent air/water temperature regression relations.[28]

Water Temperature

Auke Creek daily mean water temperatures (1980-2016) were supplied in spreadsheet format by NOAA staff. Raw data were recorded at the Auke Creek Hatchery weir at the lower end of the stream. Between 1980-1999, stream temperatures were manually monitored each morning with liquid-in-glass thermometers. As of 2000, stream temperatures were recorded automatically by datalogger, and daily values represent the average of multiple measurements taken systematically throughout the day. From 2000-2014, daily means were based on observations obtained every 4 hours by a Vemco Minilog-T data logger (Wing et al. 2006). As of 2014, daily means were based on hourly readings from an Onset HOBO analog data logger. Observations in 2016 were unavailable prior to 29-June at the time of this analysis, limiting some analyses of temperature during peak Sockeye migration (June/July).

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 datalogger 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.

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

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[27] *n* = 1 corresponds to the “observed” daily mean air temperature time-series.

[28] 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 and resulting daily water temperature estimates (Hyatt et al. 2015).

Air / Water Temperature Relationships

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

Equation 1: $T_w = \alpha + \beta * T_a$; where
T_w is the *estimated daily mean water temperature*;
T_a is the *7-day mean air temperature index*;
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 daily mean water temperature;
T_a is the 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;
β represents the air temperature at the inflection point.

Evidence of hysteresis[29] in a water body was statistically evaluated for both linear and logistic models; if hysteresis is present (as it usually is for all but the fastest-moving steep-slope water-bodies), it is necessary to use separate warming and cooling season regression models to most accurately define air/water temperature relations at a particular site.

For the logistic analysis, hysteresis was assessed by comparison of the *Nash-Sutcliffe Coefficient* (NSC) value for the all-season model versus the averaged NSC values for the separate warming and cooling season models (Mohseni et al. 1998):

Equation 3: $Hysteresis = [(NSC_w + NSC_c) / 2 - NSC_{all}] \geq 0.01$; where
NSC_w = NSC for warming season;
NSC_c = NSC for cooling season;
NSC_{all} = NSC for all seasons combined.

For linear models, the significance of hysteresis is tested using an additional categorical "season" predictor (signifying different seasonal model intercepts), and/or an air/water interaction effect (indicating significant differences in seasonal model slopes) for the Type III model sum of squares (SAS 1987).

[29] Hysteresis relates to 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 waterbody in summer-to-fall, thermal de-stratification in 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.

Water Temperature Time-Series Reconstruction

Model Calibration

Linear and logistic regression relations described above were developed using site-specific daily mean water temperature (MWT) as a function of the regional air temperature index (7-day centered MAT variate) for the Auke Bay Air Temperature Standard.

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

Years with consistent and apparently unbiased water temperature observations associated with a maximum range of temperature values for both warming and cooling "seasons" (described below) were preferred for characterizing the all-year air/water temperature relationship. Years of evident bias or excessive anomalies in the water temperature observations were not evident in the time-series. Data years not used for model validation were used for validation of statistical relations via Pearson correlation analysis.

Seasonal Change-Point

To determine whether seasonally-distinct regression relations were required, the air/water temperature data for each site 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", or change point.[30] 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 multi-year calibration data for both linear and logistic models. If hysteresis was detected in either case, linear and logistic models were then fitted to the all-year data for each of the warming and cooling seasons separately.

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[30] 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 timing of the winter season change point was not required for the purpose of this analysis.

MODEL VALIDATION

Site-specific linear and nonlinear air/water regression parameter estimates were tested for statistical significance, and applied to the air temperature indices to estimate 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 Auke Creek reference site.

Precipitation

Daily precipitation records (GHCN data[31]) were obtained from the NOAA NCEI data portal associated with the three meteorological stations identified in the Air Temperature section above:

1. AUKE BAY (USC00500464) for 1963-2016;
2. JUNEAU AIRPORT (USW00025309) for 1941-1942, 1948-2016;
3. JUNEAU DOWNTOWN (USC00504092:1900-1965; USC00504094: 1965-2016).

Daily precipitation totals (inches) were converted to millimeters.

Multi-day Mean Precipitation Index

Bell et al. (2017) found the cumulative 6-day mean index for regional precipitation to have the highest correlation with Auke Creek daily water levels between July and October ($r^2 = 0.72$). This index was calculated for each GHCN station above, and cross-correlated to identify inter-site regression relations to statistically define a long-term "precipitation standard" for the Auke Bay region (Table 5).

Auke Bay "Precipitation Standard", 1900-2016

The Auke Bay "precipitation standard" was derived as a predictor variable for estimating Auke Creek water levels back to 1900. This variable consists of the 6-day cumulative mean daily precipitation index for the AUKE BAY station (after Bell et al. 2017), infilled where missing and extended back to 1900 with estimates based on statistical relations with nearby meteorological stations, as follows.

Logarithmic statistical relations ($Y = aX^b$) were established between the AUKE BAY 6-day cumulative mean daily precipitation time-series and the 6-day cumulative mean daily precipitation for:

1. JUNEAU INTERNATIONAL AIRPORT (1941-2016; 89% complete)[32], approximately 10 km southeast of AUKE BAY ($r_s = 0.93$, n = 1597, Table 5), and

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[31] GHCN-Daily – online documentation: https://www1.ncdc.noaa.gov/pub/data/cdo/documentation/GHCND_documentation.pdf

[32] JUNEAU INTERNATIONAL AIRPORT station: USW00025309 (53.36°N x 134.56°W and elev. 4.9 m)

2. JUNEAU DOWNTOWN (1900-2016)[33], a warmer and wetter urban location atop the Juneau Federal Building approximately 31 km southeast of the AUKE BAY station (r_s = 0.83, n = 1266, Table 5). Data completeness ranged from 54% (1900-1965) to 72% (1965-2016)[34 35 36]

Statistical analyses were based on the 'summer months' (June-September) but extended to include October in order to capture upper precipitation extremes in the relations. An increment of 1 mm was applied to all precipitation variables to accommodate zeros prior to logarithmic transformation. Model calibration was restricted to every 5th observation to reduce the influence of autocorrelation effects.

Missing AUKE BAY values for these months were then estimated based on corresponding regression coefficients for (1) JUNEAU AIRPORT, where available, and (2) JUNEAU DOWNTOWN, in decreasing order of correlation. The resulting cumulative 6-day mean precipitation index dataset is referred to here as the AUKE BAY PRECIPITATION STANDARD. Remaining missing values after this process accounted for <1% of the AUKE BAY precipitation standard spanning 1900-2016, located in 1904, and 1913-1916. The extended time-series was summarized for the Sockeye migration months and tested for trends and 'regime shifts' using parametric and non-parametric trend statistics (Kundzewicz and Robson 2000; Rodionov 2005).

Water Level

Water level estimates (in feet Above Sea Level (ASL), i.e. above the zero tide-line) were obtained from spot measurements taken daily at 8:00 a.m. at the Auke Creek weir and converted to meters ASL. Observations extend continuously for the adult Sockeye migration period (June-September) from 2006 to 2016.

Water Level Time-Series Reconstruction

Linear relationships were established between daily Auke Creek water level and the selected AUKE BAY regional precipitation and air temperature standard time-series to extend the water level time-series prior to 2006 and to estimate intermittent missing values. Model calibration was based on Jun-Oct data (where daily water level data were available) subsetted for every 5th observation to reduce the influence of autocorrelation effects within time-series.

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[33] JUNEAU DOWNTOWN station: USC00504092 (58.3°N x 134.4°W, elev: 22-54 m): 1900-1965; and USC00504094 (58.3°N x 134.4°W, elev: 7.6 - 15.2 m): 1965-2016. Complete years were limited to: 1900-1916, 1943-1972, 1976-1993, 1998, 2003-2016.

[34] Missing data from the GHCN data for JUNEAU DOWNTOWN were first infilled from the ALASKA CLIMATE RESEARCH CENTER for secondary station JUNEAU DWTN (1900-1999), which are based on the same GHCN JUNEAU DOWNTOWN data, where available, but utilize secondary observations from a priority list of federal, regional, state, and local weather and climate networks for missing GHCN data blocks of one month or more (e.g. 1917-1942).

[35] JUNEAU DNTN station (ALASKA CLIMATE RESEARCH CENTER): http://climate.gi.alaska.edu/acis_data

[36] ACRS APPLIED CLIMATE INFORMATION SYSTEM documentation: http://www.rcc-acis.org/docs_datasets.html

Linear regression was used to model observed daily water level against the 6-day cumulative mean AUKE BAY PRECIPITATION STANDARD alone, plus an additional term based on a multi-day cumulative mean AUKE BAY AIR TEMPERATURE STANDARD (see *Multi-day Mean Air Temperature Index*, above)[37]. For the latter, stepwise selection methods were used to identify the most parsimonious two-term model including precipitation and temperature components significant at the $\alpha = 0.05$ level. As both of these precipitation and air temperature predictors extend from 1900-2016, the linear model that provided maximum explained variance was selected to estimate Auke Creek daily water levels for the summer months from 1900-2016. This provided an AUKE CREEK DAILY WATER LEVEL STANDARD variable.

Goodness-of-fit was assessed using correlation of observed versus predicted AUKE CREEK water levels and subjective examination of time-series plots. Univariate statistical analyses were applied to the AUKE CREEK DAILY WATER LEVEL STANDARD for the migration period to determine threshold percentiles to identify drought (< 10th percentile), moderate (10-90th percentile) and flood (90-100th percentile) categories for exceedance analyses.

TREND AND EXCEEDANCE ANALYSES

Air Temperature and Precipitation

Historic regional air temperature data (based on AUKE STANDARD daily MAT) and precipitation (AUKE STANDARD daily MAT) were summarized by year to obtain the mean value during the migratory months (June-September, 1900-2015), and plotted to review the long-term time trend in regional air temperature conditions during the migratory period. Non-parametric test statistics were calculated over the 116-year period (1900-2015) for detection of trends in the mean (Mann-Kendall) and step changes in the mean (rank sum) (Kundzewicz and Robson 2000). Regime shift detection using sequential t-test analysis (STARS 6.2 software) was applied to mean Jun-Sep air temperature and the cumulative mean 6-day precipitation variable after prewhitening using a target $p = 0.05$, year cutoff length = 20, tuning constant = 2 and a subsample size = 12 (Rodionov 2004).

Monthly mean air temperatures of 20°C are considered an upper threshold for salmonid freshwater life history stages (Mote et al. 2003). Historic mean daily AUKE STANDARD air temperature data were analyzed for the frequency of dates in each year and month (June-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 weather conditions.

[37] The temperature term was incorporated to address some warm periods characterized by minor amounts of precipitation that, based on precipitation only, yielded overestimates in water level.

<u>Water Temperature</u>

Reconstructed daily mean water temperature (MWT) data were summarized by site and year (1900-2015) at Auke Creek to determine mean values during the summer months (June-September), and plotted to review the long-term time trend in site-specific water temperature conditions during the migratory period.

A 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 (June-September).[38] 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.

<u>Water Level</u>

For exceedance analyses, both “low flow” and “high flow” dates are of potential interest, since, conceivably, either flow extreme may negatively impact upstream migration. However, preliminary review of water level data suggested that low flows might be the primary issue for adult migrants in Auke Creek, as shifts in seasonal precipitation and snowmelt patterns may be leading to extreme low flow periods restricting or delaying fish ascent into the lake (Kovach et al. 2013).

For “low flow” exceedance analyses, estimated daily water levels based on statistical relations between Auke Creek weir observations (2006-2016) and regional precipitation indices were used. The frequency of dates for which observed water levels were less than the lower 10th percentile was calculated by year and month (June-September), and summarized by decade. From these data, the frequency of annual periods in which flow levels continuously remained below the lower threshold, 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. Similar analyses were applied to “high flow” levels (>75th percentile) and “flood” levels (>90th percentile).

MIGRATION, WATER TEMPERATURE AND WATER LEVEL

To examine the inter-annual impacts of temperature and climate conditions on annual migration, the Julian dates associated with annual time-to-50% (TT50%) were cross-correlated with mean annual water temperature and level plus several indices of ‘extreme’ high water temperature (>18ºC) and low water level (< 6.5 m), including the annual frequency (days) and mean and maximum continuous duration (days) of extreme events. In addition, annual TT50% was categorized by PDO[39],

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[38] Insufficient data exist to contrast inter-annual results at higher temperature thresholds (i.e. >18°C).

[39] Years were classified by PDO (Pacific Decadal Oscillation) phase, as defined by the NOAA NCEI PDO index at https://www.ncdc.noaa.gov/teleconnections/pdo/.

ENSO[40], PDO/ENSO[41], and ‘warm’ Auke Creek temperature years[42]. The Kruskal-Wallis statistic based on non-parametric one-way analysis of means was used to examine differences in the TT50% due to each of these classifications.

To examine intra-annual impacts, daily mean water temperature and water level estimates were merged with daily Sockeye migration rate data to test the null hypothesis that daily migration rates were not associated with changes in water temperature and discharge.

Spearman correlation and robust parametric regression analyses were used to explore the relationship between the arcsin-transformed daily migration index as a function of observed daily water temperature and log-transformed estimated water levels, after zeros, outliers, and leverage points were removed to normalize the data.

For migration rate data, the 75th percentile (P75) was used as the threshold to define whether a daily migration rate value was a negative versus positive anomaly, and the 95th percentile of migration rates was used to define whether a positive migration rate was “moderate” (i.e. 75th - 95th percentile) or “high” (>= 95th percentile).

Observed water temperature values near the upper tolerances of Sockeye salmon were infrequent; thus the maximum Auke temperature threshold available for statistical testing was at the lower end of known thermal impact levels, i.e. 18°C (Hyatt et al. 2015). This corresponded approximately to the P95 of observed water temperatures in Auke Creek between 1980 and 2015.

For water level, the 10th percentile (~6.44 m ASL) of observed all-year daily water levels at the weir in Auke Creek during the Sockeye migratory period was used to classify “extreme low” (negative) versus “moderate to high” (positive) flow events. Flood events were also considered analytically, using the P90 threshold of 6.82 m.

The frequency distribution of observed migration dates (i.e. filtered for non-zero migration rates) at varying levels of temperature and discharge was then generated to indicate the general distribution of temperature and flow conditions that were encountered by fish during the migratory period.

A similar frequency distribution of active migration dates, *weighted by the daily migration rate*, was then used to quantify *how much* migration occurred at a given temperature and discharge level. In contrast to the simple distribution of dates of migration (which omit *amount* of fish), these plots displayed the water temperature and flow conditions associated with highest migration rates (presumably most favourable to salmon migration), and, by extension, possible thermal and

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[40] Years were classified by ENSO (El Nino Southern Oscillation) phase, as defined by the NOAA NCEI ENSO index at https://www.ncdc.noaa.gov/teleconnections/enso/.

[41] Two classifications were of interest: (1) annual classifications of both PDO and ENSO indices in positive phase; (2) annual classifications of both PDO and ENSO indices in negative phase. Other combinations were omitted.

[42] ‘Warm’ Auke Creek temperature years were signified by mean Jun-Sep water temperatures > 16ºC or 95th percentile (P95) of Jun-Sep water temperatures > 19ºC. See Table 11.

hydrological limits (if any) that differentiate high versus low rates of migration.

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

RESULTS

SOCKEYE MIGRATION DATA

Daily migration data for Auke Lake Sockeye were available for 37 years between 1980 and 2016 (Table 2). Adult migrant fish counts typically commenced in mid-June, and terminated by mid-September. Maximum daily totals ranged up to 2,468 fish per day (in 2004), with an all-season average of 53 fish per day (Table 2).

Peak Sockeye migration generally spanned the month of July, with annual time-to-50% (TT50%) ranging from July 4th (1981) to August 22nd (1994). The multi-year mean TT50% (1980-2016) was approximately July 22nd (Figure 5). A weak time-trend in the TT50% was detected in the full time-series ($r = -0.26$, $P_{MK} < 0.1$, $n = 37$; Figure 6), but no ‘regime shifts’ in the mean or variance. When years for which hatchery returns may have influenced the timing (1980-1982, 1990-1995) were removed, non-parametric statistics indicated no significant trend, though a weak linear trend remained ($r = -0.36$, $P < 0.1$, $n = 28$). In both cases, rank sum analyses indicated a 7-day decrease in TT50% after 1995 ($\bar{x}_{<1996}$ = day 206; $\bar{x}_{>1995}$ = day 199; $P< 0.1$).

Total annual escapement (adults + jacks) ranged from a low of 325 fish in 1985 to 6,123 fish in 1996 (Table 2), with a 37-year mean of 2,754 ± 1,245 fish (median: 2,807 fish). Although a weak, positive trend in abundance was indicated since 1980, maximum temporal correlations were associated with polynomial fits characterized by oscillating decadal trends (Figure 7).

Large proportions of this relatively small Sockeye run often migrated upstream over the course of a few days. While mean daily migration rates hovered around 2% of total annual escapement, maximum daily migration rates commonly ranged between 10-40% for many years, and 83% in 2004 (July 28th) (Table 2). Median (P50) daily migration rates – distinguishing “negligible” versus “low” migration for the purposes of this analysis – was ~0.4%; the 75th percentile (P75, indicating “significant” migration) was ~1.6%; and the 95th percentile (P95, characterizing the threshold between “moderate” and “high” migration) was ~8.8% of the annual totals. Significant enroute mortality has not been documented in the historical record.

Annual time-series of Auke Sockeye daily migration rates (%) were plotted in

Appendix G, along with mean and maximum daily migration rates across all complete years, displaying, in some years, late onset of migration (e.g. 1986, 1993, 2004, 2009) and/or multi-modal migration pulses separated by periods of relatively low migration (e.g. 1981, 1987, 1993, 1994, 1999, 2009, 2011, 2013), evidence of environmental factors influencing migration patterns.

TEMPERATURE

The annual time-series of Auke Creek mean water temperature (MWT) observations (1980-2016) were plotted by year and site in the multi-panel plots in Appendix G. The annual plots were condensed to one plot in Figure 21 and statistically summarized for the Auke reference site in Figure 22.

Observed mean water temperature during Sockeye migration between 1980 and 2016 was 15.2 ± 2.0°C, with 95% of water temperatures less than 18.4°C (Table 11; Figure 21). The recorded maximum daily mean water temperature of 20.5°C occurred in 2004. The summers of 1989, 1990, 1992, 1997, 1998, 2004, 2005, 2009, 2013, 2014 and 2015 were consistently represented in the warmest years of observed data for various temperature indices (e.g. mean, maximum, 75-95th percentiles). Mean water temperatures exceeded 17°C during peak Sockeye migration (July) in these years. In a subset of those years (1989, 1990, 1997, 1998, 2004, 2009), daily MWTs continuously exceeded critical adult Sockeye migration thresholds of 19-20°C for periods of 7-10 days (Figure 23; Appendix C).

Water Temperature Time-Series Reconstruction

The logistic and linear air/water temperature models were parameterized using a calibration dataset composed of 19 years of data based on Auke Creek water temperature and the Auke Bay ‘standard’ air temperature index, between 1980 and 2015 (Table 12).

Seasonal Turn-Around Point

The mid-year seasonal temperature turn-around point for Auke Creek was derived as week 30 (day 210), approximately July 29th – based on maximum mean weekly air and water temperatures for the calibration data years (Figure 24). The “warming season” therefore extended from April 1st to July 29th, followed by the “cooling season” from day 211-329, i.e. July 30th to November 25th.

Multi-Day Air Temperature Index

The multi-day AUKE air temperature index that best correlated with all-year daily mean water temperature in the lower Auke Creek was identified as the 7-day centered moving average air temperature index (7d-CMAT).

For the warming season, calibration dataset correlations were marginally improved with increasing length (no. of days) in the multi-day moving average, reaching a maximum with the 10-day CMAT (Figure 25 (top); $r_{5d\text{-}CMAT} = 0.953$; $r_{7d\text{-}CMAT} = 0.960$; $r_{10d\text{-}CMAT} \geq 0.961$; $P < .0001$; $n = 2,464$).

Similarly, for the cooling season, maximum correlation was achieved with the 10-day CMAT index (Figure 25 (bottom); $r_{7d\text{-}CMAT} = 0.958$), compared to the next highest correlate, the 7-d CMAT: $r_{7d\text{-}CMAT} = 0.954$; P < .0001; n = 1,968.

However, the 10-d CMAT index was excluded due to the undesired trade-off between high correlation versus the damping effect on daily variation in the resulting mean water temperature estimates (Hyatt et al. 2015). Thus, the AUKE 7-day CMAT index was selected as the predictor variable for subsequent air/water temperature analyses.

Model Calibration and Validation

Hysteresis was detected for logistic relations for the Auke Creek calibration dataset (Table 12) based on the difference between seasonal and all-season goodness-of-fit (NSC) coefficients (Table 13), as well as for linear relations based on significance tests for equal intercepts and equal slopes (Table 14), indicating that air/water temperature relationships were best modeled using separate seasonal components (logistic models: Figure 26; linear models: Figure 27). Logistic model parameters, 95% confidence limits, and NSC goodness-of-fit coefficients are listed in Table 13. Linear regression model output for seasonal air/water temperature relationships and calibration data are provided in Table 14.

A subset of the validation data years were plotted in Figure 28 with observed and logistically-modeled MWT output, along with daily MAT and the 7-d MAT index (linear output not shown). Average conditions were estimated reasonably well (e.g. 1983, 1993, 2003), as were non-extreme monthly statistics such as the median and other percentiles (10^{th}, 75^{th}, 95^{th}). Model estimates tended to underestimate water temperatures during warm periods (e.g. 2004, 2009), thereby yielding conservative estimates of the frequency and duration of the warm water episodes. Season-specific Pearson (r = 0.94) and ranked Spearman (r = 0.97) correlation coefficients between modeled estimates and validation data indicated that logistic model types were slightly more skilled at predicting Auke Creek water temperatures (Table 15).

For the purposes of establishing a long-term water temperature index, and for consistency with analyses in other studies (e.g. Hyatt et al. 2015), the seasonal logistic model parameters were selected as the best estimators of daily mean water temperature for Auke Creek, and were used to reconstruct historical daily water temperature estimates for the period of available air temperature data at Juneau Airport (1900-2016).

Trends in Temperature

Though weak positive trends were detected in the 36-year time-series of *observed* Auke Creek water temperatures for the migratory months (June-September 1980-2015; MK = 1.85, P < 0.1, N = 36), the trends were weaker during peak Sockeye migration (June/July, P > 0.1). Temperature increases appear to be driven by increases in August water temperatures (MK = 2.0; P < 0.1). Though no ‘regime shifts’ in the minimum, mean, or maximum water temperature observations were evident based on parametric sequential t-tests, a positive step change in the mean was detected as of 1988 using a non-parametric rank sum statistic (Z = -2.3, P < 0.05).

A long-term warming trend in the *extended* mean air temperature ‘standard’ for Auke

Bay was evident for the warmest migratory months (June-August, 1900-2015; Mann-Kendall $Z = 5.0$; $P < 0.01$; Figure 29). A significant difference in the mean was detected in 1976 and 1988, with warmer summer temperatures occurring after those years, according to non-parametric step- and difference-tests ($Z = 5.7$; $P < 0.01$).

Focusing only on the months of peak Sockeye migration (June-July), parametric and non-parametric trend analyses indicated a significant positive trend in both the mean and maximum air temperature time-series – but not the minimum or variance – since 1900 (Figure 31). While mean air temperatures have increased less than a degree from ~13°C in the early 1900s (MK = 2.6, $P < 0.05$), maximum June-July air temperatures have increased more than a degree over the century, from <18°C to >19°C (MK = 3.0, $P < 0.01$). Sequential regime shift testing after decorrelation indicated a potential positive shift in mean air temperature in 1989 and maximum air temperature in 1964 ($P < 0.01$; Figure 32).

The corresponding Auke Creek mean water temperature time-series, which is dependent on the air temperature index, necessarily reflected an analogous warming trend (Kendall's Tau-B = 0.06; $P < 0.001$; Figure 30). However, the linear trend was less than a tenth of a degree per decade.

Temperature Exceedance Analyses

A frequency analysis of regional daily mean air temperature indicated that the annual cumulative total number of $POT_{>20°C}$ dates has averaged 1-2 days per year for most of the century (near-zero for the 1920s, 1930s, and 1940s), with no statistically detectable difference between decades (Table 16, Figure 39, top).

Based on a lower threshold of 18°C, the pattern becomes a bit clearer (Figure 39, bottom), indicating some regional warming since the 1950s, with a decadal average of 1-4 days exceeding 18°C, mainly in July. The 1900s and 1920s-1950s were characterized by cooler weather, with an average of less than 1 day per year exceeding 18°C. The duration of continuous $POT_{>20°C}$ periods has remained less than 2-3 days on average over the past eleven decades, while warmer periods (1990s-2000s) showed the highest frequency (8-10) of such periods (Figure 40).

A similar frequency analysis based on estimated daily mean water temperature exceeding 18°C in Auke Creek during migration indicated that the cumulative total number of $POT_{>18°C}$ dates per year fluctuated from 4-6 days per year on average, mostly in July and August (Figure 41; Table 17). The $POT_{>18°C}$ frequency peaked significantly (KW $\chi^2 = 35.8$, $P < 0.001$) in the 1990s at 9.5 days per year and dropped back to about 4-7 days per year since the 2000s. (Note: the 2010s decade represents 2010-2016.)

The average length of Auke Creek $POT_{>18°C}$ periods was less than 6 days for most decades, with no apparent trend or significant difference between decades (Figure 42). Highest decadal frequencies of continuous exceedance periods averaging ~6 days in length occurred in the 1990s (16 events) and 2000s (11 events). Years with extended periods of elevated Auke Creek water temperature included: 1911 and 1914 (9-10 days); 1951 (9); 1965 (11); 1971 (9); 1993 (12); 1994 (15); 2004 (14); and 2013 (10) (Table 18).

HYDROLOGY

Auke Creek Water Level

The synoptic Auke Creek hydrograph based on water level observations (2006-2016) displays a seasonal increase in water levels through the migratory period (approximately June 19 through September 17; Figure 8, Figure 9). Creek water levels during migration typically ranged from a minimum of 6.34 to 7.08 m ASL (Table 3). Low water levels occurred most frequently in June, July and sometimes August following extended low rainfall periods. High water levels occurred most often in August and September in conjunction with rainfall events. Key percentiles for observed Auke Creek water levels (2006-2016) include: P10 = 6.44 m; P50 (median) = 6.61 m; P95 = 6.86 m (Table 3).

No significant trends were evident during Sockeye migration in the 11-year record of water level observations between 2006 and 2016, or for specific summer months (Figure 10, Figure 11). Above-average years in the observed data included 2006, 2011, 2012 and 2014, and 2015. High water levels in June characterized 2012 and 2014; also, 2014 and 2015 (and possibly 2008) were characterized by high water levels during peak Sockeye migration in July (Figure 11).

Observed water levels were below average in 2007, 2009, 2013 and 2016 during Sockeye migration (Figure 10). The month of June was below average in 2007, 2013 and 2015; July was below average in 2009 and 2016 (Figure 11).

Auke Creek Water Level "Standard"

Simple linear regression for Auke Creek daily water level as a function of the cumulative 6-day mean AUKE BAY PRECIPITATION STANDARD indicated that 63% of water level variation during the migration period (June-September) could be explained by precipitation over the past six days ($r = 0.79$, $n = 328$, Table 6, Figure 12, top).[43]

The 5-day cumulative mean air temperature index was the most highly correlated multi-day AUKE BAY TEMPERATURE STANDARD with daily water level, and, alone, suggested that 32% of water level variation could be explained by air temperature over the past five days ($r = -0.57$, $n = 264$, Table 7, Figure 12, bottom).

Stepwise linear regression retained both of these terms in a multiple regression model ($\alpha \ll 0.05$), with slightly improved coefficient of variation (67%; $r = 0.81$, $n = 264$, $P < 0.001$, Table 8) relative to the precipitation-only model. Although the temperature term only contributed 4.5% to the overall explained variation in this model, water level estimates based on the two-term model were slightly more correlated with observed water levels between 2006 and 2016 ($r = 0.81$, $n = 1342$, Figure 15). This is likely attributable to improved (lowered) estimates for daily water level during certain warm periods characterized by minor amounts of precipitation. In the absence of the temperature term, the model tended to overestimate water level

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[43] Logarithmic transformation of the normally-distributed water level variable did not improve model r^2.

for these periods. The negative air temperature coefficient depressed water level estimates for some high temperature dates with rain.

Modelled daily estimates were specifically unable to replicate some extended low flow periods, usually characterized by warmer-than-average temperatures, despite inclusion of an air temperature term (Figure 15: e.g. early July and late August 2007; mid-July and mid-August 2009; mid-August 2013; mid-July 2016).[44] Relative differences between observed and estimated daily water levels ranged up to 0.2 m, or 25-30% of the observed range.

At the upper extreme, predicted water levels also underestimated observed values for some high water events by similar percentages, generally later in the season, and apparently associated with large precipitation events in downtown Juneau (Figure 15: e.g. early September 2006, late-August 2009).

Deviations in the seasonal average (Jun 19 - Sep 17) of observed versus estimated water levels indicated the final model estimated seasonal Auke Creek water levels best in moderate rainfall years such as 2008, 2010, 2011, 2015 and 2016 (Figure 13, Figure 14). Estimated values tended to exceed observed values in low-water years 2007, 2009 and 2013, while observed values tended to exceed estimated values in high-water years 2006, 2012 and 2014. The all-year seasonal mean water level was equivalent for observed and estimated data (6.63 m, n = 1342, Table 9), but the minimum estimate of 6.41 m exceeded the observed minimum (6.29 m) by about 12 cm, highlighting the limitations of the statistical model to reconstruct water levels below the 10th percentile of observations. This is likely a consequence of the inability of the regression model to adequately capture hydrological extremes using localized precipitation data, especially when multi-day mean precipitation indices are used as predictors, which tend to exhibit reduced variability than daily precipitation.

Despite these limitations, the estimated water level “standard” clearly reflects annual and in-season fluctuations in water level, with the provision that it is necessarily a ‘conservative’ estimator of ‘extreme’ daily values. As such it provides additional insight into creek conditions during Sockeye migration between 1980 and 2005 when water level observations were not available (Appendix G). The standard also provides a comparable inter-annual indicator of daily creek levels dating back to 1900 that can be used for trend and exceedance analyses, described below.

Trends in Water Level Standard

The estimated water level “standard” time-series, encompassing the period of available adult Sockeye migration observations at the Auke Creek weir (1980-2016), showed a weak positive trend since the 1980s ($P < 0.10$, $n = 37$), though non-parametrically not significant ($MK = 1.4$, $P > 0.10$; Figure 16). A more significant positive trend was evident for July ($MK = 2.9$, $P < 0.05$, $n = 37$; Figure 17). Sequential t-tests indicated no regime changes.

For the extended water level standard (1900-2016) during the adult Sockeye

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[44] Logarithmic transformation did not reduce the value of the y-intercept (representing the minimum estimated water level possible (6.41 m) when the six-day mean precipitation was zero).

migration months, the positive trend was significant (MK = 3.0, $P < 0.01$), with a statistically-significant positive step in the time-series detected at 1958 ($P < 0.01$). Sequential t-test analysis after prewhitening indicated a positive regime shift in the mean between 1965 and 1966 ($P < 0.005$; Figure 18, bottom).[45]

Weak positive trends in estimated water level since 1900 were detected for the individual months of June, July, August, but these did not demonstrate significance non-parametrically ($P > 0.05$). September, however, did exhibit a significant positive trend, and a positive step-change in the mean in 1965.[46] Minor regime changes in the monthly means were also detected by sequential t-tests for July in 1959 and for September in 1990 (Figure 19: July only) ($P < 0.001$).

Low flows in June and July in recent decades, evidently associated with delays in migration (e.g. see Appendix H; e.g. 1982, 1992, 1994, 1998, 2000, 2002, 2009), may have also been a limiting factor for early migrants historically. Though daily migrant counts were not available pre-1980, low early summer Auke Creek water levels were hind-casted for multiple years in most decades (e.g. 1910s, 1920s, 1950s; Figure 19, bottom).

Water Level Exceedance Analyses

Deciles associated with the estimated water level standard (e.g. P10 = 6.5, P50 = 6.6, P90 = 6.7 m; Table 10) – instead of those associated with raw observations – were used to provide consistent water level threshold indicators across all decades, 1900-2016.

"Low Flows"

Using the 10th percentile of the Auke Creek estimated water level standard as a threshold (~6.5 m ASL), the frequency of "extreme low flow" dates during Sockeye migration (June-September) varied from a decadal average low of ~6 dates per year in the 1930s to a high of ~18 times per year in the 1990s (Figure 43; Table 19)[47]. Only the 1990s were significantly different from the overall mean decadal frequency (11.4 days) of the time-series (KW $\chi^2 = 24.3$, $P = 0.01$). However, a positive time trend was evident in this threshold frequency indicator (MK = 2.26, $P < 0.01$), with a potential regime shift in the 1990s in the mean decadal frequency ($P < 0.05$; Figure 43, inset) and duration (days) ($P = 0.11$).

While there appears to be a slight shift in the distribution of low flow dates across months within-season – including increased frequencies in June/July and decreases

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[45] Missing precipitation values in the summers of 1904, 1913-1916 indicate that descriptive statistics in these years or decades may not be fully representative of actual conditions. However, removal of these years of above-average precipitation would likely reinforce positive time trends in water level (Figure 18).

[46] June: MK = 0.85, $P > 0.1$; July: MK = 1.8, $P > 0.05$; August: MK = 0.81, $P > 0.1$, September: MK = 4.6, $P < 0.01$, positive step at 1965 (CuSum $P < 0.01$).

[47] The frequency of low flows in the 1900s and 1910s decades may be biased high due to missing precipitation values in the summers of 1904, 1913-1916.

in September (Figure 43), no significant decadal differences or trends were found for exceedance frequencies for specific months.

A similar pattern was evident in the decadal tally of continuous $POT_{<6.5\ m}$ periods (Figure 44). While the average length of such periods (~3-6 days) between decades did not change significantly, the frequency of such periods in the 1950s and 1990s was higher than in other decades (Table 19). In those decades there was an average of >30 events per decade (i.e. ~3 events per year), lasting approximately 3-4 days each.[48] The persistence record for consecutive extreme low flow dates occurred in 1957 (20 days $POT_{<6.5\ m}$), followed by 1979 (18 days).

In recent decades, for which daily Sockeye migration data were available, highest frequencies (>10 days) of extreme low flow dates ($POT_{<6.5\ m}$) during peak Sockeye migration (July) were found in 1981, 1987, 1989, 1990, 1993, 2004, 2009 and 2016 (Table 20). Some of these years were characterized by extended continuous low flow periods (>1-2 weeks) as well (e.g. 1989, 1993, 2004, 2016; Table 21).

Specific years in which persistent, extreme low flows ($POT_{<6.5\ m}$) appear to have interrupted active Sockeye migration or delayed its onset by at least 7 days were frequently evident (e.g. 1981, 1982, 1990, 1992, 1993, 1995, 1998, 1999, 2004, 2007, 2009, 2011, 2016; Appendix H).

"High Flows"

The frequency of seasonal "high flow" dates (>90th percentile of daily Auke water levels) exhibited an increasing trend over the decades, from a low of about 5 dates per year for the first half of the century, to ~20 dates per year since the 1990s (Table 22; Figure 45, top)[49]. Mean frequencies since the 1990s were significantly greater than the long-term average, while the 1920s and 1930s were significantly lower (KW $\chi^2 = 70.1$, $P < 0.001$). Most of the gains in the $POT_{>6.7\ m}$ frequency indicator occurred in August and September. Though the mean duration of continuous high flow events, which varied from 1-5 days over the decades, was not significantly different between decades, there were significant differences in the decadal mean frequency, which trended higher in the latter half of the 20th century and first decades of the 21st (Figure 46, top).

"Extreme high flow" dates (>6.8 m, the 95th percentile of daily Auke water levels) historically occurred < 2-3 days per year on average – principally in August and September (Table 23, Figure 45, bottom). While virtually no dates with water levels exceeding 6.8 m ASL were estimated during Sockeye migration prior to the 1940s, and only ~2-3 per year occurred up to the 1980s, a significant increase in the average number of $POT_{>6.8\ m}$ events was evident as of the 1990s (KW $\chi^2 = 59.5$, $P < 0.001$), again mostly in September, but increasingly in July and August (Figure 45, bottom). Statistically, there were differences in mean duration (Figure 46,

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[48] Because this exceedance duration indicator may span multiple months, it does not provide any indication concerning within-season shifts.

[49] The frequency of high flows in the 1900s and 1910s decades may be biased low due to missing precipitation values in the summers of 1904, 1913-1916.

bottom) between decades for this indicator, with 1990s and 2010s significantly exceeding the long term mean. Maximum durations of 8-11 continuous days occurred in recent decades.

Since peak Sockeye migration is generally complete by early August, high flow events in late August and September are unlikely to pose consistent migratory impacts, except on late components of the Sockeye run (e.g. 1994). However, some years exhibited multi-day high flow events (>P95) in August, some of which persisted into September (e.g. 1983, 1991, 1998, 2002, 2006, 2009, 2011), which at least appear coincident with reductions in migration rates from significant to negligible levels (Appendix H).

MIGRATION IN RELATION TO WATER TEMPERATURE AND WATER LEVEL

Inter-Annual Effects

The median date of annual Sockeye migration (TT50%)[50] showed no correlation with the annual mean water temperature in Auke Creek ($r = 0$, $n = 36$ years; Figure 47). However, TT50% was positively correlated with various exceedance indices associated with high water temperatures, including the annual frequency (number of dates; $P = 0.03$), and the duration of continuous days ($P < 0.005$), where daily water temperature exceeded 18ºC (Table 24, Figure 48). No significant differences in the TT50% index were detected between the top 12 'warm' Auke Creek temperature years[51] versus the top 12 'cool' years[52] ($P_{kw} = 0.34$). Group sample sizes had to be reduced to $n = 5$ to detect a significant difference ($P_{kw} = 0.047$); mean TT50% for the top 5 'warm' years[53] was ~August 8th, approximately 20 days later than for the top 5 'cool' years[54] (~July 19th; Figure 51, top).

A similar analysis of annual TT50% versus water level indices revealed a negative correlation with annual mean water level ($r = -0.40$, $P = 0.01$, $n = 37$ years), indicating low water years were most often associated with later migration timing (Figure 49). The annual frequency of low water dates (where water level < 6.5 m) and the maximum continuous duration (in days) thereof were positively correlated with TT50%, again indicating that low water levels may be resulting in delayed migration ($P < 0.03$, Table 25, Figure 50). As the top 5 'low water' years equated to the top 5 'warm water' years, a similar difference (~20 days) in mean TT50% was

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[50] Note: Hatchery-reared sockeye juveniles stocked in Auke Lake contributed to adult returns in 1977-1982 and 1990-1995 (Vulstek et al. 2016; Taylor et al. 1992). Thus, annual returns data include hatchery fish for these years and may not be representative of the timing for wild Sockeye alone.

[51] TT50% = July 19th; n = 12. Classified by mean Jun-Sep water temperatures > 16ºC or 95th percentile (P95) of Jun-Sep water temperatures > 19ºC. See Table 11.

[52] TT50% = July 21st; n = 12. Classified by mean Jun-Sep water temperatures < 15ºC or 95th percentile (P95) of Jun-Sep water temperatures < 17ºC. See Table 11.

[53] Top 5 'warm' years: 1982, 1989, 1993, 1994, 2004.

[54] Top 5 'cool' years: 1981, 1983, 1988, 1995, 2012.

evident, with migration timing in the dry years occurring later relative to all other years (Figure 51, middle).

There was no significant difference in TT50% between ENSO positive phase and ENSO negative phase years.[55] Years classified into positive PDO phase showed marginally later migration timing versus years classified as negative PDO phase.[56] When PDO and ENSO phases were aligned with each other, the difference in mean TT50% was significant at the $\alpha = 0.05$ level, even though the number of years was reduced to 26 due to the omission of unaligned years (Figure 51, bottom).[57]

Intra-Annual Effects

Within season, Spearman correlation analysis indicated a weak positive relationship between the daily Sockeye migration index[58] and individual water temperature and (logged) water level indices (1980-2016; Table 26). When incorporated into a robust parametric regression analysis, however, both environmental variables exhibited a negative relationship with the Auke Creek Sockeye daily migration index (Table 27). These somewhat ambiguous statistics were likely a result of the true nonlinear relationship between migration and environmental variables – higher r^2 were associated with parabolic polynomial models rather than linear (Figure 52), logically suggesting that *moderate* values of environmental variables were most conducive to migration. A positive interaction effect for water level and temperature was also significant in the regression model, suggesting that higher migration rates were associated with both low/low and high/high flow/temperature combinations. This is not surprising given the inverse correlation between daily water levels and temperatures ($r_s = -0.60$, $P < 0.001$, $n = 1846$).

An un-weighted tally of non-zero migration dates indicated that approximately 90% of migration dates occurred when same-day Auke water levels were between 6.50 - 6.75 m (Figure 33). Weighting the frequency distribution by the daily migration rate indicated that, ignoring infrequent occurrences, “significant” daily migration rates (> 50th percentile, or 0.4% per day) occurred at water levels of 6.5 - 6.9 m, but highest migration rates occurred at a slightly narrower range of 6.6 - 6.7 m (Figure 34). “High” migration rates (> 75th percentile, or 1.6% per day) were not associated with extremely low water levels of < 6.6 m or water levels exceeding 7.0 m.

Dates of migration activity were approximately normally-distributed around 15-16°C, with the majority of dates (~80%) characterized by observed water temperatures of 13-17°C (1980-2016; Figure 35). Highest mean daily migration rates (i.e. > 75th percentile, i.e. >1.6% per day) were also associated with slightly warmer water temperatures of 14-19°C (Figure 36). Though migration activity occurred only infrequently at 19°C (~32 dates over 37 years), the daily migration rates for a small

[55] ENSO: $TT50_{ENSO-}$ = July 20th, n = 21; $TT50_{ENSO+}$ = July 23rd, n = 16; $P_{kw} = 0.18$.

[56] PDO: $TT50_{PDO-}$ = July 17th, n = 25; $TT50_{PDO+}$ = July 24th, n = 12; $P_{kw} = 0.08$.

[57] PDO/ENSO: $TT50_{-/-}$ = July 19th, n = 11; $TT50_{+/+}$ = July 24th, n = 15; $P_{kw} = 0.04$.

[58] The arcsin transform was used to normalize the percentage values associated with Daily Migration Rate (%) (Sokal and Rohlf 1969).

number of those dates were very high (>10%), notably in 1989, 1997, and 1998 (Appendix H), resulting in a spike in the weighted frequency distribution at 19°C. The events in 1997 and 1998 were accompanied by reasonably high water levels (see Appendix H).

A weighted two-way frequency distribution based on combined water level and temperature ranges indicated "high" migration (>75th percentile) occurred at a range of discharge and temperature levels, with maxima at the convergence of 14-17°C and 6.6 - 6.8 m water levels, and also at 19°C at 6.6 m (Figure 37, Figure 38).

Generally-speaking, the inverse relationship between Auke Creek water level and water temperature[59] – evident in most years – obscures to some degree the exact mechanism limiting migration. However, anomaly plots of migration rate versus water level and temperature deviations based on Auke environmental thresholds of 18°C and 6.5 m water level (Appendix H) indicated subjectively that the most consistent environmental impact in the historical data was a *delay in the onset of migration* – and a possible *interruption of active migration* – due to low discharge levels. When low Auke Creek flows persisted into the migratory period, moderate-to-high migration rates (> 1.6 - 2.0% per day) were generally inhibited until water levels rose above 6.5 m ASL. This effect was evident in most years (e.g. 1982, 1986, 1994, 2001, 2008, etc.) with few exceptions (notably: a few days in early July in 1989) (Appendix H). Some years in which migration counts commenced later in the season appear to be correlated with low creek flows in June (e.g. 1983, 1986, 1993, 1999, 2007, 2009).

High migration rates at water temperatures exceeding 18°C were rare, though not non-existent (e.g. 1989, 1997, 1998). Higher water levels appeared to mitigate 19 degree water temperature conditions in both 1997 and 1998, enabling high migration activity in early July. However, in 1989, high migration was recorded July 10-12 despite low water levels (< 6.5 m) and high water temperatures (>18-19°C) (Appendix H).

High water temperatures (>18°C) may have also played a role in delaying upstream migrants. In 2004, when warm water (17-20°C) and low water levels through June and mid-July were finally replaced by moderate water levels > 6.6 m by July 24th, significant fish counts did not commence until water temperatures dropped below 17°C a few days later (July 28th; Appendix H). As there were only zero/negligible fish counts prior to July 28th, however, it is not clear whether significant numbers of fish were actually present (i.e. holding in Auke Bay).

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[59] Linear model: $r = -0.65$; $n > 3{,}000$; $P < 0.001$. Log- and power-transforms of water level or water temperature data did not improve model $r^2 = 0.42$.

DISCUSSION

Sockeye Migration and Water Temperature Conditions

Over the past 60 years, mean air temperature across Alaska has increased by almost 2°C, about double the rate observed elsewhere in the U.S.A. (Taylor 2008b; Chapin et al. 2014). Auke Creek has undergone significant warming *since 1971*, with mean annual water temperatures rising more than 1°C (<6.5°C to >7.5°C) (Kovach et al. 2013).

Despite these trends, the more limited temperature observation record (1980 - 2016) used here indicated generally hospitable conditions for the specific life-stage associated with adult Sockeye migration. Observed water temperatures (mid-June to mid-September) averaged 15.2 ± 2.0°C. For 95% of dates of adult migration, mean daily water temperatures remained below 18°C. For the month of *peak* Sockeye migration (July), mean daily water temperatures were 16.1 ± 1.6°C, with 95% of dates below 19°C.

Still, small changes in daily mean water temperature have been shown to contribute to significant changes in the frequency of dates exceeding biologically-important thresholds for salmon (Hyatt et al. 2015; Martins et al. 2011). These changes may contribute to enroute- or pre-spawn mortality (Hinch and Martins 2011), and population-level changes in migratory behaviour (Taylor 2008b).

The summers of 1989, 1990, 1992, 1997, 1998, 2004[60], 2005, 2009, 2013, 2014 and 2015 were consistently represented in the warmest years of Auke Creek data. Daily mean water temperatures (MWT) often exceeded 17°C during peak Sockeye migration (July) in these years. In a subset of those years (1989, 1990, 1997, 1998, 2004, 2009), daily MWTs exceeded critical adult Sockeye migration thresholds of 19-20°C for continuous periods of 7-10 days.

Physiological studies on adult migrants in other Sockeye populations (e.g. Fraser River in British Columbia) indicate quantifiable stock-specific differences in survival in response to freshwater temperatures, but also indicate that, at least for some stocks, thermal tolerance is tightly coupled to the range of temperatures to which the stock was historically exposed (Martins et al. 2011). Whether exposure to elevated temperatures during the short passage through Auke Creek (<1 km in length) incurs any substantive impact on the Sockeye stock is unclear, but theoretically, relatively small increases in freshwater temperature may negatively affect even a northern population habituated to a lower temperature range. Temperature impacts may take the form of increased pre-spawn mortality in the lake or on the spawning grounds weeks or months later, via increased incidence of disease (Martins et al. 2012). Auke Lake Sockeye tag studies in 2012 found 12% of recoveries (equivalent to nine fish) died unspawned, six of which were exposed to creek temperatures of 15.7 °C (Ray et al. 2014). Mean stream temperature from June-September 2012 was 14.4 °C. Previous tag studies in 1991 and 1992 detected 28-31% pre-spawn

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[60] The maximum daily mean water temperature recorded in Auke Creek (20.5°C) occurred in 2004.

mortality (Nelson 1993; in Ray et al. 2014), perhaps associated with slightly higher mean Jun-Sep temperatures in those years (14.9-15.2°C; Appendix G).

Since 1980, migration timing changes in response to rising freshwater temperatures have been evident for Auke salmonids (including jack Sockeye, but not adult Sockeye), including a significant trend towards earlier run timing and a reduced range of migration dates (Kovach et al. 2013)[61]. Kovach et al. (2012) found that a late-migrating sub-population of Auke Creek Pink salmon virtually disappeared over the course of a few years (1989-1993), corresponding to a period of relatively high freshwater temperatures.

No significant differences were detected in the mean annual Sockeye return timing indicator used here (TT50%)[62], across the range of Auke Creek seasonal mean water temperatures (Figure 47). Kovach et al. (2013) obtained similar results, and suggested therefore that Auke Sockeye may have more biological 'plasticity' in migration timing, perhaps related to a more extended maturation period after upstream migration (up to one month in Auke Lake) than Pink or Coho salmonids, which spawn immediately after entering Auke Creek, and tend to be migrating earlier in response to freshwater temperatures. It should be noted, however, that water temperature exceedance indices (e.g. frequency and duration of days exceeding 18 ºC threshold) were positively correlated with TT50% (Figure 48), suggesting warm water conditions may actually have a quantifiable delay effect on migration timing. If that is the case, then metrics of water temperatures in the vicinity of the upper biological thresholds for salmon may be more important determinants of variation in migration timing than an arithmetic mean annual temperature index.

Sockeye migration timing flexibility (Kovach et al. 2013) may be important under changing oceanic conditions, as the annual median upstream migration date (TT50%) does appear to occur approximately *one week later* during positive phases of the PDO (P = 0.08) as well as combined positive PDO/ENSO phases (P = 0.04). This may suggest that under 'warm' ocean conditions associated with these indices, Sockeye may be arriving later to Auke Bay. Alternatively, the warmer, drier local conditions in the northeast Pacific and Alaska – generally associated with warm-phase PDO/ENSO – likely manifest in Auke Creek conditions (low flows, elevated temperatures) that lead to upstream migration delays.

With respect to within-season effects of water temperature on daily migration rates, Auke Sockeye exhibit similar migration behaviour as is evident in other Sockeye stocks – which is a reduction or stoppage in fish passage as water temperatures

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[61] Though Kovach et al. (2013) did not detect any changes in median upstream migration timing for returning adult Sockeye (1980-2010), 4 of 6 additional years have been earlier than the long-term average TT50% (Vulstek et al. 2016) incurring a weak negative trend in the time-series ($P_{MK} < 0.1$, n = 37 years; Figure 6).

[62] Hatchery-reared sockeye juveniles stocked in Auke Lake contributed to adult returns in 1977-1982 and 1990-1995. Thus, annual returns data include hatchery fish for these years and may not be representative of the timing for wild sockeye alone (Vulstek et al. 2016).

approach/exceed 18-19ºC (Hyatt et al. 2015; Hyatt and Stockwell 2003)[63]. Eighty percent of migration activity occurred at 13-17ºC, with highest daily migration rates (>75th percentile) most frequently occurring between 14-17ºC (Figure 35). A small percentage (2%) of non-zero migration dates occurred at 19ºC, however, which were associated with very high migration rates (mean 4%; range: 3-16%; Figure 36) – these somewhat anomalous high-temperature-migration events were generally characterized by high water levels as well, likely keeping water temperatures below debilitating levels of 20+ ºC, and thereby mitigating temperature impacts. At temperatures of 20ºC, both migration activity and migration rate were at their lowest in the period of record.

We extended the temperature trend analysis by reconstructing daily mean air temperatures back to 1900, based on linear relations between Juneau-area meteorological time-series. A warming trend in the extended daily mean AIR TEMPERATURE 'STANDARD' for Auke Bay (1900-2016) was evident for adult Sockeye migratory months ($P < 0.01$), and characterized by significant differences in the mean in 1976[64] and 1988[65], with warmer summer air temperatures occurring after those years. The stepwise shift appearing in the temperature data in 1976 corresponds to a shift of the PDO index from a negative phase to a positive phase (Mantua and Hare 2002)[66]. A full 'regime shift' (Rodionov 2004) in air temperature, however, was not detected until 1988-1989 (Figure 32) – corresponding to the beginning of some of the warmest years in the Auke watershed (Kovach et al. 2012).

The Auke Creek daily mean water temperature time-series (1900-2016), statistically-derived from the air temperature index, necessarily reflected an analogous warming trend. The upward trend in air and water temperatures in the Auke watershed, and associated regime shift in the late 1970s (and positive step-change in the late 1980s) resulted in a significant increase in the frequency of dates in which air and water temperatures exceeded 18ºC (Figure 39, Figure 41). The decade of the 1990s was characterized by a doubling of the mean annual frequencies – mainly in July and August – relative to the long-term decadal average. The peak exceedance in the 1990s averaged less than 10 days of the season, however.

Although no trends were indicated in the mean duration of 'heat waves' where freshwater temperatures continuously exceeded 18ºC, the frequency of such events (averaging ~6 days long) was also elevated in the 1990s and 2000s (Figure 42). While these indicators have 'settled' somewhat since 2000, likely in conjunction with shifts to negative phases in PDO and ENSO ocean indices for 9 of 17 years, the decade of the 1990s (where 9 out of 10 years were associated with a warm phase

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[63] Anomaly plots (Appendix H) for 1990, 1998, 2004 and 2009 might best exhibit the inverse relation between water temperature and daily migration rates.

[64] Based on a non-parametric rank sum trend analysis.

[65] Based on a sequential t-test 'regime shift' analysis.

[66] Synoptic conditions associated with the positive PDO (Pacific Decadal Oscillation) phase are characterized by increased southerly air flow and warm air advection into Alaska during the winter, resulting in positive temperature anomalies.

for either or both of PDO and ENSO indices), may be reasonably representative of temperature conditions in southeast Alaska under expected climate change.[67]

Sockeye Migration and Water Level Conditions

While the inverse relationship between Auke Creek daily water temperature and water level obscures to some degree the exact mechanism limiting upstream migration for Sockeye, the most consistent environmental impact evident in the historical data was a *delay in the onset of migration* – and a possible *interruption of active migration* – due to low water levels in early summer.

Though highly variable on an annual basis, the seasonal hydrological pattern in Auke Creek typically displays a general increase in mean water level from a late-winter low to an autumn high after the peak Sockeye migration period (Figure 8). The pattern is characteristic of mixed nival-pluvial coastal systems in northern latitudes, where peak precipitation occurs in autumn, freezing temperatures promote snowfall rather than rainfall in winter (Eaton and Moore 2010). In the Auke watershed, snowmelt-driven late spring and early summer creek flows largely depend on winter snow-pack accumulations, which appear to vary widely from year-to-year in the Juneau area, in spite of, or perhaps due to, trends in global and regional warming (Winski et al. 2017).

While precipitation across Alaska is projected to increase during all seasons by the end of this century, the state is likely to become drier due to greater evaporation caused by warming temperatures (Chapin et al. 2014). Drier, warmer conditions may exacerbate environmental impacts already emerging for adult Auke Creek migrants (Kovach et al. 2013).

The vast majority of adult Sockeye migration in Auke Creek occurred between 15-17ºC at moderate water levels (6.6-6.8 m), or at 14ºC and 6.8 m coincident with rain events, often late in the season (Figure 38). While moderate-to-high migration rates (> 2.0% per day) also spiked at 19ºC, high migration rates were almost entirely inhibited until water levels rose above 6.5 m ASL – i.e. the lower 10th percentile of Jun-Sep water levels (Appendix H: e.g. 1982, 1986, 1994, 2001, 2008). At the other extreme, high migration rates occurred up to the 99th percentile of Auke Creek water levels (i.e. 6.95 m), indicating Sockeye migration rates were less impacted by ‘flood events’ than ‘drought’ conditions (Appendix H: e.g. 1996, 1998, 2008, 2011, 2014, 2015).

The absence of high daily migration rates above 7.0 m ASL does still suggest an upper threshold for Auke Creek Sockeye, which might become a factor if positive trends in water level continue, or oceanic climate change generates increasingly frequent storm events (Winksi et al. 2017). High water velocity associated with river discharge has been correlated with higher energy expenditures (Salinger and Anderson 2006), slower migration rates, and migration delays in salmonids (Fenkes et al. 2016). Migrants are more likely to succumb to pre-spawn mortality after high-

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[67] Mean annual temperatures in Alaska are projected to increase an additional 1 to 2°C by the 2050s due to climate change, with larger increases in winter (Chapin et al. 2014).

flow-induced 'burst swimming' efforts to traverse hydraulically-challenging locations (Burnett et al. 2014; Hinch et al. 2002), which may exacerbate thermal impacts on fish condition and survival (Rand et al. 2006).

Partitioning the significant positive trend in the AUKE WATER LEVEL STANDARD (Jun-Sep 1900-2016: $P < 0.01$) into component months of adult Sockeye migration indicates that the trend is largely driven by increases in rainfall in September ($P < 0.01$), since trends in other summer months were not significant at the $\alpha = 0.05$ level. September also exhibited a positive 'regime shift' in the mean in 1990 ($P < 0.01$), concurrent with the rise in air temperatures at the end of the 1980s (Kovach et al. 2012). This trend translated into a significant increase in the decadal frequency and duration of high-flow events (>6.8 m) as of the 1990s (Figure 45, Figure 46). This has potentially negative consequences for Auke Sockeye migrants. However, mean 'flood' days to date peaked at ~7 per year in the 1990s, with mean duration <4 days in that decade (maximum: 11 days), conditions which (healthy) Sockeye can typically endure. Since the largest increases in precipitation to date have occurred in September at the tail end of upstream migration, negative impacts, if any, are unlikely to seriously impact the Sockeye run as a whole.[68]

On the other hand, increases in fall rains do not reduce the frequency of low flow (< 6.5 m) impacts that are already limiting upstream migration during peak Sockeye migration in early summer. The frequency of such summer 'drought' events also trended upwards ($P < 0.01$), and peaked significantly in the 1990s at an average of 18 days per year (entirely in June, July and August; Figure 43), with an average of three continuous events of 5-6 days average length (maximum: 13-17 days) persisting into the 2000s (Figure 44). The high frequency of low flow dates in the last three decades have likely resulted in later migration timing and migration delays, forcing fish to hold in the marine environment. Migratory and reproductive success may be reduced for Sockeye holding for two or more weeks in the marine environment, due to predators, parasites, and energy depletion (Hyatt et al. 2015).

Since water temperature and water level tend to co-vary, the exact mechanism limiting upstream migration remains difficult to ascertain empirically. Statistical evidence that water levels may be exerting a stronger influence on upstream migration timing than temperatures may be indicated, however, by the relative significance of correlations with seasonal mean water levels vs seasonal mean water temperatures (Figure 47 vs Figure 49). Also, the plotted distribution of annual data points indicates that, at least in some years, one or the other factor could be driving migration timing. For example, the years 1982, 1989-1994, 2004 and 2016 figure prominently in the set of 'warm dry' years. The years 1993, 1994, and 2004 appear as extremes for both high water temperature and low water level, whereas 1982 and 1989 appear principally as low water level extremes (Figure 47 - Figure 50). Low sample sizes, however, and the influence of strong leverage points (1993

[68] This is not to discount the potential impact of increasingly frequent heavy fall rains on egg-to-fry survival via scour events on the spawning grounds (Shanley and Albert 2014) – but that is outside of the scope of this study.

and 1994[69]), limit any conclusions.

Trends towards increased precipitation in the fall-winter are also unlikely to affect migrants, though there could be impacts on subsequent life-stages (Shanley and Albert 2014). More restricting for upstream migrants is the apparent trend towards lower early summer water levels, which are demonstrably delaying migration already. Current trends in low water events, with or without exacerbating warm water temperatures, may be contributing to population-level changes in Auke Sockeye migration timing.

RECOMMENDATIONS

1. Extend analysis back to 1963 to include all years where daily Sockeye migrant counts are available.

Adult Sockeye migrants have been tallied at the Auke Creek weir since 1963. Daily counts prior to 1980 were not available for this analysis, but inclusion of previous years where fish counts were 2x greater might provide further insight into migration behaviour and timing at denser migrant levels under different temperature regimes.

2. Automate Auke Creek daily water level recordings.

Water level observations are currently obtained via daily spot measurements with unknown error variance; observation errors and missing values would be reduced if daily mean values were derived from multiple daily readings representative of the 24-hour day, preferably by automated datalogger. If implemented, it would be important to maintain daily spot measurements across a full range of water levels to calibrate the historic time-series with the automated datalogger time-series.

3. Improve reconstruction of Auke Creek water level estimates based on full-featured hydrological models.

Modelled daily water level estimates, based on multi-day precipitation and air temperature indices, were unable to replicate some extended low flow periods which were characterized by warmer-than-average temperatures. This may indicate that, after extended low flow periods, minor amounts of rainfall (< 5-10 mm per day) may be insufficient to saturate the watershed, especially during extended warm periods. Relative differences between observed and estimated daily water levels ranged up to 0.2 m, or 25-30% of the observed range, resulting in biased-high estimates of a biologically-important factor for migrating salmon. At the upper extreme, predicted water levels also underestimated observed values for some high water events by similar percentages, generally later in the season, and apparently associated with large precipitation events as far away as downtown Juneau. Missing meteorological,

[69] The early 1990s, including 1993 and 1994, were return years for hatchery Sockeye in the 1986-1989 brood year enhancement experiment (Taylor et al. 1992).

geological, and land cover factors may be important here to solve Auke Creek water balances – using a hydrological simulation model such as Raven (Craig 2018).

4. Mitigate low water level impacts.

If further analysis indicates that water levels are increasingly limiting to upstream migration under climate change, consider engineering a hydrological solution (e.g. flow controls, fish ladders, etc.) to eliminate barriers and reduce migration stress. Target water levels to facilitate Sockeye migration were estimated to be in the range of 6.5 – 6.8 m ASL, based on statistically-reconstructed water level data.

5. Monitoring spawning grounds.

The majority of Auke Sockeye spawn in stream environments, particularly in Lake Creek and Lake Creek 2, thus, sustaining the stock is dependent on adequately protecting associated hydrological and riparian function from anthropogenic impacts (Ray et al. 2014). Digital monitoring of environmental variables is instrumental in assessing seasonal and annual changes in flow, water temperature, and stream morphology. High resolution, site-specific digital observations would enable reconstruction and modelling of historic conditions to provide insight into annual variations in spawning success and freshwater productivity.

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Climate data for Juneau, Alaska (Downtown, 1981–2010 normals, extremes 1890–present) [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °F (°C)	60 (16)	57 (14)	61 (16)	72 (22)	80 (27)	87 (31)	89 (32)	87 (31)	85 (29)	68 (20)	64 (18)	59 (15)	89 (32)
Average high °F (°C)	34.6 (1.4)	36.7 (2.6)	40.8 (4.9)	49.1 (9.5)	56.9 (13.8)	62.4 (16.9)	63.4 (17.4)	62.6 (17)	56.6 (13.7)	48.4 (9.1)	39.8 (4.3)	36.7 (2.6)	49.0 (9.4)
Daily mean °F (°C)	30.4 (−0.9)	32.1 (0.1)	35.5 (1.9)	42.2 (5.7)	49.6 (9.8)	55.4 (13)	57.4 (14.1)	56.4 (13.6)	51.2 (10.7)	43.7 (6.5)	35.6 (2)	32.3 (0.2)	43.5 (6.4)
Average low °F (°C)	26.2 (−3.2)	27.6 (−2.4)	30.1 (−1.1)	35.3 (1.8)	42.3 (5.7)	48.4 (9.1)	51.4 (10.8)	50.2 (10.1)	45.8 (7.7)	39.0 (3.9)	31.4 (−0.3)	27.8 (−2.3)	38.0 (3.3)
Record low °F (°C)	−20 (−29)	−15 (−26)	−5 (−21)	12 (−11)	26 (−3)	32 (0)	39 (4)	32 (0)	28 (−2)	13 (−11)	−7 (−22)	−10 (−23)	−20 (−29)
Average precipitation inches (mm)	7.98 (202.7)	6.71 (170.4)	6.29 (159.8)	4.64 (117.9)	4.96 (126)	4.42 (112.3)	5.44 (138.2)	8.16 (207.3)	12.72 (323.1)	13.23 (336)	8.44 (214.4)	9.23 (234.4)	92.22 (2,342.5)
Average snowfall inches (cm)	24.2 (61.5)	15.9 (40.4)	5.4 (13.7)	0.9 (2.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.6 (1.5)	9.2 (23.4)	13.6 (34.5)	69.8 (177.3)
Average precipitation days (≥ 0.01 in)	20.8	17.3	19.1	18.5	19.0	17.9	17.3	21.0	22.3	24.5	20.8	20.7	239.2
Average snowy days (≥ 0.1 in)	8.3	5.3	5.0	0.7	0	0	0	0	0	0.2	4.1	5.8	29.4
Source: NOAA[20][23]													

Climate data for Juneau, Alaska (Juneau Int'l, 1981–2010 normals,[19] extremes 1890–present) [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °F (°C)	57 (14)	57 (14)	61 (16)	74 (23)	82 (28)	87 (31)	90 (32)	87 (31)	85 (29)	68 (20)	64 (18)	59 (15)	90 (32)
Mean maximum °F (°C)	44.5 (6.9)	45.3 (7.4)	48.8 (9.3)	61.7 (16.5)	71.1 (21.7)	77.9 (25.5)	77.3 (25.2)	76.1 (24.5)	65.7 (18.7)	55.5 (13.1)	47.1 (8.4)	45.0 (7.2)	80.3 (26.8)
Average high °F (°C)	32.8 (0.4)	35.2 (1.8)	39.6 (4.2)	48.4 (9.1)	56.6 (13.7)	62.2 (16.8)	63.9 (17.7)	62.7 (17.1)	55.7 (13.2)	47.0 (8.3)	37.8 (3.2)	34.1 (1.2)	48 (8.89)
Daily mean °F (°C)	28.3 (−2.1)	30.1 (−1.1)	33.8 (1)	40.8 (4.9)	48.6 (9.2)	54.6 (12.6)	56.9 (13.8)	55.9 (13.3)	50.0 (10)	42.4 (5.8)	33.4 (0.8)	29.9 (−1.2)	42.06 (5.58)
Average low °F (°C)	23.7 (−4.6)	25.0 (−3.9)	28.0 (−2.2)	33.3 (0.7)	40.6 (4.8)	46.9 (8.3)	50.0 (10)	49.0 (9.4)	44.4 (6.9)	37.8 (3.2)	29.1 (−1.6)	25.6 (−3.6)	36.12 (2.28)
Mean minimum °F (°C)	6.0 (−14.4)	9.0 (−12.8)	13.6 (−10.2)	23.2 (−4.9)	31.7 (−0.2)	38.8 (3.8)	43.6 (6.4)	41.0 (5)	32.8 (0.4)	24.5 (−4.2)	14.3 (−9.8)	7.5 (−13.6)	−1.4 (−18.6)
Record low °F (°C)	−22 (−30)	−22 (−30)	−15 (−26)	6 (−14)	25 (−4)	31 (−1)	36 (2)	27 (−3)	23 (−5)	11 (−12)	−5 (−21)	−21 (−29)	−22 (−30)
Average precipitation inches (mm)	5.35 (135.9)	4.13 (104.9)	3.78 (96)	2.94 (74.7)	3.40 (86.4)	3.24 (82.3)	4.60 (116.8)	5.73 (145.5)	8.64 (219.5)	8.63 (219.2)	5.99 (152.1)	5.84 (148.3)	62.27 (1,581.6)
Average snowfall inches (cm)	27.7 (70.4)	16.8 (42.7)	11.6 (29.5)	1.1 (2.8)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.8 (2)	13.1 (33.3)	15.6 (39.6)	86.7 (220.2)
Average precipitation days (≥ 0.01 in)	20.6	16.6	18.9	17.0	16.3	15.8	17.7	19.1	22.4	23.9	20.9	20.6	229.8
Average snowy days (≥ 0.1 in)	10.6	7.9	6.8	1.3	0.0	0.0	0.0	0.0	0.0	0.6	5.9	10.0	43.1
Average relative humidity (%)	79.9	80.8	79.4	76.8	76.3	78.3	81.3	84.3	87.9	87.7	85.1	82.8	81.7
Mean monthly sunshine hours	80.9	89.2	137.3	182.3	231.7	189.3	182.9	161.6	109.6	66.2	58.5	41.2	1,530.7
Percent possible sunshine	36	34	37	42	44	35	34	34	28	21	25	20	34
Source: NOAA (relative humidity and sun 1961–1990)[20][21][22]													

Table 1. JUNEAU AIRPORT (top) AND JUNEAU DOWNTOWN (bottom) region climate normals (1981-2010). (Source: NOAA)

	Auke										
	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											
1980	45	13JUN	01OCT	102	1,445	4,570	0.26	0.88	11.47	2.22	31.62
1981	43	01JUL	05OCT	95	1,323	4,089	0.15	0.81	14.14	2.33	32.36
1982	31	19JUL	30SEP	43	487	1,334	0.52	4.12	13.19	3.23	36.51
1983	47	11JUL	25SEP	38	347	1,805	0.50	1.72	9.25	2.13	19.22
1984	41	27JUN	20SEP	24	316	975	0.51	1.54	9.33	2.44	32.41
1985	47	25JUN	19SEP	7	57	325	0.92	2.46	9.54	2.13	17.54
1986	38	24JUN	10SEP	27	333	1,033	0.48	2.03	21.10	2.63	32.24
1987	50	23JUN	09SEP	58	544	2,896	0.54	1.80	9.29	2.00	18.78
1988	56	09JUL	20OCT	25	248	1,392	0.43	1.87	7.47	1.79	17.82
1989	52	10JUL	25SEP	54	1,111	2,807	0.18	0.77	8.66	1.92	39.58
1990	54	26JUN	14SEP	64	1,093	3,452	0.19	1.19	9.41	1.85	31.66
1991	60	03JUL	01OCT	46	485	2,764	0.25	1.63	7.72	1.67	17.55
1992	51	13JUL	19SEP	33	616	1,668	0.60	1.68	4.80	1.96	36.93
1993	45	12JUL	20SEP	68	688	3,058	0.65	2.88	7.68	2.22	22.50
1994	62	04JUL	01OCT	62	624	3,869	0.59	1.65	6.57	1.61	16.13
1995	58	18JUL	02OCT	58	452	3,371	0.40	2.58	8.93	1.72	13.41
1996	69	28JUN	23SEP	89	497	6,123	0.54	2.19	5.77	1.45	8.12
1997	65	25JUN	19SEP	72	1,347	4,705	0.30	0.68	7.27	1.54	28.63
1998	58	07JUL	22SEP	37	600	2,139	0.21	1.12	8.74	1.72	28.05
1999	60	12JUL	23SEP	28	459	1,681	0.48	0.77	7.88	1.67	27.31
2000	48	29JUN	17SEP	52	1,019	2,513	0.28	1.43	6.88	2.08	40.55
2001	60	27JUN	24SEP	67	646	4,009	0.34	1.95	9.12	1.67	16.11
2002	51	03JUL	30AUG	59	346	3,012	0.66	3.09	8.10	1.96	11.49
2003	49	20JUN	12SEP	69	1,994	3,397	0.15	0.41	5.33	2.04	58.70
2004	30	28JUL	22SEP	99	2,468	2,978	0.20	0.50	7.79	3.33	82.87
2005	54	30JUN	18SEP	56	693	3,019	0.50	1.46	11.23	1.85	22.95
2006	64	26JUN	15SEP	29	321	1,868	0.37	1.58	6.21	1.56	17.18
2007	63	09JUL	18SEP	47	909	2,942	0.34	1.36	3.77	1.59	30.90
2008	56	07JUL	12SEP	23	382	1,260	0.40	0.67	10.40	1.79	30.32
2009	37	30JUN	02SEP	109	1,183	4,048	0.30	2.40	19.22	2.70	29.22
2010	53	25JUN	03SEP	39	264	2,063	0.63	1.84	8.39	1.89	12.80
2011	43	30JUN	04SEP	56	356	2,426	0.45	3.38	10.88	2.33	14.67
2012	55	20JUN	28AUG	29	342	1,569	0.57	1.91	5.48	1.82	21.80
2013	53	28JUN	03SEP	39	450	2,060	0.24	2.09	6.94	1.89	21.84
2014	61	14JUN	06SEP	56	509	3,443	0.52	1.19	10.75	1.64	14.78
2015	58	26JUN	03SEP	81	500	4,720	0.92	2.10	7.22	1.72	10.59
2016	44	01JUL	17SEP	57	591	2,519	0.40	1.67	14.41	2.27	23.46
1980-2016	1,911	13JUN	17SEP	53	2,468	101,902	0.40	1.58	8.83	1.94	82.87

Table 2. Annual migration statistics for Sockeye counted at the weir, Auke Creek. Mean and maximum daily average migrant count, annual total counts, and daily migration rate (%) statistics. Restricted to non-zero daily counts for migration period.

	Water Level (m)				Percentiles								
	Dates	Mean	Std	Skew	Min	P5	P10	P25	P50	P75	P90	P95	Max
Year													
2006	91	6.69	0.14	0.14	6.45	6.47	6.49	6.57	6.71	6.78	6.86	6.94	7.05
2007	91	6.55	0.14	0.67	6.38	6.39	6.39	6.44	6.52	6.68	6.75	6.78	6.92
2008	91	6.65	0.10	0.59	6.49	6.50	6.53	6.58	6.63	6.72	6.79	6.84	6.93
2009	91	6.56	0.16	0.65	6.34	6.35	6.37	6.43	6.54	6.66	6.78	6.83	7.04
2010	91	6.60	0.09	-0.55	6.36	6.43	6.49	6.53	6.61	6.67	6.71	6.74	6.78
2011	91	6.66	0.16	0.49	6.43	6.44	6.47	6.52	6.64	6.77	6.86	6.91	7.08
2012	91	6.68	0.14	0.09	6.43	6.45	6.49	6.57	6.69	6.77	6.85	6.89	7.04
2013	91	6.55	0.13	0.44	6.37	6.38	6.39	6.44	6.54	6.64	6.74	6.78	6.85
2014	91	6.69	0.12	0.59	6.52	6.53	6.55	6.60	6.67	6.77	6.87	6.92	6.98
2015	91	6.67	0.13	-0.11	6.39	6.43	6.49	6.57	6.68	6.77	6.83	6.87	7.01
2016	91	6.59	0.14	0.46	6.36	6.37	6.42	6.50	6.58	6.68	6.78	6.85	6.96
All	1001	6.63	0.14	0.27	6.34	6.39	6.44	6.52	6.61	6.73	6.82	6.86	7.08

Table 3. Observed water level statistics at the AUKE CREEK WEIR (2006-2016), during the adult Sockeye migration period, mid-June to mid-September.

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	AukeBay LogAvg PPT3Day	AukeBay LogAvg PPT5Day	AukeBay LogAvg PPT6Day	AukeBay LogAvg PPT7Day	AukeBay LogAvg PPT10Day
LogWaterLevel	0.64506 <.0001 260	0.74296 <.0001 263	0.74718 <.0001 263	0.73688 <.0001 263	0.73834 <.0001 264

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	LogAuke BayAvg PPT3Day	LogAuke BayAvg PPT5Day	LogAuke BayAvg PPT6Day	LogAuke BayAvg PPT7Day	LogAuke BayAvg PPT10Day
LogWaterLevel	0.68754 <.0001 260	0.78831 <.0001 263	0.80306 <.0001 263	0.80840 <.0001 263	0.79570 <.0001 264

	Airport LogAvg PPT3Day	Airport LogAvg PPT5Day	Airport LogAvg PPT6Day	Airport LogAvg PPT7Day	Airport LogAvg PPT10Day
LogWaterLevel	0.57332 <.0001 264	0.72010 <.0001 264	0.75401 <.0001 264	0.76440 <.0001 264	0.75661 <.0001 264

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	Log Airport Avg PPT3Day	Log Airport Avg PPT5Day	Log Airport Avg PPT6Day	Log Airport Avg PPT7Day	Log Airport Avg PPT10Day
LogWaterLevel	0.61616 <.0001 264	0.74617 <.0001 264	0.78981 <.0001 264	0.78818 <.0001 264	0.79168 <.0001 264

	Downtown LogAvg PPT3Day	Downtown LogAvg PPT5Day	Downtown LogAvg PPT6Day	Downtown LogAvg PPT7Day	Downtown LogAvg PPT10Day
LogWaterLevel	0.53905 <.0001 212	0.58362 <.0001 245	0.57040 <.0001 253	0.56403 <.0001 253	0.56734 <.0001 257

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	Log Downtown Avg PPT3Day	Log Downtown Avg PPT5Day	Log Downtown Avg PPT6Day	Log Downtown Avg PPT7Day	Log Downtown Avg PPT10Day
LogWaterLevel	0.57654 <.0001 212	0.62975 <.0001 245	0.61783 <.0001 253	0.61714 <.0001 253	0.61093 <.0001 257

Table 4. Spearman correlation statistics for Auke Creek water level (Jun-Sep, 2006-2016) as a function of cumulative *n*-day mean daily precipitation indices (where n=3, 5, 6, 7 and 10 days) for AUKE BAY (top), JUNEAU AIRPORT (middle), and JUNEAU DOWNTOWN (bottom). Statistics for selected multi-day index (6-day moving average) based on maximum correlation.

The CORR Procedure

4 Variables: AukeBayAvgPPT6Day AirportAvgPPT6Day DowntownAvgPPT6Day AukePPT6DayStandard

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum
AukeBayAvgPPT6Day	1597	5.55792	4.70744	4.51667	0	29.80000
AirportAvgPPT6Day	2103	4.76194	4.30909	3.66667	0	34.96667
DowntownAvgPPT6Day	3142	7.09974	6.71584	5.33400	0	61.13333
AukePPT6DayStandard	3495	5.05023	4.13374	4.23721	0	29.80000

Pearson Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	AukeBay Avg PPT6Day	Airport Avg PPT6Day	Downtown Avg PPT6Day	Auke PPT6Day Standard
AukeBayAvgPPT6Day	1.00000 1597	0.90279 <.0001 1597	0.75125 <.0001 1266	1.00000 <.0001 1597
AirportAvgPPT6Day	0.90279 <.0001 1597	1.00000 2103	0.79362 <.0001 1750	0.92442 <.0001 2103
DowntownAvgPPT6Day	0.75125 <.0001 1266	0.79362 <.0001 1750	1.00000 3142	0.84095 <.0001 3142
AukePPT6DayStandard	1.00000 <.0001 1597	0.92442 <.0001 2103	0.84095 <.0001 3142	1.00000 3495

Spearman Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	AukeBay Avg PPT6Day	Airport Avg PPT6Day	Downtown Avg PPT6Day	Auke PPT6Day Standard
AukeBayAvgPPT6Day	1.00000 1597	0.92742 <.0001 1597	0.82837 <.0001 1266	1.00000 <.0001 1597
AirportAvgPPT6Day	0.92742 <.0001 1597	1.00000 2103	0.85560 <.0001 1750	0.94530 <.0001 2103
DowntownAvgPPT6Day	0.82837 <.0001 1266	0.85560 <.0001 1750	1.00000 3142	0.90672 <.0001 3142
AukePPT6DayStandard	1.00000 <.0001 1597	0.94530 <.0001 2103	0.90672 <.0001 3142	1.00000 3495

Table 5. Pearson and Spearman correlation statistics for AUKE BAY (AukeBayAvgPPT6Day), JUNEAU AIRPORT (AirportAvgPPT6Day), and JUNEAU DOWNTOWN (DowntownAvgPPT6Day) regional cumulative mean 6-day precipitation indices (Jun-Oct). Also included is the Auke Bay 6-day Precipitation Standard, constructed from regression relations between AukeBayAvgPPT6Day as a linear function of AirportAvgPPT6Day and DowntownAvgPPT6Day.

Dependent Variable: WaterLevel Weir Water Level (m)

Number of Observations Read	3510
Number of Observations Used	328
Number of Observations with Missing Values	3182

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	3.98477	3.98477	563.27	<.0001
Error	326	2.30625	0.00707		
Lack of Fit	276	1.94001	0.00703	0.96	0.5950
Pure Error	50	0.36624	0.00732		
Corrected Total	327	6.29101			

Root MSE	0.08411	R-Square	0.6334
Dependent Mean	6.64625	Adj R-Sq	0.6323
Coeff Var	1.26552		

Parameter Estimates

Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	6.50706	0.00748	869.82	<.0001
Auke Precipitation Standard (6-d BMAT)	1	0.02208	0.00093021	23.73	<.0001

Table 6. Regression statistics for Auke Creek water level as a function of cumulative *6*-day mean daily precipitation index (AUKEPPT6DAYSTANDARD), June-October, 2006-2016.

Dependent Variable: WaterLevel Weir Water Level (m)

Number of Observations Read	3510
Number of Observations Used	264
Number of Observations with Missing Values	3246

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.75131	1.75131	125.80	<.0001
Error	262	3.64742	0.01392		
Lack of Fit	210	3.06771	0.01461	1.31	0.1244
Pure Error	52	0.57971	0.01115		
Corrected Total	263	5.39873			

Root MSE	0.11799	R-Square	0.3244
Dependent Mean	6.63681	Adj R-Sq	0.3218
Coeff Var	1.77780		

Parameter Estimates

Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	7.09622	0.04160	170.59	<.0001
Auke Air Temperature Standard (5-d BMAT)	1	-0.03577	0.00319	-11.22	<.0001

Table 7. Regression statistics for Auke Creek water level as a function of cumulative *5*-day mean air temperature index (AUKEAIR5DAYSTANDARD), June-October, 2006-2016.

Dependent Variable: WaterLevel Weir Water Level (m)

Number of Observations Read	3510
Number of Observations Used	264
Number of Observations with Missing Values	3246

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	3.61119	1.80560	263.64	<.0001
Error	261	1.78753	0.00685		
Lack of Fit	261	1.78753	0.00685	.	.
Pure Error	0	0	.		
Corrected Total	263	5.39873			

Root MSE	0.08276	R-Square	0.6689
Dependent Mean	6.63681	Adj R-Sq	0.6664
Coeff Var	1.24695		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Squared Semi-partial Corr Type I
Intercept	Intercept	1	6.71842	0.03711	181.06	<.0001	.
AukePPT6DayStandard	Auke Precipitation Standard (6-d BMAT)	1	0.01828	0.00111	16.48	<.0001	0.62391
AukeAIR5DayStandard	Auke Air Temperature Standard (5-d BMAT)	1	-0.01525	0.00256	-5.95	<.0001	0.04499

Table 8. Step-wise multiple regression statistics for Auke Creek water level as a function of cumulative *6*-day mean daily precipitation index (AUKEPPT6DAYSTANDARD) and cumulative *5*-day mean air temperature index (AUKEAIR5DAYSTANDARD), June-October, 2006-2016.

Auke Water Level

------------------------------------ Site=Auke ------------------------------------

The CORR Procedure

2 Variables: WaterLevel WaterLevelStandard

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum
WaterLevel	1342	6.63444	0.14184	6.63245	6.29412	7.07745
WaterLevelStandard	1342	6.63369	0.11344	6.62028	6.41256	7.09209

Pearson Correlation Coefficients, N = 1342
Prob > |r| under H0: Rho=0

	Water Level	Water Level Standard
WaterLevel Weir Water Level (m)	1.00000	0.81022 <.0001
WaterLevelStandard	0.81022 <.0001	1.00000

Spearman Correlation Coefficients, N = 1342
Prob > |r| under H0: Rho=0

	Water Level	Water Level Standard
WaterLevel Weir Water Level (m)	1.00000	0.82468 <.0001
WaterLevelStandard	0.82468 <.0001	1.00000

Table 9. Correlation statistics for observed Auke Creek Water Level vs estimated Auke Creek Water Level Standard, June-October, 2006-2016.

Auke Creek Water Level Exceedance Analysis
Based on Auke Creek Est Discharge (6 <= MonthNum <= 9)

The UNIVARIATE Procedure
Variable: WaterLevelStandard

Moments

N	14235	Sum Weights	14235
Mean	6.60920705	Sum Observations	94082.0624
Std Deviation	0.09150091	Variance	0.00837242
Skewness	0.81120674	Kurtosis	1.31876777
Uncorrected SS	621927.003	Corrected SS	119.172989
Coeff Variation	1.38444618	Std Error Mean	0.00076691

Basic Statistical Measures

Location		Variability	
Mean	6.609207	Std Deviation	0.09150
Median	6.598167	Variance	0.00837
Mode	6.451545	Range	0.86794
		Interquartile Range	0.12064

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	8617.924	Pr > |t|	<.0001
Sign	M	7117.5	Pr >= |M|	<.0001
Signed Rank	S	50662365	Pr >= |S|	<.0001

Quantiles (Definition 5)

Level	Quantile
100% Max	7.26962
99%	6.88039
95%	6.77037
90%	6.72751
75% Q3	6.66333
50% Median	6.59817
25% Q1	6.54270
10%	6.50291
5%	6.48084
1%	6.44651
0% Min	6.40168

Table 10. Descriptive statistics for estimate Auke Creek Water Level Standard, June-September, 1900-2016.

	Water Temperature						Percentiles			
	Dates	Min	Mean	Max	Std	Skew	P25	P50	P75	P95
Year										
1980	91	10.80	14.58	16.70	1.39	-0.94	14.3	14.8	15.3	16.6
1981	91	11.00	14.39	17.80	1.71	-0.28	13.1	14.6	15.7	16.9
1982	91	12.10	15.10	18.40	1.57	-0.45	14.0	15.3	16.4	17.0
1983	91	10.00	14.63	18.30	2.04	-0.42	12.2	15.2	16.3	17.0
1984	91	11.90	14.20	16.60	1.23	-0.20	13.1	14.4	15.2	16.0
1985	91	10.30	13.80	16.80	1.84	-0.02	12.2	13.7	15.4	16.6
1986	91	12.00	14.27	16.60	1.48	0.17	13.1	14.0	15.8	16.6
1987	91	10.60	15.11	19.90	2.21	-0.38	13.3	15.5	17.0	17.8
1988	91	11.10	13.33	15.70	0.91	-0.08	12.8	13.4	13.9	14.7
1989	91	13.30	16.75	19.90	1.56	-0.03	15.3	16.7	18.1	19.1
1990	91	12.40	16.04	19.40	1.95	0.01	14.4	15.8	17.7	19.1
1991	91	10.40	14.94	18.70	2.29	-0.35	13.0	15.4	16.9	18.3
1992	91	10.30	15.16	19.80	1.93	-0.01	14.3	15.0	16.3	19.0
1993	91	13.40	16.11	18.80	1.49	-0.21	15.0	16.3	17.4	18.3
1994	91	11.40	15.47	18.30	1.65	-0.42	14.5	15.4	17.0	17.8
1995	91	12.20	15.64	18.50	1.59	-0.26	14.5	15.8	16.8	18.0
1996	91	11.10	14.16	19.10	1.74	0.85	12.9	14.0	15.1	18.0
1997	91	14.20	16.68	19.80	1.52	0.36	15.5	16.6	17.7	19.4
1998	91	11.00	15.82	21.00	2.60	-0.45	13.8	16.5	17.8	19.5
1999	91	11.10	15.13	19.90	2.07	-0.09	13.3	15.5	16.3	18.5
2000	91	10.70	14.84	18.10	1.83	-0.25	13.5	14.9	16.4	17.4
2001	91	11.47	15.29	18.37	1.83	-0.42	14.0	15.7	16.7	18.0
2002	91	11.32	14.24	17.52	1.65	0.08	12.5	14.2	15.6	16.9
2003	91	10.00	14.90	19.33	1.89	-0.08	14.0	15.0	16.0	18.0
2004	91	12.40	17.45	20.49	1.91	-0.83	16.7	17.6	18.8	20.2
2005	91	12.40	16.30	20.02	1.84	-0.33	14.9	16.7	17.5	19.3
2006	91	11.58	14.67	18.60	1.94	0.20	13.1	14.4	16.5	17.7
2007	91	12.05	15.76	18.77	1.35	-0.38	15.2	15.9	16.5	18.2
2008	91	11.06	13.84	17.52	1.48	0.33	12.7	14.0	14.7	16.5
2009	91	12.07	15.77	20.22	2.53	0.19	13.4	15.6	17.7	20.0
2010	91	13.63	15.57	18.83	1.26	0.86	14.6	15.2	16.3	18.1
2011	0									
2012	91	10.03	14.42	17.55	1.94	-0.26	13.0	14.5	16.2	17.2
2013	91	14.15	16.50	19.63	1.11	0.27	15.6	16.4	17.4	18.3
2014	91	13.60	16.24	19.70	1.50	0.21	15.2	16.2	17.4	19.0
2015	91	10.60	15.23	19.20	2.09	-0.33	13.7	15.4	17.1	18.0
2016	80	12.27	16.12	18.33	1.46	-0.63	15.5	16.2	17.3	18.2
All	3265	10.00	15.23	21.00	1.99	-0.06	13.8	15.3	16.7	18.4

Table 11. Statistical summary of observed daily mean water temperature data for AUKE CREEK during Sockeye migration (mid-June to mid-September) (Source: NOAA). All statistics are derived from daily mean temperatures from *N* annual dates. For example, *MIN* and *MAX* are the minimum and maximum of the daily mean temperature estimates, and therefore are not the observed extremes.

------------------------- Site=Auke -------------------------

	Calibration		Validation	
	Warming	Cooling	Warming	Cooling
	Observations	Observations	Observations	Observations
Year				
1980			135	105
1981	135	105		
1982	135	105		
1983	135	105		
1984			135	105
1985	135	105		
1986			135	105
1987	135	105		
1988	135	105		
1989			135	105
1990	135	105		
1991			135	105
1992	135	105		
1993			135	105
1994			135	105
1995			135	105
1996			135	105
1997	135	105		
1998	135	105		
1999	135	105		
2000			135	105
2001	135	105		
2002			135	105
2003			135	105
2004	135	105		
2005	135	105		
2006	135	105		
2007	135	105		
2008			135	105
2009	135	105		
2010			135	105
2011			0	0
2012			135	105
2013	135	105		
2014			135	105
2015	134	78		

Table 12. Number of annual water temperature observations available for Auke Creek air/water temperature model calibration and validation analyses, partitioned into warming and cooling seasons at July 29th for separate seasonal relations. Calibration years were selected based on maximum linear correlation between seasonal air/water time-series and maximum range of temperature observations (not shown).

Auke Air/Water Logistic (Intercept) Model - All Seasons 1980-2015 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	4	536365	134091	65114.2	<.0001
Error	3742	7706.0	2.0593		
Uncorrected Total	3746	544071			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness
alpha	19.7299	0.1979	19.3418	20.1180	0.1459
beta	10.3858	0.0814	10.2263	10.5454	0.0689
gamma	0.3198	0.00832	0.3035	0.3361	0.0409
mu	3.2256	0.1172	2.9958	3.4553	-0.0886

Auke Air/Water Logistic (Intercept) Model - Warming Season 1980-2015 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	4	299263	74815.7	42726.1	<.0001
Error	1928	3376.0	1.7511		
Uncorrected Total	1932	302639			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness
alpha	19.4852	0.2223	19.0493	19.9211	0.1854
beta	10.0853	0.0872	9.9143	10.2564	-0.0119
gamma	0.3424	0.0119	0.3190	0.3658	0.0254
mu	1.6235	0.2196	1.1928	2.0543	-0.1907

Auke Air/Water Logistic (Intercept) Model - Cooling Season 1980-2015 - Calibration

Source	DF	Sum of Squares	Mean Square	F Value	Approx Pr > F
Model	4	239561	59890.3	57960.3	<.0001
Error	1810	1870.3	1.0333		
Uncorrected Total	1814	241432			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits		Skewness
alpha	23.5447	0.5936	22.3804	24.7089	0.3259
beta	11.1342	0.2538	10.6364	11.6320	0.2915
gamma	0.1886	0.00737	0.1741	0.2030	0.000533
mu	1.9450	0.2062	1.5407	2.3494	-0.1726

Auke - Logistic (Intercept) Model - Nash-Sutcliffe Coefficient 1980-2015 - Calibration Years
Goodness of Fit for Season Data & Hysteresis Check against NSC for All Data

Obs	Season Numerator	Season Denominator	NSC Season Data	NSC All Data	NSC Season - NSC All	Result
1	5246.31	86687.05	0.93948	0.91154	0.027944	Hysteresis detected

Table 13. Logistic regression output for air/water temperature relationship between the AUKE 7d-CMAT (air temperature index) and calibration data for AUKE CREEK daily mean water temperatures: seasons combined (top); warming season (middle); cooling season (bottom). Hysteresis was detected ($NSC_{seasonal} - NSC_{all} = 0.028$).

Auke Air/Water Linear Model - Warming Season 1980-2015 - Calibration

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	48698	48698	22449.5	<.0001
Error	1930	4186.60312	2.16922		
Corrected Total	1931	52885			

Root MSE	1.47283	R-Square	0.9208
Dependent Mean	11.36981	Adj R-Sq	0.9208
Coeff Var	12.95386		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	Intercept	1	-1.21091	0.09040	-13.39	<.0001	-1.38821	-1.03360
AukeBay_7DMAT	7d-MAT	1	1.17854	0.00787	149.83	<.0001	1.16311	1.19397

----------------------------------- Site=Auke Dataset=Calibration Season=Cooling -----------------------------------

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	30840	30840	18860.5	<.0001
Error	1812	2962.87775	1.63514		
Corrected Total	1813	33802			

Root MSE	1.27873	R-Square	0.9123
Dependent Mean	10.69857	Adj R-Sq	0.9123
Coeff Var	11.95232		

Parameter Estimates

Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Intercept	Intercept	1	3.95715	0.05754	68.77	<.0001	3.84430	4.07001
AukeBay_7DMAT	7d-MAT	1	0.78997	0.00575	137.33	<.0001	0.77869	0.80125

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

Source	DF	Type III SS	Mean Square	F Value	Pr > F
AukeBay_7DMAT	1	76440.92322	76440.92322	27924.5	<.0001
Season	1	1660.05888	1660.05888	606.43	<.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
AukeBay_7DMAT	1	18282.98567	18282.98567	9569.22	<.0001
Season	1	4610.82925	4610.82925	2413.28	<.0001
AukeBay_7DMAT*Season	1	3096.64967	3096.64967	1620.77	<.0001

Table 14. Linear regression output for air/water temperature relationship between the Auke 7d-CMAT (air temperature index) and calibration data for the lower Auke Creek daily mean water temperatures: warming season (top); cooling season (middle). Type III sum of squares for season effect (test for equal intercepts) and for season interaction effect (test for equal slopes) were both highly significant ($P < 0.0001$), indicating hysteresis.

---- Site=Auke Dataset=Validation Season=Warming ---

Pearson Correlation Coefficients, N = 2292
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.94362	0.92985
Daily MWT	<.0001	<.0001

---- Site=Auke Dataset=Validation Season=Cooling ---

Pearson Correlation Coefficients, N = 2228
Prob > |r| under H0: Rho=0

	Logistic Model Water Temp	Linear Model Water Temp
WaterT	0.96949	0.95537
Daily MWT	<.0001	<.0001

Table 15. Comparison of Pearson correlation coefficients for observed (WaterT) versus estimated AUKE CREEK daily mean water temperature (from logistic and linear models) for validation data years: warming season (top); cooling season (bottom).

Annual Frequency & Mean Duration (days) for POT20c Event

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1900s	1	2	2.0	2	
1910s	4	1	3.0	5	1.8
1920s	0				
1930s	0				
1940s	0				
1950s	0				
1960s	4	1	1.0	1	0.0
1970s	2	1	1.5	2	0.7
1980s	2	2	2.5	3	0.7
1990s	8	1	1.4	3	0.7
2000s	10	1	2.3	7	1.8
Total	31	1	1.9	7	1.4

Annual Frequency & Mean Duration (days) for POT20c Event

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1900s	1	2	2.0	2	
1910s	4	1	3.0	5	1.8
1920s	0				
1930s	0				
1940s	0				
1950s	0				
1960s	4	1	1.0	1	0.0
1970s	2	1	1.5	2	0.7
1980s	2	2	2.5	3	0.7
1990s	8	1	1.4	3	0.7
2000s	10	1	2.3	7	1.8
Total	31	1	1.9	7	1.4

Table 16. Frequency analysis of decadal mean number of dates per month in which regional "standard" daily mean air temperature at AUKE BAY 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 (June-September), by decade (bottom).

Auke - Decadal Mean Monthly MWT Peaks > 18c

Site: Auke Creek

	Years in Decade	Mean No. Days				Mean Annual Total
		Jun	Jul	Aug	Sep	
Decade						
1900s	10	0.5	1.2			1.7
1910s	10	1.4	2.1	1.1		4.6
1920s	10		0.1	0.2		0.3
1930s	10		0.4			0.4
1940s	10	0.6				0.6
1950s	10		0.9			0.9
1960s	10	0.9	1.0	0.9		2.8
1970s	10		1.9	2.5		4.4
1980s	10	0.6	1.7	0.7		3.0
1990s	10	1.4	4.5	3.6		9.5
2000s	10	1.2	2.5	2.9		6.6
2010s	6	1.7	0.7	1.8		4.2

Auke - Annual Frequency & Mean Duration (days) for POT18c Events

	POT Event Duration (days)				
	N	Min	Avg	Max	Std
Decade					
1900s	3	3	5.7	7	2.3
1910s	9	1	5.1	10	3.9
1920s	2	1	1.0	1	0.0
1930s	1	4	4.0	4	
1940s	2	2	3.0	4	1.4
1950s	1	9	9.0	9	
1960s	5	2	5.6	11	3.5
1970s	7	4	6.1	9	1.8
1980s	8	1	3.8	7	1.8
1990s	16	1	5.9	15	3.7
2000s	16	1	5.7	14	4.4
Total	70	1	5.3	15	3.4

Table 17. Frequency analysis of decadal mean number of dates per month in which estimated mean water temperature in Auke Creek 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 (June-September), by decade (bottom).

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1900s	1900	0				
	1901	0				
	1902	0				
	1903	0				
	1904	0				
	1905	1	7	7.0	7	
	1906	1	3	3.0	3	
	1907	0				
	1908	0				
	1909	1	7	7.0	7	
	Total	3	3	5.7	7	2.3
1910s	Year					
	1910	1	1	1.0	1	
	1911	2	8	9.0	10	1.4
	1912	0				
	1913	0				
	1914	1	9	9.0	9	
	1915	3	1	3.7	9	4.6
	1916	1	5	5.0	5	
	1917	0				
1910s	1918	1	2	2.0	2	
	1919	0				
	Total	9	1	5.1	10	3.9
1920s	Year					
	1920	0				
	1921	0				
	1922	0				
	1923	1	1	1.0	1	
	1924	0				
	1925	1	1	1.0	1	
	1926	0				
	1927	0				
	1928	0				
	1929	0				
	Total	2	1	1.0	1	0.0
1930s	Year					
	1930	0				
	1931	0				
	1932	0				
	1933	0				
1930s	1934	1	4	4.0	4	
	1935	0				
	1936	0				
	1937	0				
	1938	0				
	1939	0				
	Total	1	4	4.0	4	
1940s	Year					
	1940	0				
	1941	0				
	1942	0				
	1943	0				
	1944	1	2	2.0	2	
	1945	0				
	1946	0				
	1947	0				
	1948	1	4	4.0	4	
	1949	0				
	Total	2	2	3.0	4	1.4

(Continued)

Table 18. Min., mean and max. length (days) and total frequency of periods in which estimated mean water temperature in Auke Creek continuously exceeded 18°C (June - September), by year.

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1950s	1950	0				
	1951	1	9	9.0	9	
	1952	0				
	1953	0				
	1954	0				
	1955	0				
	1956	0				
	1957	0				
	1958	0				
	1959	0				
	Total	1	9	9.0	9	
1960s	Year					
	1960	0				
	1961	0				
	1962	0				
	1963	0				
	1964	0				
	1965	2	4	7.5	11	4.9
	1966	1	4	4.0	4	
	1967	1	2	2.0	2	
Decade	Year					
1960s	1968	0				
	1969	1	7	7.0	7	
	Total	5	2	5.6	11	3.5
1970s	Year					
	1970	0				
	1971	1	9	9.0	9	
	1972	1	5	5.0	5	
	1973	0				
	1974	0				
	1975	1	4	4.0	4	
	1976	1	6	6.0	6	
	1977	1	8	8.0	8	
	1978	1	5	5.0	5	
	1979	1	6	6.0	6	
	Total	7	4	6.1	9	1.8
1980s	Year					
	1980	1	1	1.0	1	
	1981	0				
	1982	2	4	4.5	5	0.7
	1983	0				

(Continued)

Table 18, cont'd. Min., mean and max. length (days) and total frequency of periods in which estimated mean water temperature in Auke Creek continuously exceeded 18°C (June - September), by year.

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
1980s	1984	1	3	3.0	3	
	1985	0				
	1986	0				
	1987	1	3	3.0	3	
	1988	0				
	1989	3	3	4.7	7	2.1
	Total	8	1	3.8	7	1.8
1990s	Year					
	1990	3	4	5.0	6	1.0
	1991	1	7	7.0	7	
	1992	1	6	6.0	6	
	1993	3	2	8.0	12	5.3
	1994	1	15	15.0	15	
	1995	0				
	1996	1	6	6.0	6	
	1997	3	1	3.0	4	1.7
	1998	1	3	3.0	3	
	1999	2	4	5.0	6	1.4
	Total	16	1	5.9	15	3.7

		POT Event Duration (days)				
		N	Min	Avg	Max	Std
Decade	Year					
2000s	2000	0				
	2001	1	1	1.0	1	
	2002	1	1	1.0	1	
	2003	1	4	4.0	4	
	2004	3	7	10.7	14	3.5
	2005	1	7	7.0	7	
	2006	1	1	1.0	1	
	2007	1	2	2.0	2	
	2008	0				
	2009	2	9	9.0	9	0.0
	2010	1	1	1.0	1	
	2011	0				
	2012	0				
	2013	3	1	7.0	10	5.2
	2014	0				
	2015	1	3	3.0	3	
	Total	16	1	5.7	14	4.4
Total		70	1	5.3	15	3.4

Table 18, cont'd. Min., mean and max. length (days) and total frequency of periods in which estimated mean water temperature in Auke Creek continuously exceeded 18°C (June - September), by year.

Decadal Mean Monthly Frequency of Flow < 650 mm

Site: Auke Creek

	Years in Decade	Mean No. Days				Mean Annual Total
		Jun	Jul	Aug	Sep	
Decade						
1900s	10	4.2	4.6	1.1		9.9
1910s	10	2.0	3.2	1.8		7.0
1920s	10	2.9	5.1	3.7		11.7
1930s	10	3.2	0.7	1.5	0.5	5.9
1940s	10	3.0	2.8	2.2	0.1	8.1
1950s	10	4.1	5.6	5.2	0.2	15.1
1960s	10	2.9	4.4	3.1	0.2	10.6
1970s	10	0.7	4.5	5.4	0.2	10.8
1980s	10	2.3	6.6	2.7	0.3	11.9
1990s	10	4.8	8.6	4.7		18.1
2000s	10	4.1	4.8	5.7		14.6
2010s	7	4.6	5.1	3.4		13.1

Mean Duration (days) of Flow < 650 mm

	POT Event Duration (days)							
	N	Min	Avg	Max	Std	P10	MED	P90
Decade								
1900s	22	1	4.5	13	3.9	1.0	3.0	12.0
1910s	16	1	4.3	13	3.4	1.0	4.0	10.0
1920s	27	1	4.3	14	3.4	1.0	3.0	10.0
1930s	17	1	3.4	13	3.1	1.0	2.0	7.0
1940s	25	1	3.1	11	2.5	1.0	2.0	7.0
1950s	32	1	4.7	20	4.2	1.0	4.0	9.0
1960s	23	1	4.6	12	3.3	1.0	4.0	10.0
1970s	25	1	4.3	18	3.6	1.0	4.0	8.0
1980s	29	1	4.1	15	3.3	1.0	3.0	9.0
1990s	33	1	5.5	17	3.7	2.0	4.0	11.0
2000s	26	1	5.6	13	4.0	1.0	4.5	13.0
2010s	21	1	4.2	15	3.7	2.0	3.0	7.0
Total	296	1	4.4	20	3.6	1.0	3.0	9.0

Table 19. Decadal mean number of dates per month in which estimated water level in Auke Creek was less than 6.50 m ASL (top). Min., mean and max. duration (days) of $POT_{<6.50}$ periods, by decade (bottom). See Figure 43 and Figure 44.

Monthly and Annual No. Dates < 650 mm

		Freq POT650 mm Dates				Total Days
		Jun	Jul	Aug	Sep	
Decade	Year					
1980s	1980	6	0	0	0	6
	1981	0	11	4	0	15
	1982	7	8	2	0	17
	1983	4	4	0	0	8
	1984	0	4	5	0	9
	1985	0	1	0	0	1
	1986	4	7	0	0	11
	1987	0	16	5	0	21
	1988	0	0	0	0	0
	1989	2	15	11	3	31
1990s	1990	2	13	4	0	19
	1991	11	0	1	0	12
	1992	6	8	0	0	14
	1993	6	16	7	0	29
	1994	0	8	17	0	25
	1995	5	10	4	0	19
	1996	8	10	0	0	18
	1997	4	5	3	0	12
	1998	6	7	6	0	19

Monthly and Annual No. Dates < 650 mm

		Freq POT650 mm Dates				Total Days
		Jun	Jul	Aug	Sep	
Decade	Year					
1990s	1999	0	9	5	0	14
2000s	2000	2	4	1	0	7
	2001	3	4	8	0	15
	2002	4	0	4	0	8
	2003	1	7	7	0	15
	2004	12	12	15	0	39
	2005	4	0	7	0	11
	2006	7	4	0	0	11
	2007	0	0	6	0	6
	2008	0	1	0	0	1
	2009	8	16	9	0	33
2010s	2010	2	2	3	0	7
	2011	4	6	0	0	10
	2012	2	7	4	0	13
	2013	13	5	7	0	25
	2014	0	0	3	0	3
	2015	9	1	7	0	17
	2016	2	15	0	0	17

(Continued)

Table 20. Mean number of dates per month in which estimated water level in Auke Creek was less than 6.50 m ASL (<10th percentile) June-September, by year (1980-2016).

Mean Duration (days) of Flow < 650 mm

		POT Event Duration (days)							
		N	Min	Avg	Max	Std	P10	MED	P90
Decade	Year								
1980s	1980	1	6	6.0	6		6.0	6.0	6.0
	1981	2	4	7.5	11	4.9	4.0	7.5	11.0
	1982	3	3	5.7	9	3.1	3.0	5.0	9.0
	1983	5	1	1.6	3	0.9	1.0	1.0	3.0
	1984	2	4	4.5	5	0.7	4.0	4.5	5.0
	1985	1	1	1.0	1		1.0	1.0	1.0
	1986	4	2	2.8	3	0.5	2.0	3.0	3.0
	1987	6	1	3.5	8	2.6	1.0	2.5	8.0
	1989	5	2	6.2	15	5.5	2.0	4.0	15.0
1990s	1990	3	4	6.3	8	2.1	4.0	7.0	8.0
	1991	1	11	11.0	11		11.0	11.0	11.0
	1992	2	3	7.0	11	5.7	3.0	7.0	11.0
	1993	4	3	7.3	16	6.1	3.0	5.0	16.0
	1994	3	3	8.3	17	7.6	3.0	5.0	17.0
	1995	6	2	3.2	5	1.3	2.0	3.0	5.0
	1996	5	1	3.6	5	1.5	1.0	4.0	5.0
	1997	3	3	4.0	6	1.7	3.0	3.0	6.0
	1998	3	3	6.3	8	2.9	3.0	8.0	8.0
	1999	3	3	4.7	6	1.5	3.0	5.0	6.0

(Continued)

Mean Duration (days) of Flow < 650 mm

		POT Event Duration (days)							
		N	Min	Avg	Max	Std	P10	MED	P90
Decade	Year								
2000s	2000	3	1	2.3	4	1.5	1.0	2.0	4.0
	2001	3	2	5.0	8	3.0	2.0	5.0	8.0
	2002	2	4	4.0	4	0.0	4.0	4.0	4.0
	2003	3	1	5.0	7	3.5	1.0	7.0	7.0
	2004	5	1	7.8	13	5.9	1.0	10.0	13.0
	2005	3	1	3.7	7	3.1	1.0	3.0	7.0
	2006	2	4	5.5	7	2.1	4.0	5.5	7.0
	2007	1	6	6.0	6		6.0	6.0	6.0
	2008	1	1	1.0	1		1.0	1.0	1.0
	2009	3	8	11.0	13	2.6	8.0	12.0	13.0
2010s	2010	3	2	2.0	2	0.0	2.0	2.0	2.0
	2011	3	2	3.3	6	2.3	2.0	2.0	6.0
	2012	3	2	4.0	7	2.6	2.0	3.0	7.0
	2013	4	2	6.3	13	5.0	2.0	5.0	13.0
	2014	1	3	3.0	3		3.0	3.0	3.0
	2015	5	1	3.2	6	1.8	1.0	3.0	6.0
	2016	2	2	8.5	15	9.2	2.0	8.5	15.0
Total		109	1	4.9	17	3.7	1.0	4.0	11.0

Table 21. Min., mean and max. length (days) and number of periods in which estimated water levels in Auke Creek was < 6.50 m ASL (<10th percentile) June-September, by year (1980-2016).

Decadal Mean Monthly Flow > 674 mm

Site: Auke Creek

	Years in Decade	Mean No. Days				Mean Annual Total
		Jun	Jul	Aug	Sep	
Decade						
1900s	10			0.1	3.1	3.2
1910s	10		1.1	1.4	2.1	4.6
1920s	10		0.1		0.5	0.6
1930s	10		0.1	0.9	1.0	2.0
1940s	10	0.1	1.3	0.9	3.1	5.4
1950s	10	0.5	1.6	3.9	3.8	9.8
1960s	10	0.5	2.9	4.8	6.1	14.3
1970s	10	0.4	0.9	3.7	5.4	10.4
1980s	10	0.8	1.8	2.9	4.9	10.4
1990s	10	0.9	2.1	4.6	10.5	18.1
2000s	10	0.5	2.7	4.3	11.1	18.6
2010s	7	1.1	4.1	7.3	10.4	23.0

Mean Duration (days) of Flow > 674 mm

	POT Event Duration (days)							
	N	Min	Avg	Max	Std	P10	MED	P90
Decade								
1900s	7	1	4.6	12	3.9	1.0	3.0	12.0
1910s	20	1	2.2	7	1.8	1.0	2.0	5.5
1920s	5	1	1.2	2	0.4	1.0	1.0	2.0
1930s	9	1	2.0	3	0.9	1.0	2.0	3.0
1940s	18	1	3.0	7	1.6	1.0	3.0	5.0
1950s	28	1	3.5	9	2.3	1.0	3.0	7.0
1960s	42	1	3.3	14	2.6	1.0	2.0	6.0
1970s	30	1	3.4	10	2.1	1.0	3.0	5.5
1980s	30	1	3.4	15	3.4	1.0	2.0	7.5
1990s	36	1	5.0	26	4.8	1.0	3.5	11.0
2000s	42	1	4.4	13	3.0	1.0	3.5	9.0
2010s	37	1	4.3	14	3.6	1.0	3.0	10.0
Total	304	1	3.7	26	3.1	1.0	3.0	7.0

Table 22. Decadal mean number of dates per month in which estimated water level in Auke Creek was greater than 6.74 m ASL (top). Min., mean and max. duration (days) of $POT_{>6.74}$ periods, by decade (bottom).

Decadal Mean Monthly Flow > 681 mm

Site: Auke Creek

	Years in Decade	Mean No. Days				Mean Annual Total
		Jun	Jul	Aug	Sep	
Decade						
1900s	10					
1910s	10					
1920s	10					
1930s	10					
1940s	10		0.6	0.1	0.4	1.1
1950s	10	0.1		0.6	0.9	1.6
1960s	10	0.1	0.6	1.0	1.4	3.1
1970s	10			0.5	1.2	1.7
1980s	10		0.1	0.7	0.8	1.6
1990s	10		0.3	1.1	5.3	6.7
2000s	10		0.1	1.0	3.6	4.7
2010s	7		1.4	2.6	2.4	6.4

Mean Duration (days) of Flow > 681 mm

	POT Event Duration (days)							
	N	Min	Avg	Max	Std	P10	MED	P90
Decade								
1940s	7	1	1.6	3	0.8	1.0	1.0	3.0
1950s	8	1	1.9	3	0.8	1.0	2.0	3.0
1960s	12	1	2.5	8	2.2	1.0	2.0	6.0
1970s	9	1	1.8	3	1.0	1.0	1.0	3.0
1980s	5	1	2.8	8	3.0	1.0	1.0	8.0
1990s	18	1	3.7	11	3.1	1.0	3.0	10.0
2000s	18	1	2.6	6	1.8	1.0	2.0	6.0
2010s	12	1	3.6	8	2.7	1.0	3.0	7.0
Total	89	1	2.7	11	2.3	1.0	2.0	6.0

Table 23. Decadal mean number of dates per month in which estimated water level in Auke Creek was greater than 6.81 m ASL (top). Min., mean and max. duration (days) of $POT_{>6.81}$ periods, by decade (bottom).

Pearson Correlation Coefficients
Prob > |r| under H0: Rho=0
Number of Observations

	MeanWT	Freq18	Dur18	DurMax18
JulDate Day of Year	0.00937 0.9567 36	0.35514 0.0335 36	0.48417 0.0028 36	0.47783 0.0032 36

Table 24. Correlation coefficient, probability, and sample size for correlation analysis between median Julian date of annual migration (i.e. TT50%, 1980 – 2015) versus Auke Creek mean annual water temperature (MeanWT) and water temperature exceedance indices, including: annual frequency of dates exceeding 18ºC (Freq18); mean duration (days) of periods continuously exceeding 18ºC (Dur18); maximum duration (days) of periods continuously exceeding 18ºC (DurMax18).

Pearson Correlation Coefficients, N = 37
Prob > |r| under H0: Rho=0

	MeanWL	Freq	Dur	DurMax
JulDate Day of Year	-0.40367 0.0132	0.35459 0.0313	0.19158 0.2560	0.37547 0.0220

Table 25. Correlation coefficient, probability, and sample size for correlation analysis between median Julian date of annual migration (i.e. TT50%, 1980 – 2015) versus Auke Creek mean annual water level (MeanWL) and water level exceedance indices, including: annual frequency of dates below 6.5 m (Freq); mean duration (days) of periods continuously below 6.5 m (Dur); maximum duration (days) of periods continuously below 6.5 m (Dur).

Simple Statistics

Variable	N	Mean	Std Dev	Median	Minimum	Maximum
MigArcsin	1846	0.0001408	0.05013	-0.01575	-0.01984	0.94201
Year	1846	1999	10.27517	1999	1980	2016
Date	1846	14377	3749	14441	7475	20708
WaterT	1846	15.11708	1.82571	15.20000	10.60000	20.21500
LogWaterLevel	1846	6.49715	0.01451	6.49635	6.46458	6.56212
Migrants	1846	55.05905	144.62454	10.00000	1.00000	2468

Pearson Correlation Coefficients, N = 1846
Prob > |r| under H0: Rho=0

	Year	Date	WaterT	Log Water Level	Migrants
MigArcsin Arcsin (Daily Migration Rate (%))	-0.02837 0.2231	-0.02995 0.1984	0.07634 0.0010	0.09414 <.0001	0.92178 <.0001

Spearman Correlation Coefficients, N = 1846
Prob > |r| under H0: Rho=0

	Year	Date	WaterT	Log Water Level	Migrants
MigArcsin Arcsin (Daily Migration Rate (%))	-0.00987 0.6716	-0.02629 0.2590	0.12931 <.0001	0.16117 <.0001	0.94917 <.0001

Table 26. Correlation analysis between arcsin transform of non-zero Daily Migration Rate (%) and Auke Creek water temperature and water level indices (1980 – 2016).

Migration Rate vs Water Temp & Water Level

The ROBUSTREG Procedure

Model Information

Data Set	WORK.REGRESS
Dependent Variable	MigArcsin
Number of Independent Variables	2
Number of Observations	1846
Method	M Estimation

Number of Observations Read	1846
Number of Observations Used	1846

Parameter Information

Parameter	Effect
Intercept	Intercept
WaterT	WaterT
LogWaterLevel	LogWaterLevel
WaterTLogWaterLevel	WaterT*LogWaterLevel

Summary Statistics

Variable	Q1	Median	Q3	Mean	Standard Deviation	MAD
WaterT	13.8000	15.2000	16.5000	15.1171	1.8257	1.9509
LogWaterLevel	6.4866	6.4963	6.5067	6.4972	0.0145	0.0148
WaterT*LogWaterLevel	89.6780	98.6395	106.9	98.2021	11.7312	12.6018
MigArcsin	-0.0188	-0.0158	-0.00321	0.000141	0.0501	0.00541

Parameter Estimates

Parameter	DF	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	1	2.0405	0.3754	1.3048	2.7762	29.55	<.0001
WaterT	1	-0.1738	0.0247	-0.2223	-0.1254	49.44	<.0001
LogWaterLevel	1	-0.3181	0.0578	-0.4313	-0.2049	30.34	<.0001
WaterT*LogWaterLevel	1	0.0269	0.0038	0.0194	0.0343	49.83	<.0001
Scale	1	0.0047					

Table 27. Regression analysis between arcsin transform of non-zero Daily Migration Rate (%) and Auke Creek water temperature and water level indices (1980 – 2016).

FIGURES

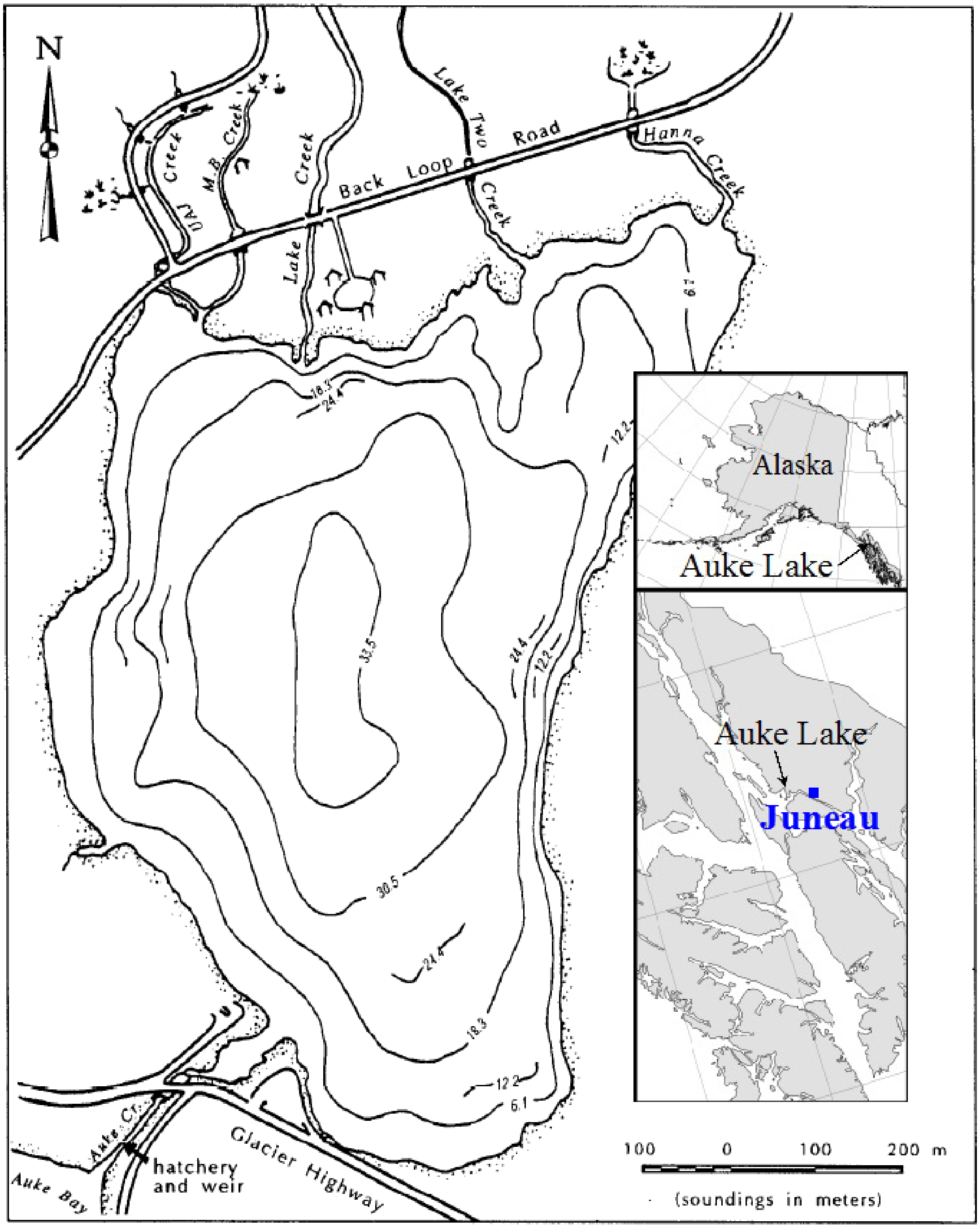


Figure 1. Auke study area locator map (adapted from Taylor et al. 2002). For Sockeye aggregation sites and spawning locations, see Ray et al. 2014.

Figure 2. Meteorological stations at AUKE BAY, JUNEAU AIRPORT, and JUNEAU DOWNTOWN. Source: NOAA NCEI Map Application V 2.2.0 [Dec 2018].

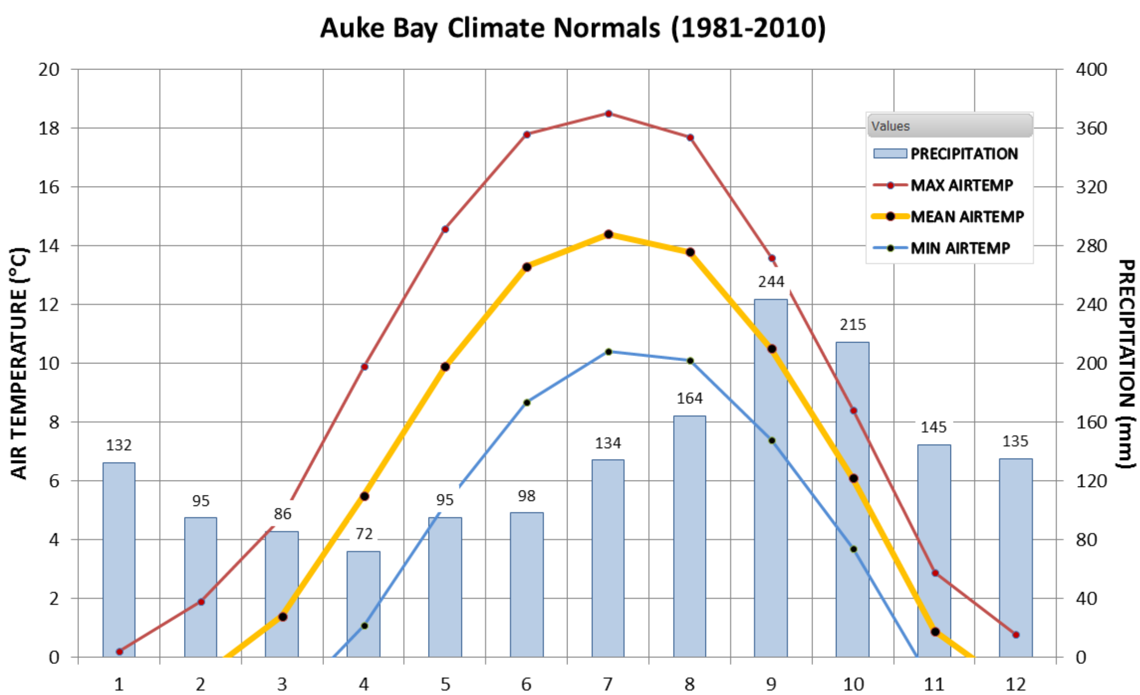


Figure 3. AUKE BAY climatology, 1981-2010 (station USC 500464). Source: NOAA NATIONAL WEATHER SERVICE [downloaded April 2017 from: https://www.ncdc.noaa.gov].

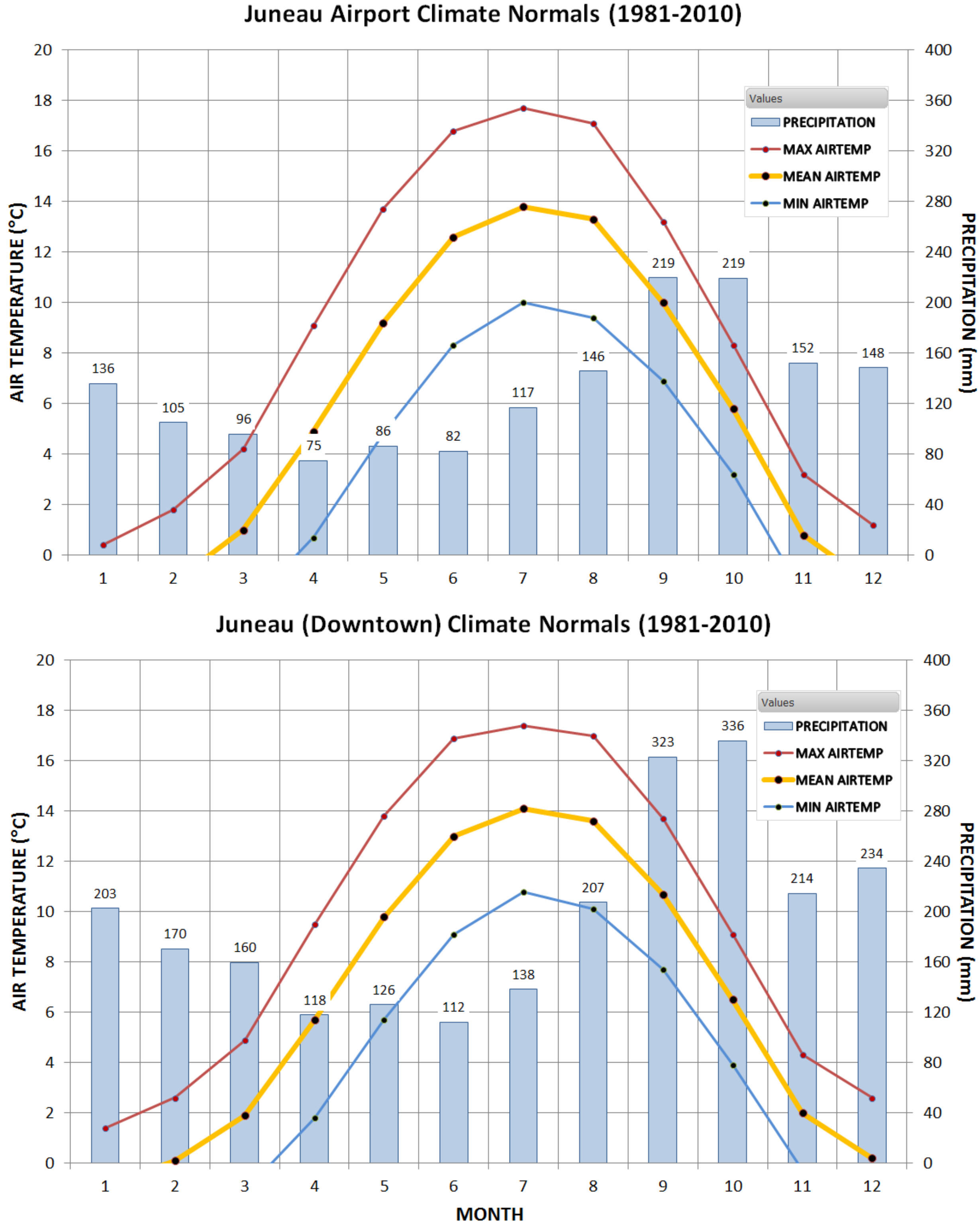


Figure 4. JUNEAU region climatology, 1981-2010 (AIRPORT station USW25309, top; DOWNTOWN, station USC504094, bottom). Source: NOAA NATIONAL WEATHER SERVICE [downloaded April 2017 from: https://www.ncdc.noaa.gov].

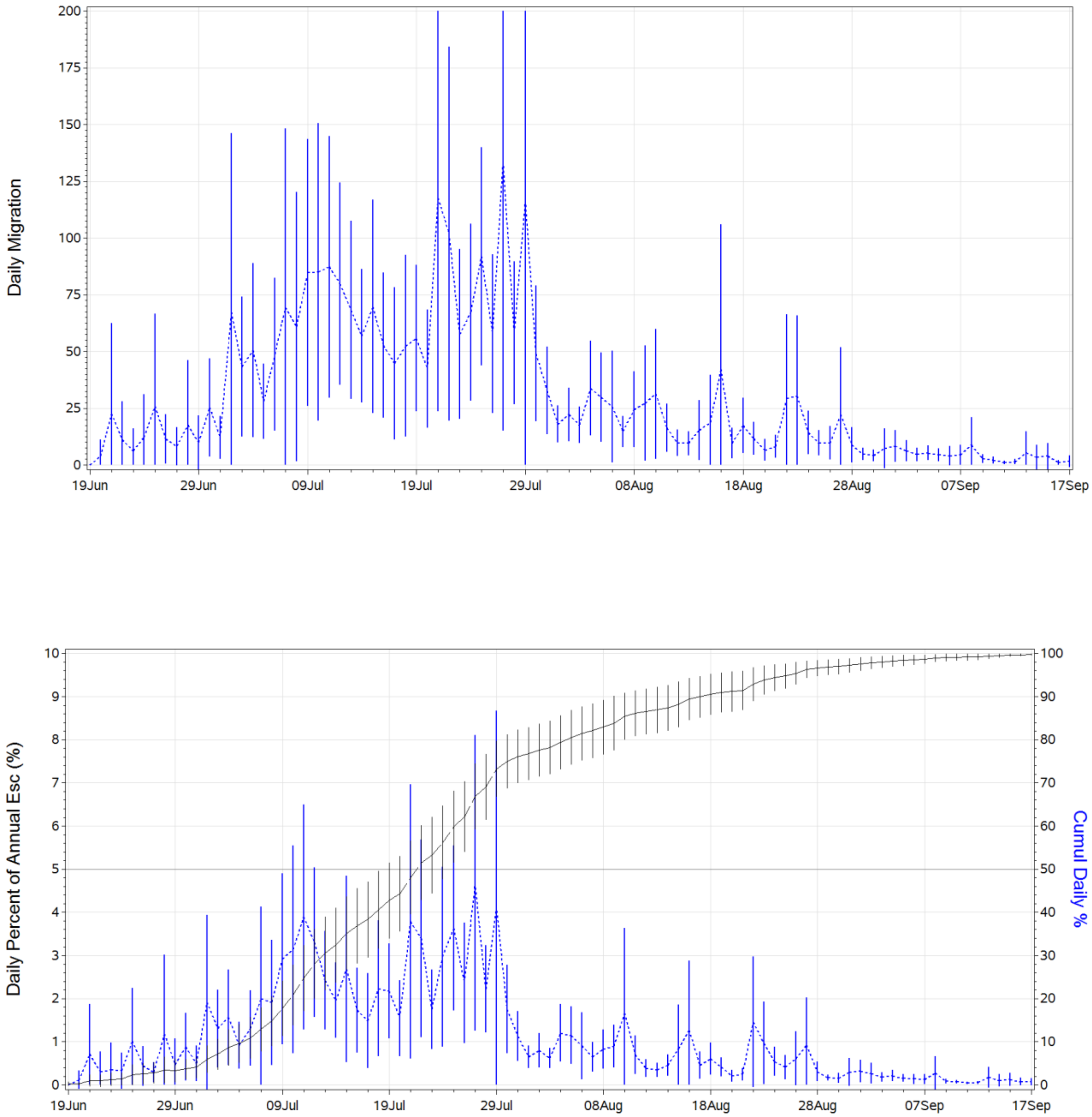


Figure 5. Historical Sockeye migration timing based on mean daily visual counts in Auke Creek (1980-2016). Mean and variance (95% CI) of average daily migrant counts (top) and mean daily % and cumulative % of total annual escapement (bottom). Time-to-50% ~ July 22nd (Source: ADFG, NOAA).

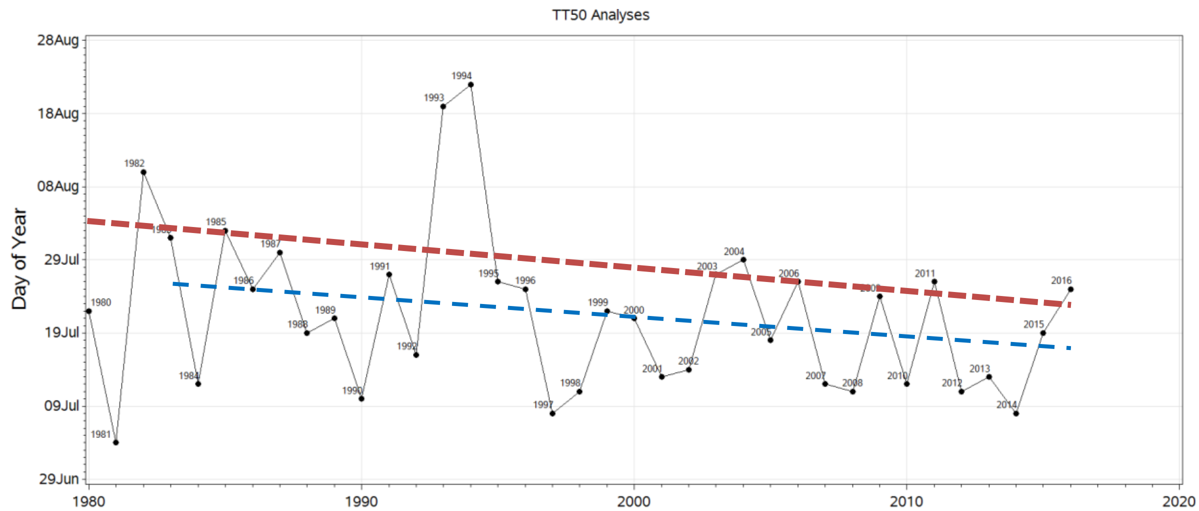


Figure 6. Trend in median date of upstream Sockeye migration (TT50%). Red dashed line represents linear trend over all years 1980-2016 (r = -0.26, MK = -1.66, $P_{MK} < 0.1$, n = 37). Blue dashed line omits years (1980-1982, 1990-1995) potentially influenced by hatchery returns (r = -0.36, MK = -1.64, $P_{MK} > 0.1$, n = 28).

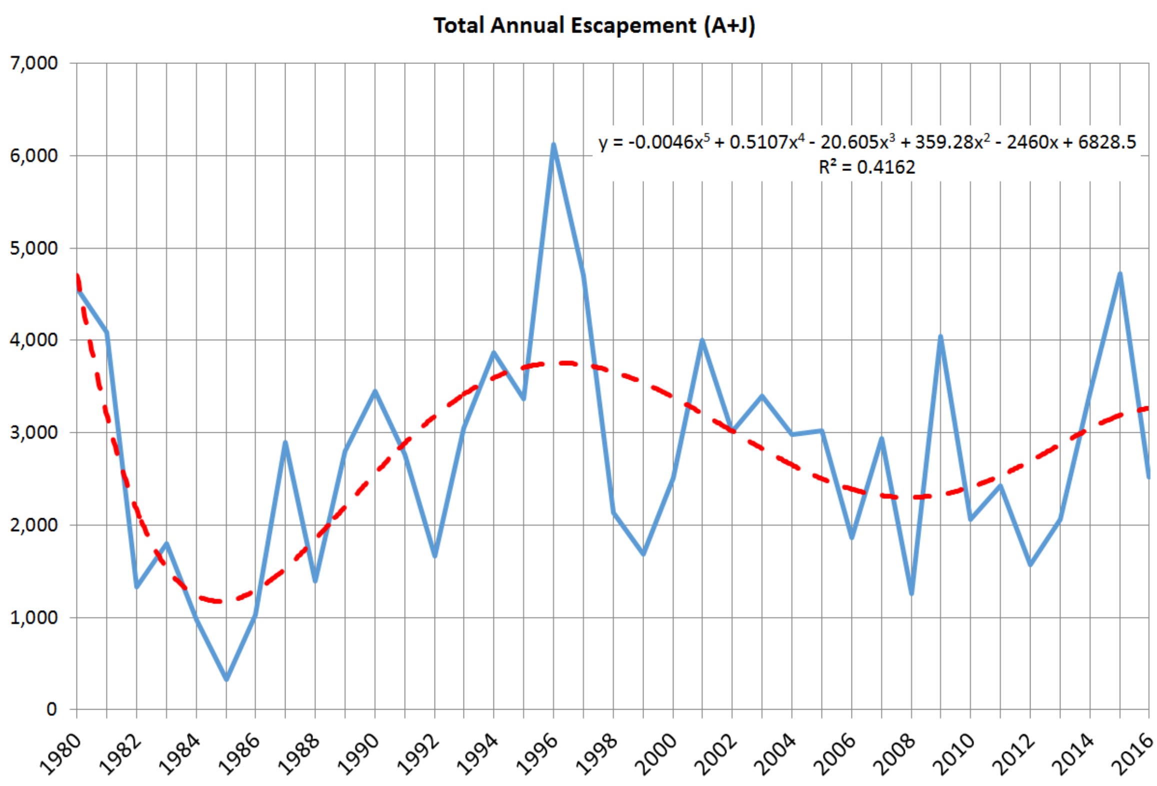


Figure 7. Total annual Sockeye escapement, Auke Creek (1980-2016).

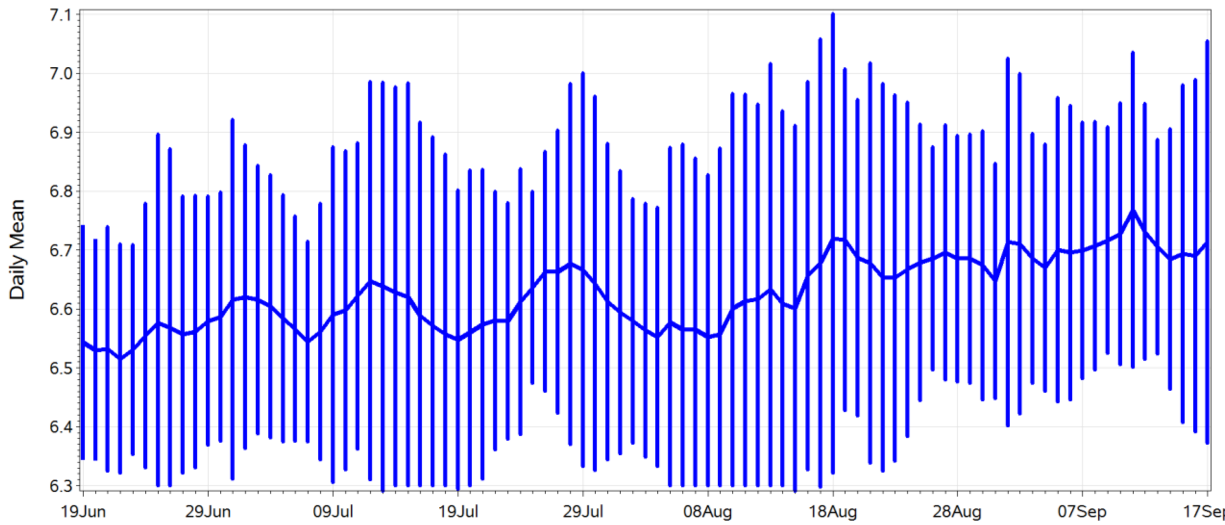


Figure 8. Daily mean water level (m) ± standard deviation during the Sockeye migration period (observed, Jun-Sep 2006-2016) from Auke Creek weir.

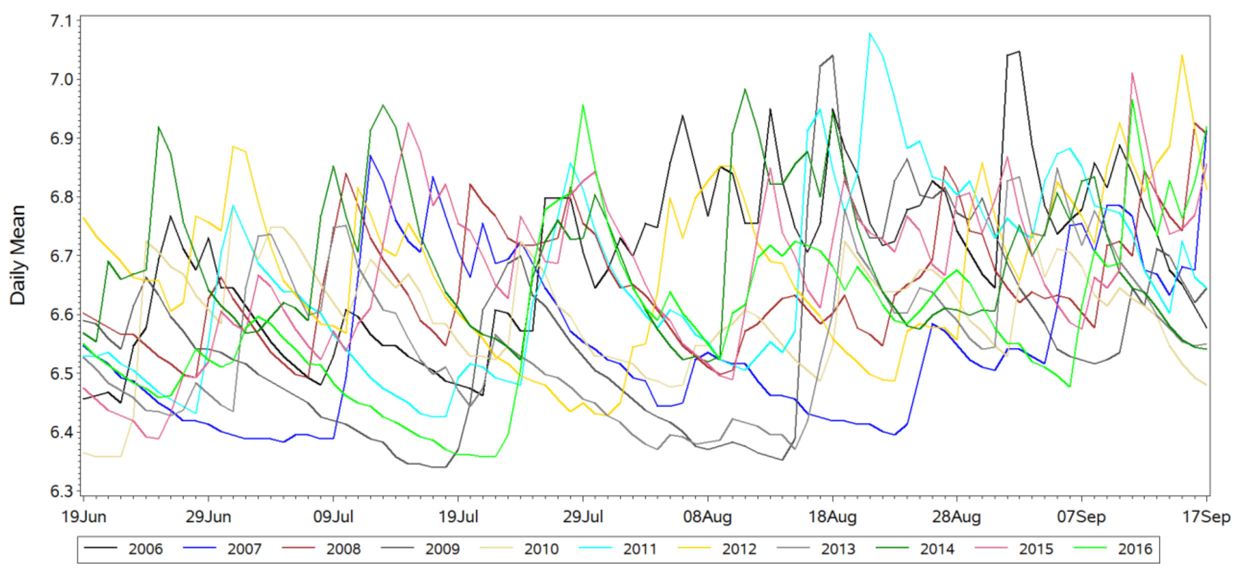


Figure 9. Observed AUKE CREEK (Weir) mean daily water level (m) by year, 2006-2016.

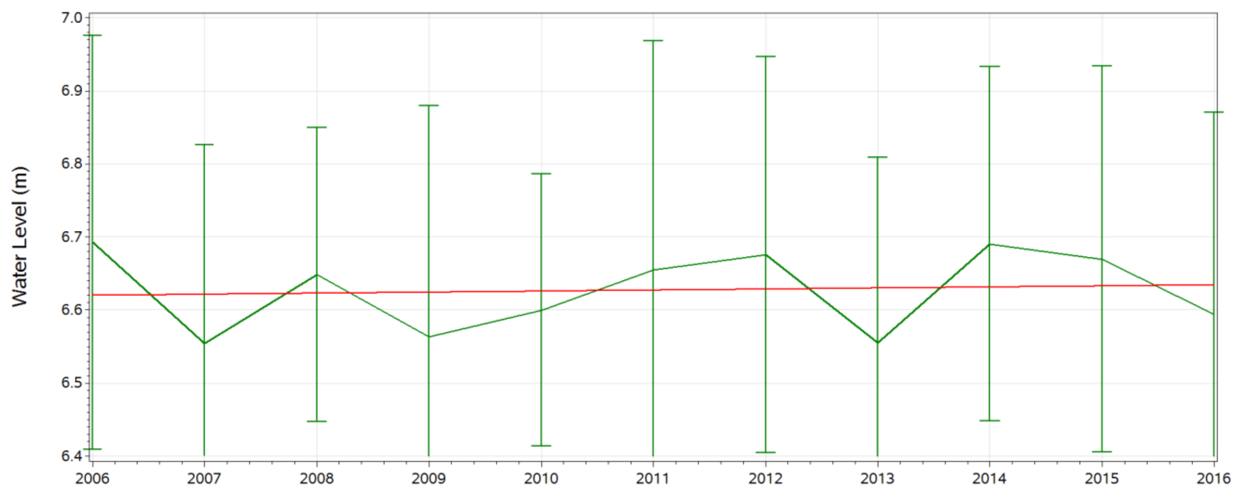


Figure 10. Observed AUKE CREEK (WEIR) mean water level ± 2 std deviations, 2006-2016 (June 19 – September 17). No significant trend (P > 0.05).

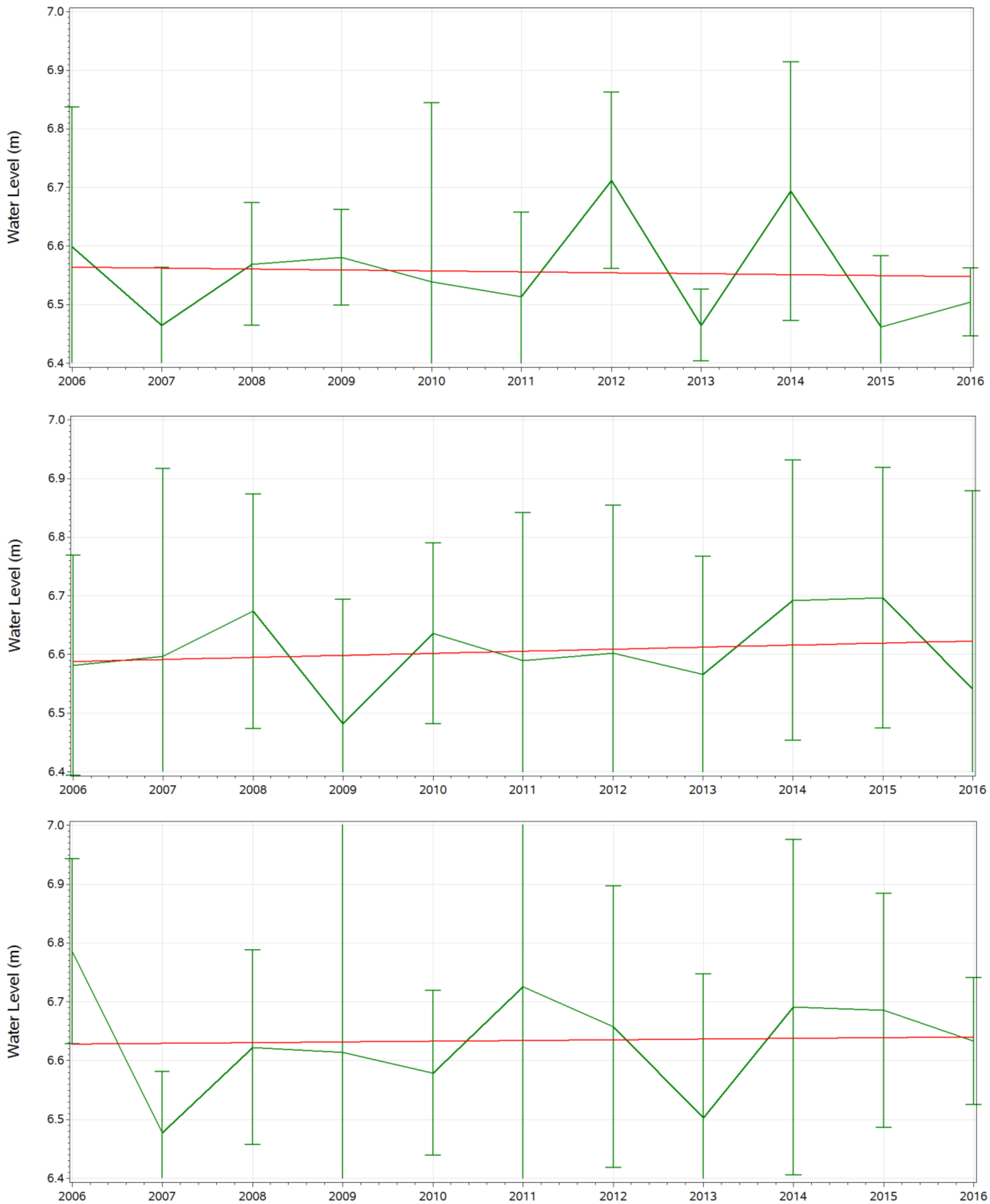
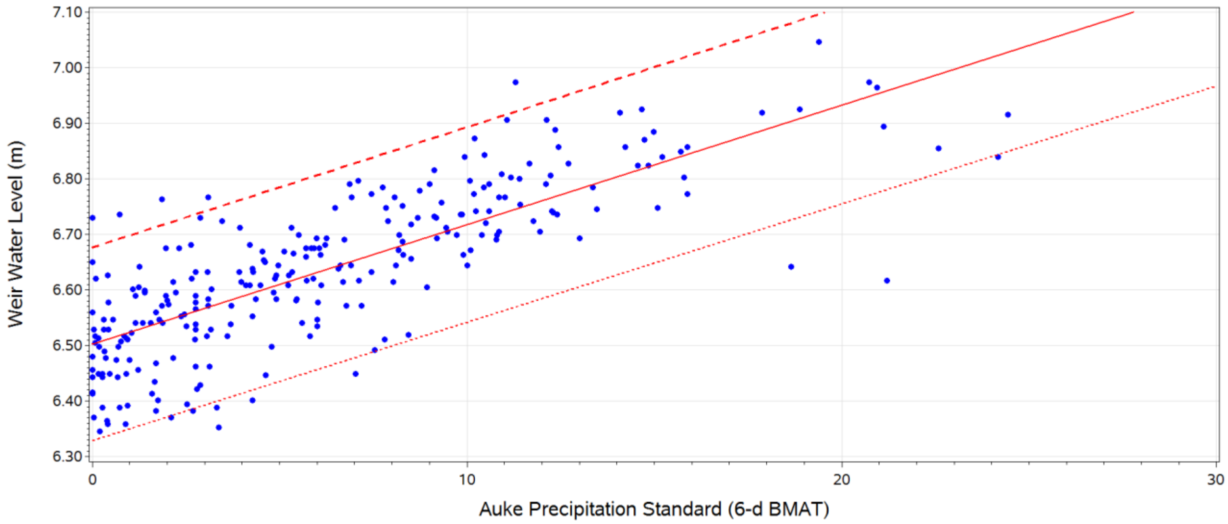


Figure 11. Observed AUKE CREEK (WEIR) mean water level ± 2 std deviations, 2006-2016 by month: June (top), July (middle), August (bottom).



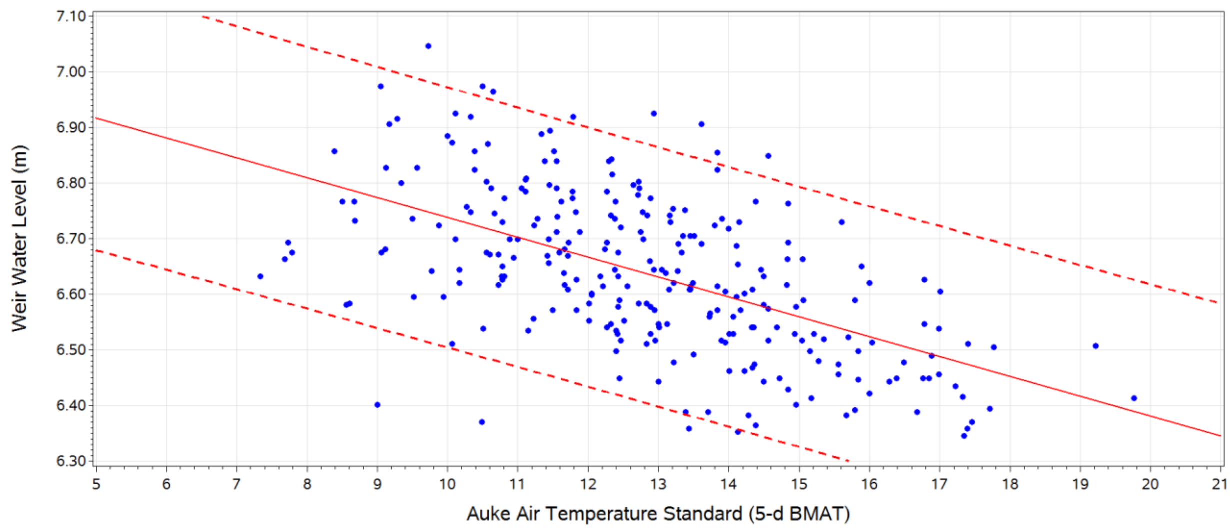


Figure 12. AUKE CREEK daily water level (m) as a function of the 6-day cumulative mean daily precipitation index (top), and the 5-day cumulative mean air temperature index (bottom), 2006-2016. See Table 6 - Table 7 for regression statistics.

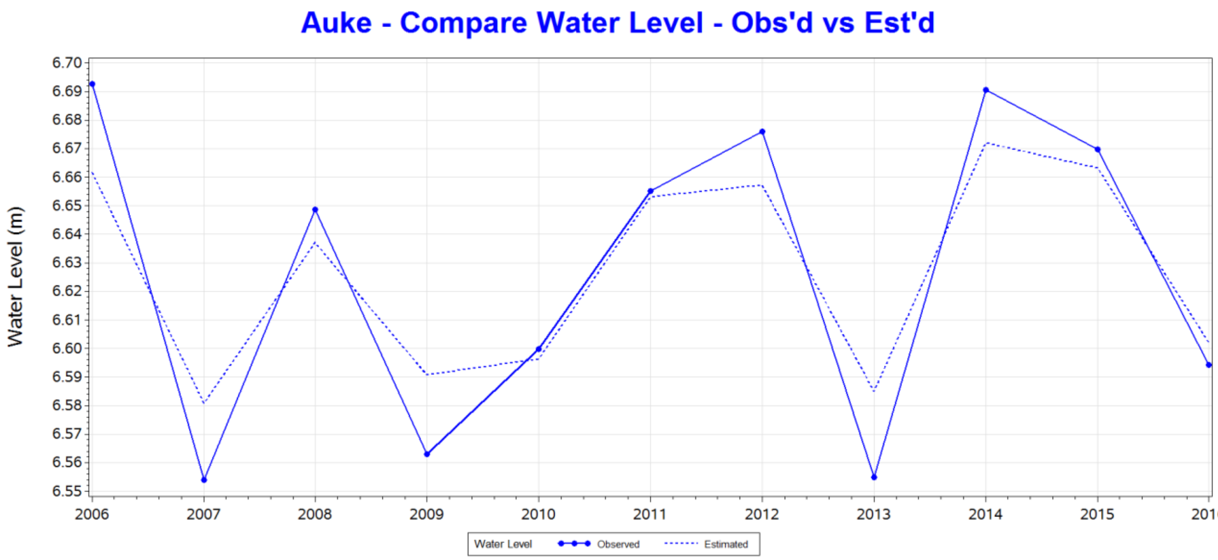


Figure 13. Comparison of AUKE CREEK mean water level (averaged Jun 19 - Sep 17), by year (observed: solid blue line; estimated “standard”: dashed blue line).

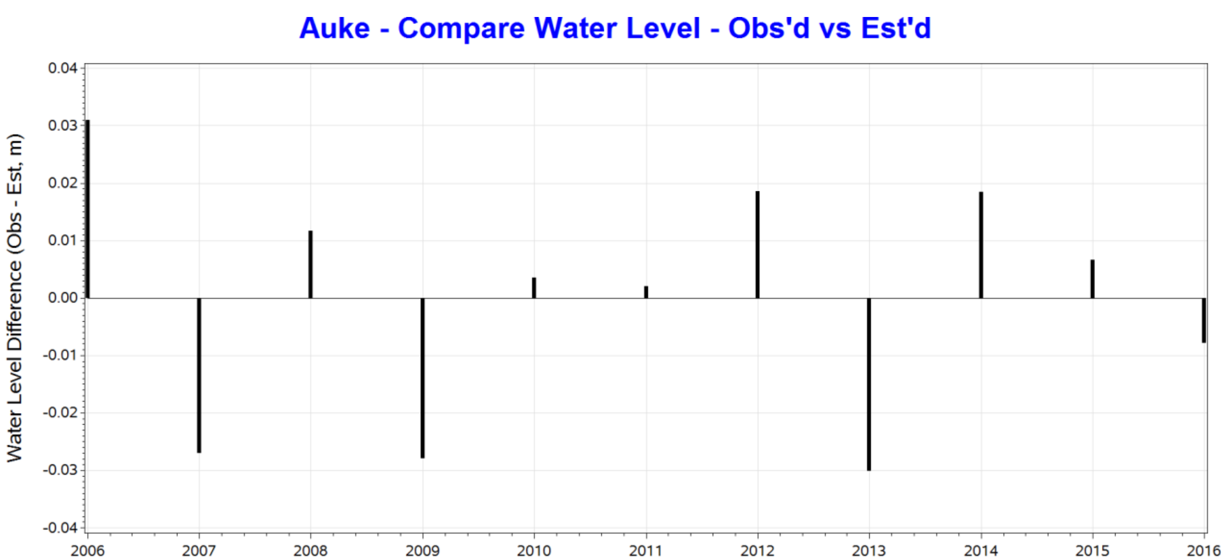


Figure 14. Observed – Estimated AUKE CREEK mean summer water level (Jun 19 - Sep 17), by year.

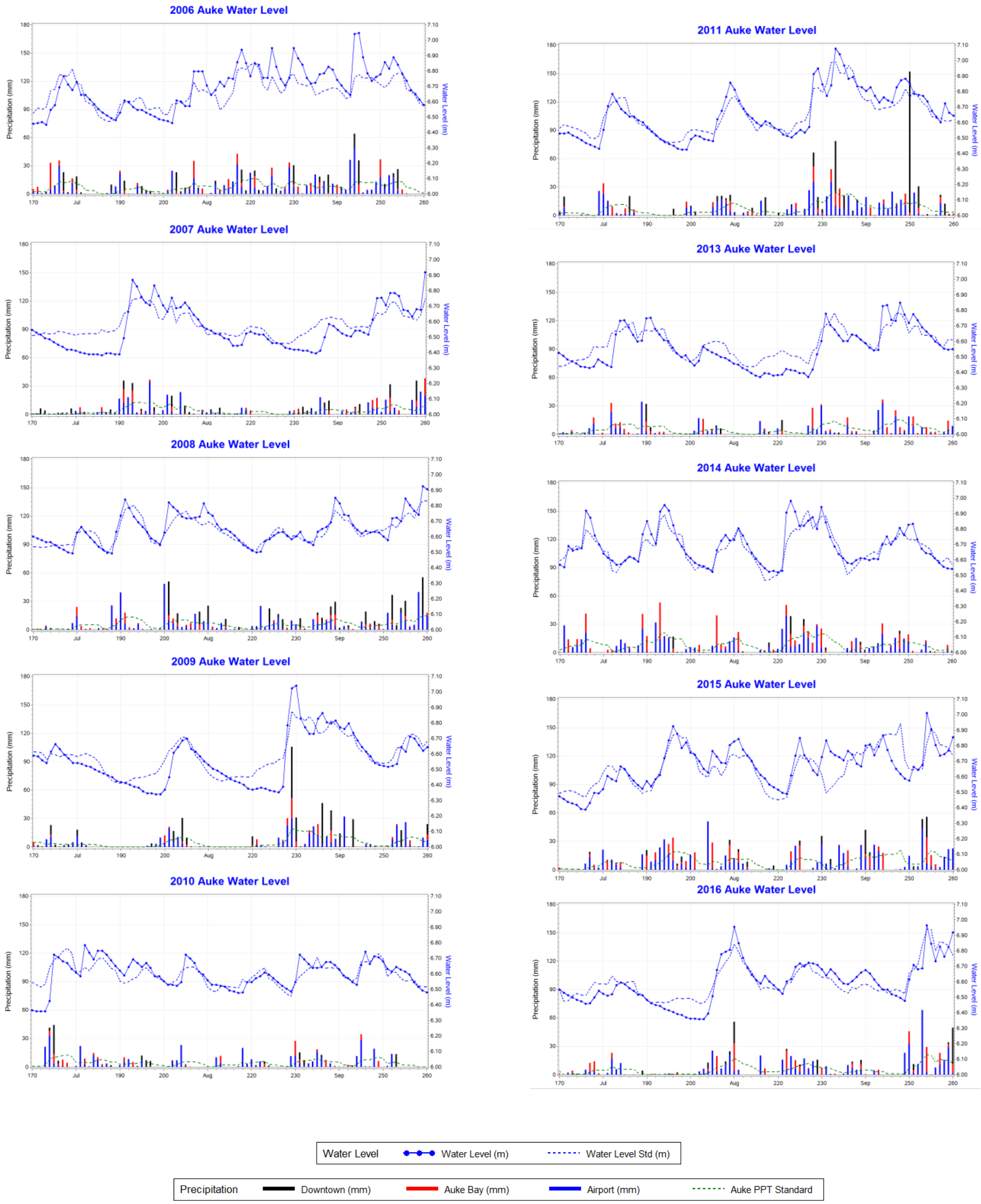


Figure 15. AUKE CREEK observed (blue line) and estimated (blue dashed line) daily water level (m) for a sub-sample of years, along with regional precipitation at AUKE BAY, JUNEAU AIRPORT and JUNEAU DOWNTOWN stations (bars) and AUKE cumulative 6-day MEAN PRECIPITATION STANDARD..

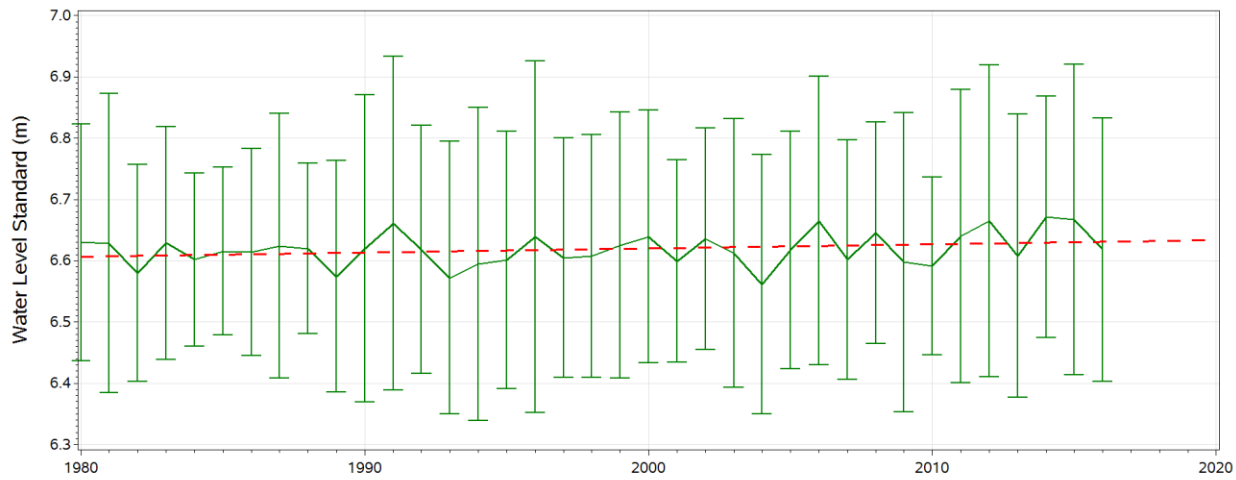


Figure 16. Trends in estimated Auke Creek summer water level ± 2 standard deviations, Jun-Sep, 1980-2016 (P < 0.10).

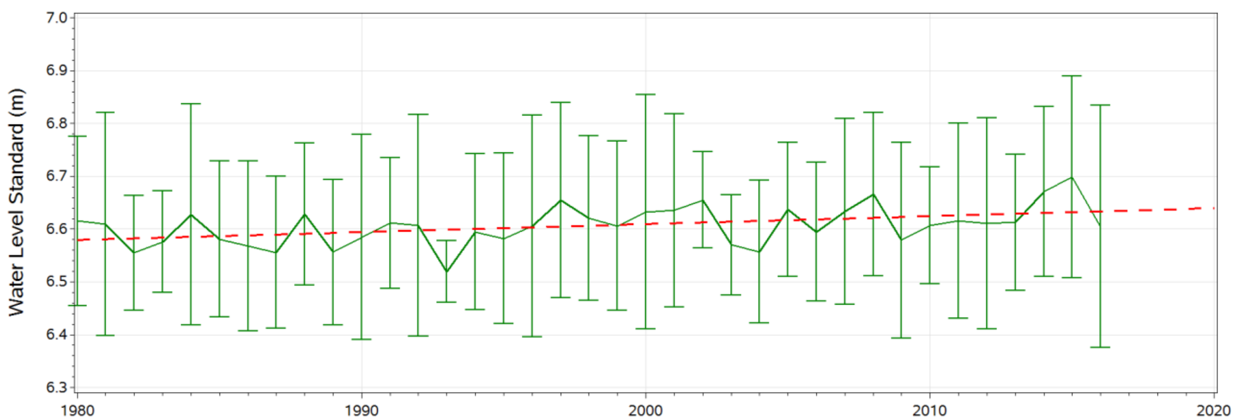
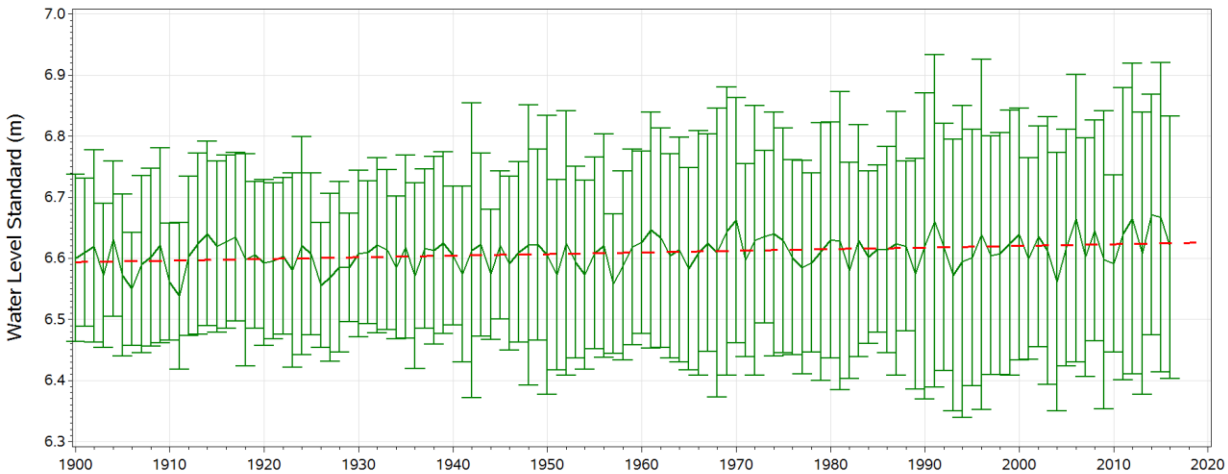


Figure 17. Trends in estimated Auke Creek JULY water level ± 2 standard deviations, 1980-2016. July water level shows positive trend (MK ≥ 2.9, P < 0.05, N = 37).



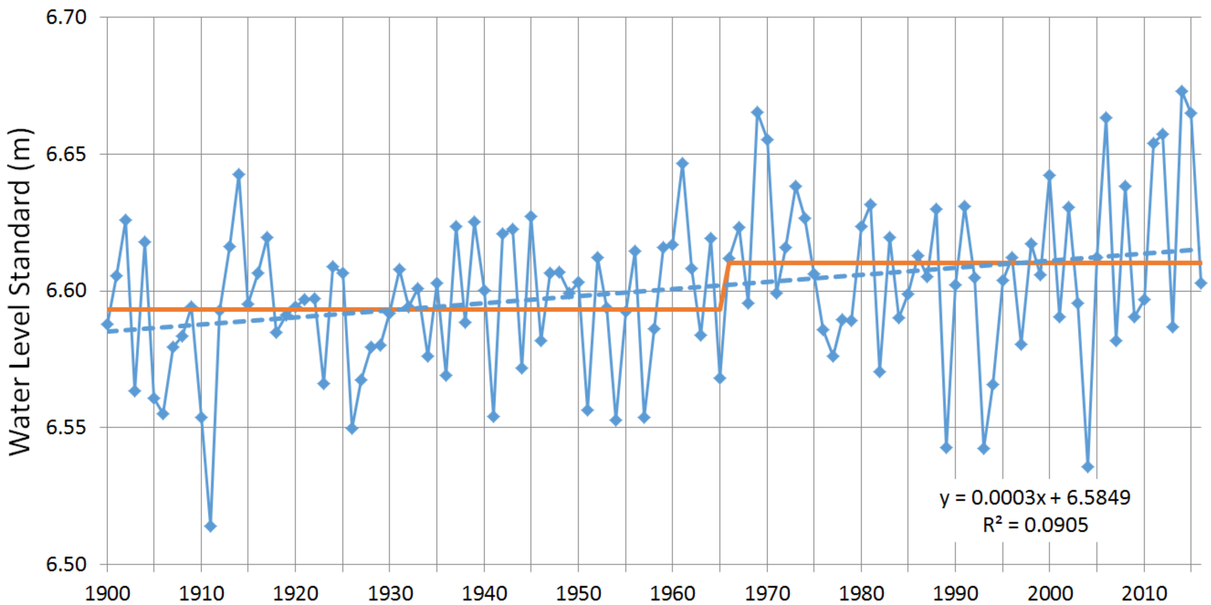


Figure 18. Trends in estimated Auke Creek summer (Jun-Sep) water level ± 2 standard deviations, 1900-2016 (top, P < 0.01), and regime shifts in the June-September water level mean (bottom).

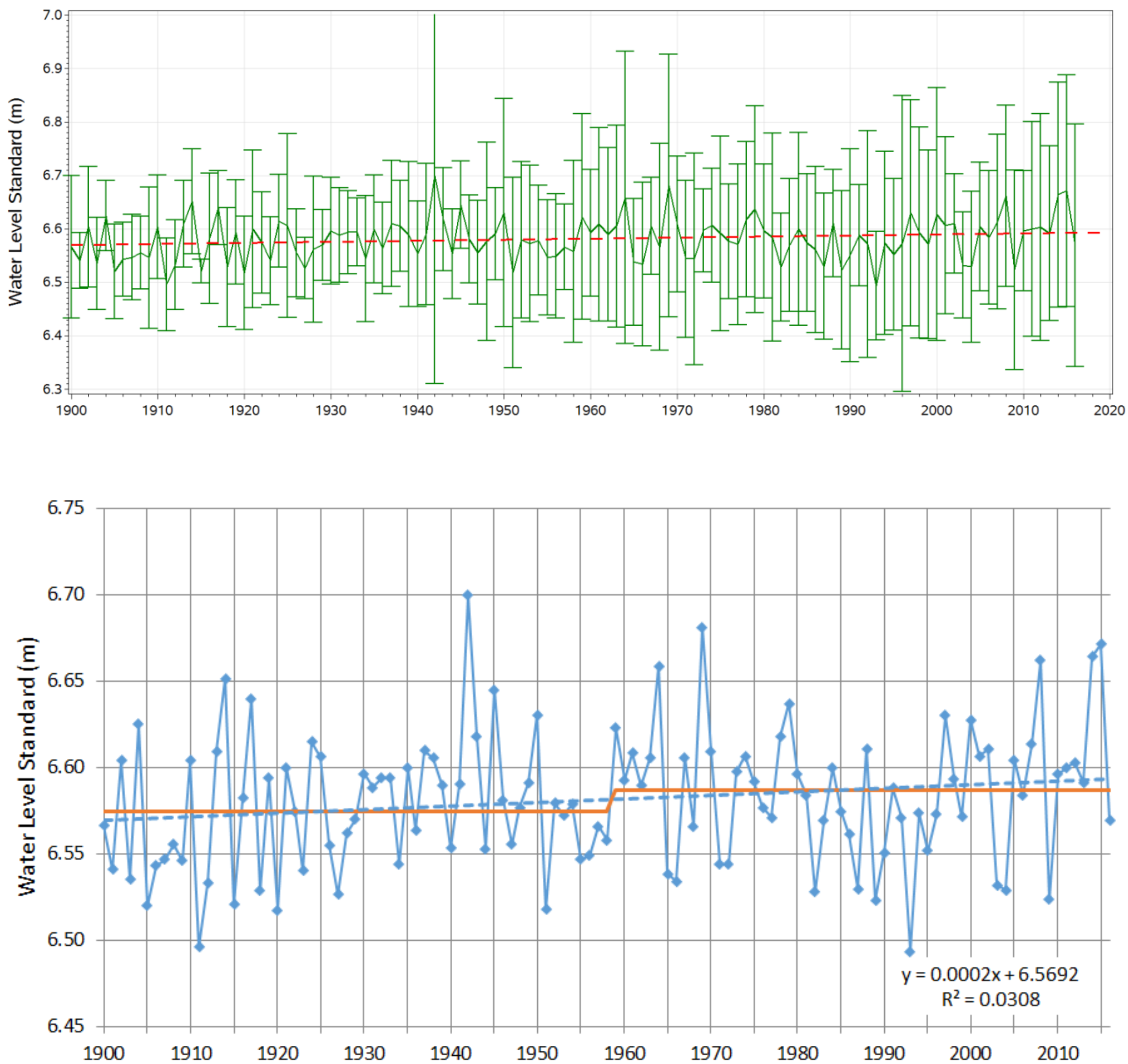


Figure 19. Trends in estimated Auke Creek JULY water level ± 2 standard deviations, 1900-2016 (top), and regime shifts in JULY water level mean (bottom). Water level shows positive trend since 1900 (MK = 1.8, P < 0.1, N = 117).

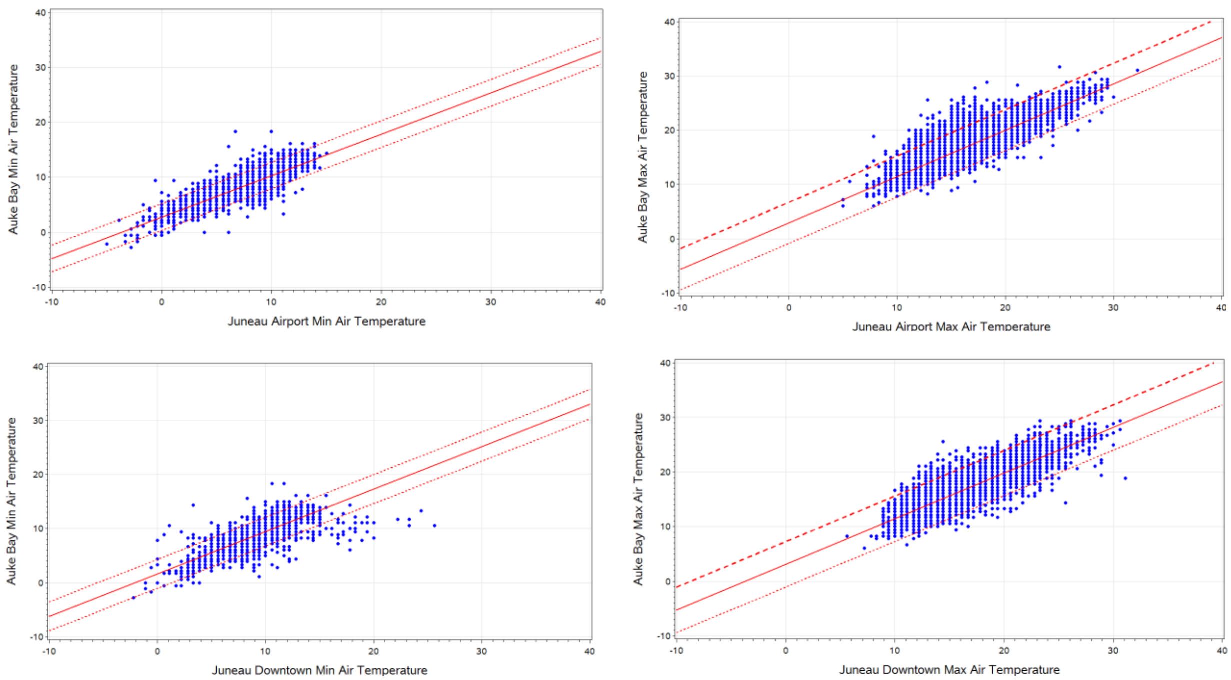


Figure 20. Observed Auke Bay daily minimum (left) and maximum (right) air temperature variates as a function of Juneau Airport (top) and Juneau Downtown (bottom) station air temperature. Regression statistics by air temperature variate and station location below.

Location	X-Variate	N	A-Coeff	B-Coeff	Adj. r^2
Juneau Airport	Min Air Temp	6,519	2.76	0.755	0.72
Juneau Airport	Max Air Temp	6,484	2.95	0.854	0.77
Juneau Downtown	Min Air Temp	4,762	1.62	0.785	0.66
Juneau Downtown	Max Air Temp	4.726	3.10	0.835	0.72

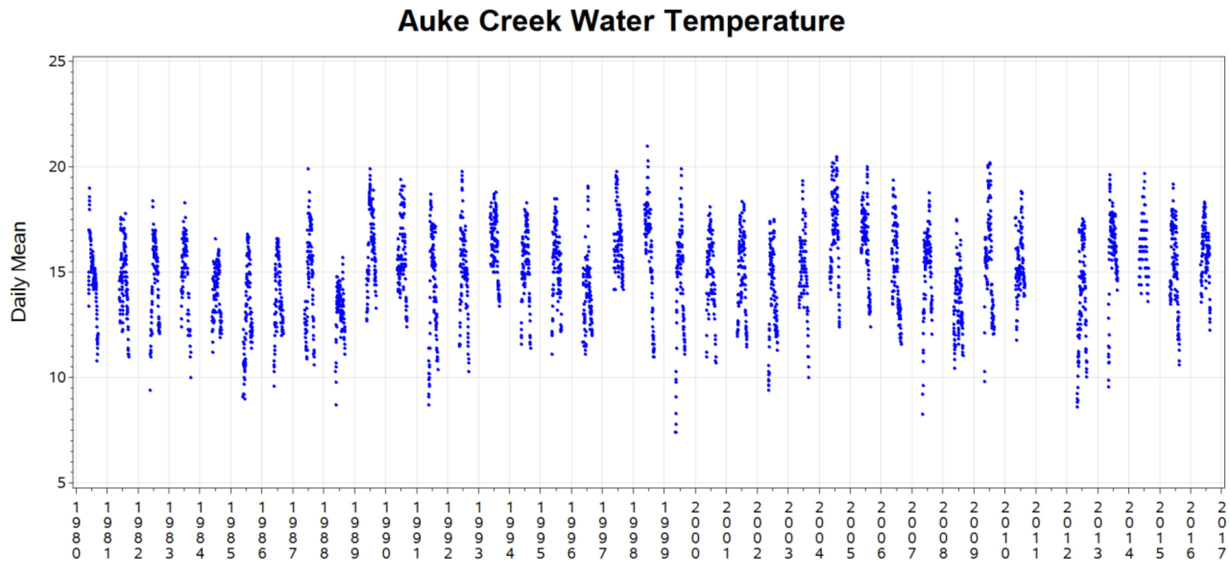


Figure 21. Auke Creek daily water temperature observations, mid-June to mid-September, 1980-2016. Source: NOAA.

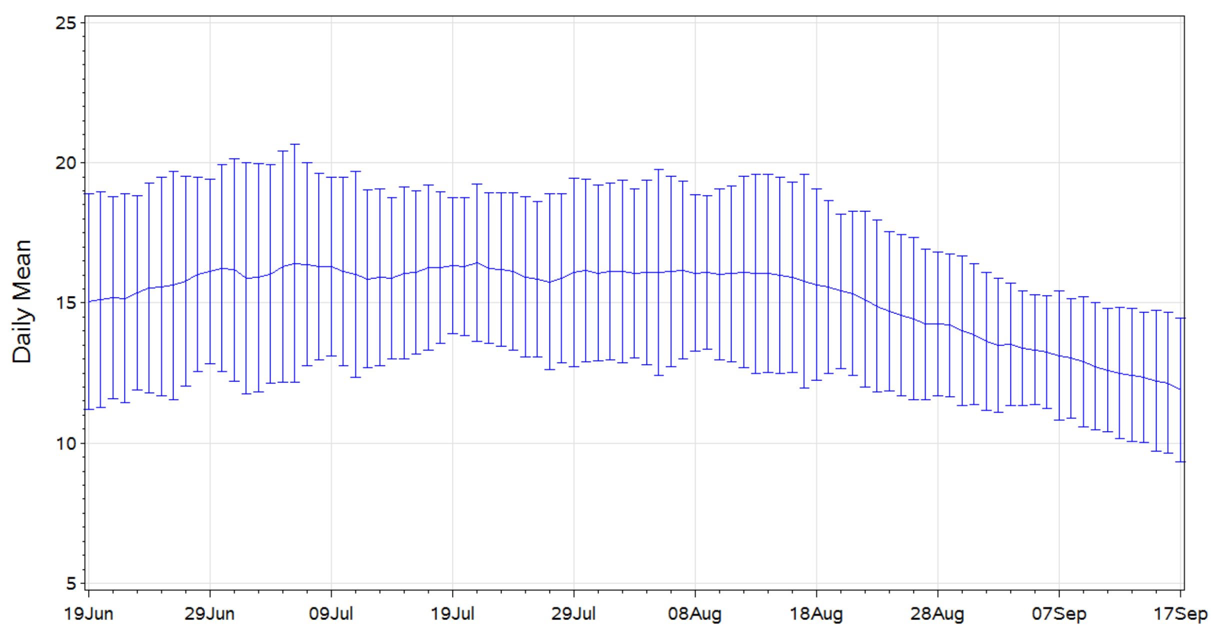


Figure 22. Summer thermograph of mean daily water temperature ± two standard deviations for Auke Creek daily water temperature, 1980-2016.

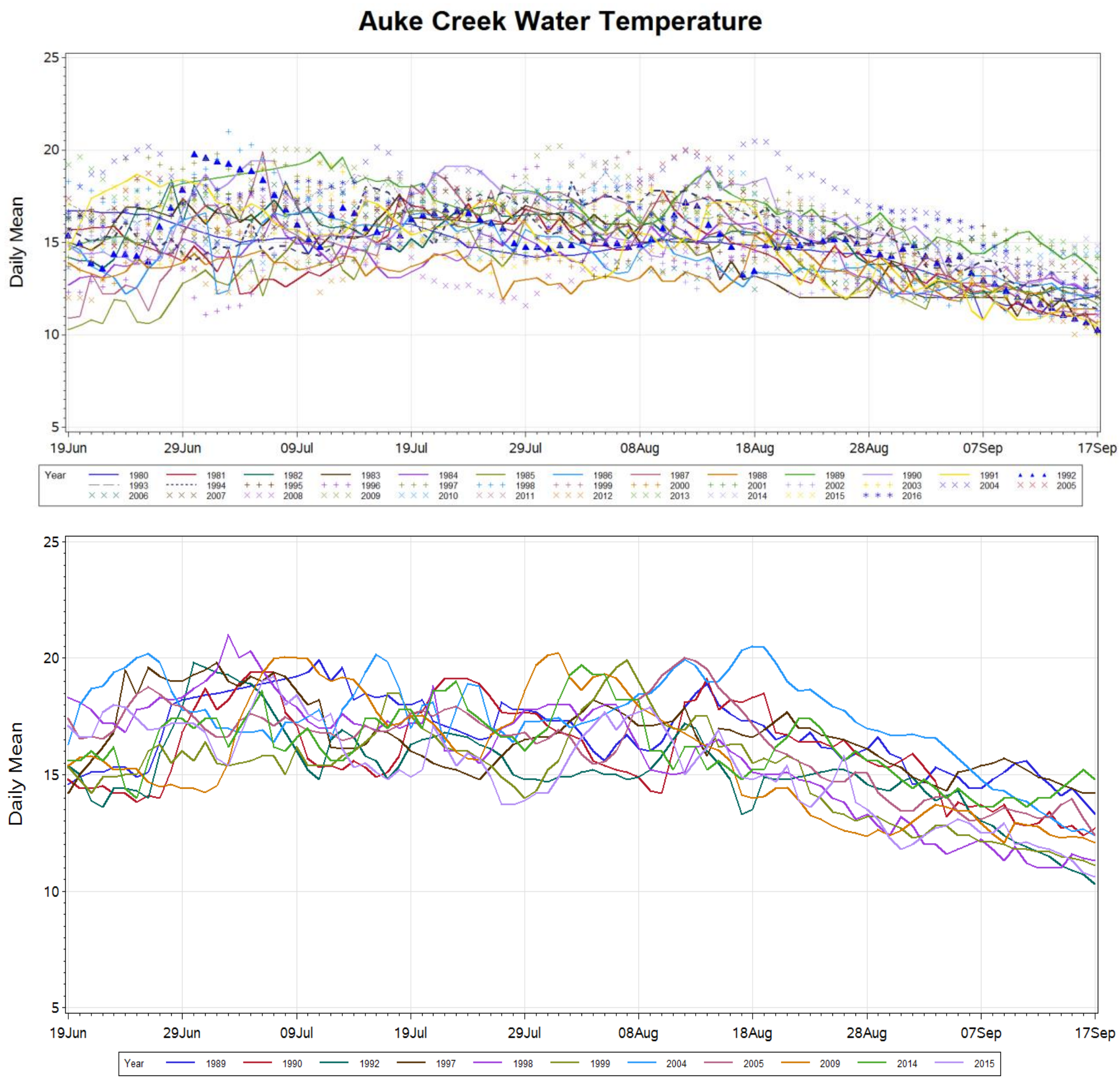


Figure 23. Auke Creek daily water temperature observations, mid-June to mid-September, 1980-2016 (top), and “top 10” warm years (bottom). Source: NOAA.

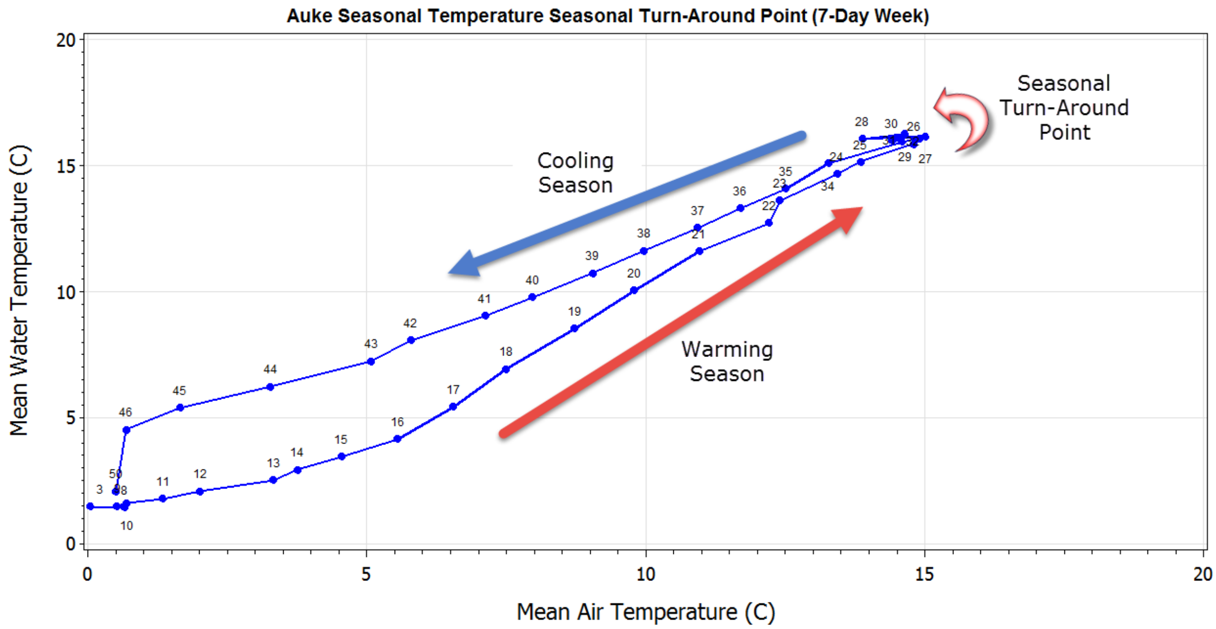


Figure 24. Derivation of seasonal turn-around point for lower AUKE CREEK, based on maximum weekly mean air and water temperature data (1980-2015). The seasonal turn-around point ranged from week 27-33; the median turn-around point was week 30 (day 210), approximately July 29th. The “warming season” therefore extends from April 1st to July 29th, followed by the “cooling season” from day 211-329, i.e. July 30th to November 25th.

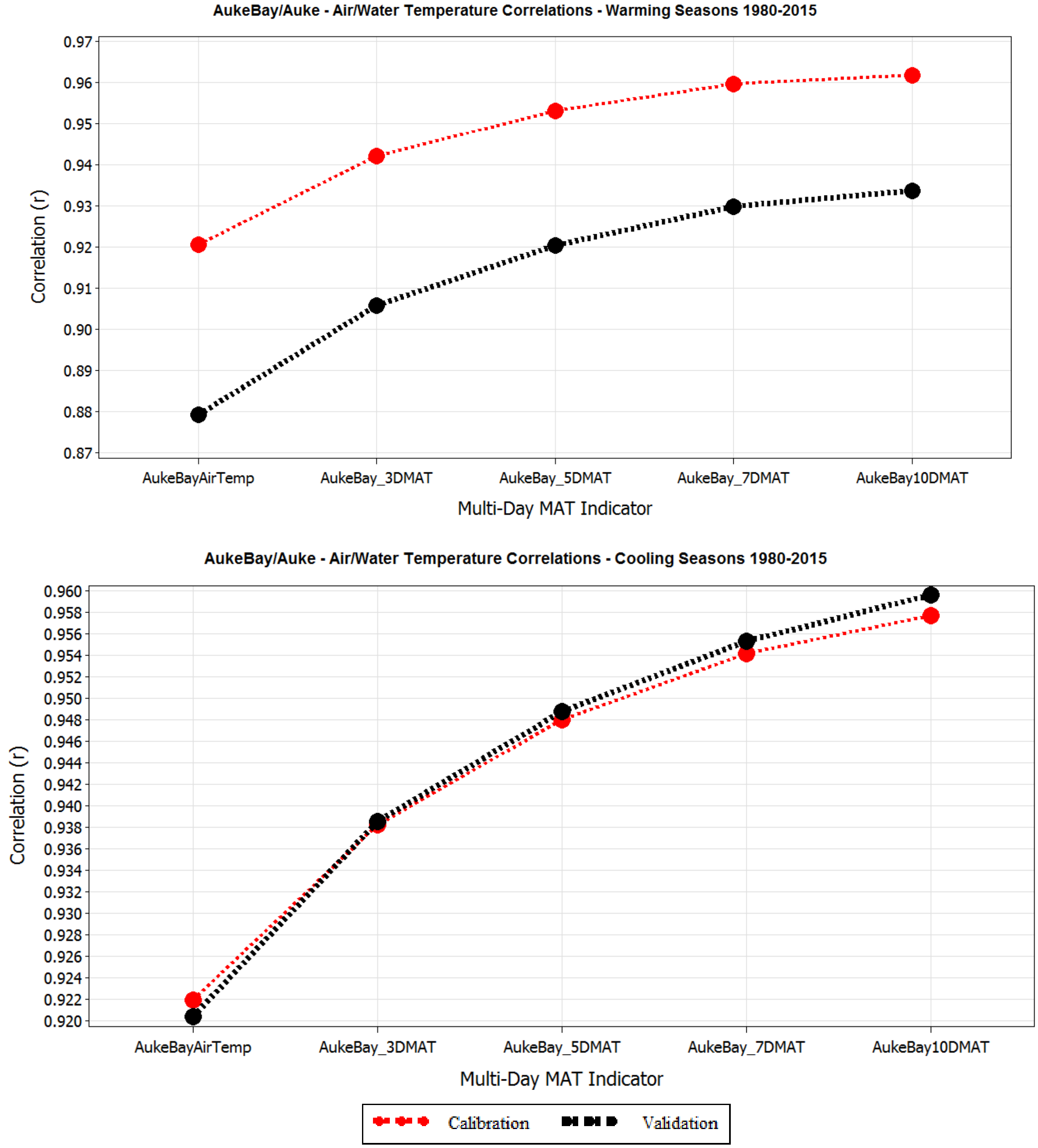
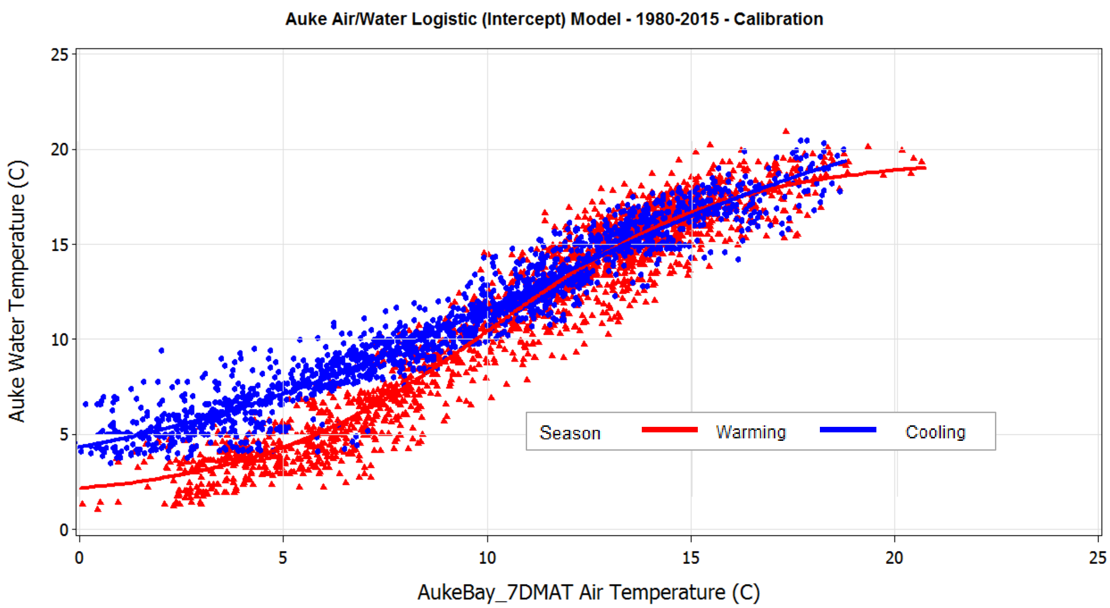


Figure 25. Derivation of optimum regional air temperature index for air/water temperature analyses, based on maximum all-year correlation between various AUKE BAY STANDARD multi-day mean air temperature indicators (MATs) with AUKE CREEK daily mean water temperature (MWT) for calibration (red) and validation (black) data, for warming season (top), cooling season (bottom). AUKE air temperature indicators include (l-r): AUKE BAY STANDARD AIRTEMP (same day mean); AUKE BAY STANDARD 3-day centered moving average air temperature (3d-MAT), 5d-MAT, 7d-MAT, and 10d-MAT.



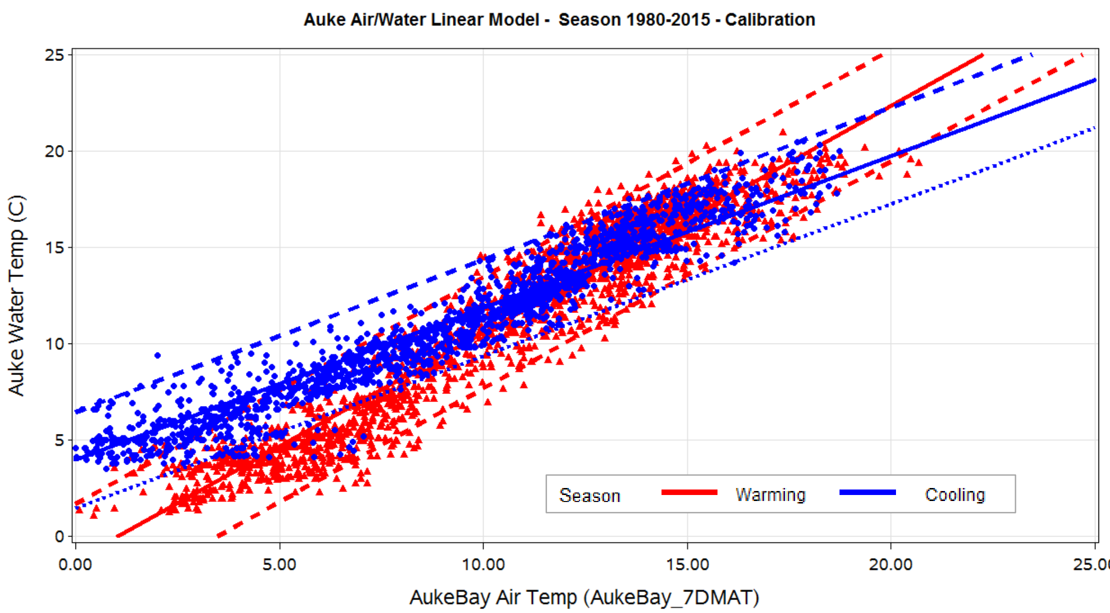


Figure 27. Linear regression fits for air/water temperature relationship for lower AUKE CREEK daily mean water temperature as a function of the AUKE 7d-MAT for calibration data years (see Table 12), by season (warming: red; cooling: blue).

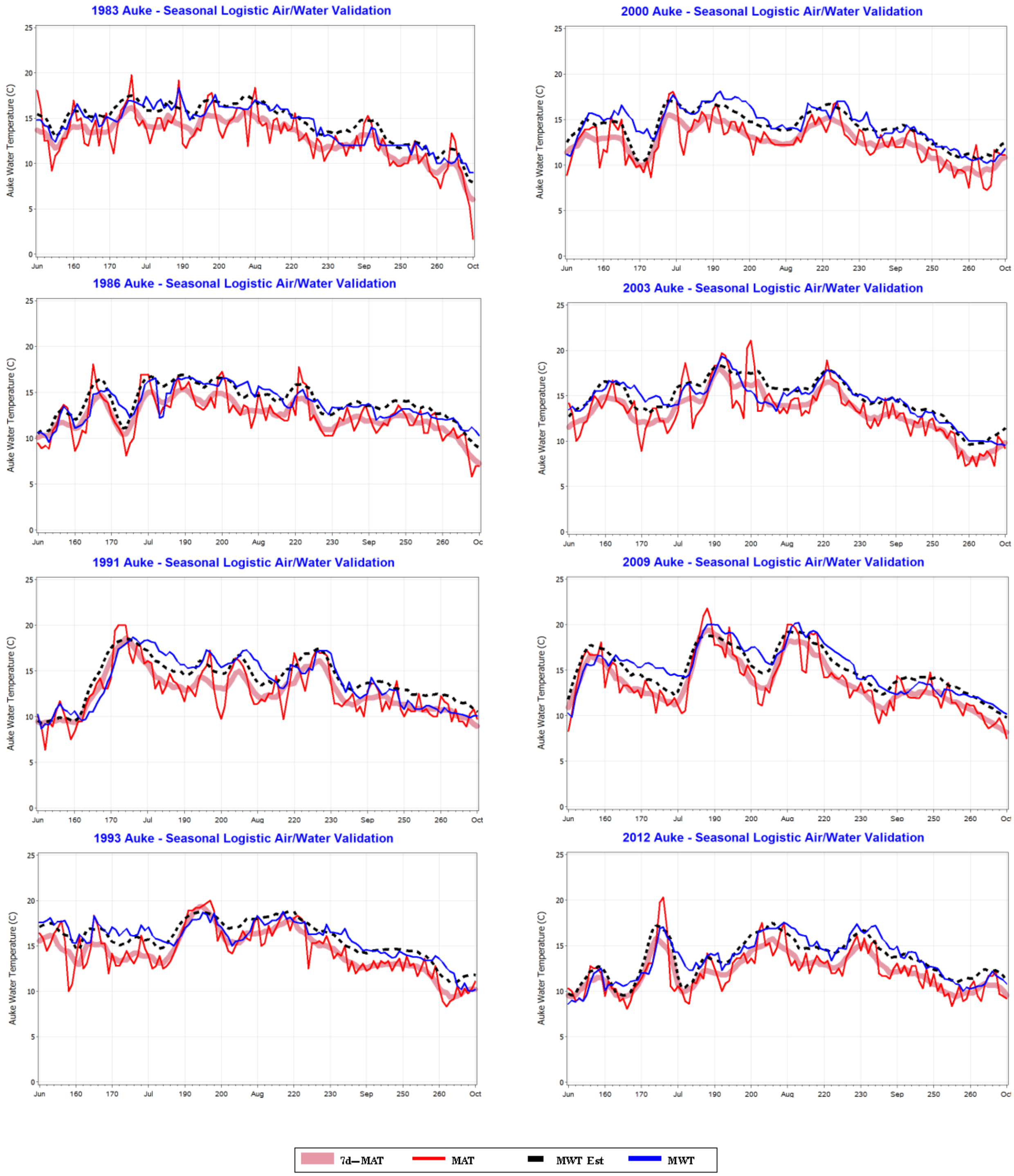


Figure 28. Validation plots of logistically-estimated daily mean water temperature (MWT; black dashed line) daily mean air temperature (red line), 7-day MAT index (broad pink line), and observed daily mean water temperature (blue solid line) for Auke Creek.

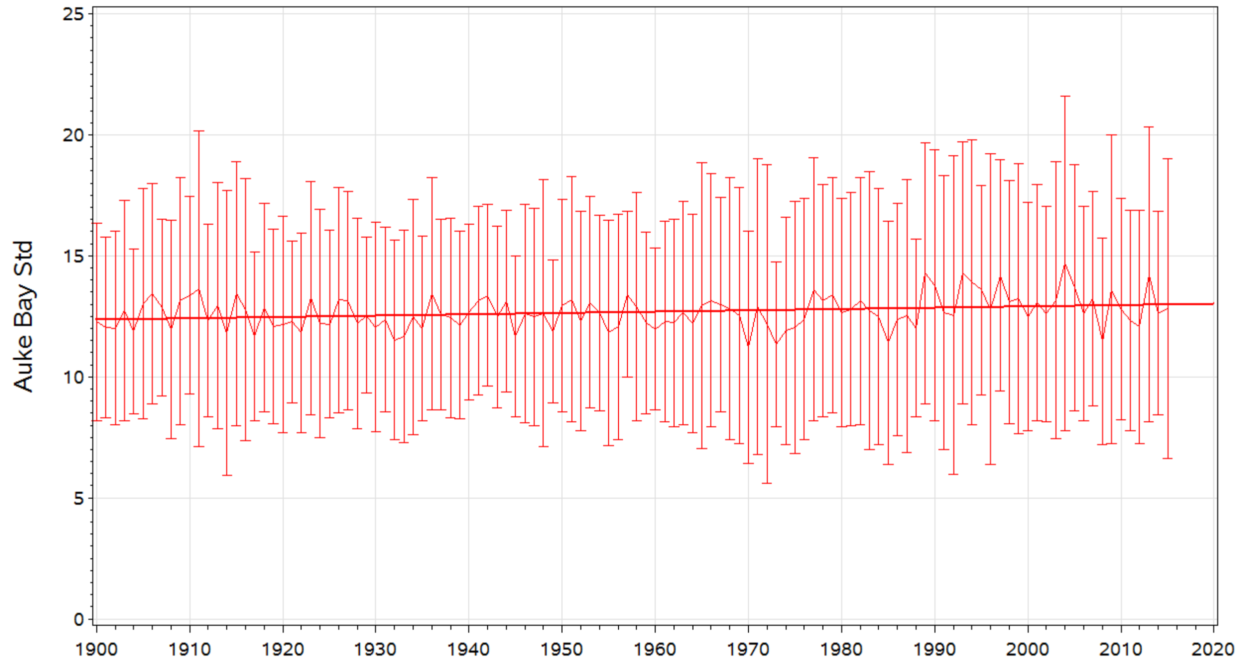


Figure 29. Estimated Auke Bay meteorological station mean June-August air temperature ± 2 std deviations, 1900-2015. Long-term warming trend is evident (Y = 2.3 + 0.0053 * Year; r = 0.07; Mann-Kendall Z = 5.0; P < 0.01).

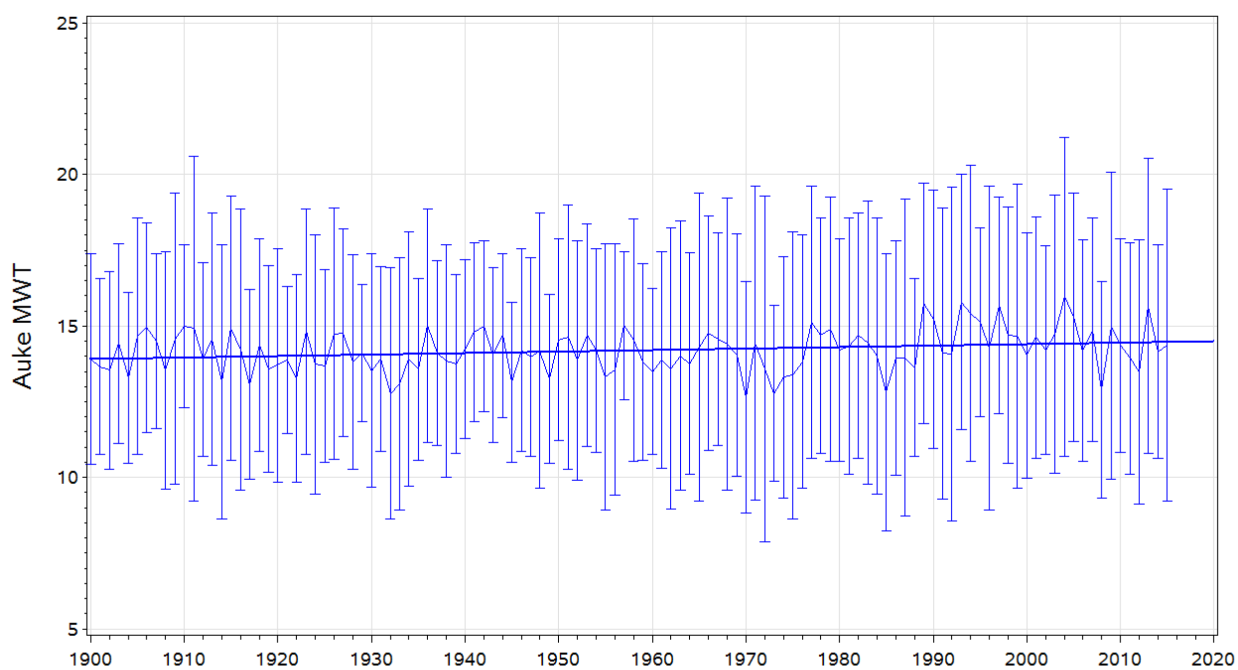


Figure 30. Estimated mean AUKE CREEK June-August water temperature ± 2 std deviations, 1900-2015, based on seasonal logistic air/water temperature regression models (Y = 4.4 + 0.0050 * Year; r = 0.02; Kendall Tau(b): 0.060; P < 0.001).

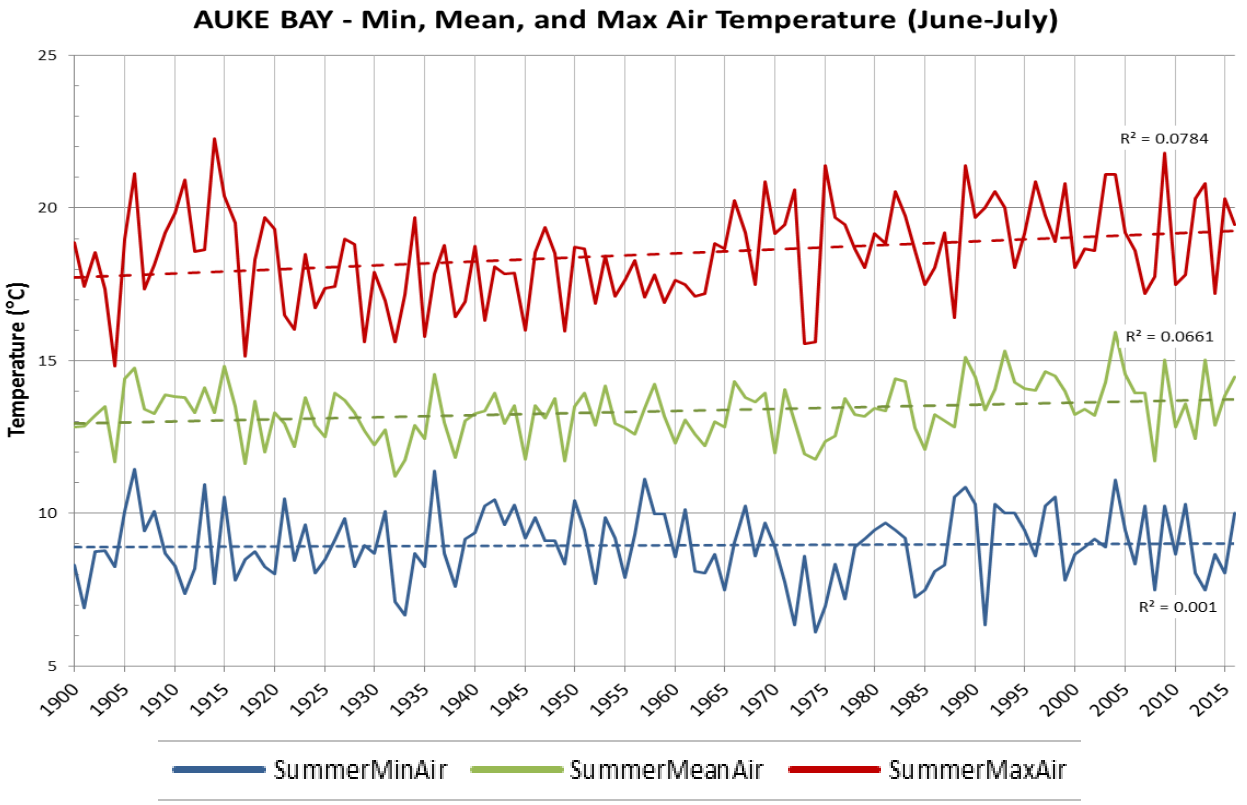


Figure 31. Observed and estimated AUKE BAY meteorological station mean June-July (peak migration) air temperature, 1900-2015. Long-term warming trend is evident in mean (MK = 2.6, $P < 0.05$) and maximum air temperatures (MK = 3.0, $P < 0.01$).

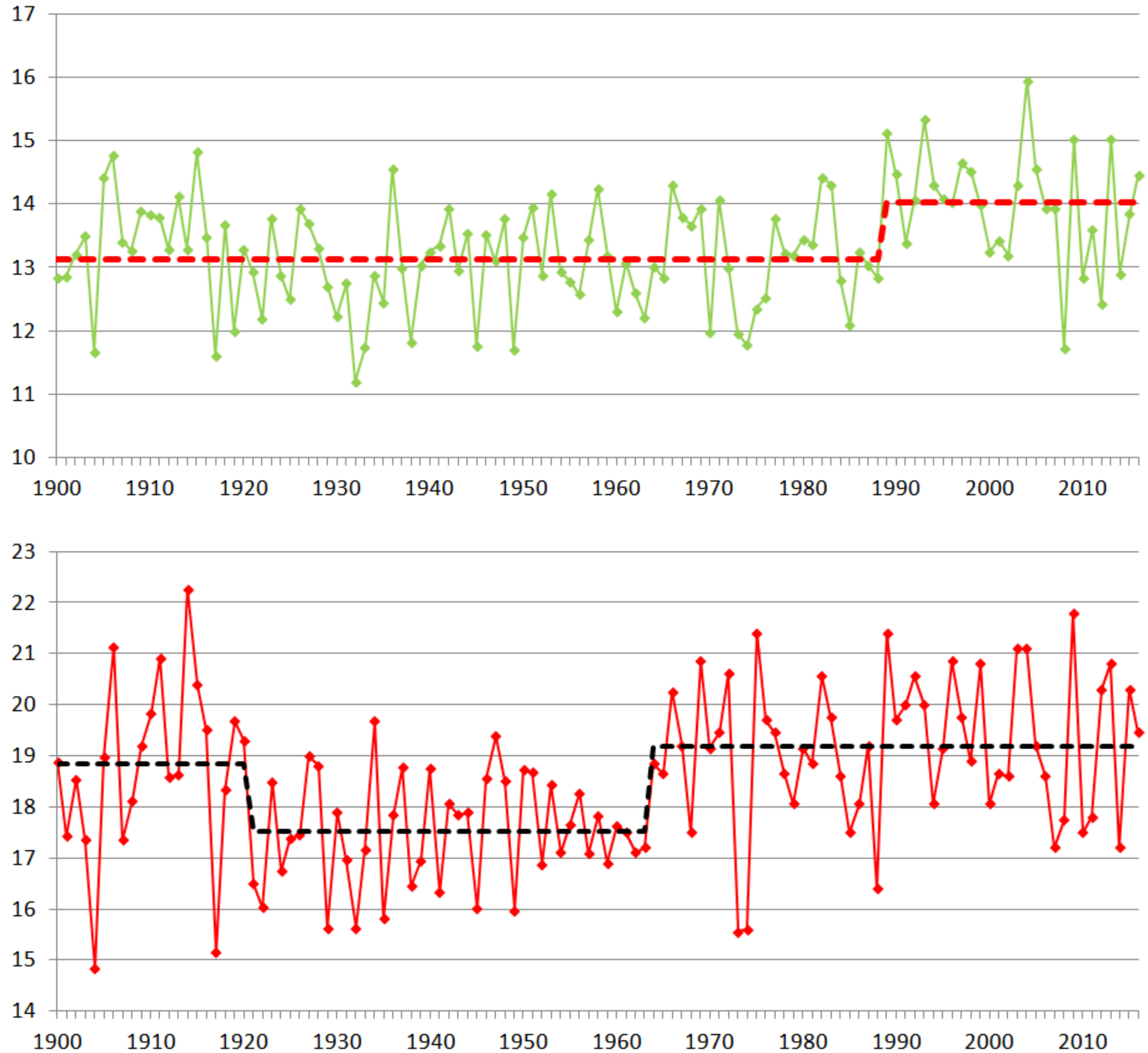


Figure 32. Estimated AUKE BAY meteorological station mean June-July air temperature, 1900-2015. Sequential t-test analysis indicated regime shifts in mean air temperature (top) in 1989 ($P < 0.01$), and max air temperature (bottom) in 1920 and 1964 ($P < 0.01$).

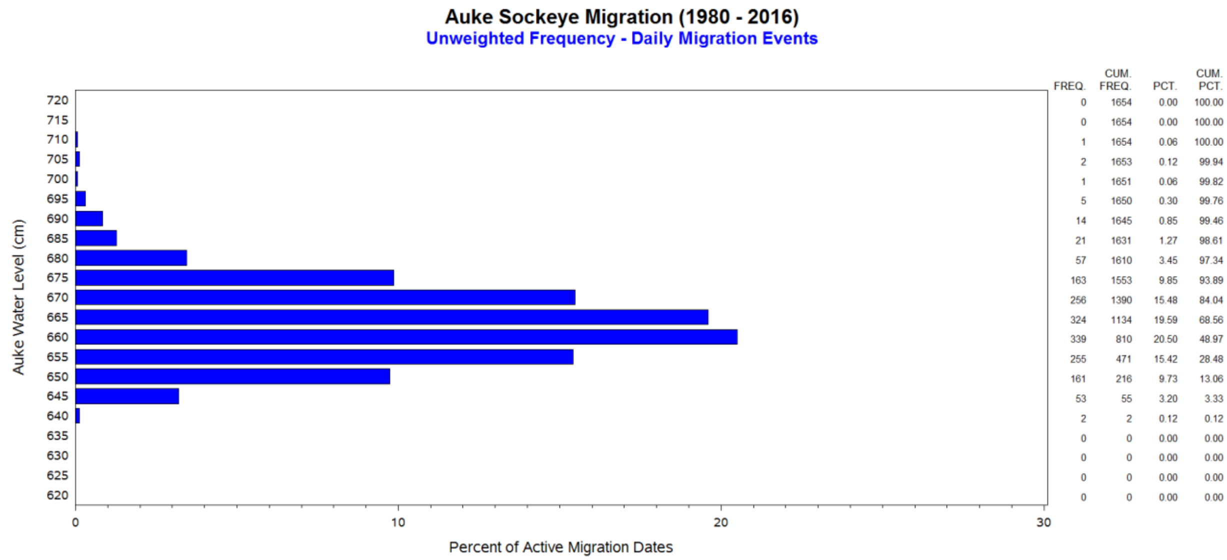


Figure 33. Frequency plot of historical Sockeye migration (un-weighted tally of non-zero migration dates), at varying levels of estimated Auke Creek stage height (1980 - 2016). Most migration activity (90% of migration dates) occurred at Auke Creek water level midpoints of 6.50 - 6.75 m (i.e. P50 - P90 of estimated water levels).

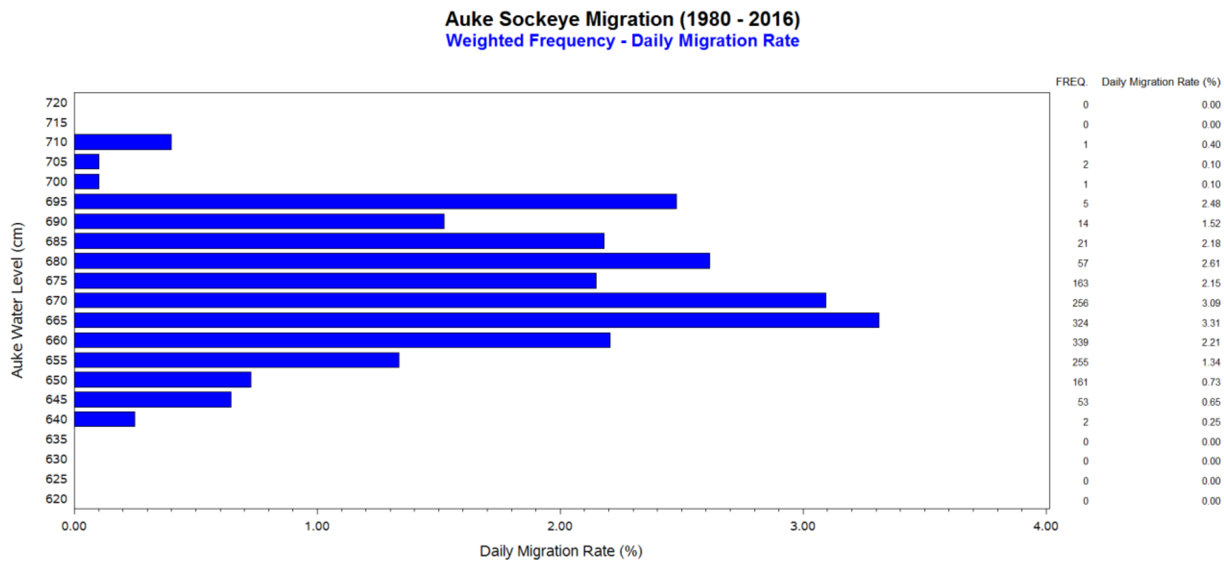


Figure 34. Frequency plot of historical non-zero Sockeye migration dates, weighted by daily migration rate, at varying levels of estimated Auke Creek stage height (1980 - 2016). Moderate daily migration rates (> P50 = 0.4%) occurred across a wide range of water levels (6.5 - 6.9 m), with highest migration rates (> P75 = 1.6%) at 6.6 - 6.8 m. Water levels below 6.6 m or exceeding 7.0 m were not associated with high migration rates.

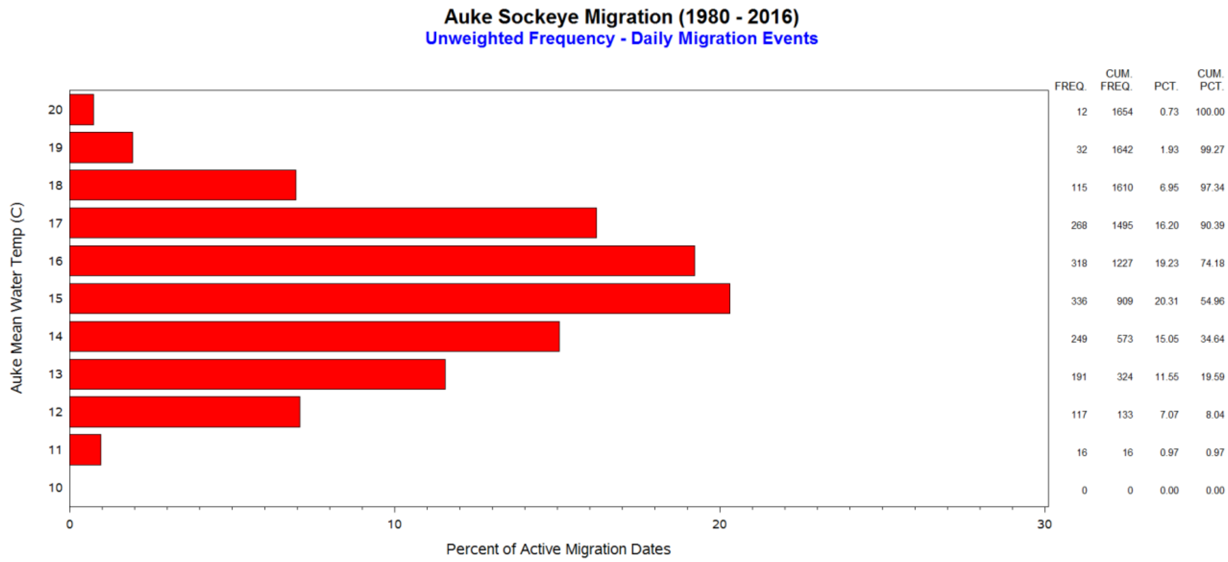


Figure 35. Frequency plot of historical Sockeye migration (un-weighted tally of non-zero migration dates), at varying levels of Auke Creek water temperature (1980 - 2016). ~80% of migration activity occurred at daily mean temperatures of 13 - 17°C.

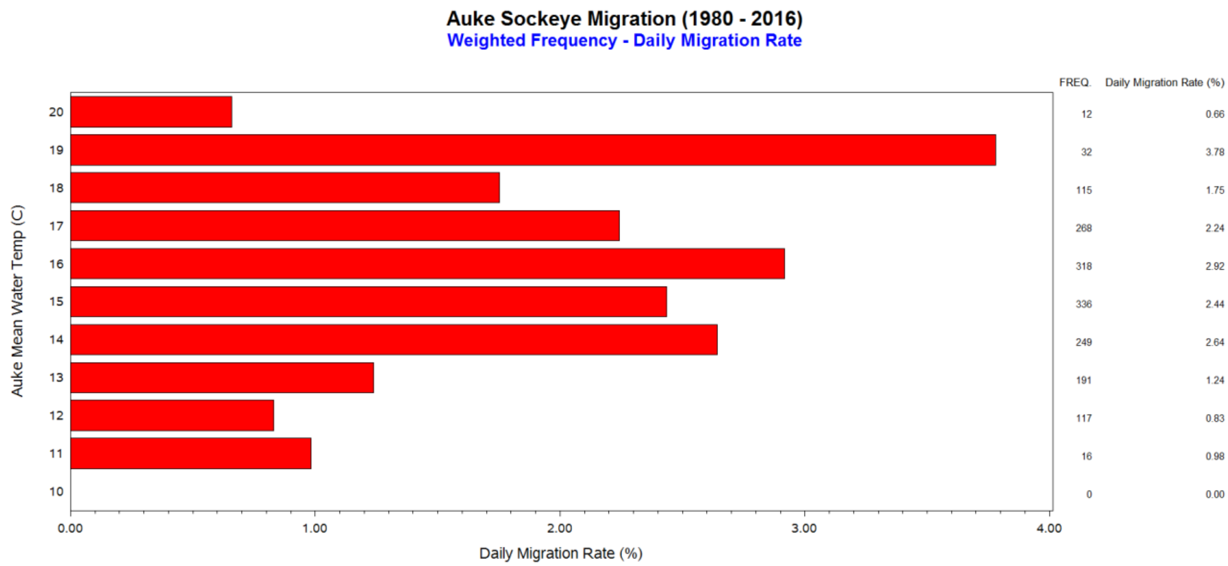


Figure 36. Frequency plot of historical non-zero Sockeye migration dates, weighted by daily migration rate, at varying levels of Auke Creek water temperature (1980 - 2016). Highest mean daily migration rates (> P75 = 2% per day) were associated with daily mean water temperatures of 14 - 17°C, with occasional high migration rates also occurring at 19°C.

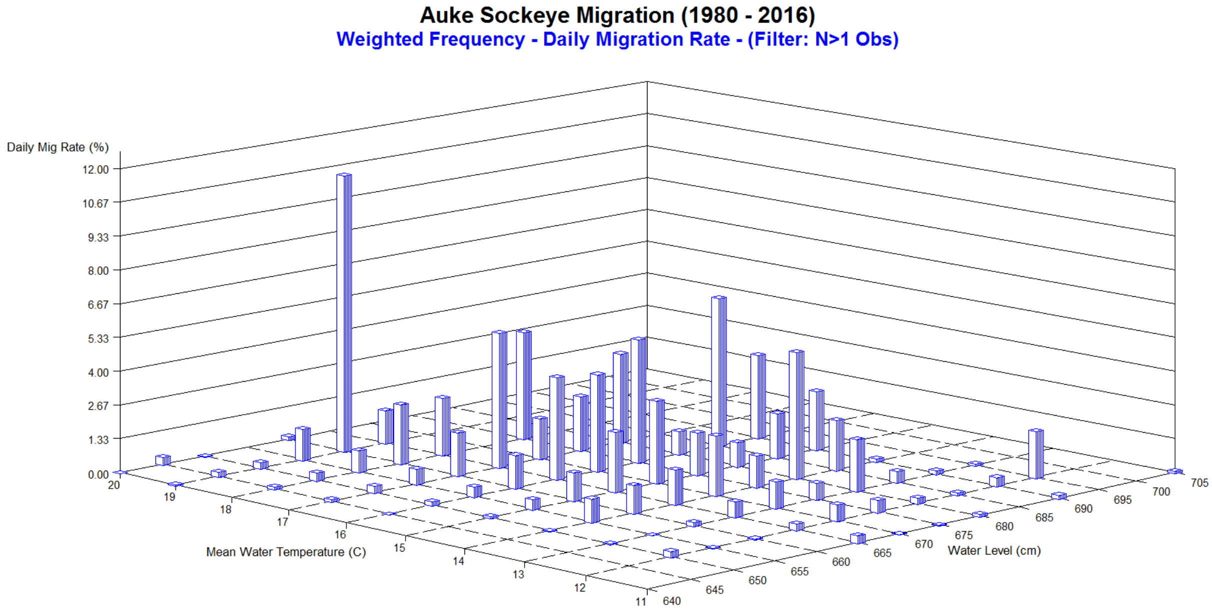


Figure 37. Weighted bi-variate frequency distribution of historical Sockeye daily migration rates at varying levels of Auke Creek water temperature and estimated water level. Moderate-to-high migration rates (>2% per day) were found at a wide range of discharge and temperature levels, with maxima at the convergence of 14 - 17°C at higher water levels (>6.6 - 6.9 m) and at 19°C at 6.6 m.

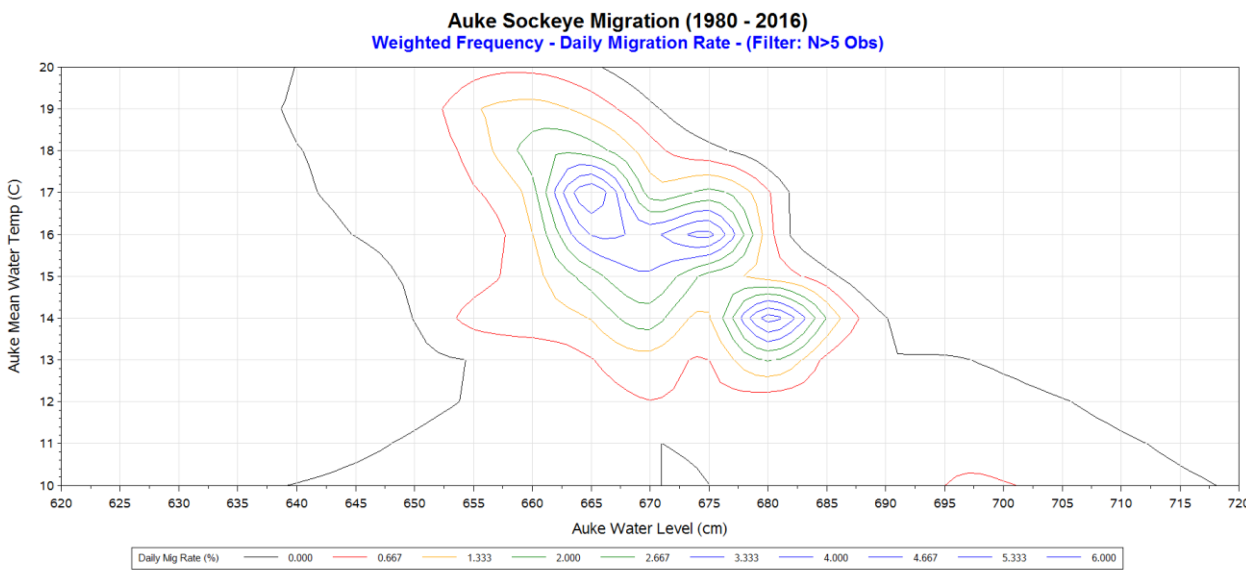


Figure 38. Smoothed contour plot of historical Sockeye daily migration rates at varying levels of Auke Creek water temperature and estimated water level, filtered to remove low-frequency events (N<5). Moderate-to-high migration rates (>2% per day) were found at the convergence of 14 - 17°C at water levels of 6.6 - 6.8 m.

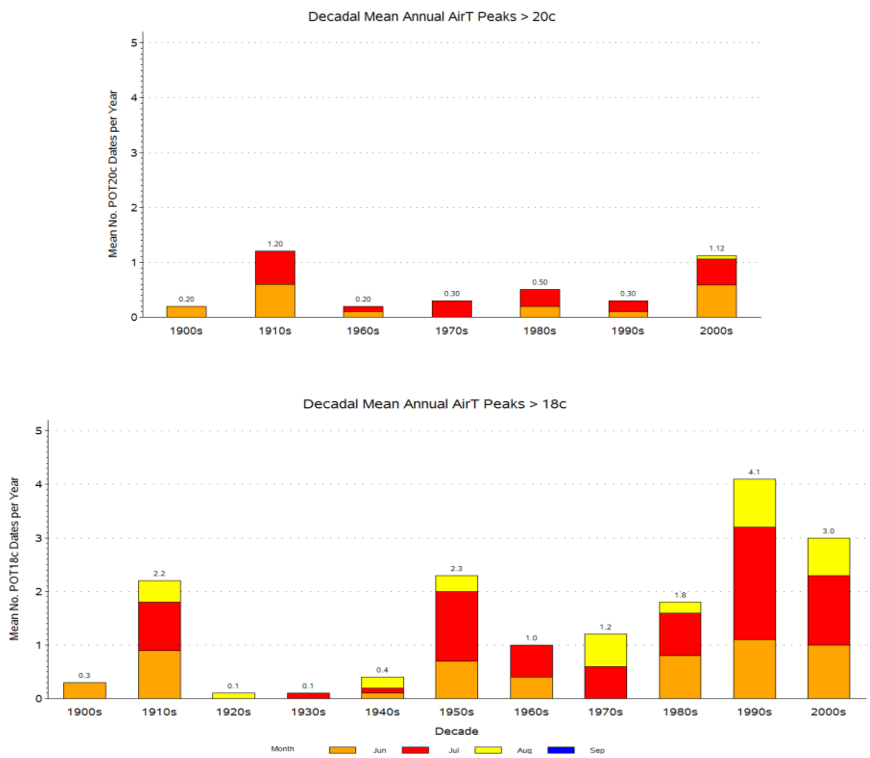


Figure 39. Frequency analysis of decadal mean number of dates per month in which estimated daily mean air temperature (at AUKE BAY station; Jun-Sep) exceeded 20°C (top) and 18°C (bottom). (Note: 2010s represents 2010-2015.)

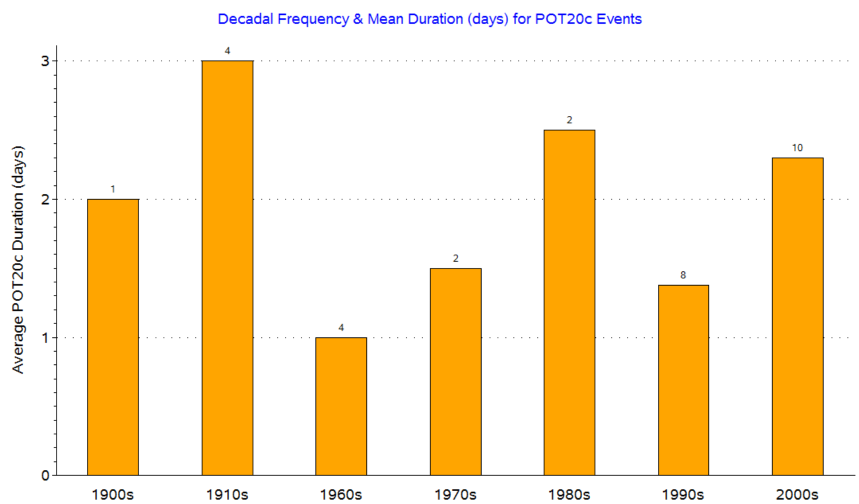


Figure 40. Mean length (days) and total decadal frequency of periods in which regional daily mean air temperature (at AUKE BAY station) exceeded 20°C during Jun-Sep. (Note: 2010s represents 2010-2015.)

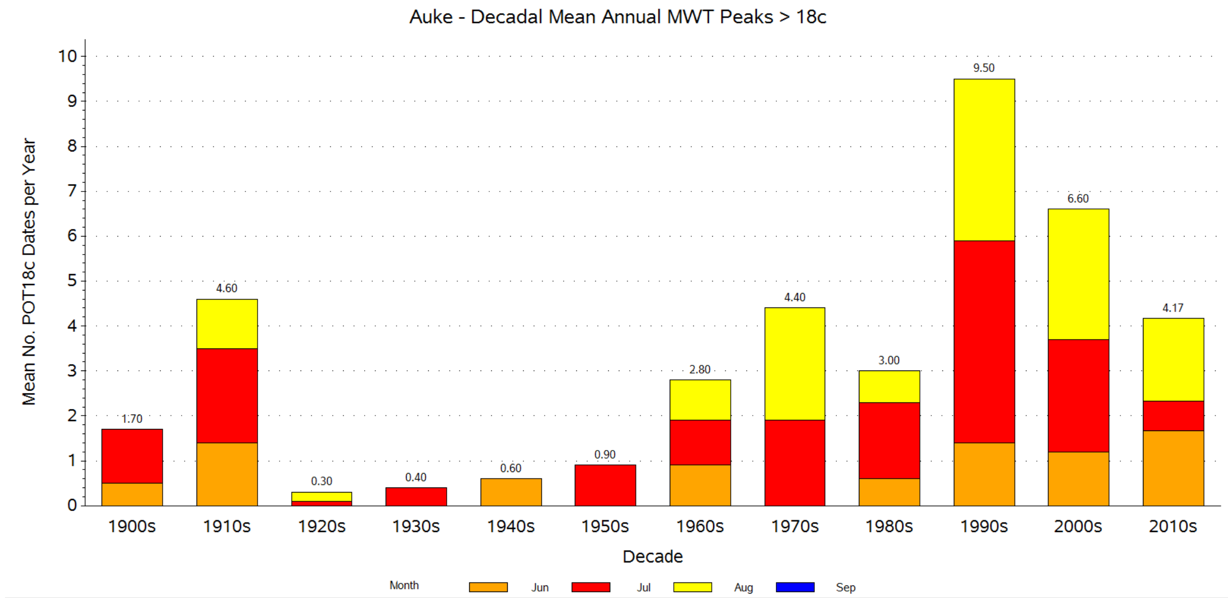


Figure 41. Frequency analysis of decadal mean number of dates per month (Jun-Sep) in which estimated mean water temperature in Auke Creek exceeded 18°C. (Note: 2010s represents 2010-2015.)

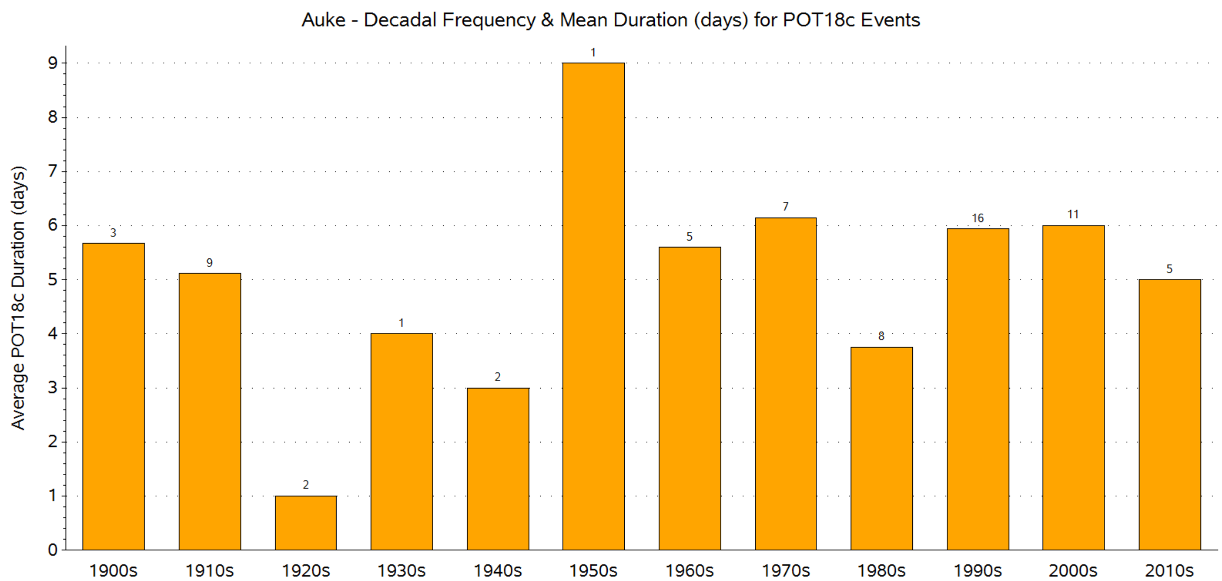


Figure 42. Mean length (days) and total decadal frequency of periods in which estimated daily mean water temperature (Jun-Sep) in Auke Creek continuously exceeded 18°C, by decade. (Note: 2010s represents 2010-2015.)

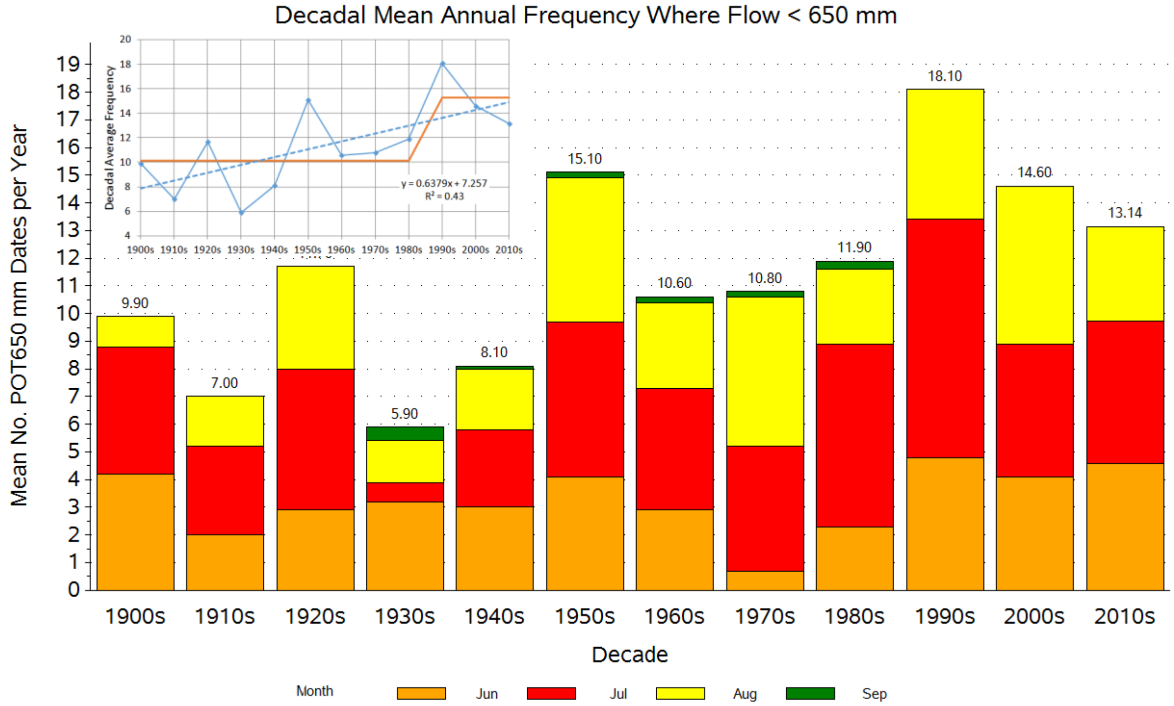


Figure 43. Frequency analysis of decadal mean number of “low flow” dates (i.e. <10th percentile of June-September flows: ~6.50 m) by month in Auke Creek (Note: 2010s represents 2010-2016). Inset: Linear trend and sequential t-test regime shift analysis.

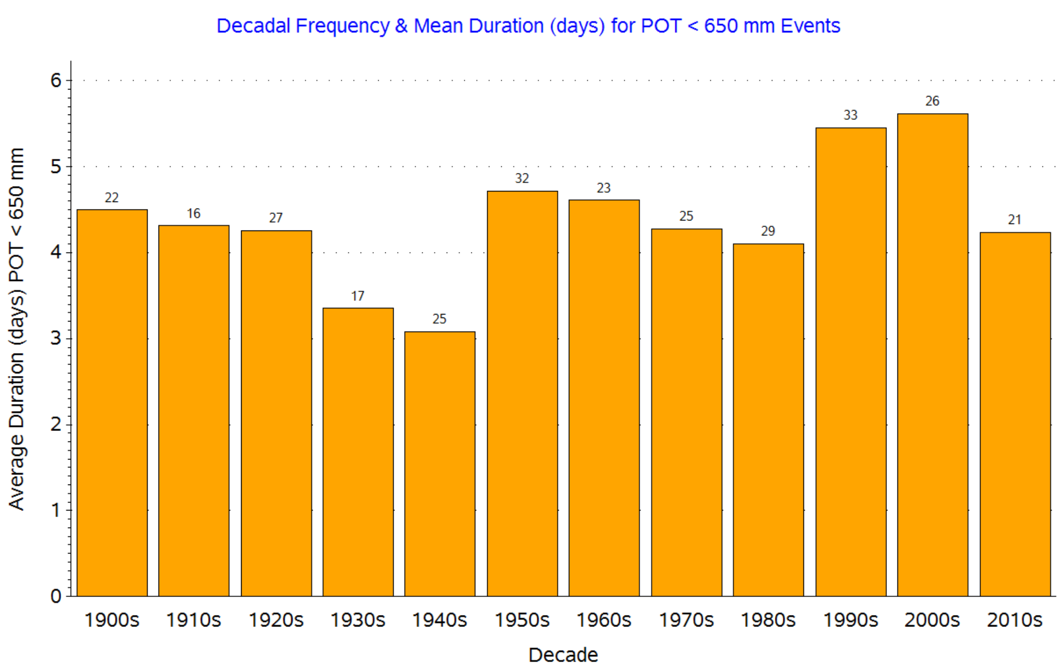


Figure 44. Mean length (days) and frequency of “low flow” periods in which Auke Creek water level continuously remained below the 10th percentile of June-September flows: ~6.50 m. (Note: 2010s represents 2010-2016).

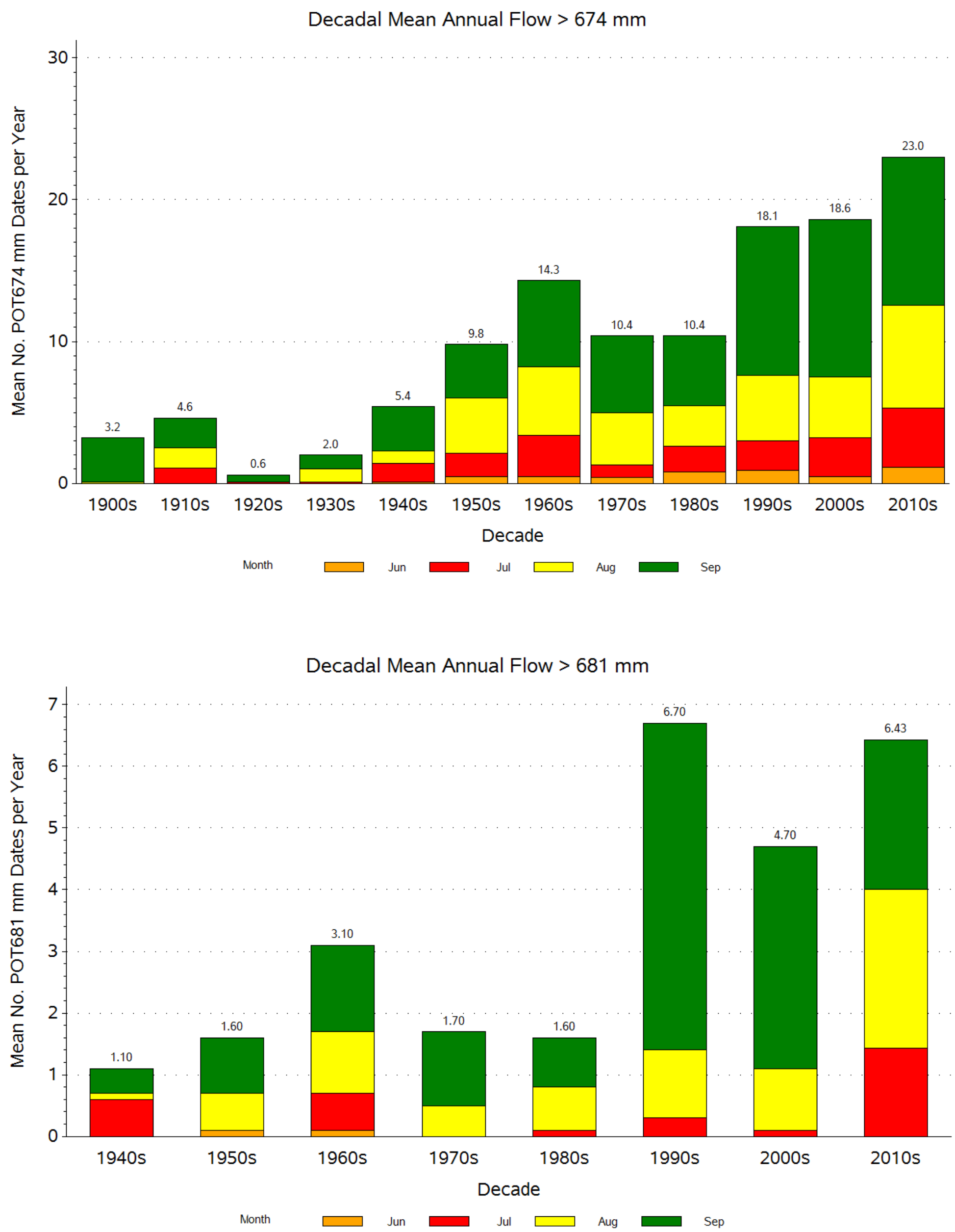
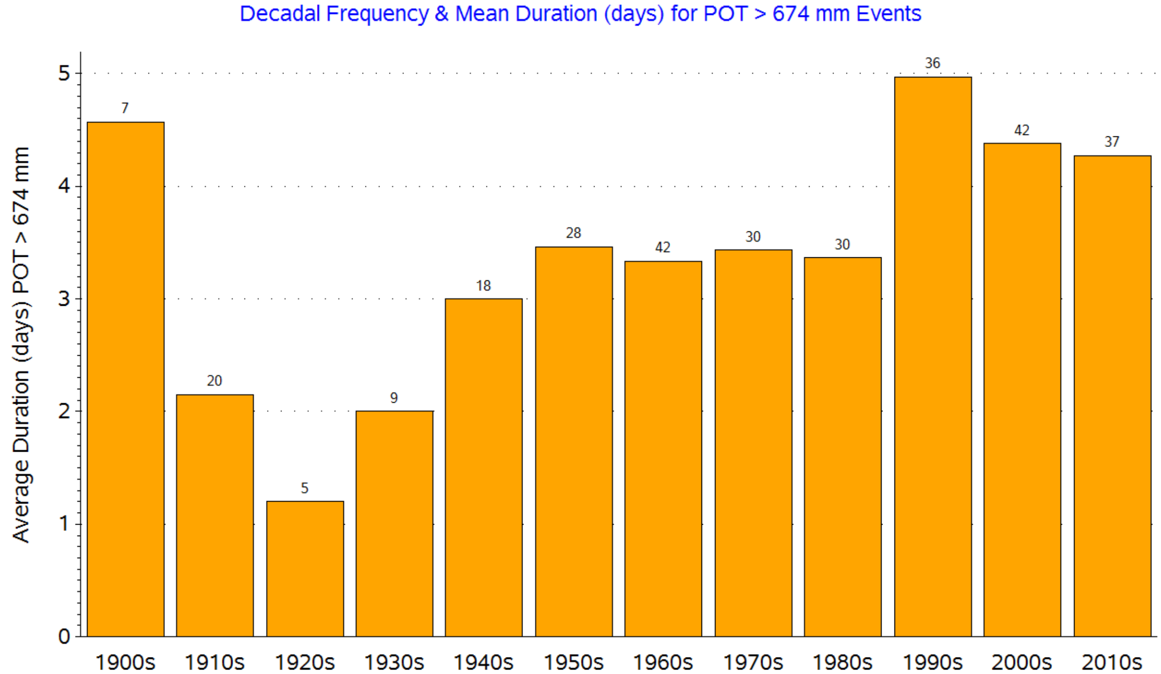


Figure 45. Frequency analysis of decadal mean number of “high flow” dates by month in Auke Creek (i.e. >90th percentile of June-September flows: ~6.7 m (top); >95th percentile of June-September flows: ~6.8 m (bottom)) (Note: 2010s represents 2010-2016).



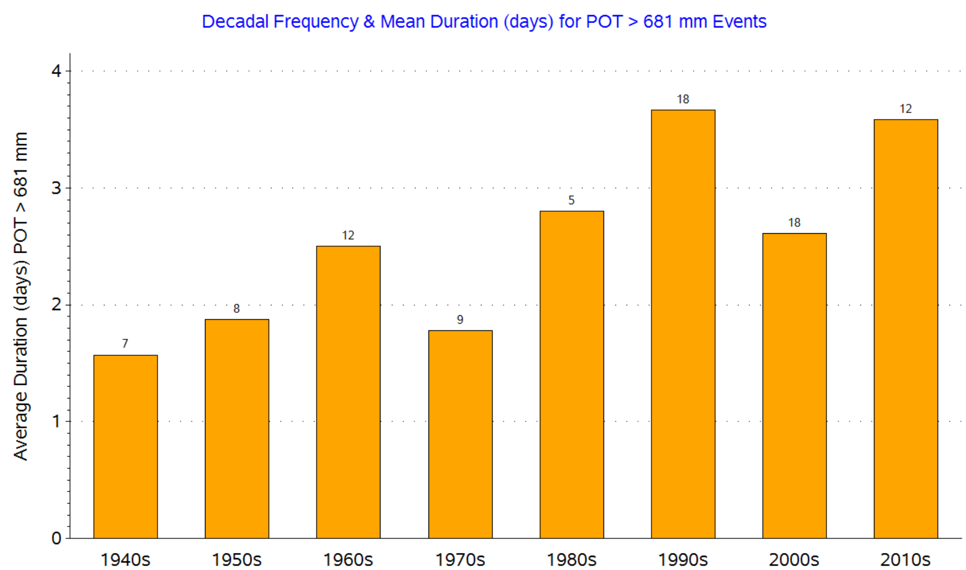


Figure 46. Mean length (days) and frequency of summer “high flow” periods in which Auke Creek water levels continuously remained above ~6.74 m (i.e. >75th percentile of June-September flows; top) and above ~6.81 m (>95th percentile; bottom). (Note: 2010s = 2010-2016).

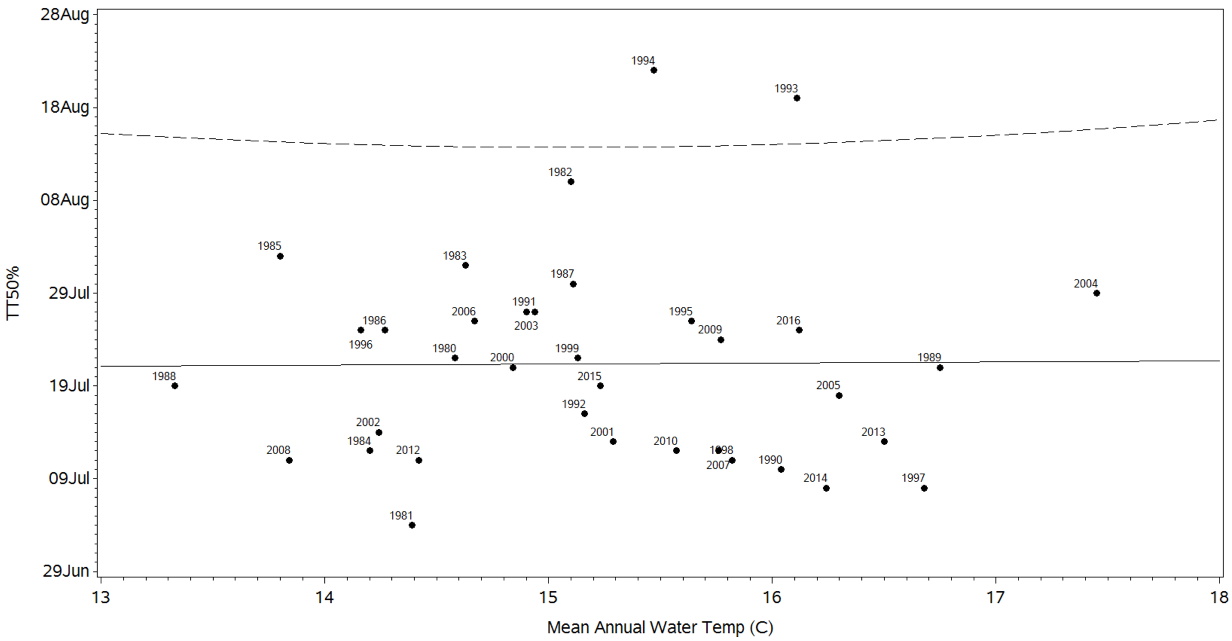


Figure 47. Regression analysis of annual time-to-50% (median migration date) as a function of annual mean daily water temperature in Auke Creek (r = 0.0, P > 0.95).

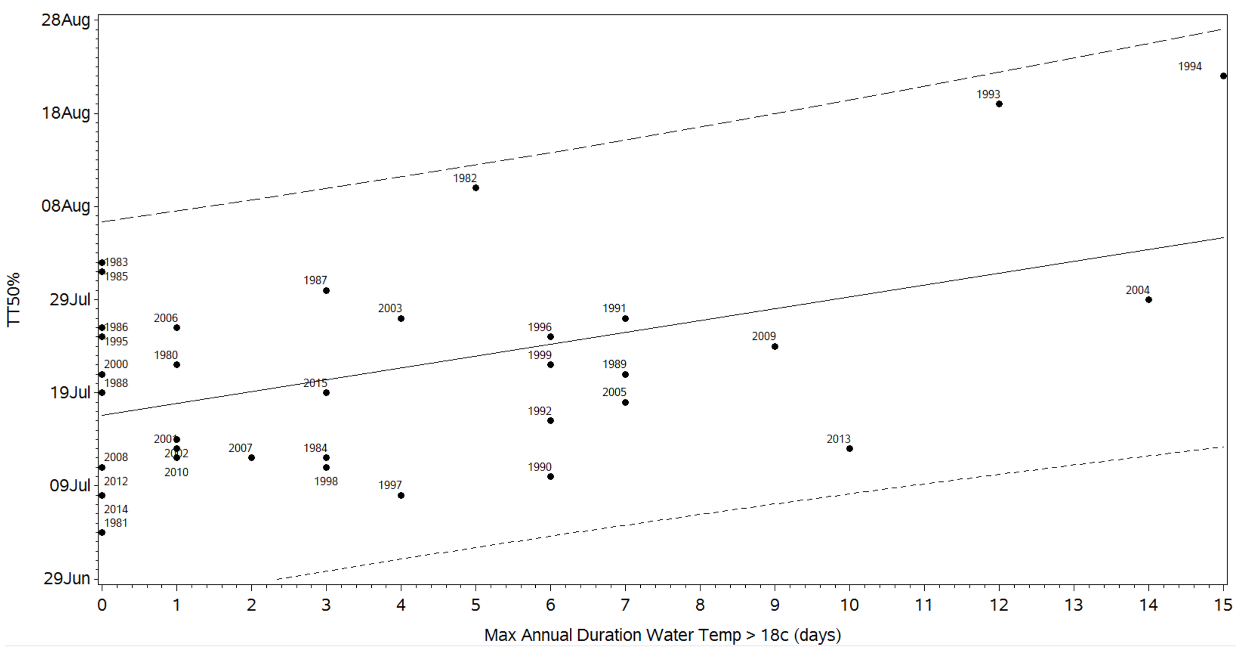


Figure 48. Regression analysis of annual time-to-50% (median migration date) as a function of annual maximum duration (days) for which daily mean water temperature continuously exceeded 18°C in Auke Creek (r = 0.48, P < 0.01).

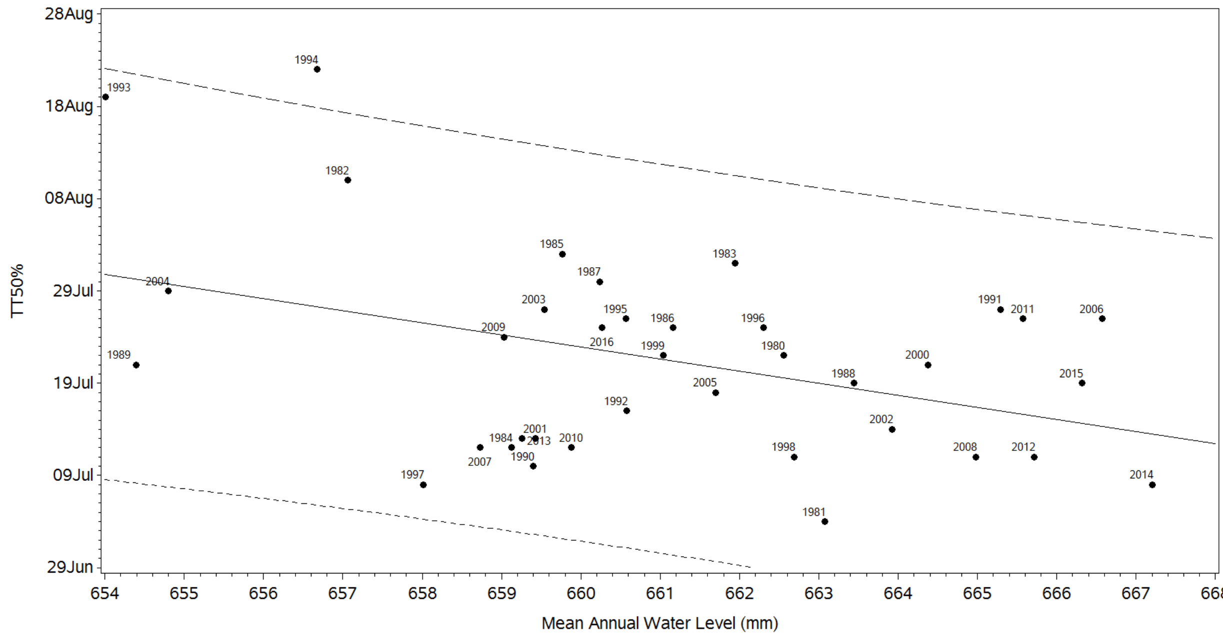


Figure 49. Regression analysis of annual time-to-50% (median migration date) as a function of annual mean daily water level in Auke Creek (r = -0.40, P = 0.01).

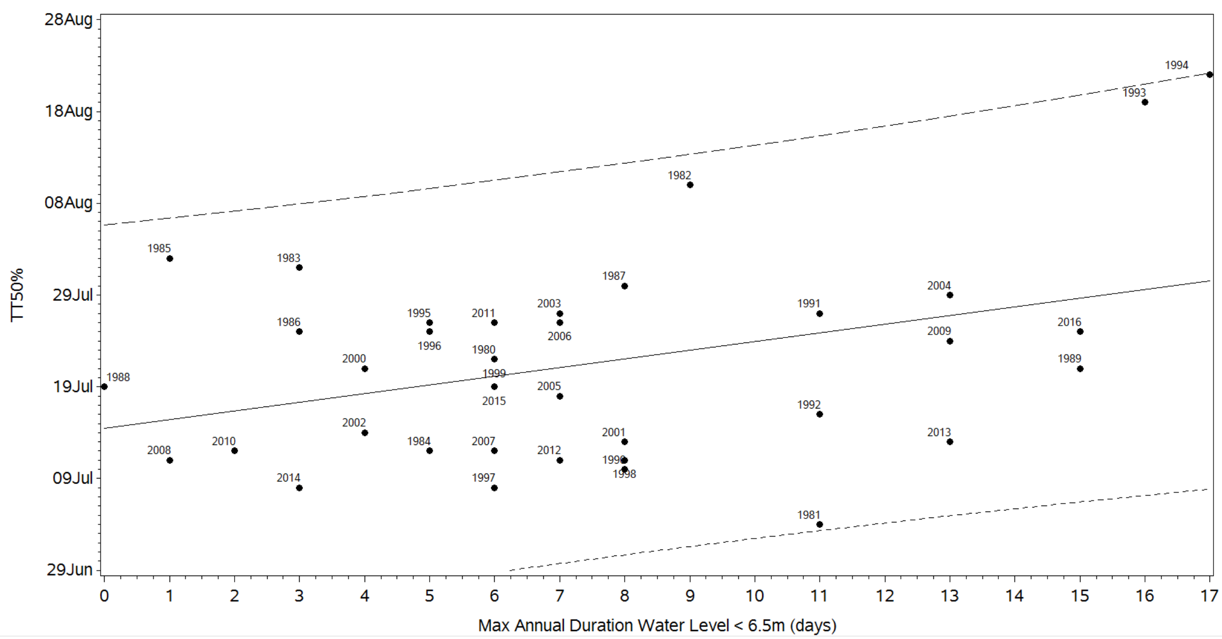
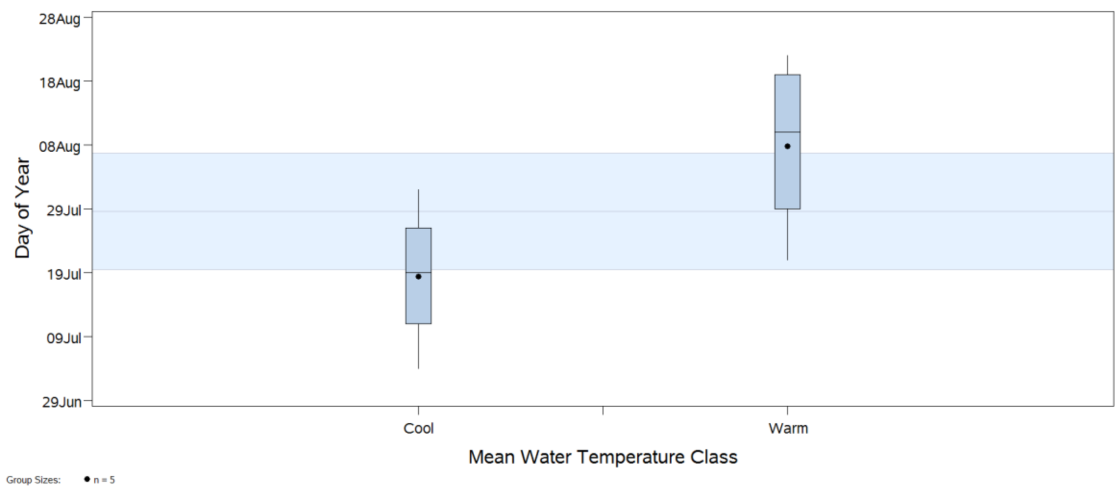
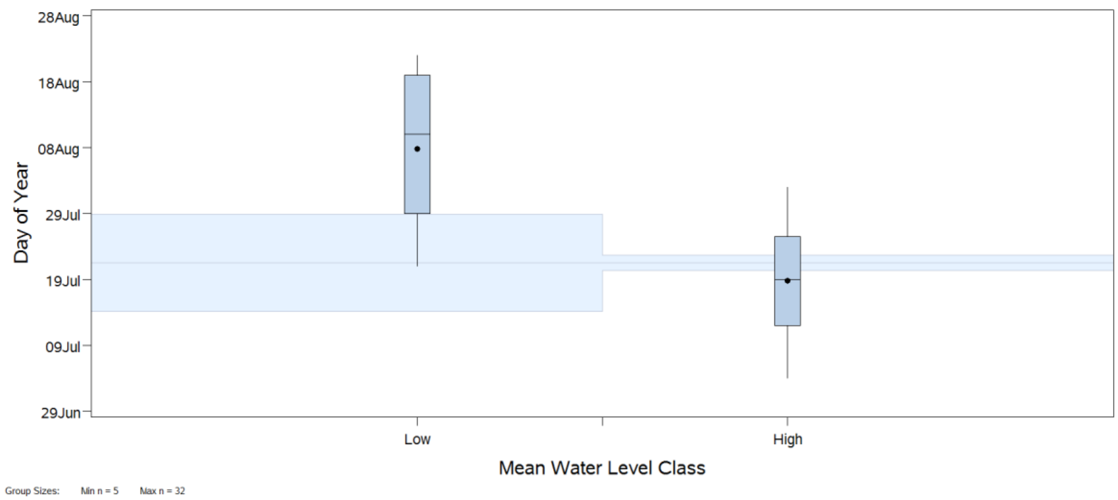


Figure 50. Regression analysis of annual time-to-50% (median migration date) as a function of annual maximum duration (days) for which daily mean water level was continuously less than 6.5 m in Auke Creek (r = 0.37, P = 0.02).





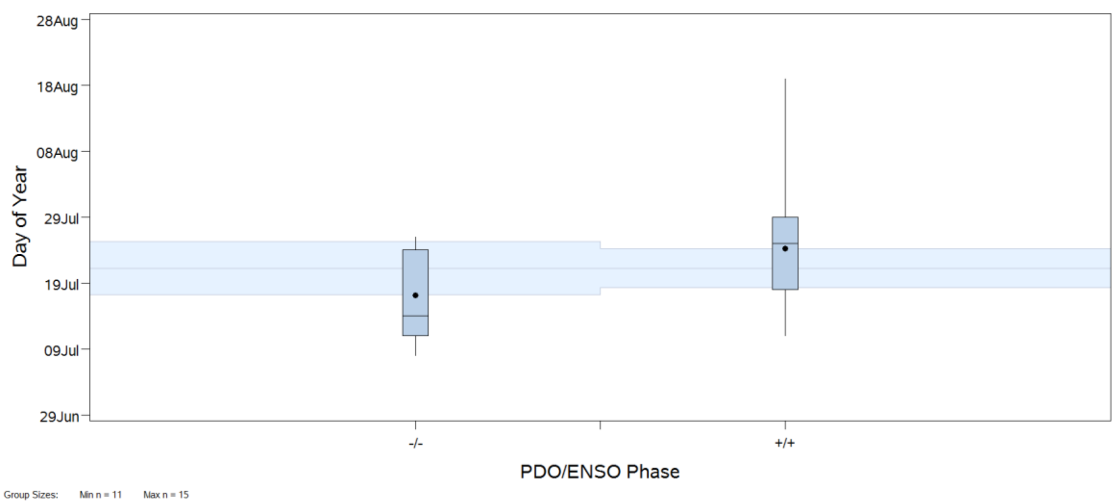


Figure 51. Box charts of mean time-to-50% (TT50%) for daily Sockeye migration (1980-2016) classified into the top 5 ‘cool’ vs top 5 ‘warm’ seasonal mean water temperature (top; $P_{kw} < 0.05$), top 5 ‘low’ versus top 5 ‘high’ water years (middle; $P < 0.01$), and aligned PDO/ENSO phases (bottom; $P_{kw} < 0.05$).

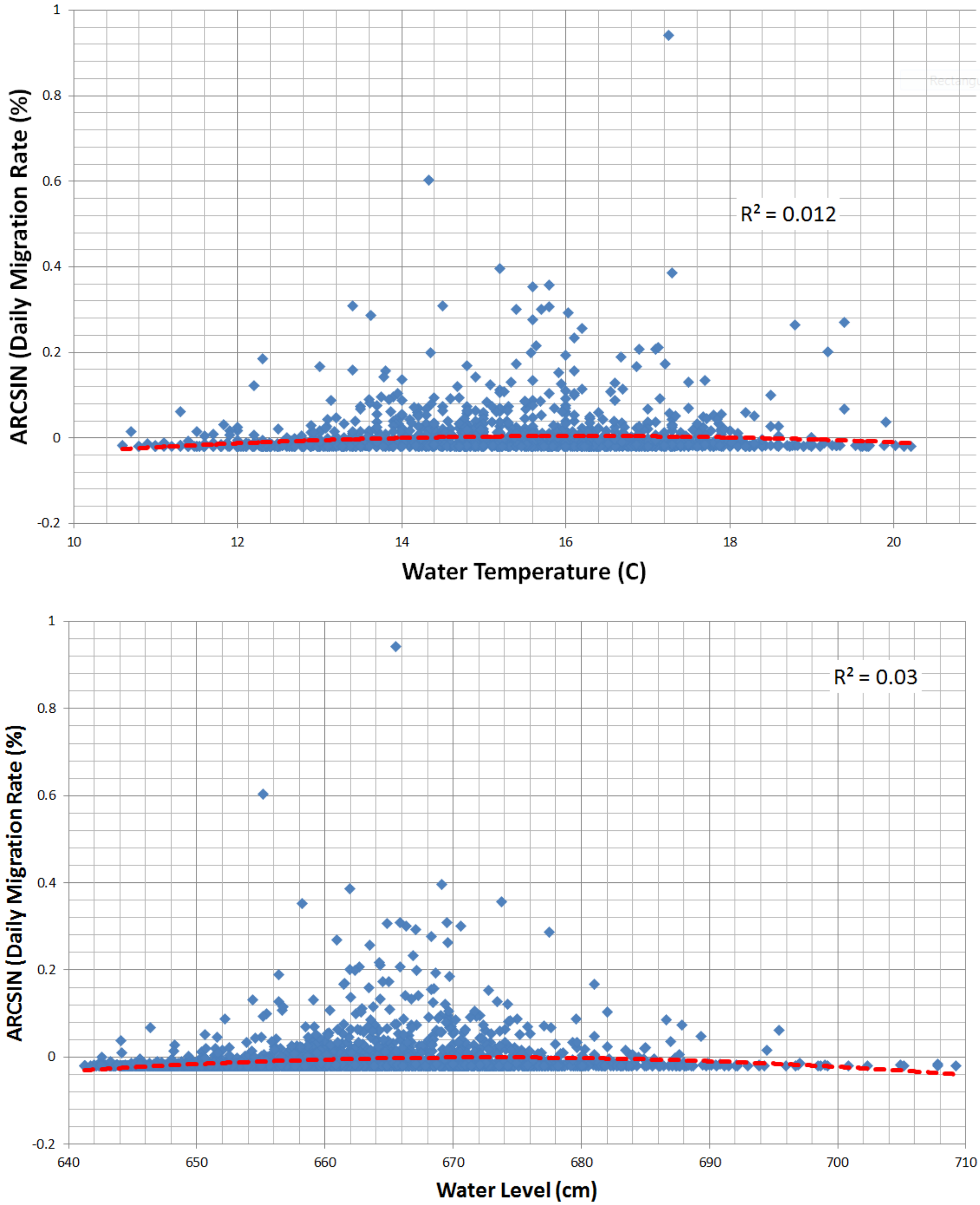
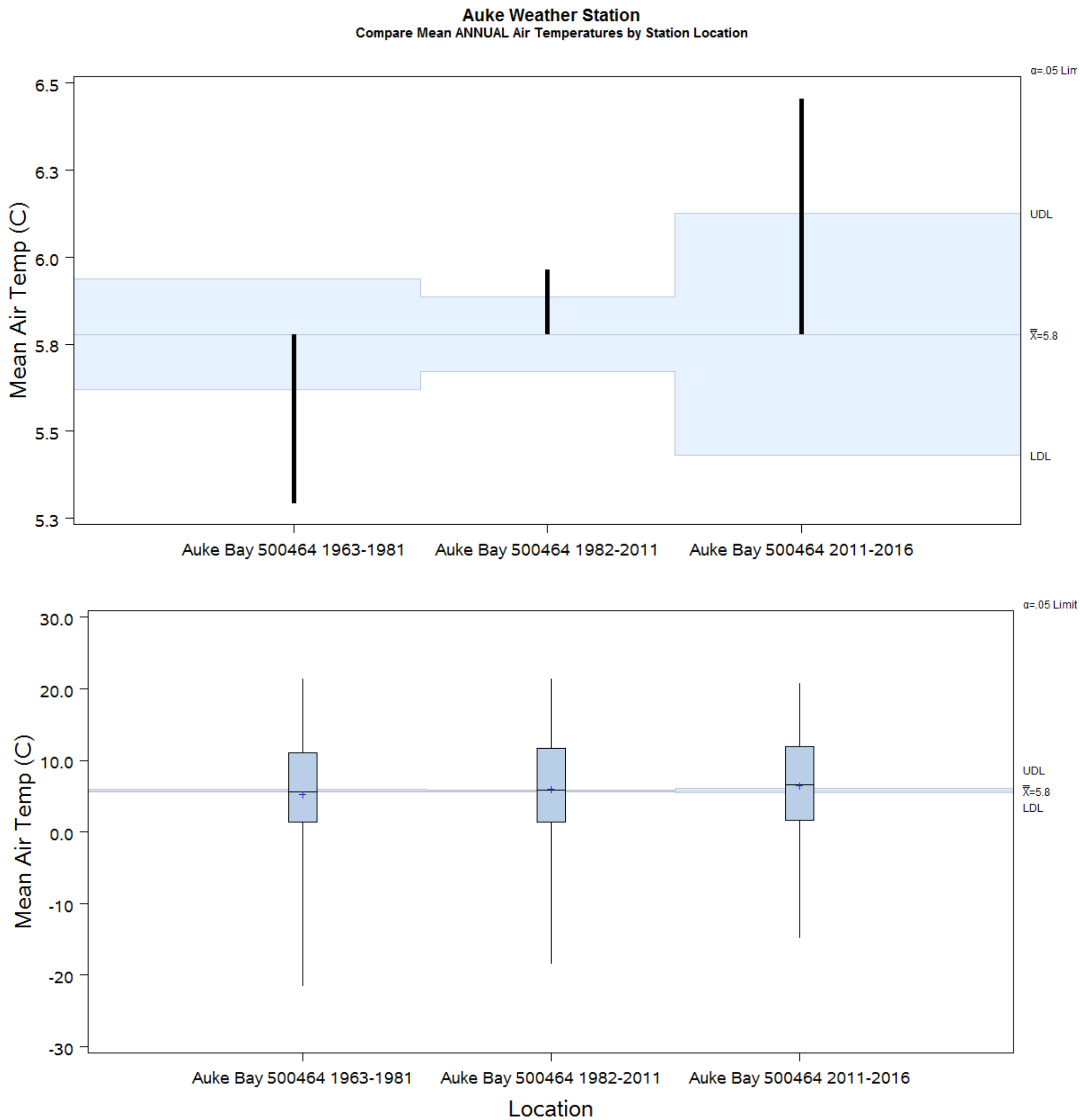


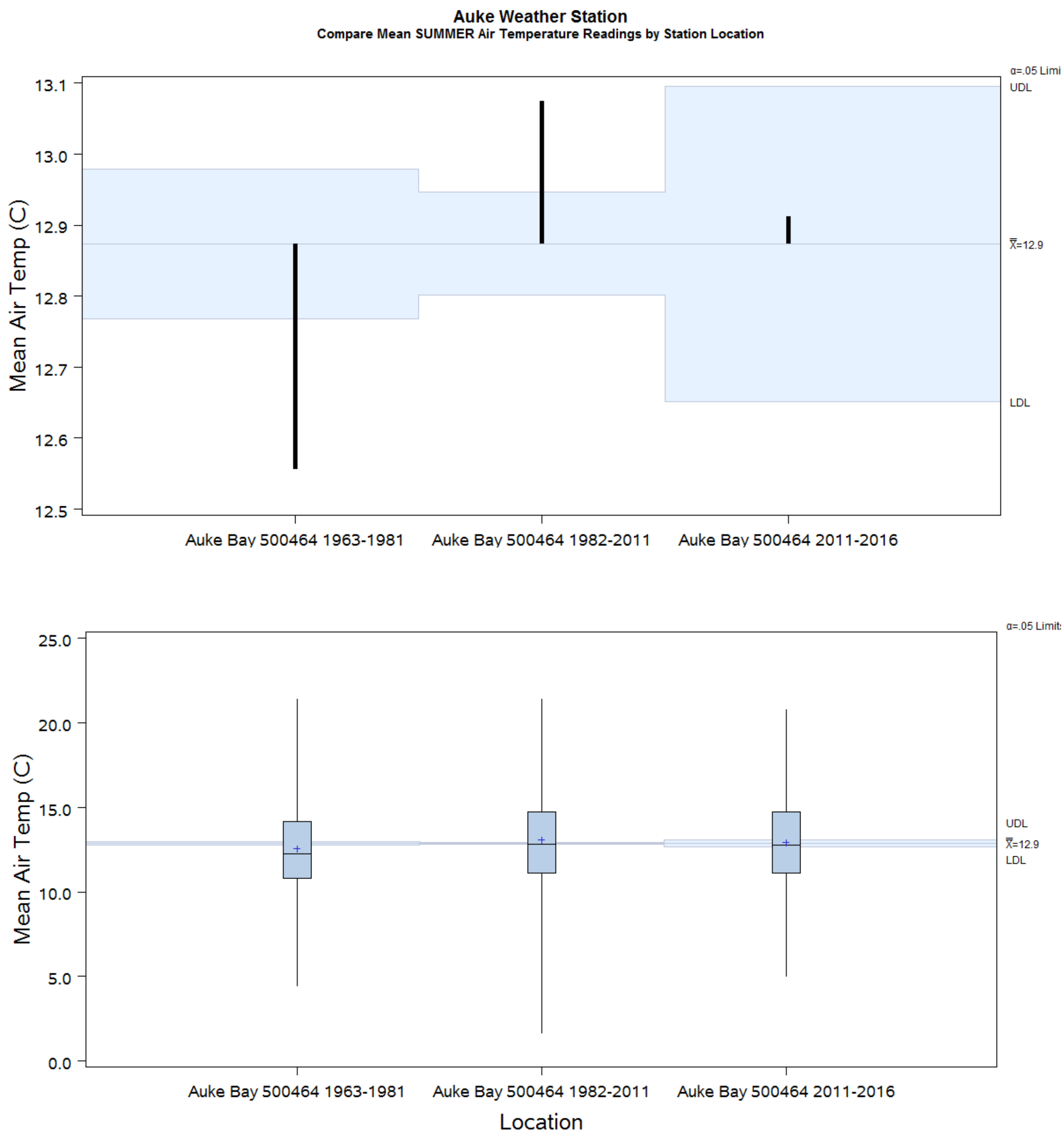
Figure 52. Daily Sockeye migration index (arcsin transform of %) as a function of observed daily water temperature (top) and estimated daily water level (bottom), 1980-2016.

APPENDICES

Appendix A. Comparison of mean annual temperatures recorded at AUKE BAY meteorological station 500464 after minor shifts in elevation and geographical location in 1982 and 2011.



Appendix B. Comparison of mean summer temperatures (June-September) recorded at AUKE BAY meteorological station 500464 after minor shifts in elevation and geographical location in 1982 and 2011.



Appendix C. AUKE CREEK daily water temperature observations, 1980-1989 (Source: NOAA).

DATE	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1-Jun	14.4	13.8	11.0	14.2	12.2	10.6	10.3	13.2	8.7	12.8
2-Jun	14.6	13.7	11.2	14.1	11.7	10.7	9.6	12.6	9.8	13.1
3-Jun	14.8	13.2	11.2	12.8	11.2	12.3	10.5	12.6	10.7	14.7
4-Jun	15.0	12.7	11.3	12.4	12.3	11.7	10.8	12.6	11.7	14.1
5-Jun	17.0	12.6	11.5	13.4	12.7	10.7	12.6	13.6	11.8	13.3
6-Jun	18.2	13.0	12.0	14.0	14.7	10.6	13.5	12.3	12.5	13.5
7-Jun	18.4	12.6	12.0	13.8	13.1	10.6	13.0	11.9	13.3	13.8
8-Jun	18.6	13.6	12.3	14.9	14.2	10.8	12.5	12.5	14.8	13.2
9-Jun	19.0	14.7	12.2	15.7	14.2	11.6	11.1	12.1	14.3	15.1
10-Jun	18.0	14.8	12.9	16.6	14.6	11.4	11.3	12.3	13.8	14.7
11-Jun	17.0	15.0	13.1	15.8	15.5	11.1	11.5	11.7	13.5	15.0
12-Jun	16.9	17.6	13.1	15.2	14.8	10.5	12.0	11.5	13.6	15.7
13-Jun	16.9	17.5	13.2	15.0	13.2	10.0	12.4	11.4	12.4	15.7
14-Jun	16.9	17.3	12.9	14.6	12.8	9.2	14.8	11.3	13.1	16.3
15-Jun	16.8	17.1	12.6	15.5	12.8	9.7	14.9	11.7	14.5	14.7
16-Jun	16.8	17.0	12.1	14.1	12.7	9.9	15.2	12.5	14.8	15.0
17-Jun	16.8	15.6	13.5	14.3	12.6	10.4	15.1	11.5	14.1	14.9
18-Jun	16.7	15.6	14.3	15.2	12.7	9.0	15.4	11.0	13.9	13.8
19-Jun	16.7	15.7	14.2	15.0	13.1	10.3	14.9	10.9	13.5	14.6
20-Jun	16.7	15.7	14.0	14.8	13.2	10.5	14.6	11.0	13.3	14.9
21-Jun	16.6	15.8	14.0	14.6	13.1	10.8	13.7	13.3	13.1	15.1
22-Jun	16.6	15.8	13.6	15.0	13.8	10.6	13.4	12.2	13.2	15.1
23-Jun	16.6	15.9	14.1	16.1	13.7	11.9	13.1	12.2	13.4	15.3
24-Jun	16.5	15.2	15.4	16.9	13.9	11.8	12.2	12.7	14.2	15.3
25-Jun	16.5	14.9	16.8	16.9	15.4	10.7	12.6	12.5	13.6	14.9
26-Jun	16.3	14.7	16.8	16.8	14.4	10.6	13.6	11.3	13.6	15.1
27-Jun	16.1	14.5	17.0	16.6	14.4	10.9	14.2	12.9	13.7	16.4
28-Jun	15.9	14.3	18.4	16.4	15.2	11.8	15.8	13.6	13.9	18.0
29-Jun	15.7	14.0	16.1	17.4	15.0	12.8	16.2	15.5	14.4	18.2
30-Jun	15.5	14.8	18.1	16.7	14.5	13.1	16.4	16.4	13.8	18.3
1-Jul	15.3	14.2	17.0	16.0	14.2	13.5	16.6	17.0	14.1	18.4
2-Jul	15.2	13.4	16.6	16.8	14.2	12.9	12.2	17.0	14.2	18.5
3-Jul	15.0	14.6	16.5	17.1	14.3	12.7	12.4	16.0	14.2	18.6
4-Jul	15.1	12.2	16.2	16.1	15.0	13.4	14.9	16.2	14.4	18.7
5-Jul	15.1	12.3	16.2	16.5	15.2	14.1	14.9	17.8	14.6	18.8
6-Jul	15.2	13.0	16.7	15.9	16.6	12.1	16.1	19.9	13.9	18.9
7-Jul	15.2	13.0	17.3	16.5	15.4	13.9	16.6	16.4	13.9	19.0
8-Jul	15.3	12.6	16.5	18.3	14.9	14.5	16.4	15.7	13.5	19.1
9-Jul	14.4	13.0	16.5	16.9	15.0	15.3	16.6	15.4	13.6	19.2
10-Jul	15.4	13.4	16.9	15.8	14.5	14.9	16.6	14.9	13.8	19.4
11-Jul	15.4	13.2	16.0	14.8	13.9	14.7	16.6	15.2	14.0	19.9
12-Jul	15.3	13.6	15.8	15.4	14.8	14.8	16.3	15.0	14.3	19.0
13-Jul	15.3	13.9	15.9	15.3	14.6	13.5	16.2	14.8	14.2	19.6
14-Jul	15.3	15.6	15.7	15.2	14.6	13.0	15.9	14.7	13.2	18.2
15-Jul	15.5	15.3	15.3	15.4	13.7	14.4	16.0	14.5	13.7	18.5
16-Jul	15.7	15.0	14.9	16.2	13.1	15.8	15.9	14.3	13.5	18.3
17-Jul	16.0	15.4	14.9	16.8	13.1	16.5	15.8	16.4	13.4	18.4
18-Jul	16.0	17.5	14.5	17.6	13.4	16.6	15.7	16.0	13.7	18.0
19-Jul	15.8	17.0	15.2	16.3	13.7	16.7	16.5	18.1	13.9	18.0
20-Jul	15.6	16.9	14.7	16.3	14.4	16.7	16.6	17.6	14.3	18.2
21-Jul	15.4	16.3	15.7	16.2	14.3	16.8	16.4	18.8	14.4	17.3
22-Jul	15.2	16.4	16.2	16.2	14.0	16.5	16.2	18.4	14.6	17.1
23-Jul	14.7	16.3	16.7	16.2	14.3	15.9	15.6	17.6	13.8	16.9
24-Jul	14.7	17.1	16.8	16.1	15.5	15.8	15.8	16.8	13.4	16.7
25-Jul	14.6	16.1	16.9	16.1	15.3	14.6	16.0	16.4	13.9	16.5
26-Jul	14.5	16.2	17.0	16.0	14.8	14.3	16.2	17.8	11.9	16.6
27-Jul	14.4	16.1	16.4	16.0	15.6	13.7	15.0	15.8	12.9	18.1
28-Jul	14.3	16.0	16.4	16.5	15.2	14.5	14.5	15.6	13.0	17.8
29-Jul	14.2	16.8	16.5	17.0	14.9	16.4	15.7	16.3	13.1	17.8
30-Jul	14.3	16.6	16.5	16.8	14.3	16.6	15.4	17.5	12.7	17.7
31-Jul	14.3	15.6	16.5	16.6	14.5	16.2	15.3	17.7	12.8	17.3
1-Aug	14.3	16.3	16.6	16.5	14.0	16.2	15.3	17.7	12.2	17.3
2-Aug	14.4	15.5	16.6	15.8	13.9	15.9	15.0	17.4	12.9	17.3
3-Aug	14.5	15.0	16.2	16.0	15.2	15.4	14.8	17.0	13.0	16.7

DATE	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
4-Aug	14.6	14.8	15.6	16.5	15.1	15.4	14.4	17.2	13.2	16.0
5-Aug	14.7	14.8	15.1	16.0	15.8	15.4	13.6	17.6	13.1	15.6
6-Aug	14.8	14.6	15.8	16.0	15.9	15.7	13.3	17.3	12.9	16.3
7-Aug	14.9	14.6	15.2	16.0	14.7	16.1	13.4	17.1	13.1	16.7
8-Aug	15.0	15.7	15.9	15.0	15.9	15.8	14.6	16.0	13.7	16.1
9-Aug	15.1	16.7	16.1	15.0	15.2	16.7	15.0	17.1	12.9	16.0
10-Aug	15.2	17.8	15.6	15.2	15.9	16.0	15.3	17.3	12.9	16.4
11-Aug	15.2	16.8	15.3	15.0	15.6	15.4	14.4	17.2	13.4	17.3
12-Aug	15.1	16.2	15.1	15.0	14.9	15.0	14.2	17.1	13.2	17.9
13-Aug	15.0	15.8	15.0	15.0	15.5	14.3	14.0	17.3	13.0	18.5
14-Aug	15.0	15.4	15.3	14.9	16.1	14.5	14.2	17.5	12.3	18.9
15-Aug	14.9	15.6	15.3	13.0	16.0	14.9	13.6	17.0	12.8	18.0
16-Aug	14.9	15.0	15.6	14.0	16.0	16.0	13.0	16.2	13.4	17.6
17-Aug	14.8	14.8	15.6	13.0	16.1	15.4	12.6	15.8	15.4	17.3
18-Aug	14.8	14.6	15.5	13.2	15.8	15.4	13.4	15.7	15.0	17.3
19-Aug	14.7	14.4	15.5	13.0	15.4	15.6	13.3	15.4	15.7	17.1
20-Aug	14.7	14.1	14.6	12.7	15.4	14.9	13.3	14.9	15.4	16.5
21-Aug	14.6	13.4	15.7	12.3	15.3	14.5	13.2	14.9	14.7	16.7
22-Aug	14.6	13.0	15.3	12.0	15.1	13.8	13.6	14.8	14.2	16.4
23-Aug	14.5	12.8	15.0	12.0	15.0	13.3	13.5	14.9	13.6	16.8
24-Aug	14.5	14.0	14.9	12.0	15.0	13.0	13.4	15.1	13.5	16.2
25-Aug	14.4	14.8	15.3	12.0	13.5	12.2	13.4	15.6	13.4	16.1
26-Aug	14.4	14.2	15.0	12.0	13.2	11.9	13.6	15.5	13.1	15.6
27-Aug	14.3	14.5	14.2	12.0	13.1	12.5	13.6	14.8	14.0	15.9
28-Aug	14.2	13.9	13.8	12.0	12.7	13.1	13.8	14.9	13.7	16.1
29-Aug	14.0	14.2	13.8	13.0	12.3	12.4	13.4	15.0	13.0	16.6
30-Aug	13.8	13.7	13.9	14.0	12.2	12.2	12.0	15.8	12.3	15.9
31-Aug	13.6	13.8	13.4	13.8	12.2	12.0	12.4	13.7	13.1	15.7
1-Sep	13.4	13.1	13.4	12.2	12.2	11.7	12.2	13.5	12.6	14.6
2-Sep	13.2	12.8	12.5	12.0	12.1	11.4	12.3	14.2	12.3	14.7
3-Sep	13.0	13.3	12.9	12.0	11.9	13.1	12.4	13.9	11.9	15.3
4-Sep	12.8	13.2	12.8	12.0	12.2	12.6	12.6	12.9	11.8	15.1
5-Sep	12.4	12.8	12.5	12.0	12.7	12.2	12.9	12.8	12.8	14.9
6-Sep	10.8	12.3	12.2	12.0	12.6	12.1	13.2	12.8	12.6	14.4
7-Sep	11.8	12.4	12.3	12.0	12.7	12.0	13.2	12.8	12.3	14.4
8-Sep	11.6	11.8	12.3	12.0	12.6	12.4	13.2	12.7	12.6	14.8
9-Sep	11.7	11.3	12.4	12.0	12.4	12.8	12.9	12.4	12.4	15.1
10-Sep	11.4	11.8	12.6	11.0	12.9	12.4	12.8	12.0	12.2	15.5
11-Sep	11.1	11.4	12.1	12.3	13.0	12.3	12.6	11.8	12.3	15.6
12-Sep	11.8	11.3	12.2	12.0	13.1	12.2	12.7	11.1	11.1	15.0
13-Sep	11.8	11.1	12.4	11.5	12.7	12.6	12.8	11.2	11.6	14.6
14-Sep	11.9	11.0	12.6	12.0	12.7	12.4	12.3	11.3	11.4	14.1
15-Sep	12.0	11.0	12.5	11.0	12.3	12.2	12.2	11.2	11.4	14.4
16-Sep	12.1	11.1	12.5	11.2	12.1	12.0	12.1	11.0	11.4	13.9
17-Sep	12.0	11.1	12.6	10.0	12.1	11.7	12.1	10.6	11.3	13.3
18-Sep	12.0	11.1	12.5	10.0	12.1	11.0	12.0	10.2	11.3	12.6
19-Sep	11.6	10.9	12.5	10.6	11.9	10.9	12.1	10.4	11.2	12.4
20-Sep	11.4	10.6	12.4	10.2	11.8	10.7	12.2	10.5	10.7	12.6
21-Sep	11.1	10.3	12.4	10.0	11.7	10.7	11.8	10.4	10.8	12.5
22-Sep	10.9	10.3	11.8	10.2	11.6	10.5	11.0	10.3	10.7	12.4
23-Sep	10.6	10.5	11.6	11.0	11.3	10.7	10.8	10.2	10.7	12.4
24-Sep	10.4	10.3	11.3	10.0	10.9	10.1	10.8	10.3	10.5	12.3
25-Sep	10.4	10.3	11.1	10.0	10.8	10.0	11.2	10.3	10.7	12.2
26-Sep	10.3	10.4	10.9	9.0	10.8	9.9	10.8	10.3	10.6	12.3
27-Sep	10.3	10.4	10.8	9.0	11.1	9.7	10.3	10.0	10.3	11.9
28-Sep	10.2	10.1	10.6	8.8	10.9	9.6	10.1	9.8	10.2	11.7
29-Sep	10.0	9.8	10.6	8.4	10.9	9.4	10.1	9.9	10.3	11.5
30-Sep	10.0	9.4	10.4	8.4	10.8	9.0	10.0	9.8	10.2	10.1

Appendix D. AUKE CREEK daily water temperature observations, 1990-1999 (cont'd).

DATE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1-Jun	15.1	9.2	11.5	17.8	12.3	12.1	14.9	15.2	16.8	7.8
2-Jun	16.1	9.1	11.5	18.1	11.6	12.2	14.8	14.2	18.0	8.3
3-Jun	16.6	9.9	11.6	17.3	11.9	12.2	15.2	14.2	16.8	9.9
4-Jun	15.8	10.8	12.0	17.7	12.6	12.7	14.4	16.8	17.4	9.1
5-Jun	14.9	11.4	12.4	17.7	13.6	13.9	14.8	16.0	17.7	9.1
6-Jun	14.5	10.8	12.6	17.8	13.6	12.8	14.8	15.5	17.5	9.8
7-Jun	14.2	10.6	13.7	16.9	13.7	13.4	14.5	15.8	17.3	10.3
8-Jun	14.1	10.2	13.2	15.4	14.7	14.2	14.4	15.8	17.8	11.4
9-Jun	15.1	10.6	13.5	15.3	14.7	15.7	14.4	15.8	18.0	12.6
10-Jun	14.9	10.0	15.3	16.3	14.9	16.9	13.5	15.8	17.3	13.2
11-Jun	15.3	9.6	17.0	15.8	15.0	16.8	13.2	16.5	17.0	13.6
12-Jun	15.2	9.7	17.1	15.3	14.7	15.9	13.0	16.8	16.3	13.1
13-Jun	15.6	10.5	17.7	15.4	16.4	15.4	11.7	16.0	16.7	14.2
14-Jun	16.2	10.5	17.6	18.3	16.7	15.0	11.5	15.2	16.0	15.2
15-Jun	15.7	11.4	16.6	17.5	16.3	14.4	12.6	15.0	15.9	15.0
16-Jun	15.2	12.1	16.1	17.1	16.6	14.0	12.7	15.0	16.1	15.8
17-Jun	15.0	12.6	15.8	16.7	16.4	14.2	12.3	16.0	16.4	16.4
18-Jun	14.7	13.8	15.4	16.3	16.0	15.8	12.3	16.0	17.1	15.2
19-Jun	14.8	14.6	15.0	17.1	15.8	16.3	12.3	14.2	18.3	15.3
20-Jun	14.4	16.0	13.9	16.8	15.4	16.4	12.9	15.0	18.1	14.8
21-Jun	14.4	17.4	13.6	16.1	15.0	16.8	12.6	15.6	17.8	14.2
22-Jun	14.5	17.7	14.4	16.6	15.3	17.4	12.8	16.2	17.2	14.9
23-Jun	14.2	18.0	14.4	16.9	15.3	16.1	13.0	16.8	17.2	14.9
24-Jun	14.2	18.3	14.3	16.2	16.1	16.0	15.7	19.5	16.8	15.0
25-Jun	13.8	18.7	14.0	16.1	15.3	15.5	16.7	18.4	17.8	15.0
26-Jun	14.1	18.4	15.9	16.3	15.0	15.0	15.7	19.6	17.9	16.0
27-Jun	14.0	18.0	16.9	17.3	14.8	15.2	15.1	19.2	18.3	16.3
28-Jun	15.2	18.3	17.9	16.7	15.2	16.4	13.6	19.0	18.2	15.5
29-Jun	16.8	18.4	19.8	17.1	14.4	17.1	12.0	19.0	18.3	16.0
30-Jun	17.8	18.2	19.6	16.2	14.0	18.5	11.1	19.3	18.7	15.6
1-Jul	18.7	18.1	19.4	15.8	14.4	18.5	11.3	19.5	19.0	16.4
2-Jul	17.8	17.2	19.3	15.7	14.8	17.8	11.5	19.8	19.5	15.5
3-Jul	18.2	17.0	19.0	15.5	14.7	17.6	11.6	19.0	21.0	15.4
4-Jul	18.9	16.7	18.9	15.4	14.9	17.5	12.2	18.8	20.0	15.5
5-Jul	19.4	17.1	18.4	15.3	16.2	17.8	14.3	19.2	20.3	15.6
6-Jul	19.4	16.8	17.6	15.0	14.4	17.2	14.3	19.0	19.5	15.8
7-Jul	19.4	16.1	16.8	15.7	14.8	16.8	14.6	19.4	18.8	15.8
8-Jul	17.7	15.7	16.0	16.1	14.8	17.0	15.6	19.2	18.2	15.0
9-Jul	17.1	15.7	15.2	17.0	14.5	17.4	14.9	18.6	17.9	16.2
10-Jul	15.7	15.3	14.8	17.3	14.4	18.0	14.4	18.0	17.3	15.4
11-Jul	15.3	15.4	16.5	17.9	14.3	18.1	14.0	18.2	17.0	15.4
12-Jul	15.4	15.4	16.9	17.9	14.7	16.5	14.4	16.2	17.0	15.4
13-Jul	15.2	15.5	16.6	18.0	15.9	16.1	14.0	16.1	17.6	15.8
14-Jul	15.6	16.1	15.8	18.7	16.2	15.7	13.8	16.1	17.2	16.0
15-Jul	15.3	17.3	15.6	18.5	18.0	15.9	13.9	16.3	17.1	16.4
16-Jul	14.9	17.1	14.8	17.6	17.9	16.0	14.8	16.9	16.9	16.8
17-Jul	15.1	16.6	15.4	18.6	17.7	17.3	15.3	16.8	17.3	18.5
18-Jul	15.8	15.9	16.3	17.4	16.9	17.0	15.6	16.5	17.0	18.5
19-Jul	17.6	15.4	16.5	17.1	16.3	17.5	15.8	16.0	17.2	17.5
20-Jul	17.7	15.6	16.6	16.5	15.5	17.3	15.8	15.8	17.2	17.0
21-Jul	18.6	15.8	16.8	16.0	14.9	17.9	15.2	15.5	18.8	16.7
22-Jul	19.1	15.9	16.7	15.0	15.9	18.5	15.0	15.3	16.0	16.2
23-Jul	19.1	16.2	16.6	15.5	16.0	17.9	14.8	15.2	16.0	16.0
24-Jul	19.1	16.7	16.3	15.6	17.3	17.4	15.3	15.0	16.0	16.0
25-Jul	18.9	17.2	16.1	15.7	17.6	17.3	15.2	14.8	15.5	15.7
26-Jul	18.3	17.3	15.8	16.2	17.4	16.7	18.0	15.3	16.0	15.4
27-Jul	17.7	16.9	15.0	16.6	17.7	16.7	18.6	15.8	17.0	14.9
28-Jul	17.6	16.3	14.8	17.9	17.2	16.2	19.0	16.3	17.2	14.5
29-Jul	17.7	16.1	14.8	18.3	16.7	16.2	19.1	16.5	17.8	14.0
30-Jul	17.6	15.2	14.7	17.8	16.0	16.2	18.4	16.6	17.8	14.3
31-Jul	17.1	14.8	14.9	17.3	15.4	15.6	18.0	16.6	18.0	15.2
1-Aug	16.8	14.3	14.9	17.5	15.6	15.6	17.2	16.8	18.0	15.6
2-Aug	16.7	14.1	15.1	17.8	18.3	15.0	16.0	17.3	18.0	16.8
3-Aug	16.5	13.8	15.2	17.8	17.0	14.0	16.2	17.7	17.3	17.8

DATE	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
4-Aug	15.6	13.2	15.0	18.1	17.3	13.2	15.1	18.2	17.8	18.2
5-Aug	15.4	13.1	15.0	18.8	17.5	13.2	15.0	18.0	18.0	19.0
6-Aug	15.2	13.6	14.8	18.0	17.5	13.6	15.0	17.8	18.0	19.6
7-Aug	15.1	15.7	14.9	18.2	17.2	14.0	14.9	17.5	17.1	19.9
8-Aug	14.9	15.5	15.2	17.7	17.2	15.0	14.8	17.1	16.2	19.0
9-Aug	14.3	15.4	15.8	17.6	17.8	15.2	14.4	17.1	15.2	18.1
10-Aug	14.2	14.7	16.5	17.5	17.8	16.4	14.0	17.2	15.1	17.2
11-Aug	16.1	14.7	17.2	17.7	17.7	15.9	13.9	17.3	15.0	17.0
12-Aug	18.1	15.3	17.0	16.3	17.8	15.6	13.8	17.9	15.1	16.9
13-Aug	18.2	15.1	16.0	16.3	17.5	14.7	13.6	16.7	16.2	17.5
14-Aug	19.1	17.1	15.5	16.3	17.3	14.7	13.4	15.8	16.3	17.5
15-Aug	17.8	17.2	14.8	16.5	17.3	14.5	14.2	17.0	16.5	16.2
16-Aug	18.2	17.2	13.3	16.2	17.0	14.0	14.3	16.9	16.0	16.3
17-Aug	18.1	17.2	13.5	17.4	16.6	14.0	14.5	16.7	15.7	16.3
18-Aug	18.3	16.9	14.9	16.5	16.3	14.2	14.8	16.6	15.1	15.5
19-Aug	18.5	15.4	14.8	16.5	16.9	14.4	15.2	16.9	15.0	15.7
20-Aug	16.8	14.4	14.8	16.4	16.2	14.6	14.8	17.3	15.0	15.5
21-Aug	16.7	13.7	14.9	16.3	15.6	15.0	14.1	17.7	15.1	15.8
22-Aug	16.4	12.7	15.0	16.9	15.0	16.7	13.3	17.0	14.8	15.6
23-Aug	16.4	13.8	15.1	16.0	14.9	16.4	13.1	17.0	14.7	14.2
24-Aug	16.4	12.8	15.2	15.5	15.0	16.4	12.3	16.7	14.5	14.0
25-Aug	16.2	12.3	15.2	15.3	15.4	16.0	12.5	16.6	14.0	13.4
26-Aug	16.5	12.0	15.0	15.0	15.5	15.8	12.8	16.5	13.8	13.3
27-Aug	15.9	12.3	14.6	14.5	15.2	15.3	13.3	16.3	13.1	13.0
28-Aug	15.6	12.5	14.4	14.6	15.2	15.3	13.0	16.1	13.3	13.2
29-Aug	15.4	14.3	14.3	14.5	15.9	14.6	13.0	15.8	12.8	13.2
30-Aug	15.3	13.6	14.7	14.4	15.2	15.2	13.9	15.5	12.4	12.9
31-Aug	15.6	13.0	14.9	14.5	14.9	14.7	13.3	15.3	13.2	12.7
1-Sep	15.9	12.4	14.3	14.2	14.9	14.4	13.3	14.9	12.8	12.3
2-Sep	15.3	12.6	13.9	14.3	13.7	13.8	13.3	14.7	12.0	12.4
3-Sep	14.7	13.0	14.1	14.0	13.6	14.0	13.2	14.5	12.0	12.8
4-Sep	13.2	12.9	14.3	13.7	13.8	14.0	13.4	14.3	11.6	12.8
5-Sep	13.8	12.9	13.4	13.8	13.4	14.1	13.7	15.1	11.8	12.4
6-Sep	13.6	11.3	13.0	14.4	13.7	15.1	13.2	15.2	12.0	12.4
7-Sep	13.7	10.8	12.8	14.2	14.0	15.9	12.7	15.4	12.2	12.1
8-Sep	13.4	11.8	12.4	14.0	14.0	15.4	12.8	15.5	11.8	12.1
9-Sep	13.7	11.4	12.1	13.9	13.0	15.1	13.1	15.7	11.3	12.0
10-Sep	12.9	10.8	11.9	13.8	12.7	14.1	12.6	15.5	11.9	11.8
11-Sep	12.8	10.8	11.7	13.8	12.7	12.2	12.0	15.2	11.2	11.8
12-Sep	12.9	10.9	11.5	13.7	12.7	12.3	12.3	14.9	11.0	11.7
13-Sep	13.4	11.2	11.1	13.4	12.0	12.5	12.1	14.8	11.0	11.7
14-Sep	12.7	11.2	10.9	13.4	11.9	12.4	12.1	14.6	11.0	11.5
15-Sep	12.8	11.0	10.7	13.4	11.7	12.3	12.2	14.4	11.6	11.4
16-Sep	12.4	10.8	10.3	13.9	11.6	13.0	12.0	14.2	11.4	11.3
17-Sep	12.7	10.4	10.3	13.6	11.4	13.0	12.1	14.2	11.3	11.1
18-Sep	12.4	11.0	10.1	13.2	11.3	13.1	11.2	14.4	11.3	11.0
19-Sep	12.1	10.6	10.1	12.6	11.1	12.8	11.2	13.8	11.4	11.0
20-Sep	11.8	10.4	10.0	12.2	10.9	12.9	10.8	13.5	11.6	11.0
21-Sep	11.8	10.4	9.9	12.0	9.9	13.3	11.0	13.0	11.8	10.8
22-Sep	11.8	10.3	10.2	10.6	9.8	13.3	10.8	12.4	11.8	10.7
23-Sep	11.7	10.2	10.1	10.2	9.8	13.4	10.1	12.4	11.9	11.0
24-Sep	11.7	10.1	10.0	10.9	9.9	13.3	10.3	12.6	11.7	11.0
25-Sep	11.4	9.9	9.6	10.1	9.7	13.5	10.2	12.2	11.8	10.1
26-Sep	11.3	10.1	9.7	10.0	9.6	12.8	10.1	12.0	11.8	10.0
27-Sep	11.3	10.1	9.8	10.2	9.4	12.9	9.8	12.0	11.8	10.0
28-Sep	11.2	10.3	9.2	10.3	9.3	13.1	9.6	11.9	11.2	10.1
29-Sep	10.5	9.9	9.4	9.7	8.9	12.9	9.2	11.7	11.2	9.5
30-Sep	10.5	9.4	9.2	9.8	9.1	12.4	9.0	11.7	11.0	9.4

Appendix E. AUKE CREEK daily water temperature observations, 2000-2009 (cont'd).

DATE	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1-Jun	13.2	12.1	10.3	13.3	14.5	16.0	16.0	9.6	13.2	12.1
2-Jun	14.0	12.7	10.1	13.3	14.5	16.2	16.0	11.3	12.3	13.4
3-Jun	14.8	12.6	9.9	13.7	14.2	15.9	14.6	12.1	12.2	14.8
4-Jun	15.7	12.3	10.6	14.3	15.0	16.1	13.9	13.1	12.1	15.7
5-Jun	15.7	12.5	9.4	14.5	15.3	17.0	13.8	13.1	11.8	15.5
6-Jun	15.5	12.3	9.9	15.5	15.2	17.4	13.5	12.7	11.8	15.6
7-Jun	15.4	12.7	10.2	15.5	15.7	18.4	13.5	10.8	10.5	16.6
8-Jun	14.9	13.6	11.5	15.5	16.1	18.2	14.1	11.2	10.9	16.6
9-Jun	15.1	13.9	12.3	15.8	15.5	17.9	15.6	13.1	11.2	16.1
10-Jun	15.1	13.4	11.9	16.7	15.2	17.9	17.0	13.2	11.5	15.5
11-Jun	16.0	13.6	12.3	16.5	15.2	17.8	17.8	13.7	11.6	16.1
12-Jun	15.5	13.5	11.8	16.7	15.2	17.8	18.7	13.1	11.3	16.7
13-Jun	16.6	13.6	12.5	16.3	15.6	17.1	18.9	12.8	11.6	16.1
14-Jun	15.9	14.0	14.9	16.5	15.1	16.3	19.4	14.0	11.5	16.0
15-Jun	15.4	14.9	16.4	16.0	15.0	16.6	19.0	15.5	11.5	16.2
16-Jun	15.0	15.3	16.8	15.8	14.8	17.5	18.6	16.5	12.0	15.9
17-Jun	13.7	15.5	17.4	16.2	15.5	18.6	18.1	16.9	13.2	15.8
18-Jun	13.7	15.9	17.3	15.5	16.3	18.0	17.2	16.0	13.6	15.3
19-Jun	13.5	16.2	16.6	15.0	18.0	17.4	16.5	15.7	14.0	15.4
20-Jun	14.0	16.3	15.9	14.3	18.7	16.5	16.5	16.4	14.5	15.7
21-Jun	13.0	16.2	15.4	14.7	18.8	16.7	16.5	16.3	15.2	15.8
22-Jun	12.8	16.1	15.8	14.8	19.4	16.5	15.3	16.2	14.8	15.6
23-Jun	13.9	15.9	16.5	15.0	19.6	16.9	15.0	15.6	14.6	15.2
24-Jun	14.9	16.1	16.1	14.8	20.0	17.8	15.2	14.8	14.6	15.2
25-Jun	16.0	16.5	15.8	14.0	20.2	18.5	14.8	13.9	14.1	15.3
26-Jun	17.0	16.7	15.5	14.0	19.8	18.8	14.1	13.7	14.3	14.7
27-Jun	17.7	17.7	15.2	13.8	18.6	18.5	14.4	14.6	14.3	14.5
28-Jun	17.2	17.4	15.6	14.0	17.8	18.0	14.5	15.1	13.6	14.6
29-Jun	16.3	17.0	16.2	14.0	17.7	17.9	14.8	15.7	13.6	14.4
30-Jun	16.2	17.3	15.9	15.5	17.8	17.5	15.1	15.3	14.3	14.4
1-Jul	15.8	17.7	15.5	16.2	17.0	17.0	15.2	15.2	15.0	14.2
2-Jul	15.6	17.5	14.9	16.3	17.0	16.6	15.1	15.7	16.2	14.5
3-Jul	15.6	17.6	14.2	15.7	16.8	16.7	16.3	15.9	17.5	15.5
4-Jul	15.9	16.9	13.8	15.2	16.8	17.3	17.4	16.4	17.5	17.3
5-Jul	17.0	16.2	13.4	15.3	16.9	17.6	18.0	15.4	17.4	18.4
6-Jul	17.0	15.3	13.5	15.2	16.4	17.5	18.6	15.4	16.8	19.4
7-Jul	16.9	14.4	14.4	15.5	17.2	17.1	18.2	15.9	15.9	20.0
8-Jul	17.1	13.6	15.5	16.5	17.2	17.5	17.7	16.0	15.0	20.1
9-Jul	17.8	13.6	15.4	17.5	17.5	17.2	17.3	15.9	13.6	20.0
10-Jul	18.1	13.9	15.7	18.5	17.8	16.9	16.7	16.0	14.0	20.0
11-Jul	17.3	13.9	15.0	19.3	16.5	16.8	17.6	16.0	14.3	19.3
12-Jul	17.2	13.8	15.0	19.2	17.8	16.8	18.1	15.5	14.3	19.0
13-Jul	17.2	14.0	15.4	18.8	18.4	16.5	17.7	15.7	14.6	19.2
14-Jul	17.5	14.1	14.6	18.0	19.4	16.6	17.0	15.7	15.0	19.1
15-Jul	17.4	14.6	14.8	17.8	20.2	17.1	16.5	15.6	14.9	18.5
16-Jul	17.0	15.3	15.4	17.0	19.9	16.8	16.3	16.7	15.2	17.7
17-Jul	17.0	15.7	15.3	16.0	18.7	16.9	16.4	16.1	14.9	17.1
18-Jul	16.6	15.6	15.0	15.5	17.0	17.1	16.5	16.5	14.2	17.2
19-Jul	16.1	16.0	15.9	15.5	18.0	17.6	16.7	16.9	13.1	17.5
20-Jul	15.2	17.2	16.6	15.2	18.1	17.8	17.4	16.8	12.9	17.6
21-Jul	15.2	18.4	16.9	14.3	16.4	17.5	16.7	15.9	12.7	17.2
22-Jul	15.2	17.8	16.0	14.2	17.8	17.8	16.9	16.3	12.6	16.6
23-Jul	14.9	16.6	16.1	14.3	18.9	17.9	17.2	16.6	12.7	16.0
24-Jul	14.0	16.3	16.0	14.2	18.8	17.6	16.8	16.3	12.3	15.7
25-Jul	14.0	15.2	15.2	14.0	17.0	17.2	16.4	16.4	12.1	15.6
26-Jul	14.2	14.5	14.7	13.3	16.9	16.9	15.9	17.0	11.8	16.7
27-Jul	14.4	14.5	14.4	14.3	16.4	16.7	15.5	17.1	12.0	17.0
28-Jul	14.0	14.4	14.2	15.3	17.3	16.7	15.6	17.4	11.6	17.3
29-Jul	14.1	14.5	13.9	15.0	17.3	16.8	17.3	17.4	12.2	18.6
30-Jul	14.1	14.7	14.8	15.3	17.4	16.3	17.2	17.0	13.2	19.7
31-Jul	14.0	14.5	15.3	15.7	17.4	16.5	16.2	16.5	12.6	20.1
1-Aug	13.7	14.8	15.9	16.0	17.0	16.9	15.6	16.4	12.9	20.2
2-Aug	15.1	15.6	17.0	15.2	17.2	16.6	15.3	16.4	13.6	19.2
3-Aug	16.8	16.3	16.9	15.3	17.3	15.9	15.1	16.4	13.6	18.6

DATE	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
4-Aug	16.4	16.3	17.0	15.2	17.6	15.5	15.2	16.1	13.8	19.2
5-Aug	16.3	16.4	17.5	15.5	17.9	15.6	14.3	16.1	14.0	19.3
6-Aug	16.2	16.5	17.4	16.3	18.0	16.0	14.0	15.9	14.9	19.2
7-Aug	16.0	16.7	16.7	16.8	18.4	16.9	13.8	15.5	15.9	18.6
8-Aug	16.0	16.4	14.7	17.3	18.5	18.3	14.1	15.5	15.8	17.9
9-Aug	15.1	16.1	14.1	17.8	18.9	18.6	13.5	16.5	15.6	17.6
10-Aug	16.0	16.3	13.9	17.7	19.6	19.3	13.5	16.7	14.7	17.3
11-Aug	17.0	16.8	13.7	17.7	19.9	19.7	13.6	17.4	14.5	17.0
12-Aug	17.0	16.8	12.9	17.2	19.7	20.0	13.3	17.9	14.5	16.8
13-Aug	17.0	17.4	12.5	16.8	19.0	19.9	13.1	18.1	14.1	16.5
14-Aug	16.4	18.0	13.1	16.5	19.0	19.5	13.2	18.2	13.8	16.2
15-Aug	15.0	18.3	13.2	16.0	19.6	18.7	13.6	18.2	14.2	16.0
16-Aug	15.0	18.1	14.1	15.2	20.3	18.2	13.6	18.4	14.7	15.6
17-Aug	14.8	18.0	13.4	15.0	20.5	17.8	13.3	18.8	14.7	14.1
18-Aug	15.0	16.9	13.2	15.2	20.5	17.2	12.5	18.2	14.6	14.0
19-Aug	15.8	16.7	13.1	15.0	19.8	16.5	13.3	17.3	15.2	14.1
20-Aug	14.5	16.7	13.2	14.8	19.0	16.1	13.6	16.7	16.5	14.4
21-Aug	14.0	16.7	12.3	14.3	18.6	15.9	13.5	16.3	16.3	14.4
22-Aug	13.0	16.8	12.2	14.3	18.7	15.6	13.5	16.0	15.2	13.9
23-Aug	13.0	16.1	12.3	14.8	18.3	15.4	13.7	15.5	14.4	13.3
24-Aug	13.5	15.8	12.5	14.7	17.9	14.9	13.5	15.5	14.3	13.1
25-Aug	13.5	15.3	12.4	14.5	17.8	14.7	12.8	15.5	13.6	12.8
26-Aug	13.5	15.2	12.4	14.7	17.3	14.7	12.9	15.2	12.7	12.6
27-Aug	14.0	14.9	12.5	14.8	17.0	15.1	12.9	15.5	12.5	12.5
28-Aug	13.6	14.8	12.1	14.3	16.9	15.1	13.0	15.5	12.8	12.4
29-Aug	13.7	14.8	12.3	14.7	16.7	14.3	12.9	16.0	12.9	12.6
30-Aug	14.4	14.4	12.2	14.3	16.7	13.8	13.0	16.2	13.0	12.4
31-Aug	14.0	14.2	11.9	14.0	16.7	13.4	13.0	15.8	13.0	12.6
1-Sep	14.2	13.8	12.2	13.2	16.6	13.4	12.1	15.3	12.8	13.0
2-Sep	13.5	13.2	12.4	13.0	16.6	13.9	11.9	14.8	12.5	13.4
3-Sep	13.4	13.1	12.7	12.7	16.2	14.0	12.5	15.0	12.7	13.7
4-Sep	13.4	13.0	13.0	12.7	15.7	14.1	13.4	14.9	12.5	13.6
5-Sep	12.8	12.7	13.5	13.3	15.3	13.4	13.2	14.3	12.6	13.4
6-Sep	12.8	12.4	13.8	13.2	14.8	13.0	13.3	13.6	13.0	13.4
7-Sep	12.0	12.3	13.2	13.2	14.4	13.1	12.8	13.5	13.1	12.9
8-Sep	12.0	12.1	12.8	12.3	14.3	13.3	12.8	13.2	12.6	12.5
9-Sep	12.0	12.1	12.2	12.0	14.0	13.6	12.4	13.1	12.4	12.1
10-Sep	12.0	12.5	12.2	12.0	13.8	13.4	12.0	13.2	12.1	13.0
11-Sep	11.6	12.4	12.0	12.0	13.5	13.3	11.9	13.3	11.5	12.9
12-Sep	11.8	12.2	12.0	12.0	13.2	13.1	11.9	13.7	11.5	12.8
13-Sep	11.6	11.5	12.1	11.5	12.9	13.2	11.7	13.9	11.4	12.4
14-Sep	10.8	11.6	12.0	11.0	12.6	13.7	12.1	13.7	11.2	12.3
15-Sep	11.0	11.8	11.7	11.0	12.7	14.0	11.6	13.3	11.1	12.4
16-Sep	10.7	12.0	11.7	10.5	12.4	13.1	11.6	12.7	11.1	12.3
17-Sep	10.5	12.0	11.3	10.0	12.5	12.4	11.6	12.1	10.8	12.1
18-Sep	10.6	11.8	10.9	10.0	12.4	11.7	11.5	11.7	11.1	12.0
19-Sep	10.8	11.8	10.7	10.0	12.0	11.4	11.3	11.6	11.0	12.1
20-Sep	10.4	11.5	11.0	10.0	11.9	11.3	11.0	11.2	10.9	11.8
21-Sep	10.2	11.3	10.8	10.0	11.6	11.4	11.1	11.0	10.7	11.5
22-Sep	10.5	11.3	10.7	9.9	11.2	11.3	11.0	10.8	10.7	11.4
23-Sep	10.4	11.1	10.6	10.0	11.1	11.3	11.0	11.0	10.6	11.3
24-Sep	11.0	10.8	10.6	9.8	10.7	11.1	11.0	10.6	10.3	11.0
25-Sep	11.3	10.7	10.7	9.6	10.5	11.0	10.3	10.3	10.1	10.7
26-Sep	11.8	10.5	10.6	9.7	10.6	10.8	10.8	10.1	10.1	10.4
27-Sep	11.1	10.5	10.7	9.5	10.3	10.5	10.6	10.0	9.6	10.2
28-Sep	11.0	10.3	10.8	9.4	10.1	10.2	10.5	9.8	9.9	10.0
29-Sep	10.7	10.1	10.7	9.9	9.9	10.1	10.1	9.6	9.7	9.8
30-Sep	10.1	10.0	10.2	10.0	9.8	9.9	10.1	9.7	9.6	9.8

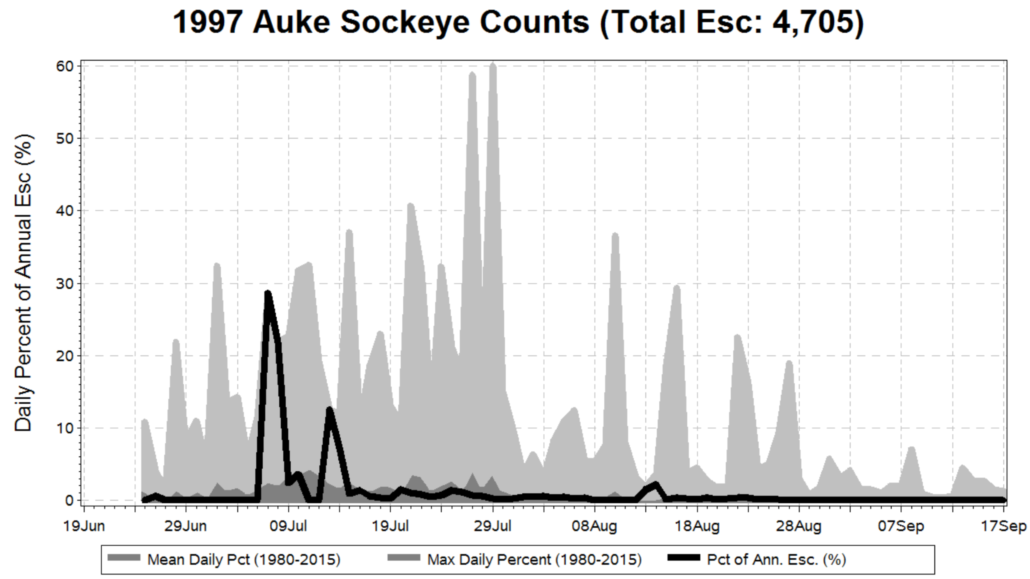
Appendix F. AUKE CREEK daily water temperature observations, 2010-2016 (cont'd).

DATE	2010	2012	2013	2014	2015	2016
1-Jun	17.2	9.3	11.5	14.8	13.9	
2-Jun	16.1	8.9	9.6	14.8	13.7	
3-Jun	15.2	9.5	10.7	14.8	13.5	
4-Jun	14.8	11.0	11.0	15.6	13.6	
5-Jun	14.4	12.0	11.1	15.6	13.8	
6-Jun	14.2	12.3	9.9	16.2	14	
7-Jun	14.7	12.5	10.7	16	14.5	
8-Jun	14.9	10.1	11.4	14.8	14.5	
9-Jun	15.2	10.8	12.0	15.2	14.6	
10-Jun	15.2	10.7	14.0	15.6	13.7	
11-Jun	13.8	11.0	15.6	16.6	14.4	
12-Jun	12.4	10.8	15.9	16.2	14.2	
13-Jun	11.8	10.6	16.2	15.6	14.5	
14-Jun	12.3	10.7	16.6	15.2	16.2	
15-Jun	12.7	11.1	17.7	15.6	17.2	
16-Jun	12.7	11.2	19.1	16.6	17.0	
17-Jun	13.3	11.3	19.4	16.0	17.3	
18-Jun	13.5	12.0	18.8	16.0	17.1	
19-Jun	13.6	12.0	19.2	15.6	17.1	
20-Jun	14.6	11.9	19.6	15.6	16.6	
21-Jun	15.1	13.0	19.0	16.0	16.6	
22-Jun	14.6	14.8	18.4	15.6	17.7	
23-Jun	15.2	16.9	17.5	16.2	18.0	
24-Jun	16.2	17.1	17.4	14.4	17.9	
25-Jun	16.0	16.0	17.8	14.0	17.4	
26-Jun	16.0	15.5	17.2	15.6	16.9	
27-Jun	15.7	14.4	16.5	17.0	17.0	
28-Jun	15.7	14.3	16.9	17.4	17.2	
29-Jun	16.2	13.6	17.0	17.4	17.2	17.6
30-Jun	15.9	12.8	17.4	17.0	17.2	18.1
1-Jul	14.9	12.4	17.6	17.4	16.8	17.9
2-Jul	14.9	12.3	17.7	17.4	15.7	17.3
3-Jul	14.8	13.1	16.8	16.2	15.4	17.6
4-Jul	14.4	12.6	16.5	17.0	16.6	17.7
5-Jul	13.9	13.1	16.5	17.8	17.8	17.9
6-Jul	13.9	13.9	16.5	18.6	19.0	17.7
7-Jul	14.2	14.1	16.9	16.2	19.2	17.7
8-Jul	15.8	14.0	16.4	16.0	18.0	18.3
9-Jul	17.0	14.2	15.6	16.6	18.4	18.3
10-Jul	17.4	12.3	15.2	17.0	17.6	18.3
11-Jul	15.6	12.9	16.2	16.2	17.3	18.0
12-Jul	15.3	13.0	15.9	15.6	17.6	18.2
13-Jul	15.2	14.1	15.9	15.6	16.1	18.2
14-Jul	14.7	14.0	16.2	16.0	15.3	17.7
15-Jul	14.6	14.2	17.1	17.4	15.5	17.4
16-Jul	14.8	15.0	17.4	17.4	15.1	17.2
17-Jul	15.0	14.7	18.2	17.0	14.8	17.3
18-Jul	15.0	14.8	18.3	17.8	15.2	17.6
19-Jul	15.0	15.0	17.5	17.8	14.9	18.1
20-Jul	15.3	16.5	16.7	17.0	15.2	17.8
21-Jul	15.2	16.7	16.4	18.6	17.1	17.0
22-Jul	15.2	16.9	16.9	18.6	16.3	16.8
23-Jul	14.9	16.9	17.7	19.0	15.4	16.7
24-Jul	14.2	16.9	17.9	17.8	15.9	15.6
25-Jul	14.1	16.9	17.7	17.4	15.7	15.1
26-Jul	14.5	17.2	17.4	17.0	14.9	15.0
27-Jul	15.0	17.6	17.0	16.6	13.7	14.6
28-Jul	16.4	17.3	16.8	16.6	13.7	14.2
29-Jul	16.4	17.0	17.4	16.0	13.9	15.2
30-Jul	16.5	16.9	17.8	16.6	14.2	15.8
31-Jul	17.4	16.3	17.8	17.0	14.2	15.7
1-Aug	17.2	16.2	17.6	18.2	14.9	15.6
2-Aug	17.1	16.1	17.2	19.3	15.8	15.6
3-Aug	17.1	15.0	17.0	19.7	16.6	15.4

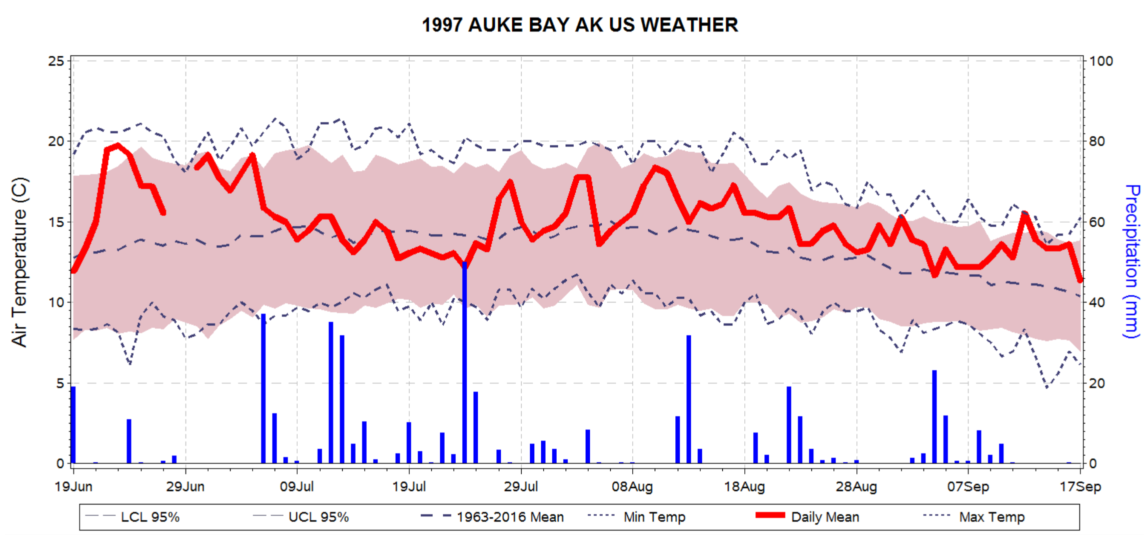
DATE	2010	2012	2013	2014	2015	2016
4-Aug	18.0	15.0	16.4	19.3	17.1	15.8
5-Aug	18.8	15.5	15.8	19.3	17.7	16.3
6-Aug	18.5	14.7	16.0	18.2	16.9	16.7
7-Aug	17.9	14.5	16.1	18.2	17.5	16.9
8-Aug	16.9	14.6	16.3	18.2	17.7	16.5
9-Aug	16.6	13.4	16.3	16.0	17.9	16.3
10-Aug	16.4	14.2	16.2	16.0	17.2	16.2
11-Aug	16.2	14.8	16.0	15.2	16.4	15.5
12-Aug	16.2	14.7	16.4	16.2	15.0	15.8
13-Aug	16.7	14.7	16.7	16.2	15.6	15.9
14-Aug	17.2	16.2	16.7	15.2	16.2	15.1
15-Aug	18.1	16.9	16.4	15.6	16.9	15.2
16-Aug	18.8	17.4	16.6	15.2	15.8	15.5
17-Aug	18.8	16.7	17.8	14.8	14.9	15.8
18-Aug	17.6	16.4	17.7	15.2	14.8	16.0
19-Aug	16.3	16.7	17.1	15.2	15.0	15.8
20-Aug	16.1	17.1	16.8	16.2	14.7	16.1
21-Aug	16.1	17.2	16.3	16.6	15.4	15.7
22-Aug	16.3	16.6	16.1	17.4	13.9	16.3
23-Aug	15.7	15.8	15.9	17.4	13.6	16.2
24-Aug	15.2	15.3	15.6	17.0	14.1	16.2
25-Aug	15.5	14.7	15.4	16.2	14.7	16.0
26-Aug	15.6	14.6	15.5	15.6	15.8	15.8
27-Aug	15.2	14.9	15.6	16.0	13.8	16.5
28-Aug	14.9	13.8	16.3	15.6	13.5	16.9
29-Aug	14.9	13.6	16.2	15.6	13.1	16.7
30-Aug	15.0	14.3	16.0	15.2	12.3	16.2
31-Aug	15.0	14.4	15.6	14.8	11.8	16.3
1-Sep	15.0	14.3	15.0	14.4	12.0	15.9
2-Sep	14.6	13.3	15.1	14.8	12.4	16.2
3-Sep	14.8	13.2	15.6	14.4	12.7	16.2
4-Sep	14.6	12.5	15.3	14.0	12.8	16.2
5-Sep	14.3	12.7	15.0	14.4	13.1	15.8
6-Sep	13.9	12.7	15.3	14.0	12.9	14.8
7-Sep	14.6	12.5	15.1	13.6	12.5	14.8
8-Sep	14.8	12.0	14.7	13.6	12.5	14.5
9-Sep	14.6	11.4	14.9	14.0	12.9	13.7
10-Sep	14.0	11.3	14.7	14.0	12.0	13.2
11-Sep	13.9	11.2	14.6	13.6	12.1	13.3
12-Sep	14.3	10.8	15.3	14.0	11.9	13.3
13-Sep	14.5	10.7	15.1	14.0	11.8	12.8
14-Sep	14.4	10.0	15.1	14.4	11.6	13.1
15-Sep	14.4	10.4	14.7	14.8	11.3	12.6
16-Sep	14.4	10.3	14.8	15.2	10.8	12.3
17-Sep	14.4	10.4	14.2	14.8	10.6	12.2
18-Sep	14.1	10.6	13.7	14.0	10.6	12.1
19-Sep	13.6	10.6	13.2	14.0	10.4	12.2
20-Sep	13.0	10.8	12.9	13.2	10.3	12.2
21-Sep	12.5	11.6	12.3	13.2	10	12.1
22-Sep	12.3	12.2	11.8	13.2	9.8	11.8
23-Sep	12.1	11.8	11.7	13.2	10.1	11.5
24-Sep	11.9	11.5	11.8	13.2	9.7	11.2
25-Sep	11.8	11.2	11.6	13.2	9.1	11.0
26-Sep	11.8	10.8	11.4	13.2	9.6	11.1
27-Sep	11.7	10.4	11.1	13.2	9.7	11.1
28-Sep	11.5	10.0	10.8	12.9	9.8	10.8
29-Sep	11.3	9.8	10.7	12.9	9.5	10.6
30-Sep	11.2	9.6	10.7	12.7	9.5	10.6

Appendix G. Multi-panel plots of daily Auke Sockeye migration in relation to environmental variables, by year, 1980-2016.

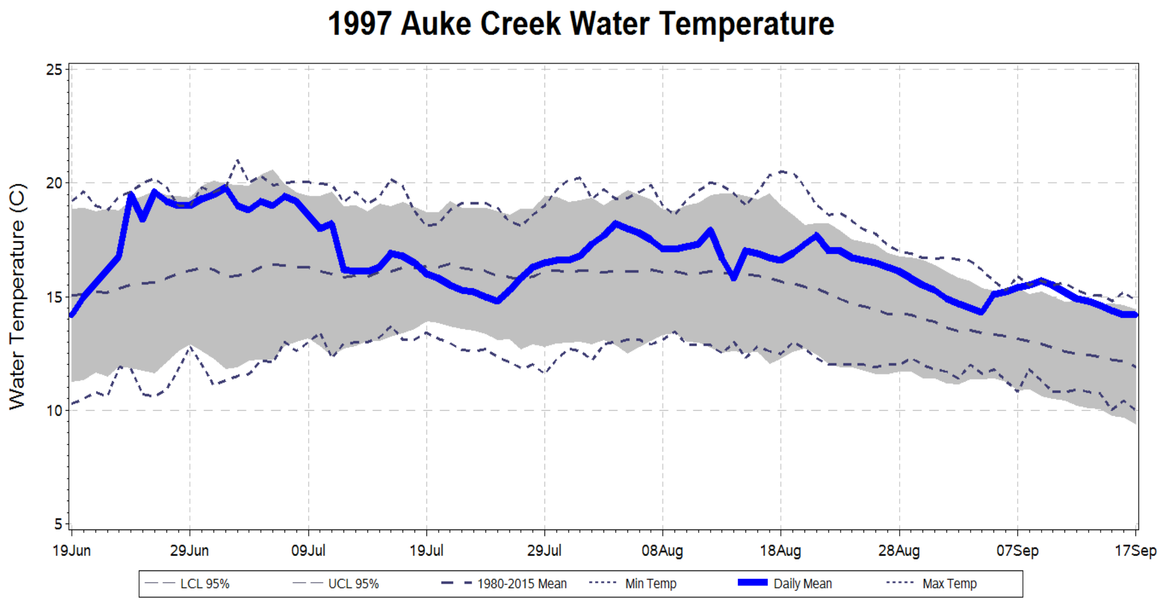
Sample plots for the year 1997 (below) display legend with vertical axis variates and horizontal axis with day of year (month label is *approximate* start of each month). Annual plots (following pages) are organized in a multi-panel format for cross-comparison of the following co-variates:



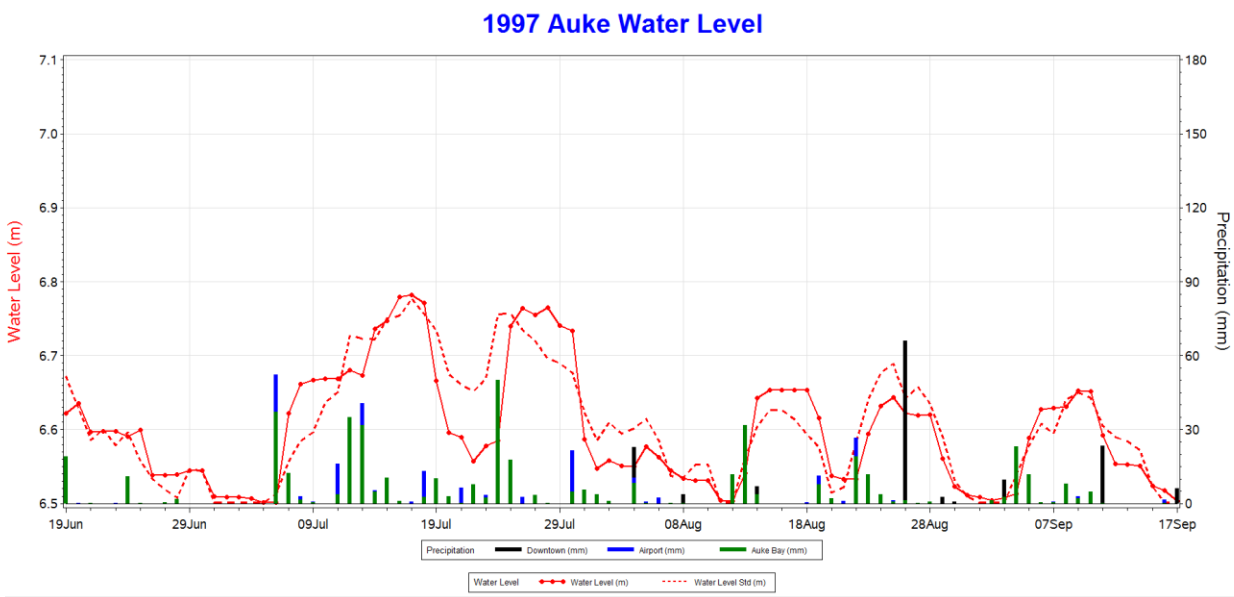
1. Daily average migrant counts (adult + jack; black line) as a percent (%) of annual total of average daily Sockeye migrants counted at Auke Creek. Historical mean daily migration % (dark gray area) and maximum daily migration % (light gray area) derived from years 1980-2016.



2. Observed precipitation (mm, blue bars), and regional daily mean air temperature (°C, red line) based on NOAA meteorological station near Juneau, AK (Auke Bay station GHCND USC00500464) with historical daily mean and variance (dashed line and red area), 1980-2015.

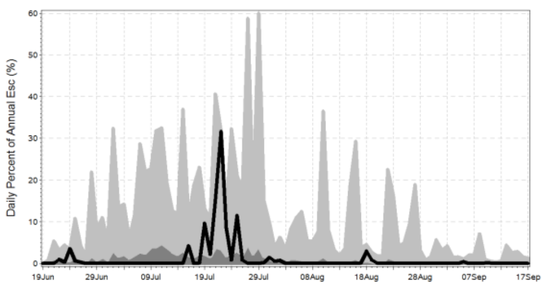


3. Observed (solid blue line) and estimated (dashed blue line) daily mean water temperature (°C) in Auke Creek, with 1980-2016 daily minimum, mean, and maximum (thin dashed lines) and variance (gray area).

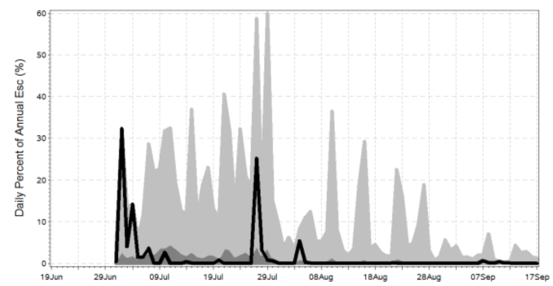


4. Daily mean water level (observed: solid red line; estimated: red dashed line) at the AUKE CREEK WEIR (m ASL), with observed precipitation (mm, bars) by meteorological station.

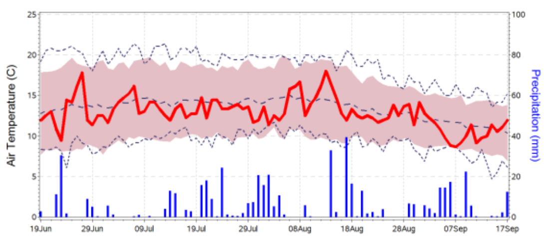
1980 Auke Sockeye Counts (Total Esc: 4,570)



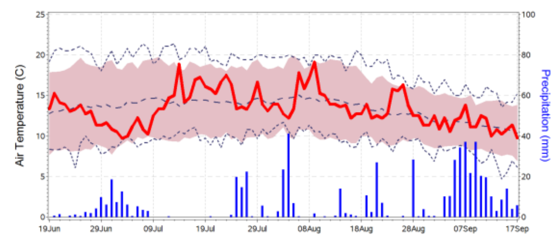
1981 Auke Sockeye Counts (Total Esc: 4,089)



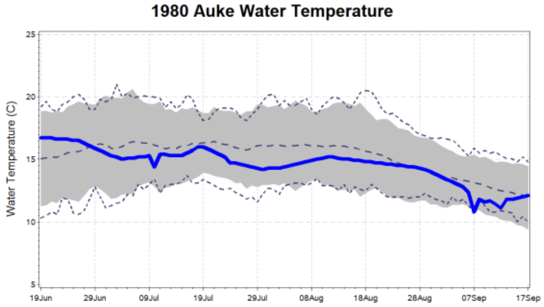
1980 AUKE BAY AK US WEATHER



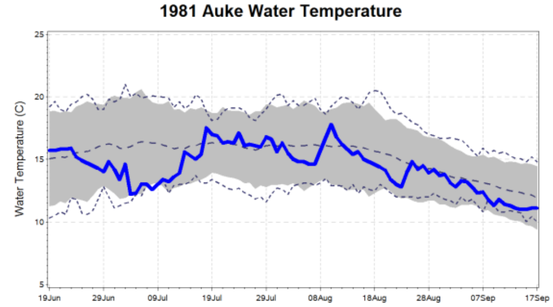
1981 AUKE BAY AK US WEATHER



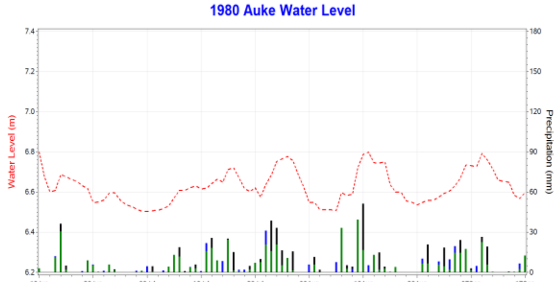
1980 Auke Water Temperature



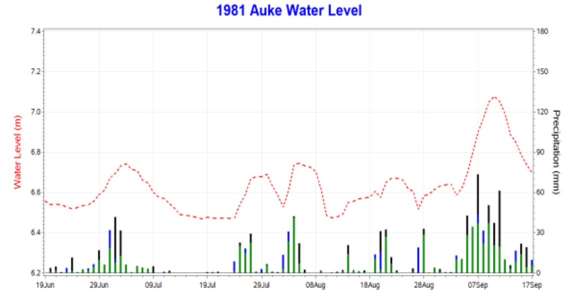
1981 Auke Water Temperature

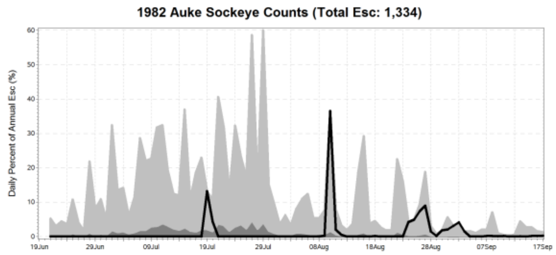


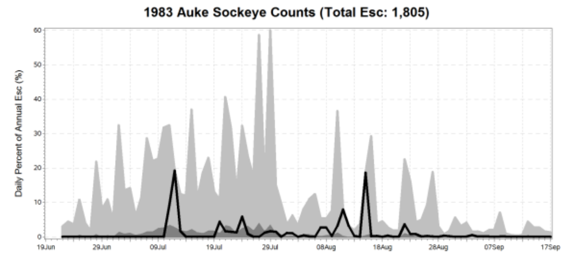
1980 Auke Water Level

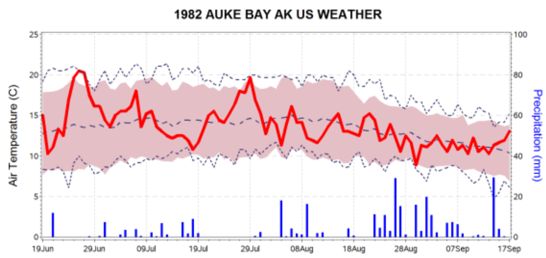


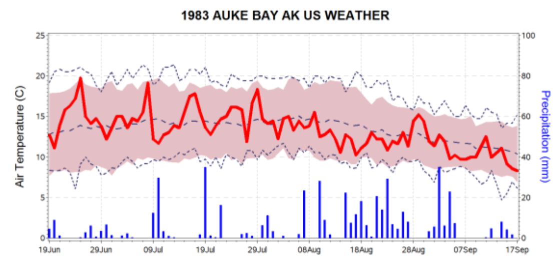
1981 Auke Water Level

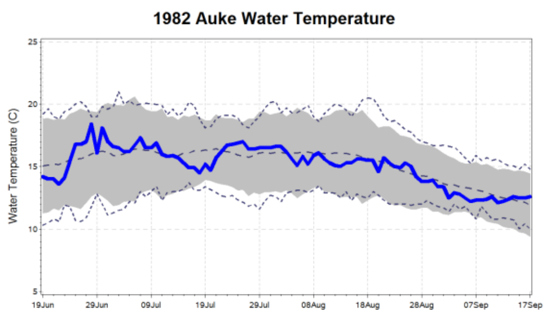


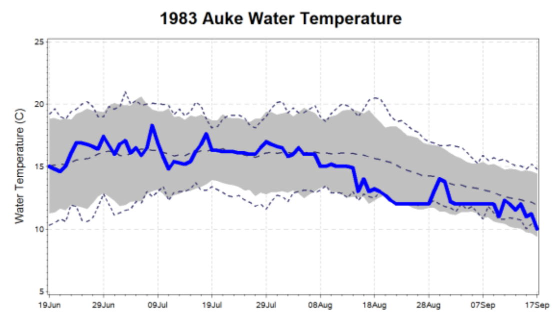

1982 Auke Sockeye Counts (Total Esc: 1,334)
Daily Percent of Annual Esc (%)

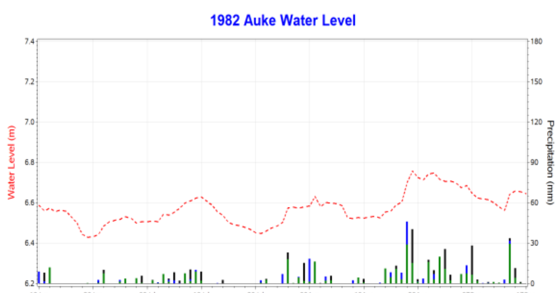

1983 Auke Sockeye Counts (Total Esc: 1,805)
Daily Percent of Annual Esc (%)

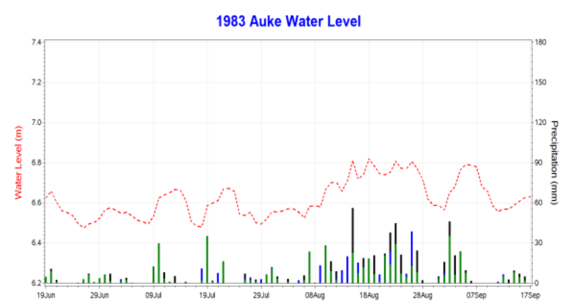

1982 AUKE BAY AK US WEATHER
Air Temperature (C)
Precipitation (mm)

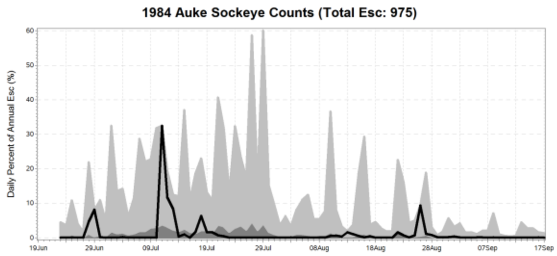

1983 AUKE BAY AK US WEATHER
Air Temperature (C)
Precipitation (mm)

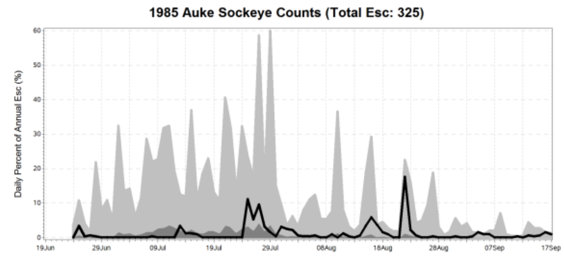

1982 Auke Water Temperature
Water Temperature (C)

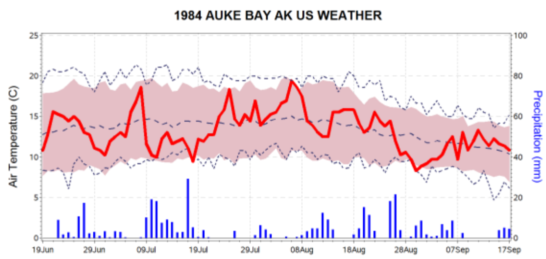

1983 Auke Water Temperature
Water Temperature (C)

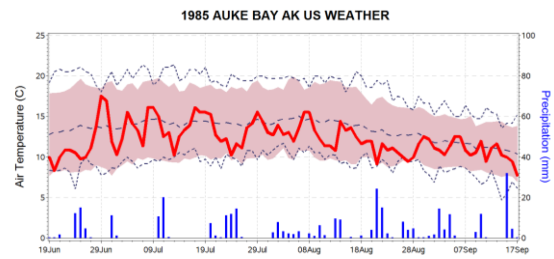

1982 Auke Water Level
Water Level (m)
Precipitation (mm)

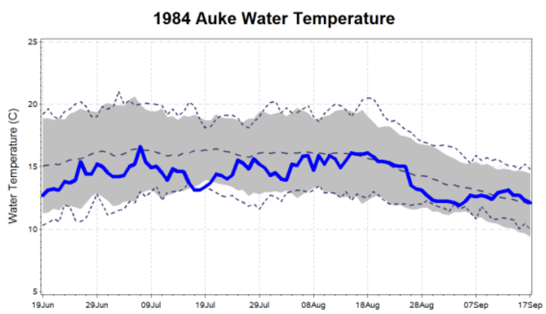

1983 Auke Water Level
Water Level (m)
Precipitation (mm)

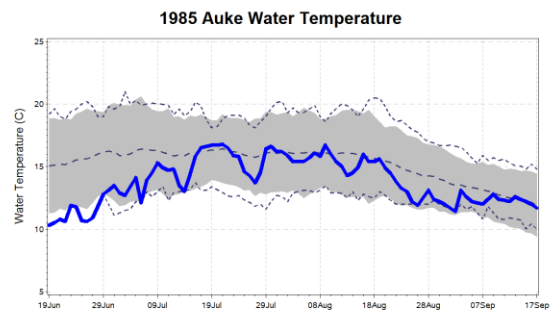

1984 Auke Sockeye Counts (Total Esc: 975)
Daily Percent of Annual Esc (%)

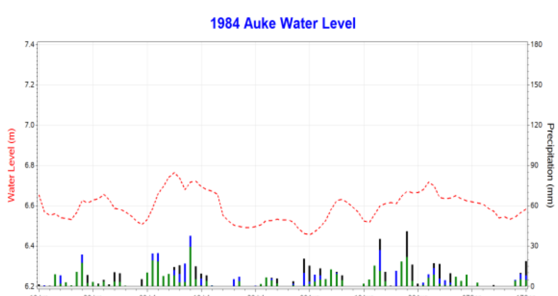

1985 Auke Sockeye Counts (Total Esc: 325)
Daily Percent of Annual Esc (%)

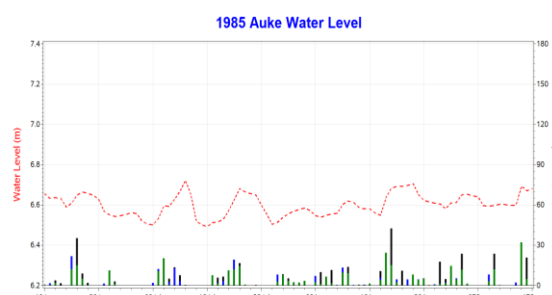

1984 AUKE BAY AK US WEATHER
Air Temperature (C)
Precipitation (mm)


1985 AUKE BAY AK US WEATHER
Air Temperature (C)
Precipitation (mm)

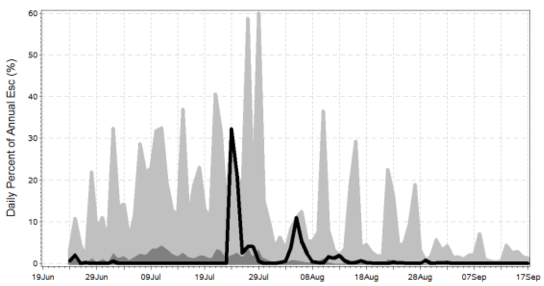

1984 Auke Water Temperature
Water Temperature (C)


1985 Auke Water Temperature
Water Temperature (C)

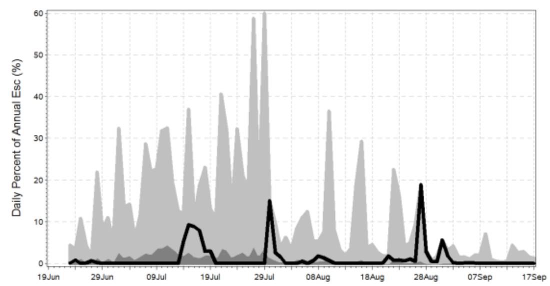

1984 Auke Water Level
Water Level (m)
Precipitation (mm)


1985 Auke Water Level
Water Level (m)
Precipitation (mm)

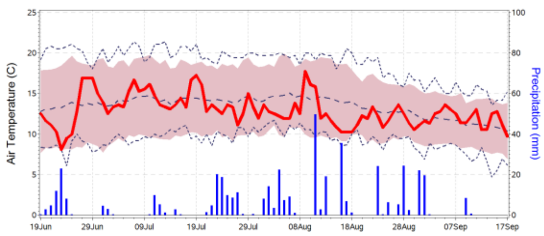
1986 Auke Sockeye Counts (Total Esc: 1,033)



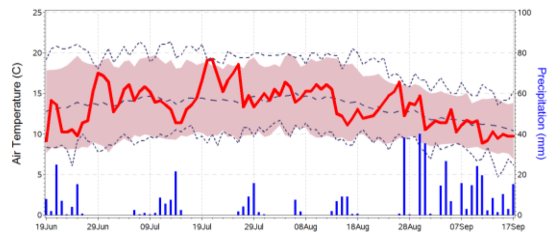
1987 Auke Sockeye Counts (Total Esc: 2,896)



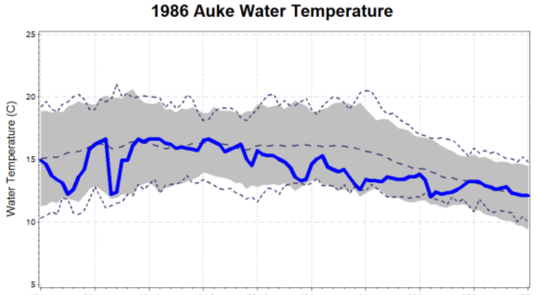
1986 AUKE BAY AK US WEATHER



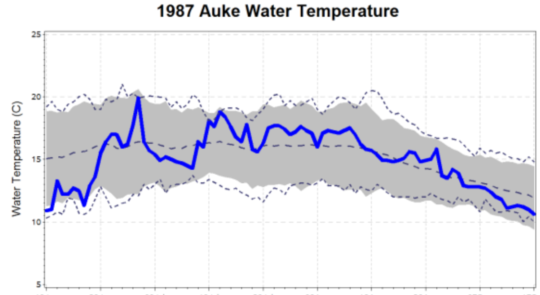
1987 AUKE BAY AK US WEATHER



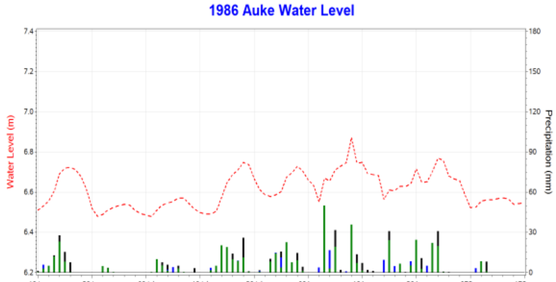
1986 Auke Water Temperature



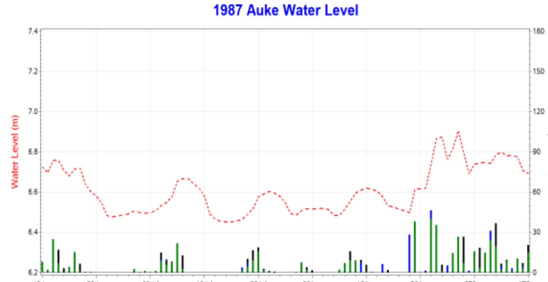
1987 Auke Water Temperature

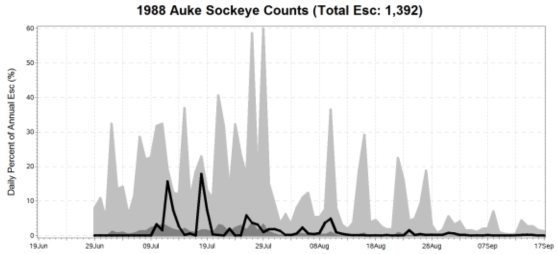


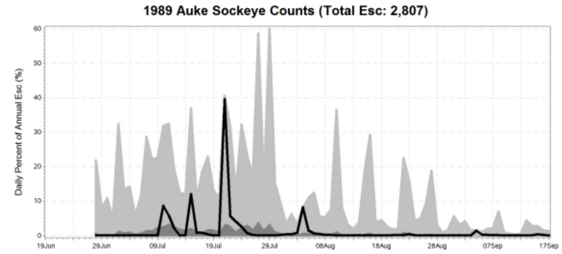
1986 Auke Water Level

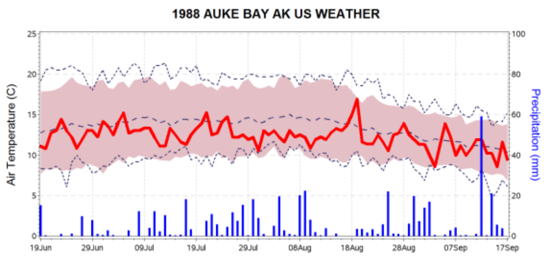


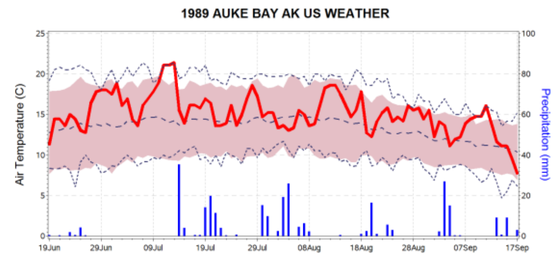
1987 Auke Water Level

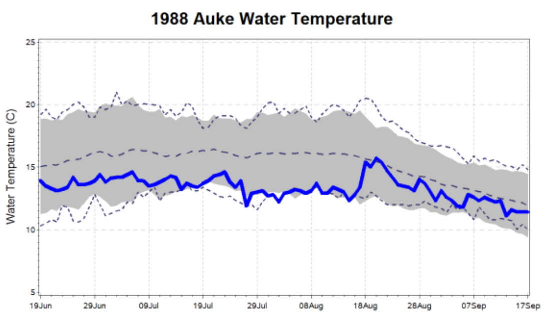


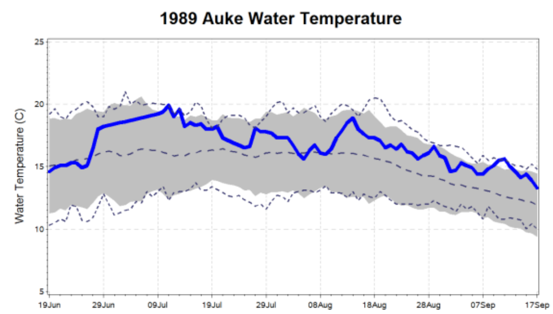

1988 Auke Sockeye Counts (Total Esc: 1,392)
Daily Percent of Annual Esc (%)

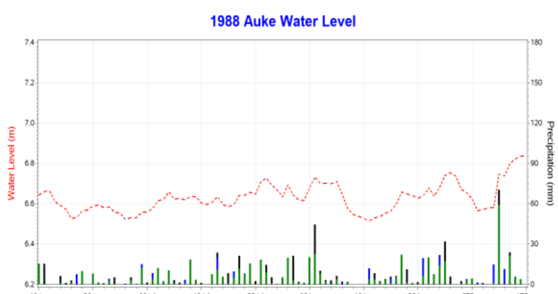

1989 Auke Sockeye Counts (Total Esc: 2,807)
Daily Percent of Annual Esc (%)

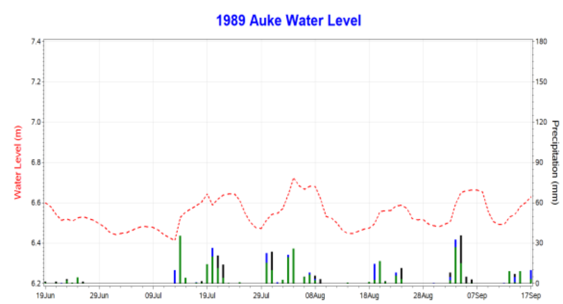

1988 AUKE BAY AK US WEATHER
Air Temperature (C)
Precipitation (mm)


1989 AUKE BAY AK US WEATHER
Air Temperature (C)
Precipitation (mm)

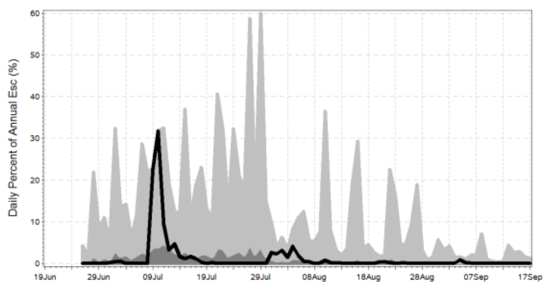

1988 Auke Water Temperature
Water Temperature (C)


1989 Auke Water Temperature
Water Temperature (C)

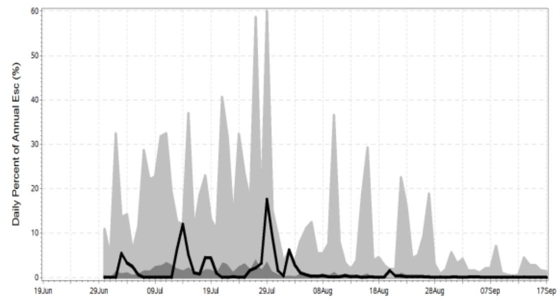

1988 Auke Water Level
Water Level (m)
Precipitation (mm)


1989 Auke Water Level
Water Level (m)
Precipitation (mm)

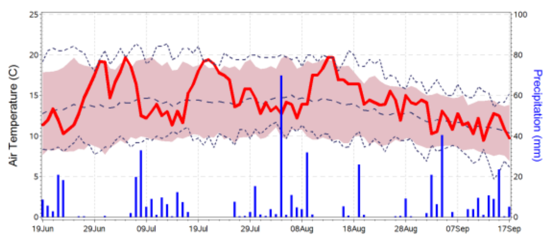
1990 Auke Sockeye Counts (Total Esc: 3,452)



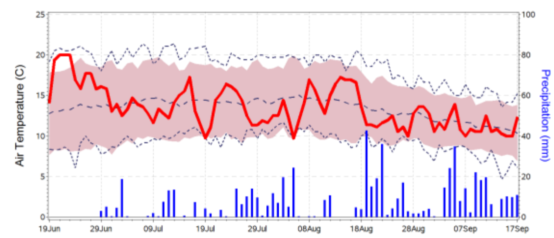
1991 Auke Sockeye Counts (Total Esc: 2,764)



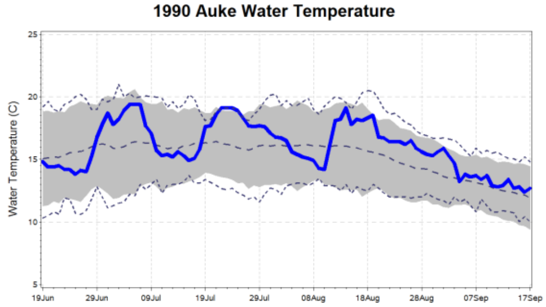
1990 AUKE BAY AK US WEATHER



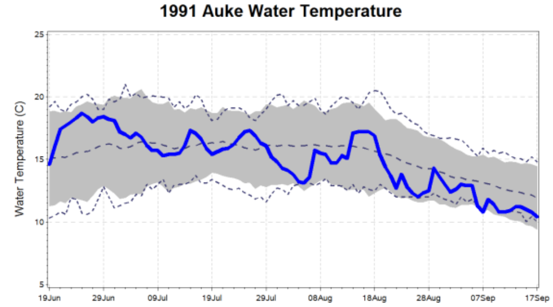
1991 AUKE BAY AK US WEATHER



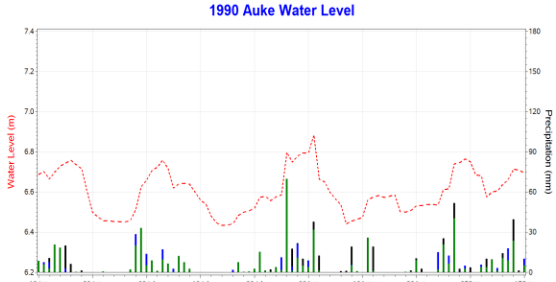
1990 Auke Water Temperature



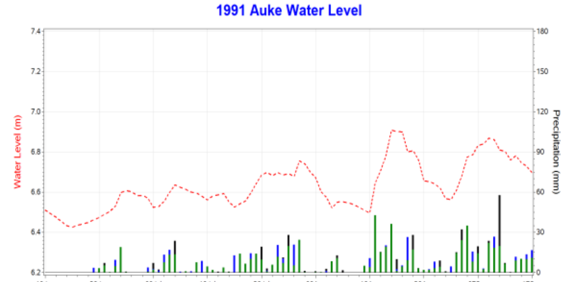
1991 Auke Water Temperature



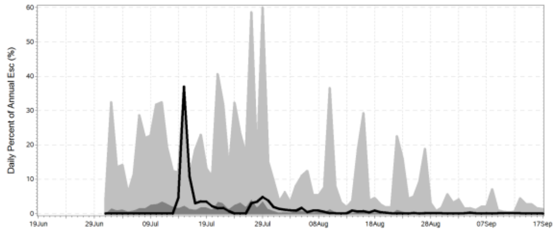
1990 Auke Water Level



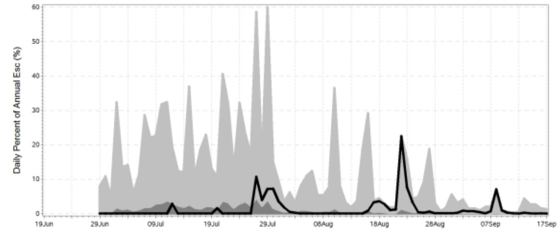
1991 Auke Water Level



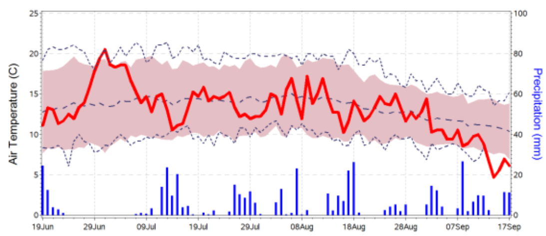
1992 Auke Sockeye Counts (Total Esc: 1,668)



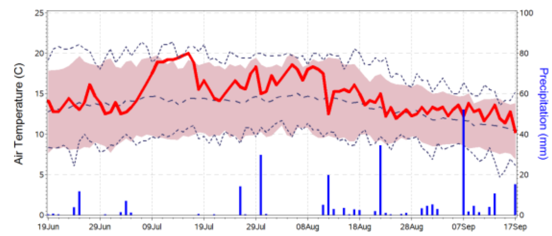
1993 Auke Sockeye Counts (Total Esc: 3,058)



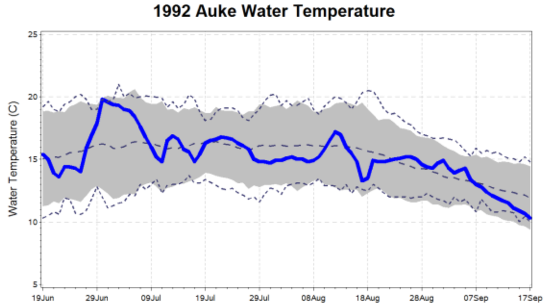
1992 AUKE BAY AK US WEATHER



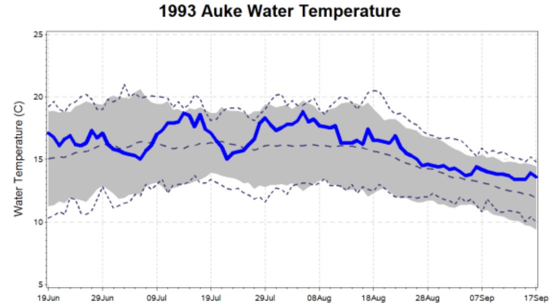
1993 AUKE BAY AK US WEATHER



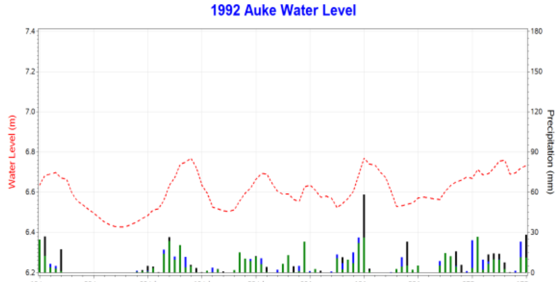
1992 Auke Water Temperature



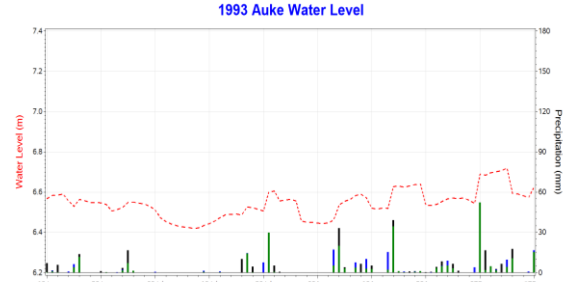
1993 Auke Water Temperature



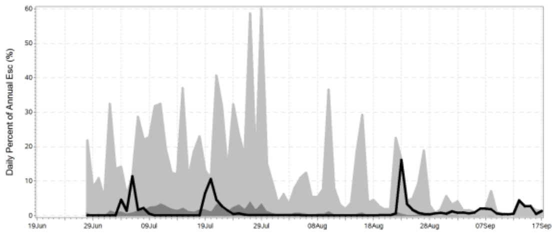
1992 Auke Water Level



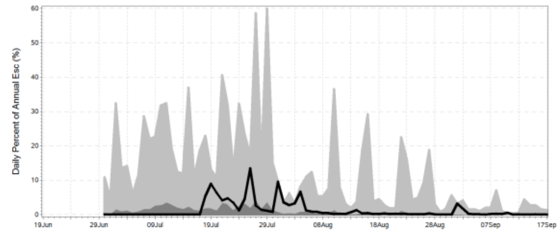
1993 Auke Water Level



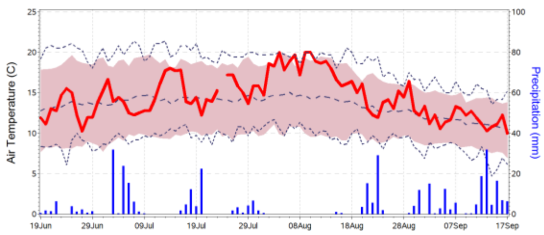
1994 Auke Sockeye Counts (Total Esc: 3,869)



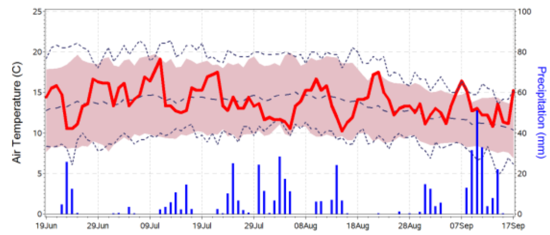
1995 Auke Sockeye Counts (Total Esc: 3,371)



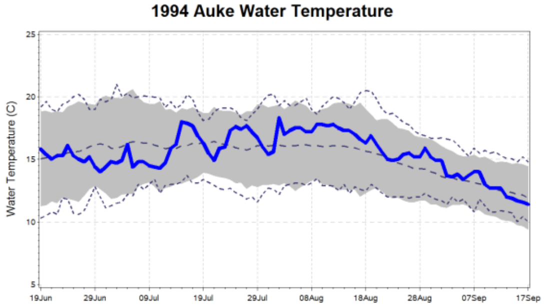
1994 AUKE BAY AK US WEATHER



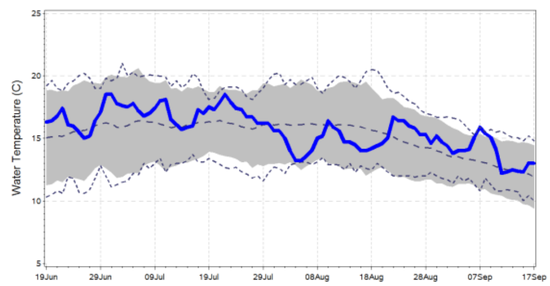
1995 AUKE BAY AK US WEATHER



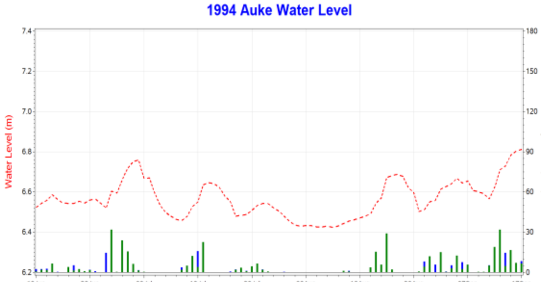
1994 Auke Water Temperature



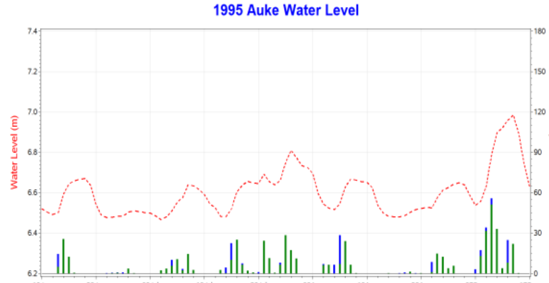
1995 Auke Water Temperature



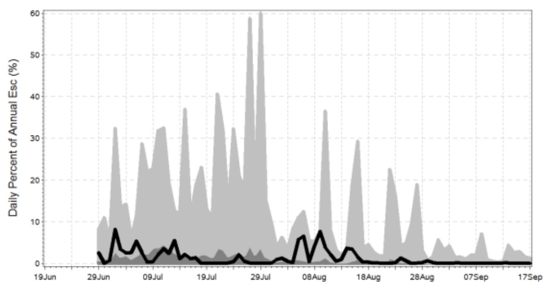
1994 Auke Water Level



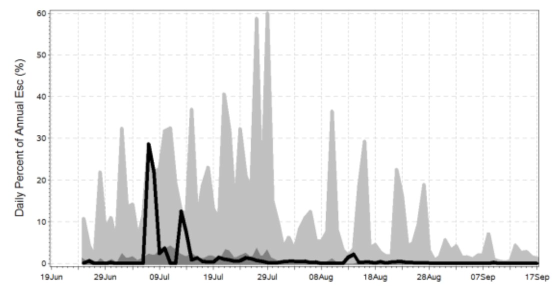
1995 Auke Water Level



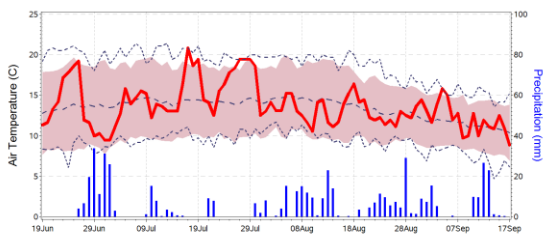
1996 Auke Sockeye Counts (Total Esc: 6,123)



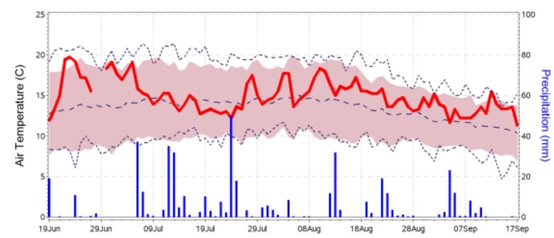
1997 Auke Sockeye Counts (Total Esc: 4,705)



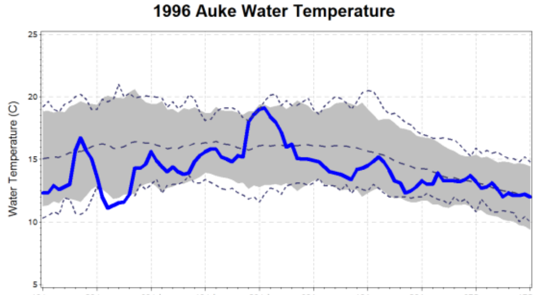
1996 AUKE BAY AK US WEATHER



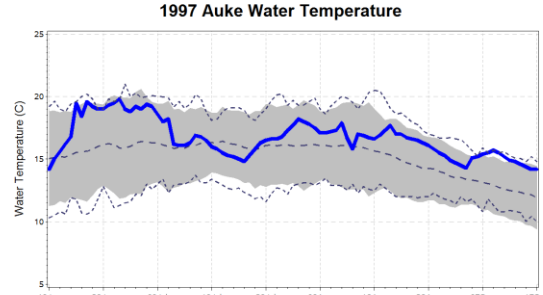
1997 AUKE BAY AK US WEATHER



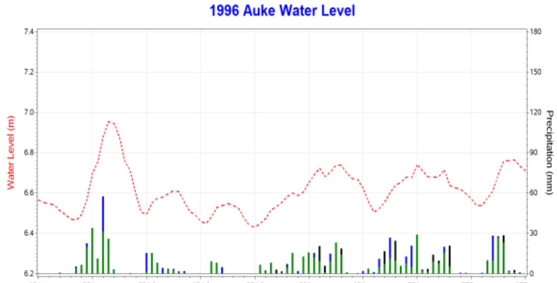
1996 Auke Water Temperature



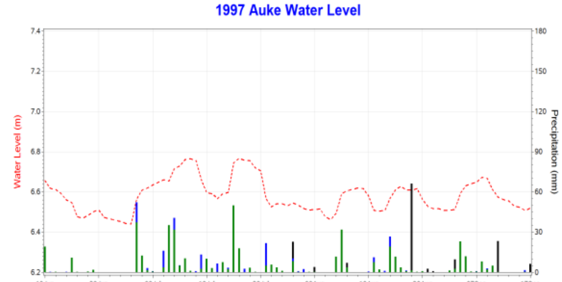
1997 Auke Water Temperature



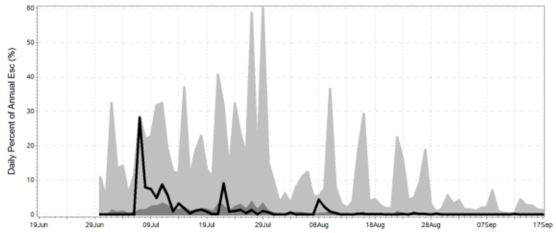
1996 Auke Water Level



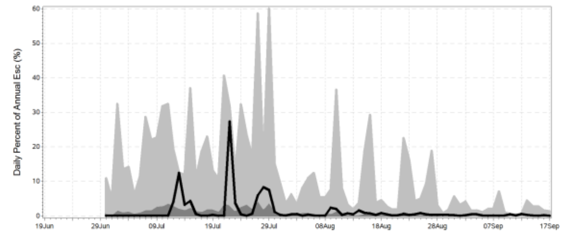
1997 Auke Water Level



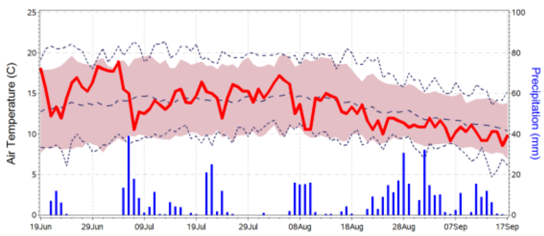
1998 Auke Sockeye Counts (Total Esc: 2,139)



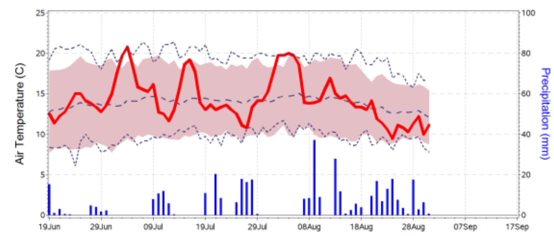
1999 Auke Sockeye Counts (Total Esc: 1,681)



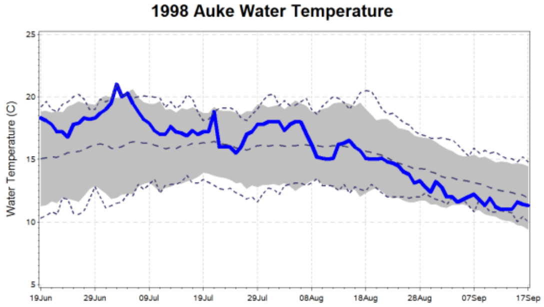
1998 AUKE BAY AK US WEATHER



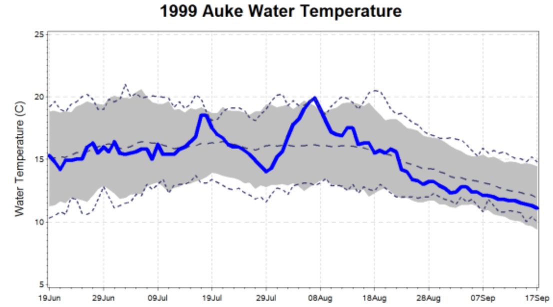
1999 AUKE BAY AK US WEATHER



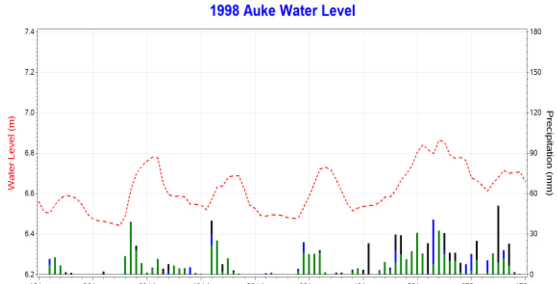
1998 Auke Water Temperature



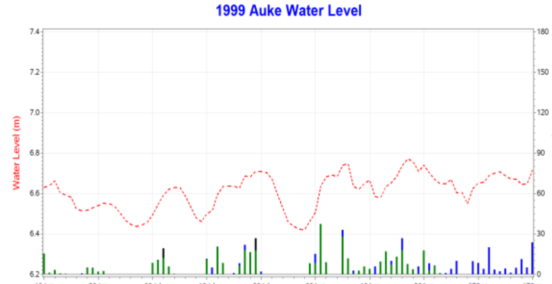
1999 Auke Water Temperature



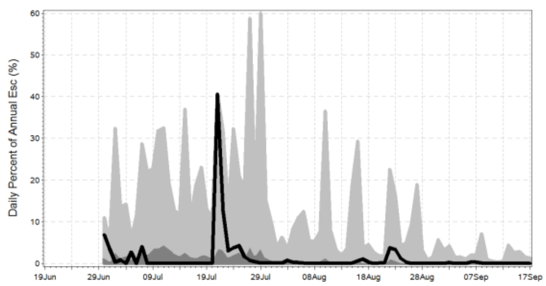
1998 Auke Water Level



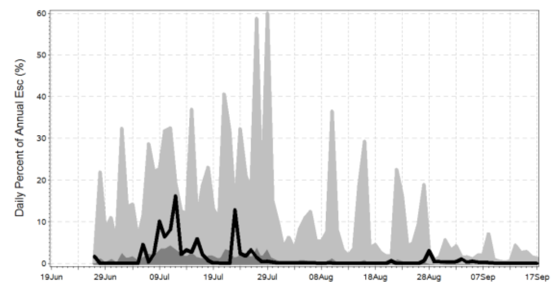
1999 Auke Water Level



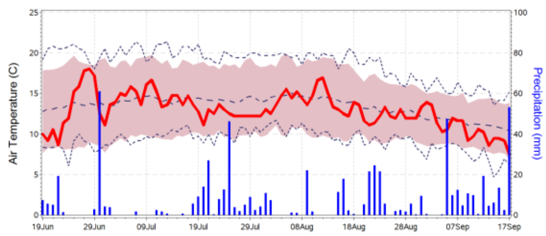
2000 Auke Sockeye Counts (Total Esc: 2,513)



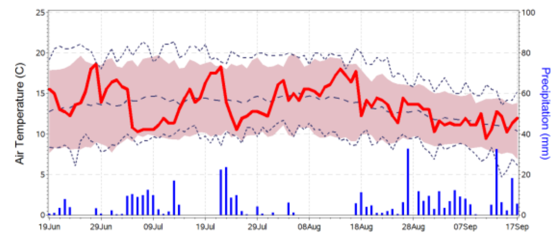
2001 Auke Sockeye Counts (Total Esc: 4,009)



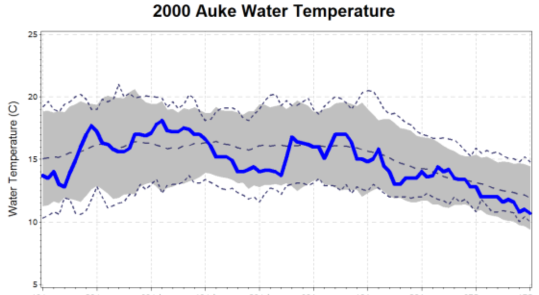
2000 AUKE BAY AK US WEATHER



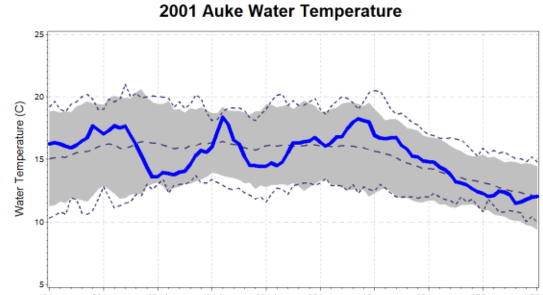
2001 AUKE BAY AK US WEATHER



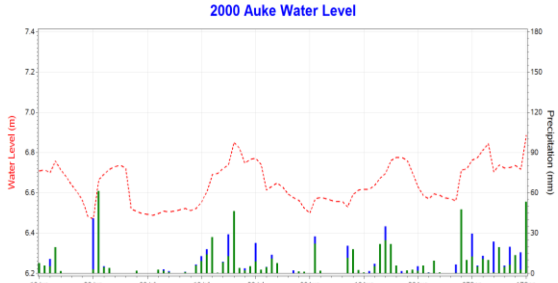
2000 Auke Water Temperature



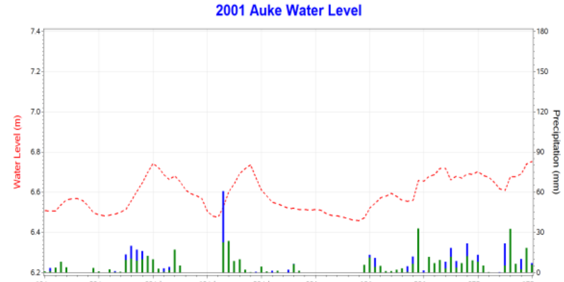
2001 Auke Water Temperature



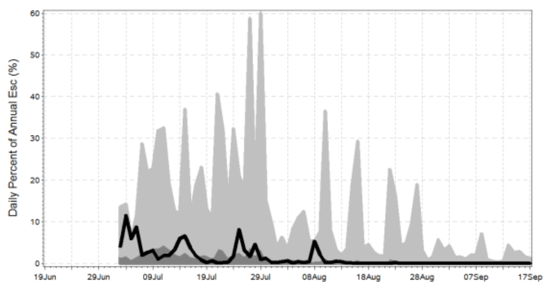
2000 Auke Water Level



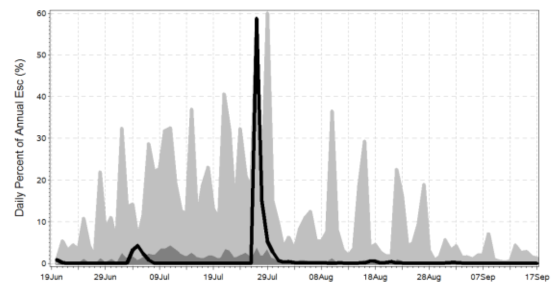
2001 Auke Water Level



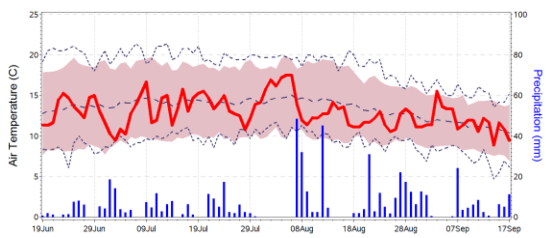
2002 Auke Sockeye Counts (Total Esc: 3,012)



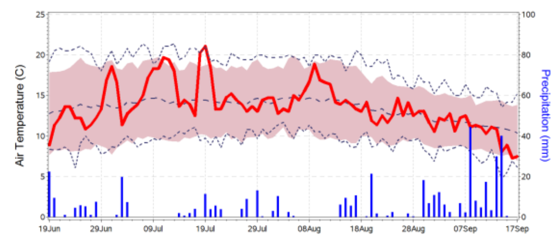
2003 Auke Sockeye Counts (Total Esc: 3,397)



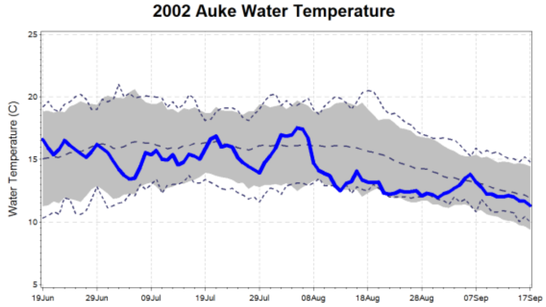
2002 AUKE BAY AK US WEATHER



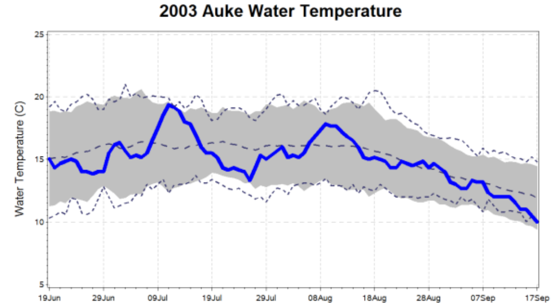
2003 AUKE BAY AK US WEATHER



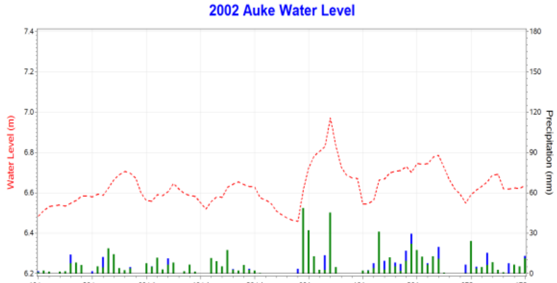
2002 Auke Water Temperature



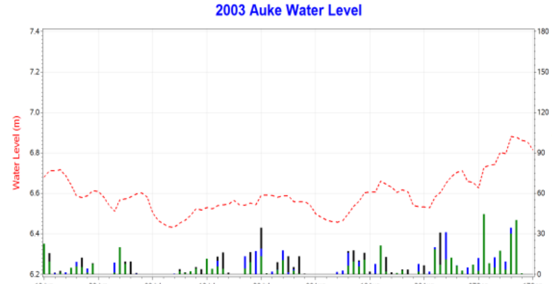
2003 Auke Water Temperature



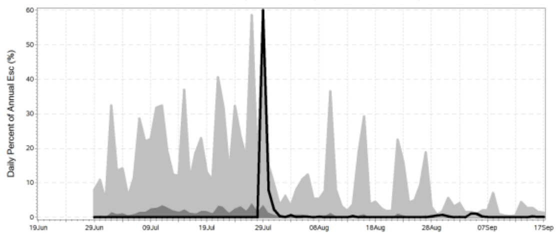
2002 Auke Water Level



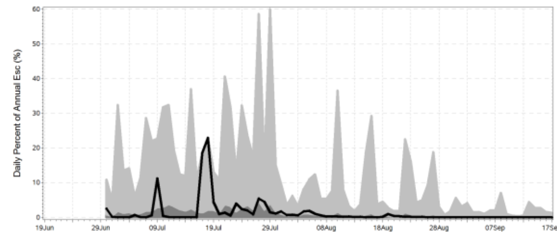
2003 Auke Water Level



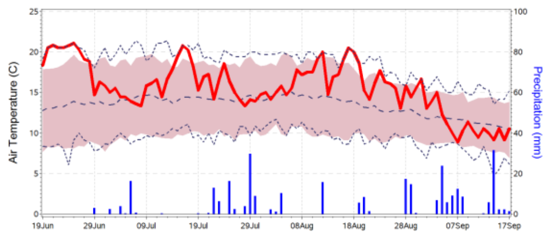
2004 Auke Sockeye Counts (Total Esc: 2,978)



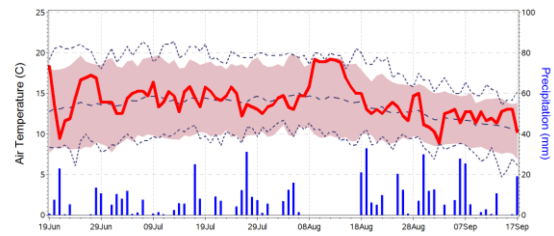
2005 Auke Sockeye Counts (Total Esc: 3,019)



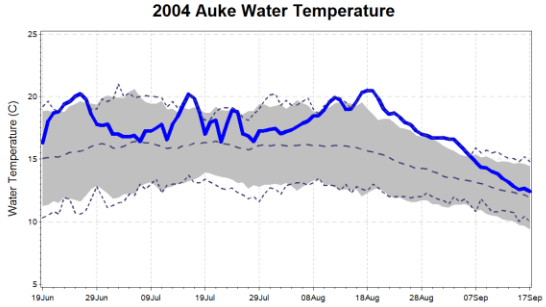
2004 AUKE BAY AK US WEATHER



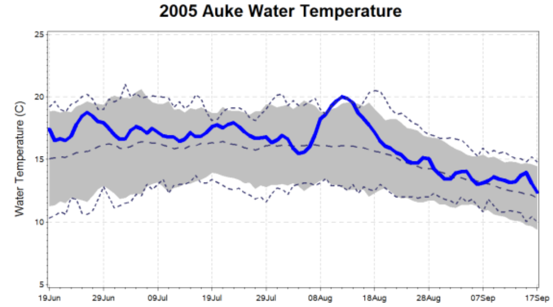
2005 AUKE BAY AK US WEATHER



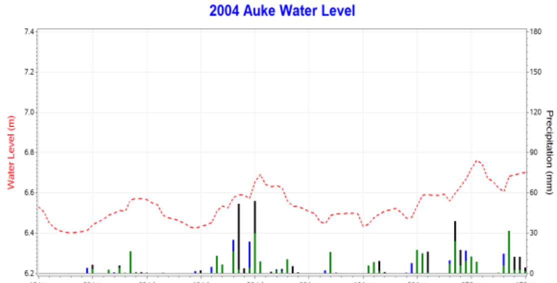
2004 Auke Water Temperature



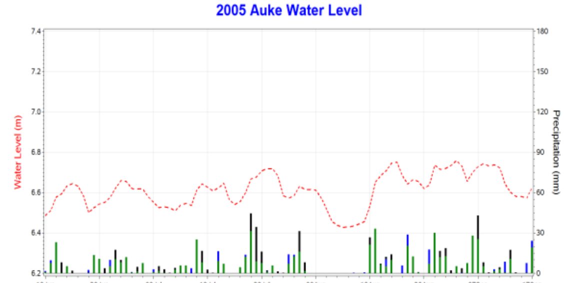
2005 Auke Water Temperature



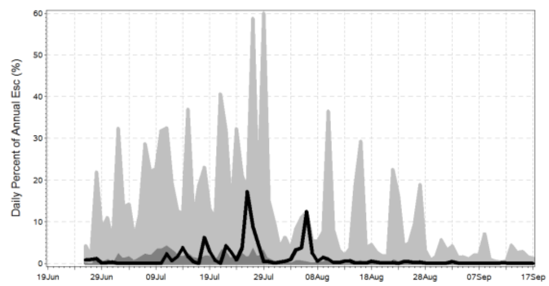
2004 Auke Water Level



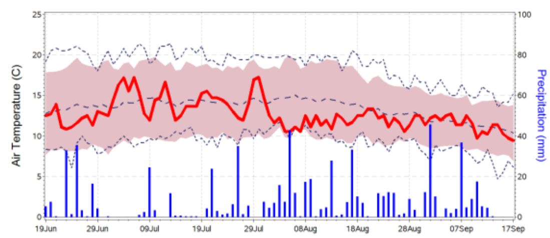
2005 Auke Water Level



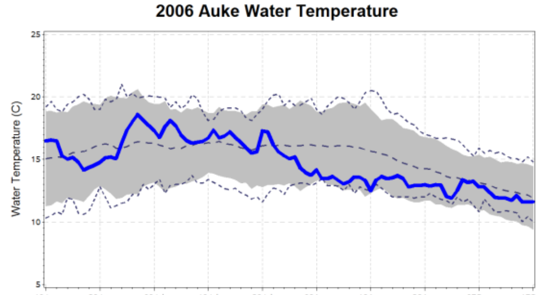
2006 Auke Sockeye Counts (Total Esc: 1,868)



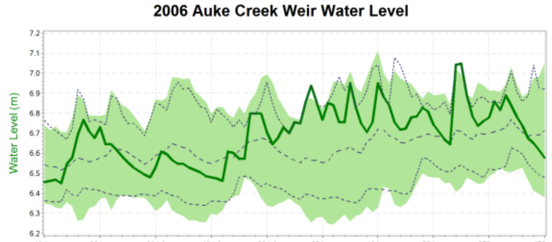
2006 AUKE BAY AK US WEATHER



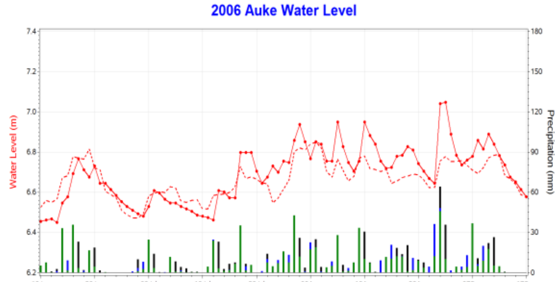
2006 Auke Water Temperature



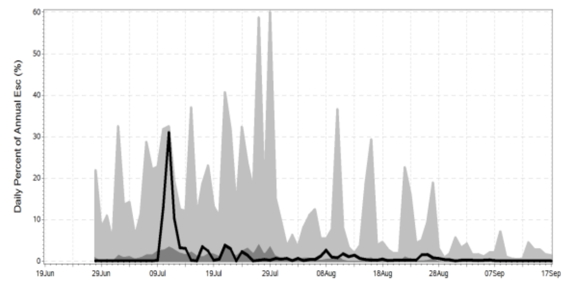
2006 Auke Creek Weir Water Level



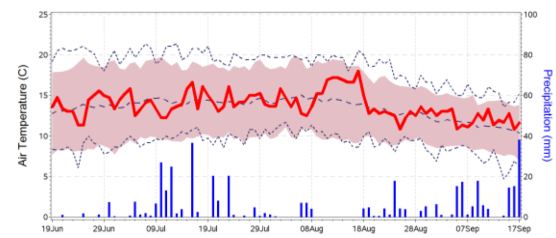
2006 Auke Water Level



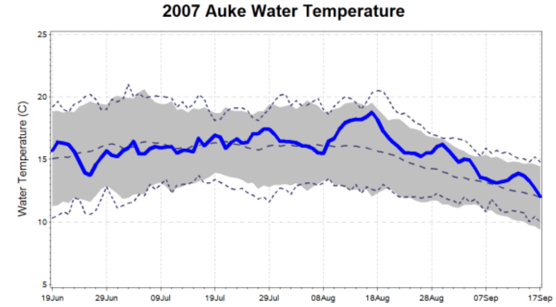
2007 Auke Sockeye Counts (Total Esc: 2,942)



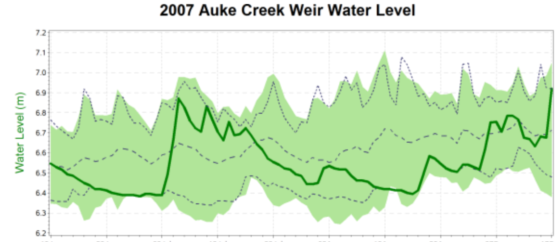
2007 AUKE BAY AK US WEATHER



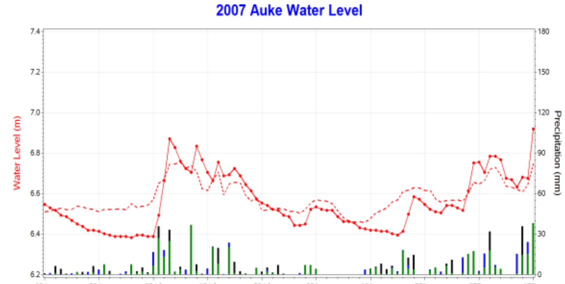
2007 Auke Water Temperature



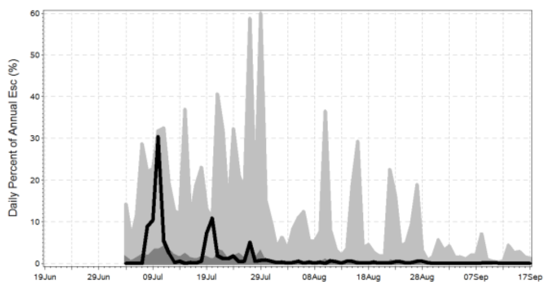
2007 Auke Creek Weir Water Level



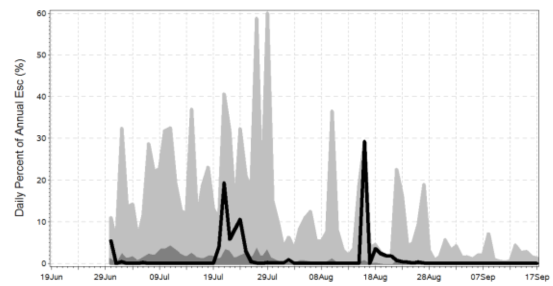
2007 Auke Water Level



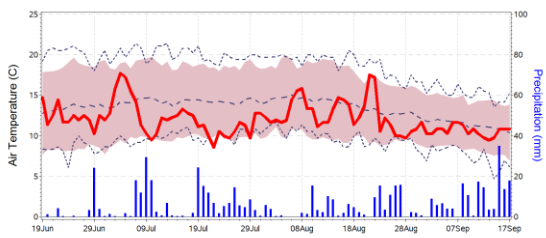
2008 Auke Sockeye Counts (Total Esc: 1,260)



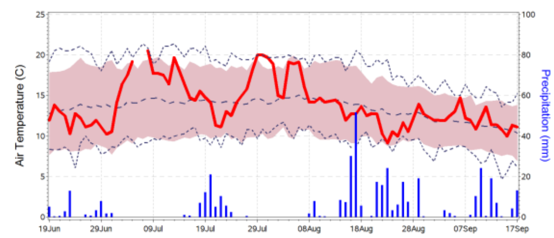
2009 Auke Sockeye Counts (Total Esc: 4,048)



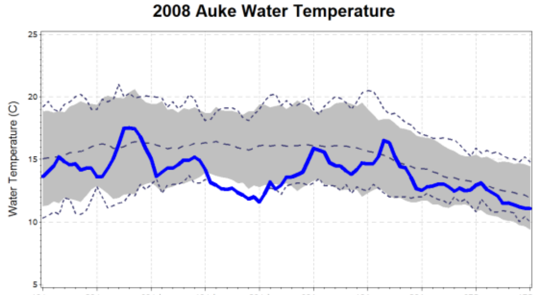
2008 AUKE BAY AK US WEATHER



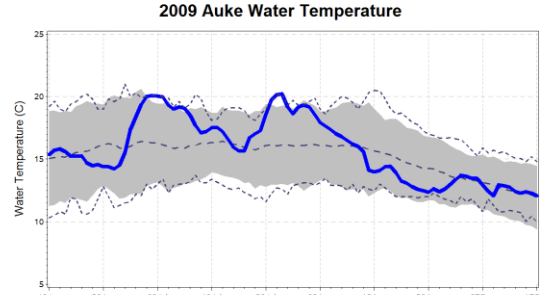
2009 AUKE BAY AK US WEATHER



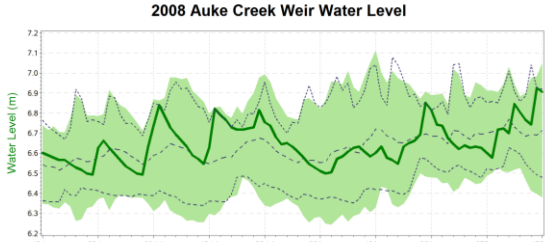
2008 Auke Water Temperature



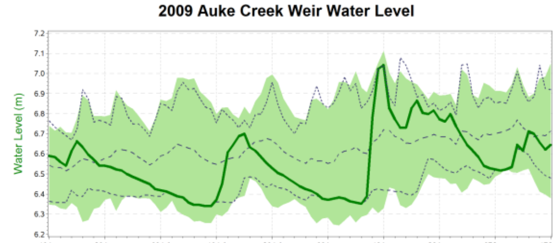
2009 Auke Water Temperature



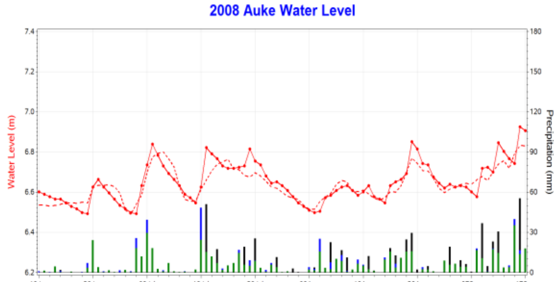
2008 Auke Creek Weir Water Level



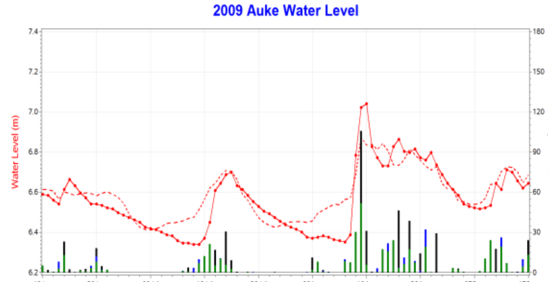
2009 Auke Creek Weir Water Level



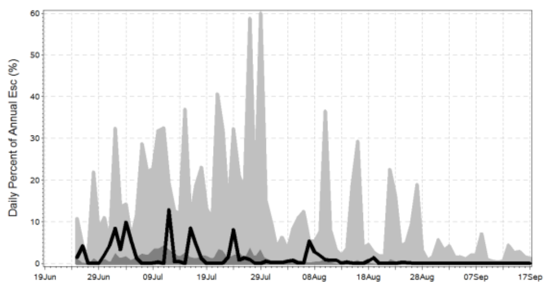
2008 Auke Water Level



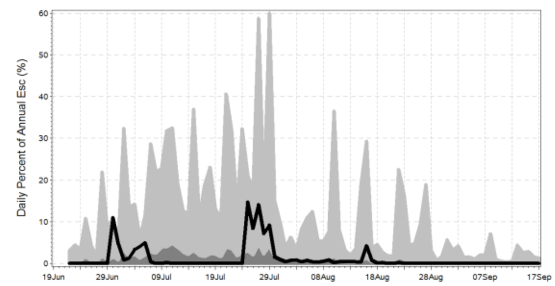
2009 Auke Water Level



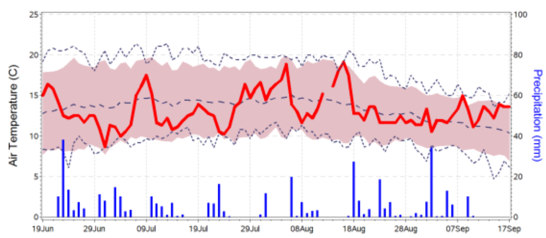
2010 Auke Sockeye Counts (Total Esc: 2,063)



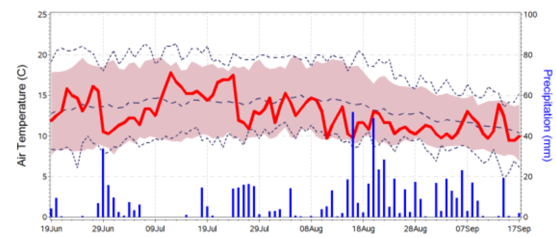
2011 Auke Sockeye Counts (Total Esc: 2,426)



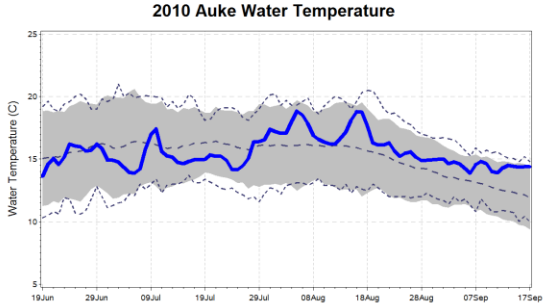
2010 AUKE BAY AK US WEATHER



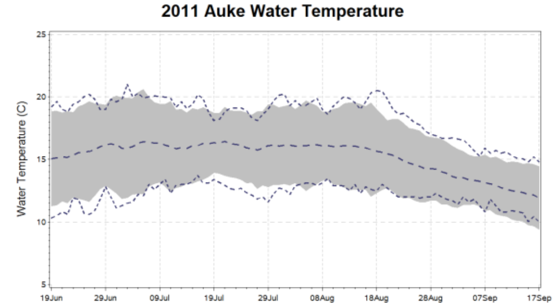
2011 AUKE BAY AK US WEATHER



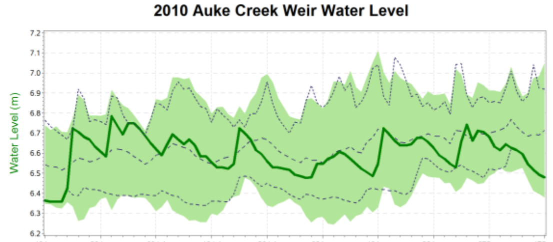
2010 Auke Water Temperature



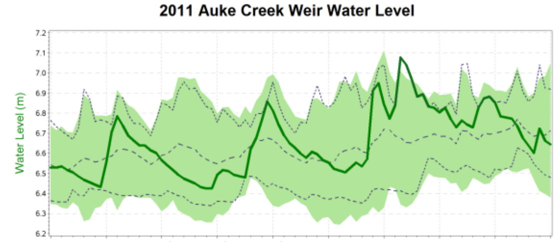
2011 Auke Water Temperature



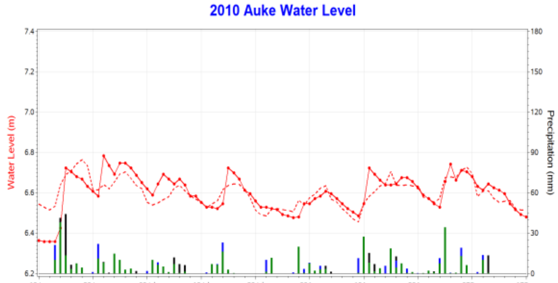
2010 Auke Creek Weir Water Level



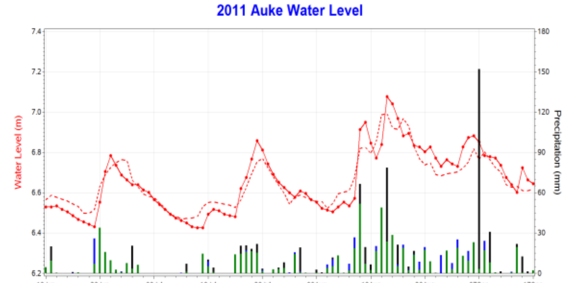
2011 Auke Creek Weir Water Level



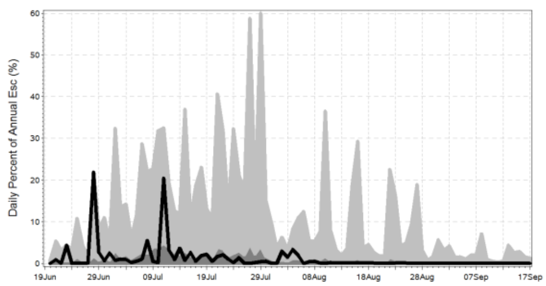
2010 Auke Water Level



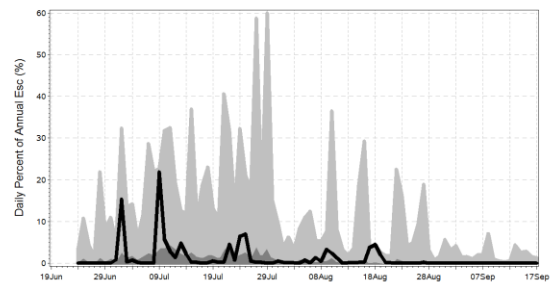
2011 Auke Water Level



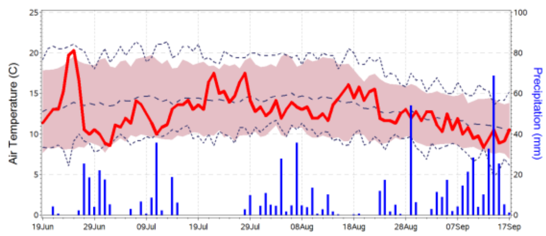
2012 Auke Sockeye Counts (Total Esc: 1,569)



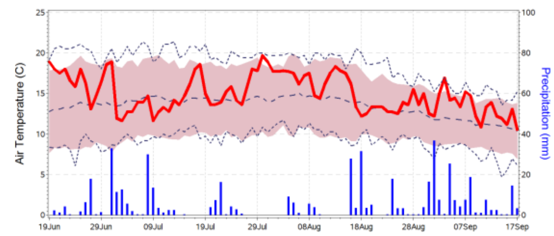
2013 Auke Sockeye Counts (Total Esc: 2,060)



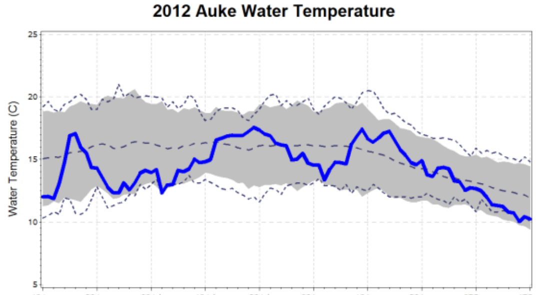
2012 AUKE BAY AK US WEATHER



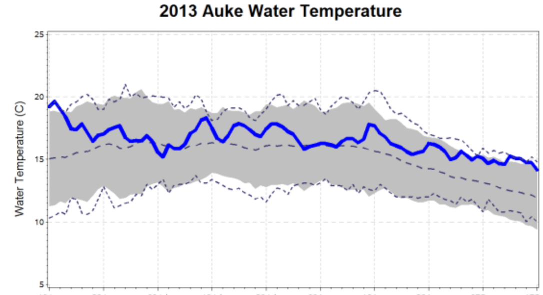
2013 AUKE BAY AK US WEATHER



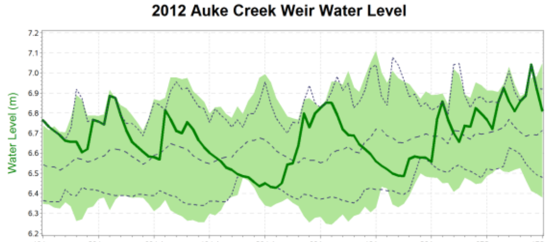
2012 Auke Water Temperature



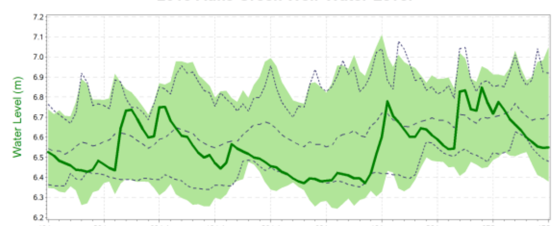
2013 Auke Water Temperature



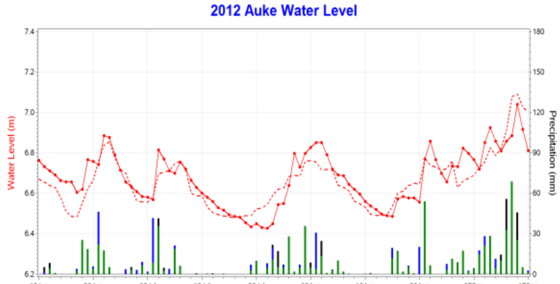
2012 Auke Creek Weir Water Level



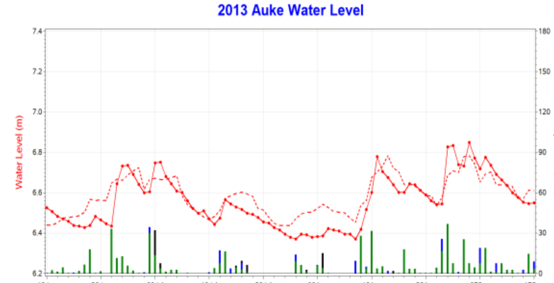
2013 Auke Creek Weir Water Level



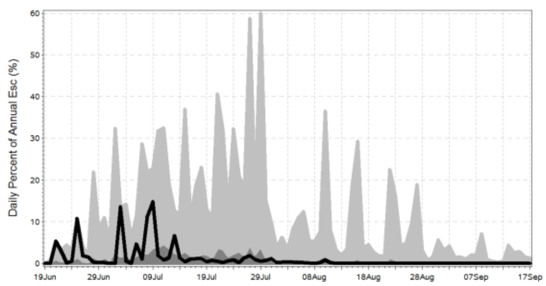
2012 Auke Water Level



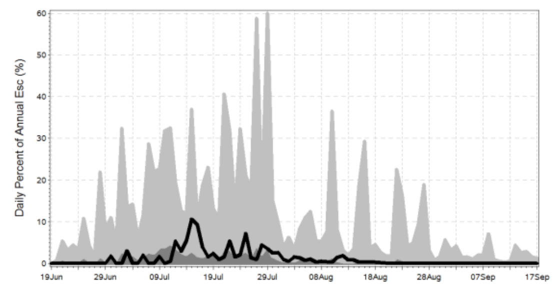
2013 Auke Water Level



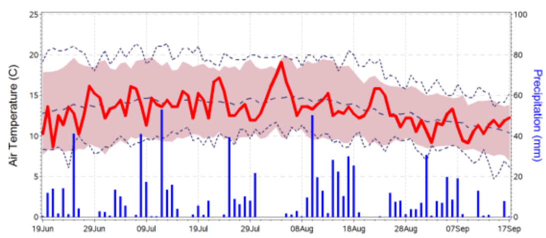
2014 Auke Sockeye Counts (Total Esc: 3,443)



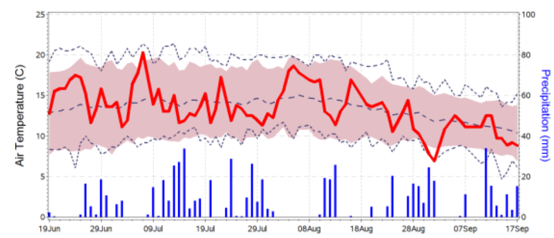
2015 Auke Sockeye Counts (Total Esc: 4,720)



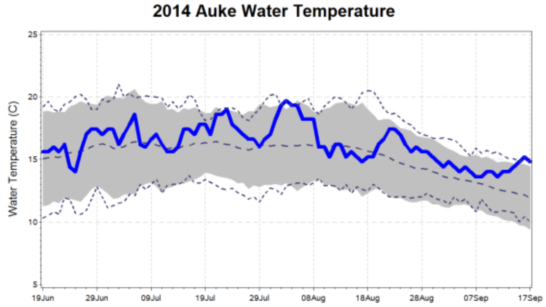
2014 AUKE BAY AK US WEATHER



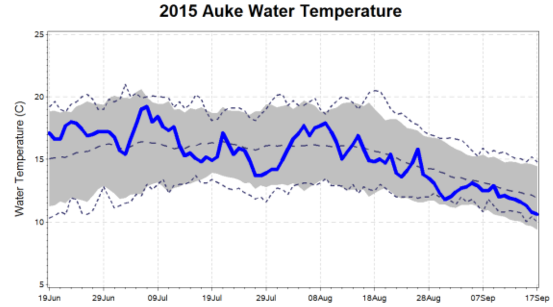
2015 AUKE BAY AK US WEATHER



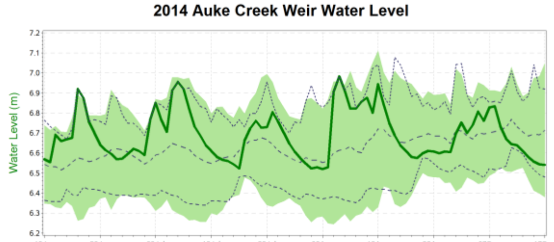
2014 Auke Water Temperature



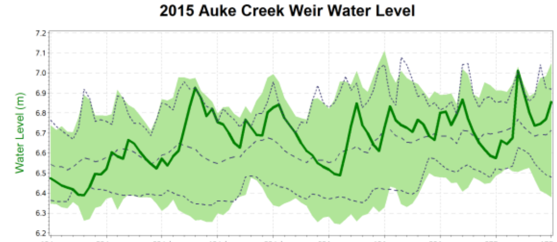
2015 Auke Water Temperature



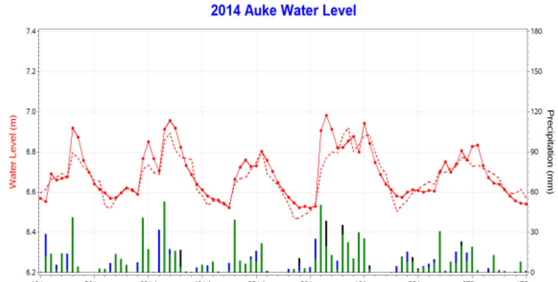
2014 Auke Creek Weir Water Level



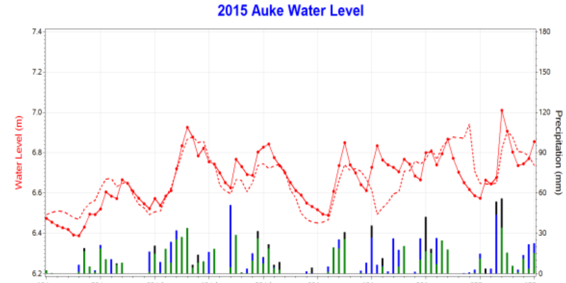
2015 Auke Creek Weir Water Level

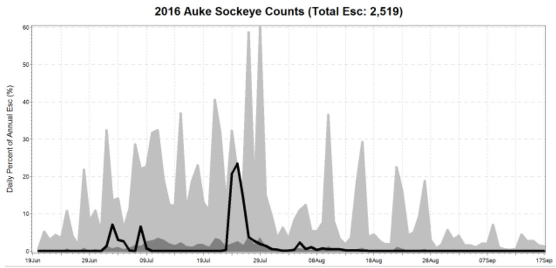


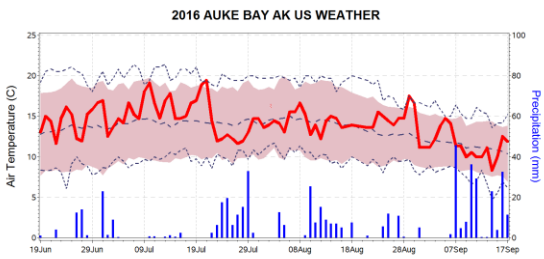
2014 Auke Water Level

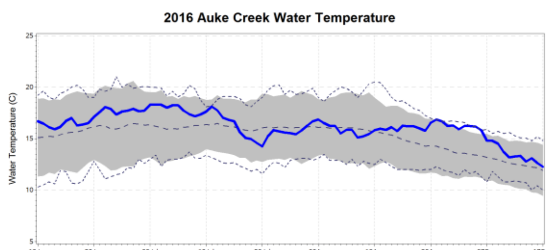


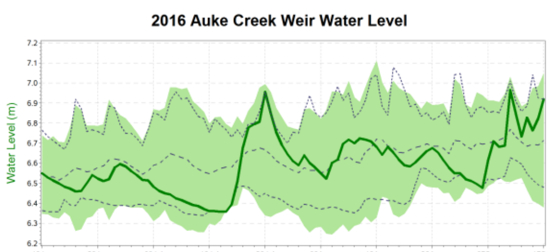
2015 Auke Water Level

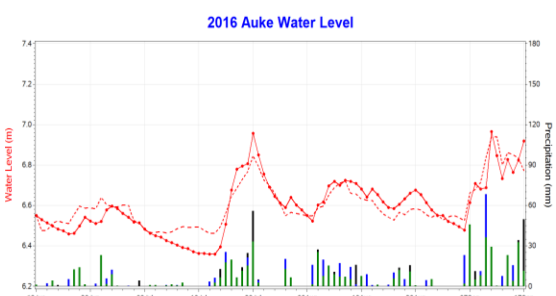



2016 Auke Sockeye Counts (Total Esc: 2,519)
Daily Percent of Annual Esc (%)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep


2016 AUKE BAY AK US WEATHER
Air Temperature (C)
Precipitation (mm)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep


2016 Auke Creek Water Temperature
Water Temperature (C)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep


2016 Auke Creek Weir Water Level
Water Level (m)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep


2016 Auke Water Level
Water Level (m)
Precipitation (mm)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep

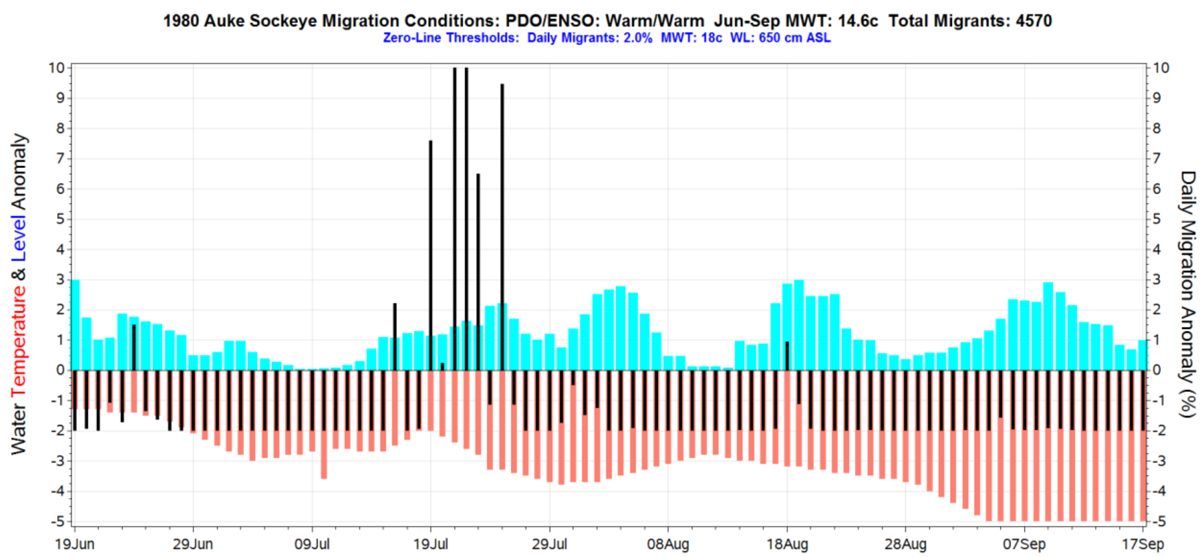
Appendix H. Annual anomaly plots for Auke Sockeye daily migration aligned with Auke Creek water temperature (observed), and water level (observed & estimated).

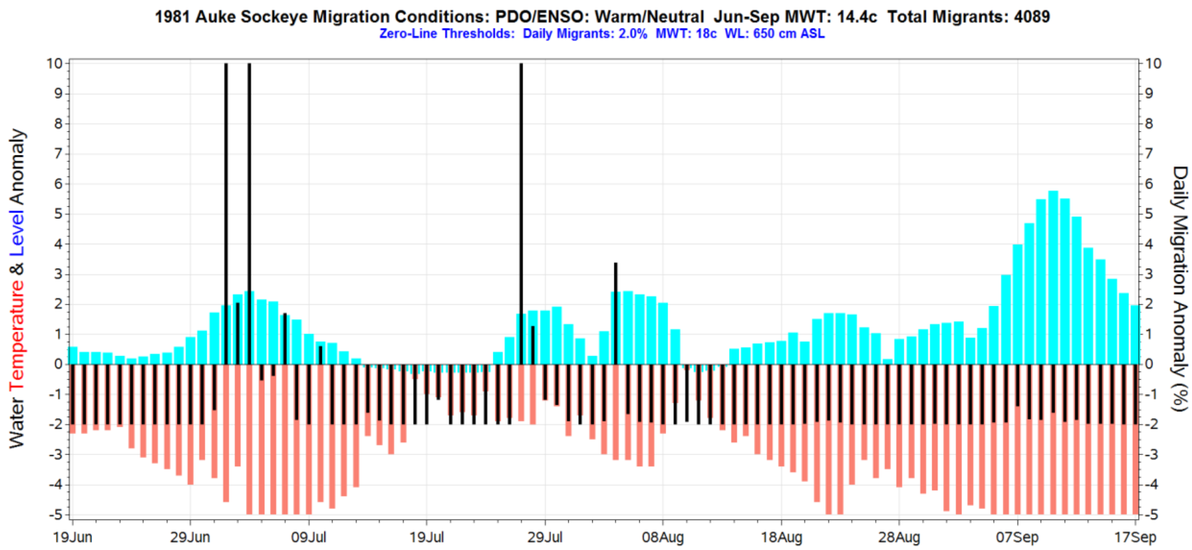
Zero-line thresholds:

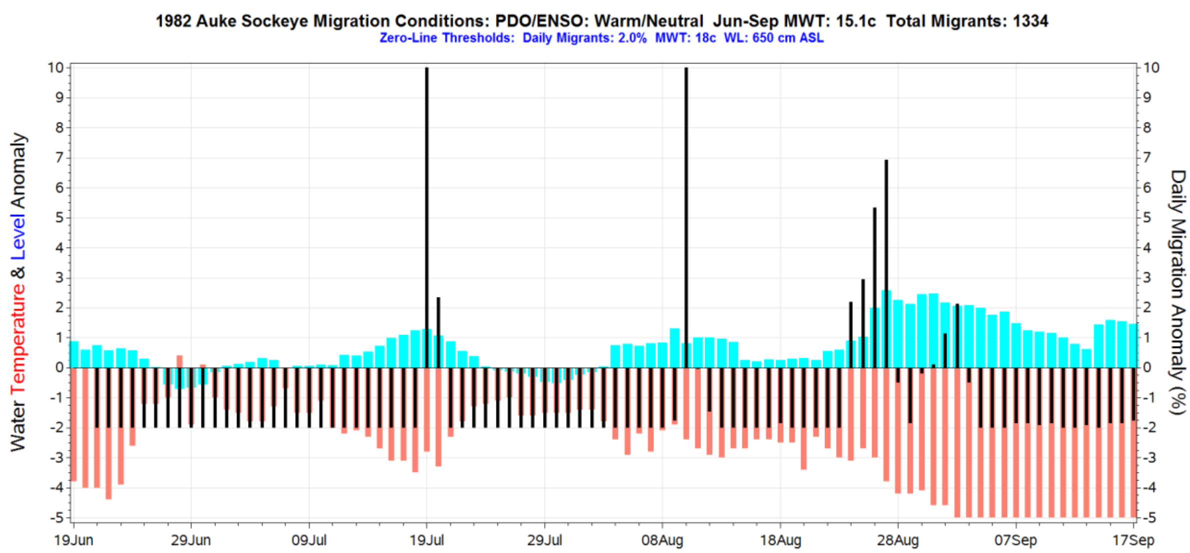
- Daily migration rate = 2% (~75th percentile of non-zero daily migration rates, 1980-2015)
- Water temperature = 18°C (~90th percentile, 1980-2015)
- Water level = 6.5 m ASL (~10th percentile, 1900-2016)

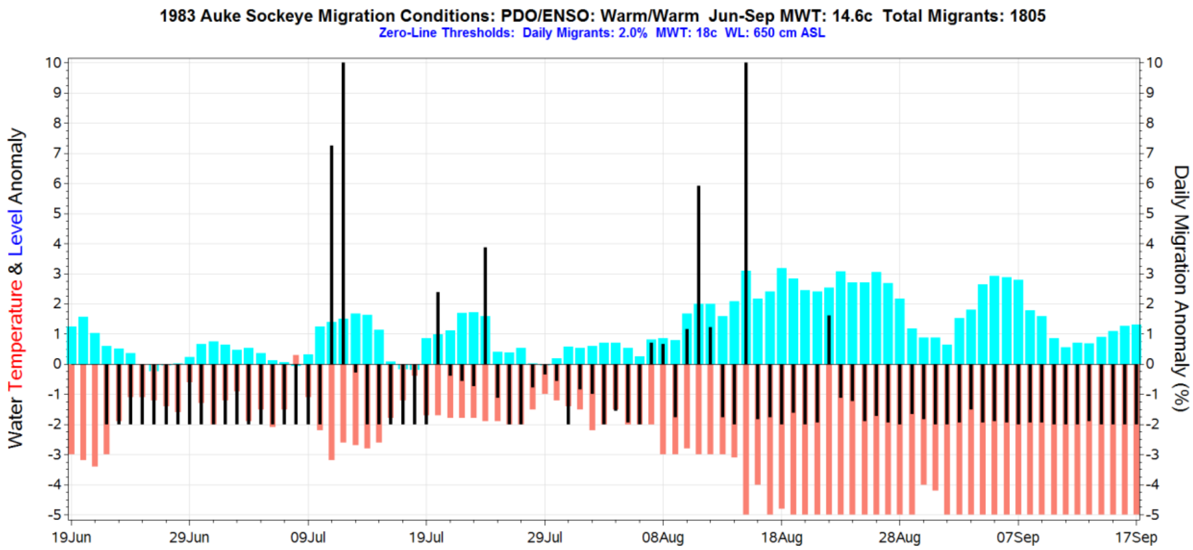
To read the plot: environmental variate anomalies are read from the primary y-axis; migration anomalies are read from the secondary y-axis.

1. Black bars are the daily migration rate (%) minus the 2% threshold (e.g. 5% is represented as 3% on the secondary y-axis (5-2 = +3%)).
2. Red bars are the estimated daily mean water temperature minus the 18°C threshold (e.g. 16°C → -2 since 16-18 = -2).
3. Blue bars are the observed daily discharge minus the 650 cm threshold, and divided by 10 to fit the axis (e.g. 680 cm → (680-650)/10 = +3.0 cm).

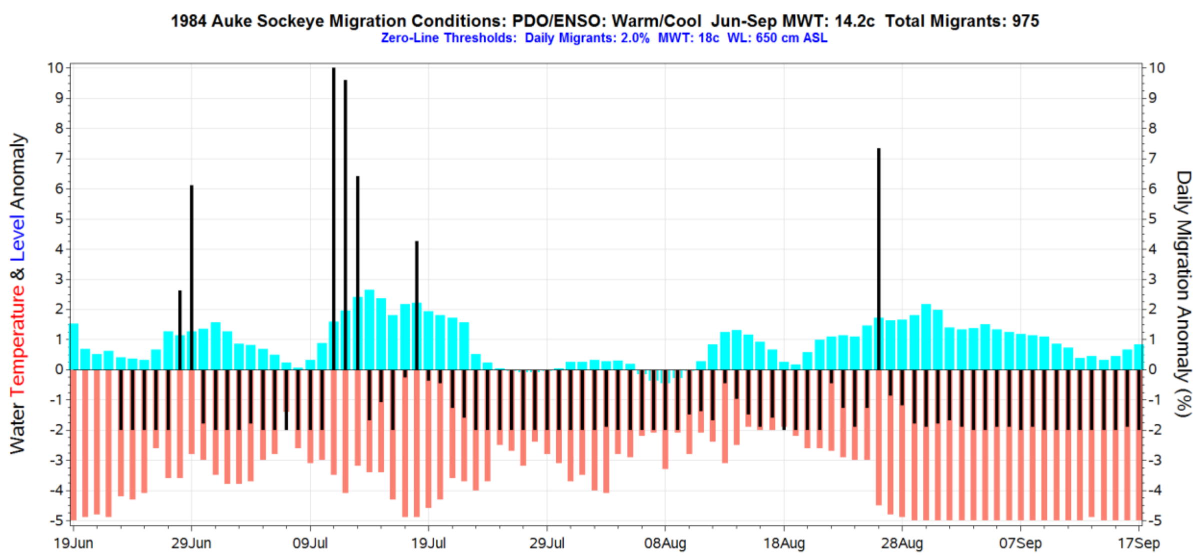



1981 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jun-Sep MWT: 14.4c Total Migrants: 4089
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep

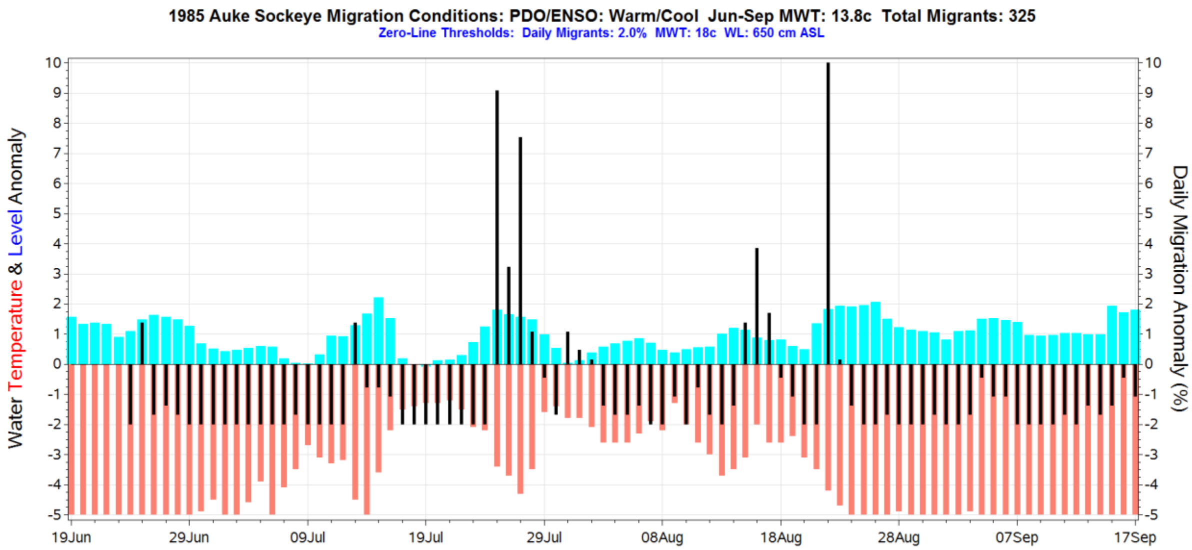

1982 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jun-Sep MWT: 15.1c Total Migrants: 1334
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep

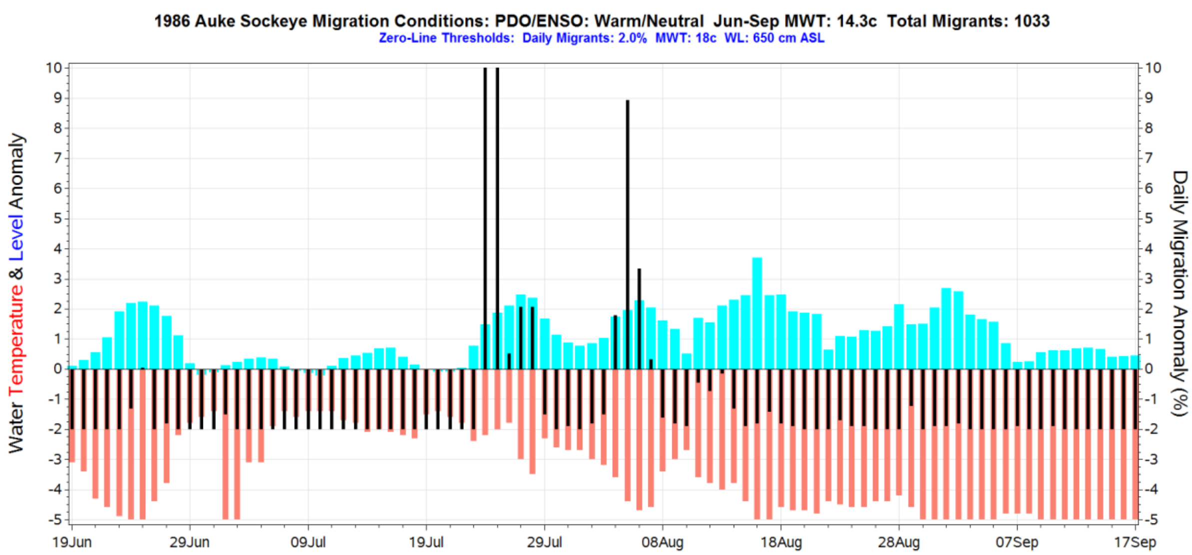


1983 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 14.6c Total Migrants: 1805
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep

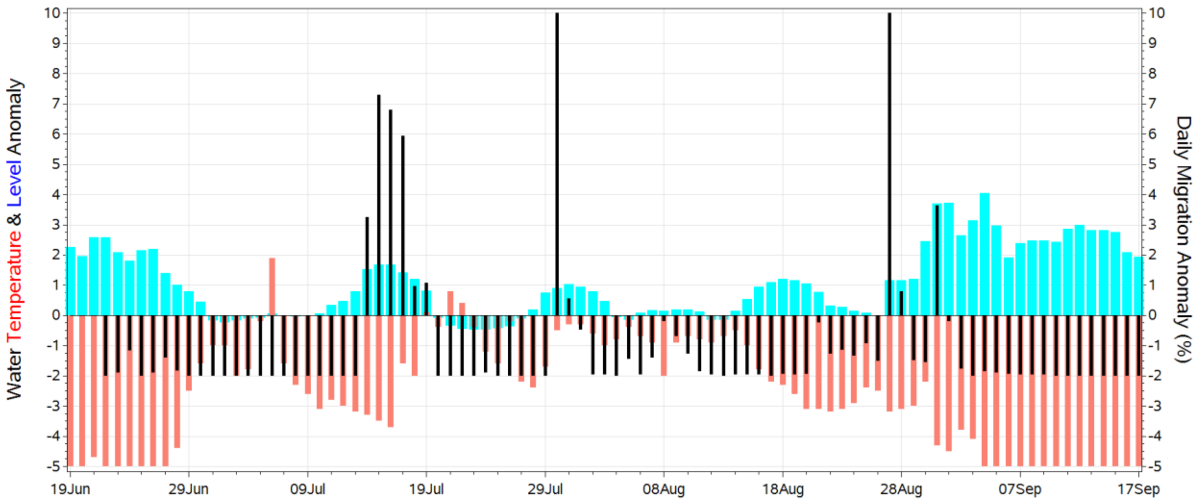


1984 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Cool Jun-Sep MWT: 14.2c Total Migrants: 975
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep

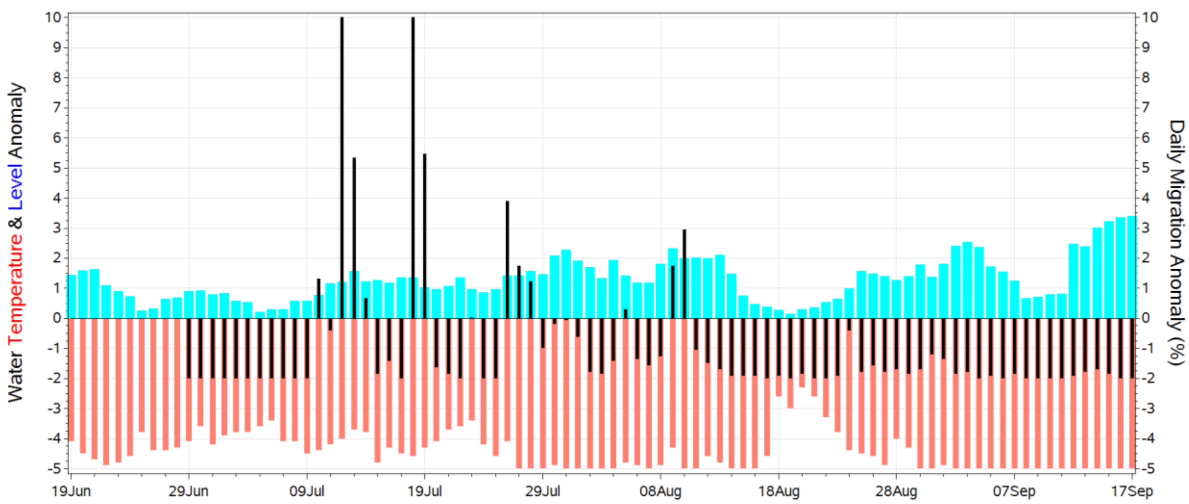

1985 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Cool Jun-Sep MWT: 13.8c Total Migrants: 325
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep

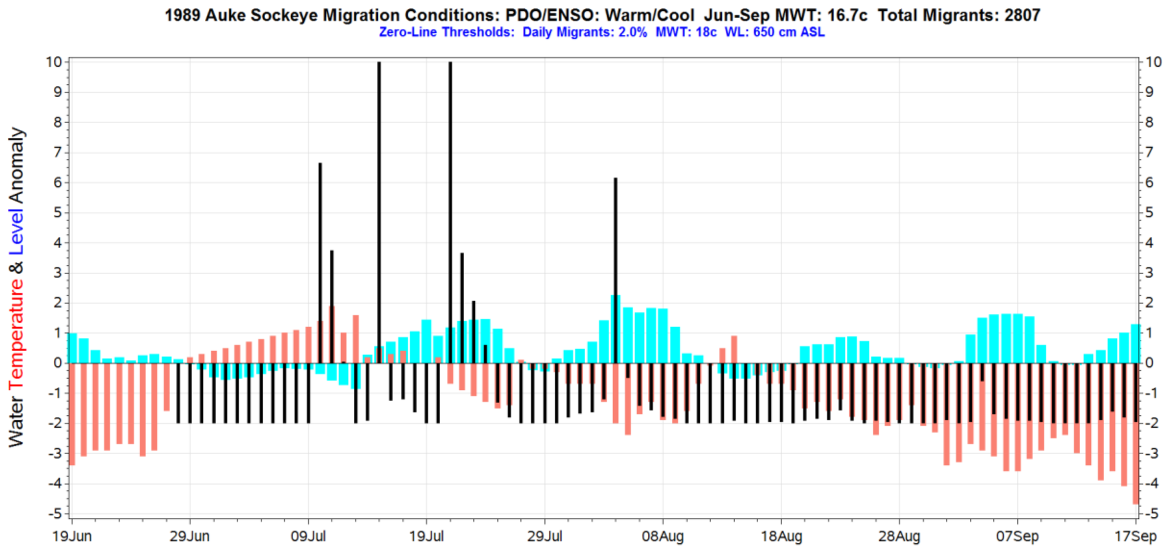

1986 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jun-Sep MWT: 14.3c Total Migrants: 1033
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep

1987 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 15.1c Total Migrants: 2896
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL



1988 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 13.3c Total Migrants: 1392
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL




1989 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Cool Jun-Sep MWT: 16.7c Total Migrants: 2807
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
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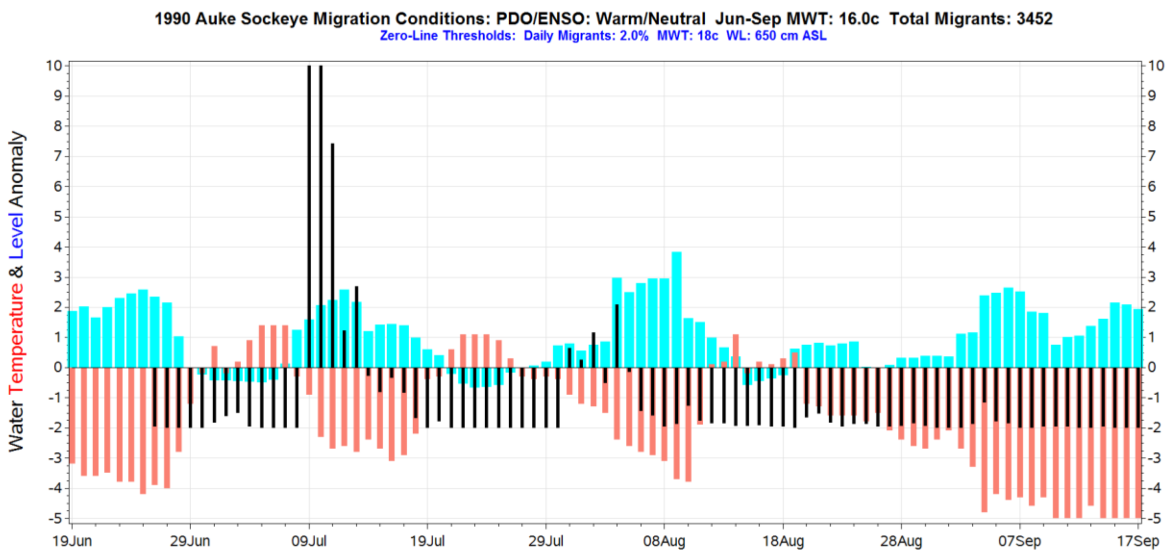
08Aug
18Aug
28Aug
07Sep
17Sep


1990 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jun-Sep MWT: 16.0c Total Migrants: 3452
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
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08Aug
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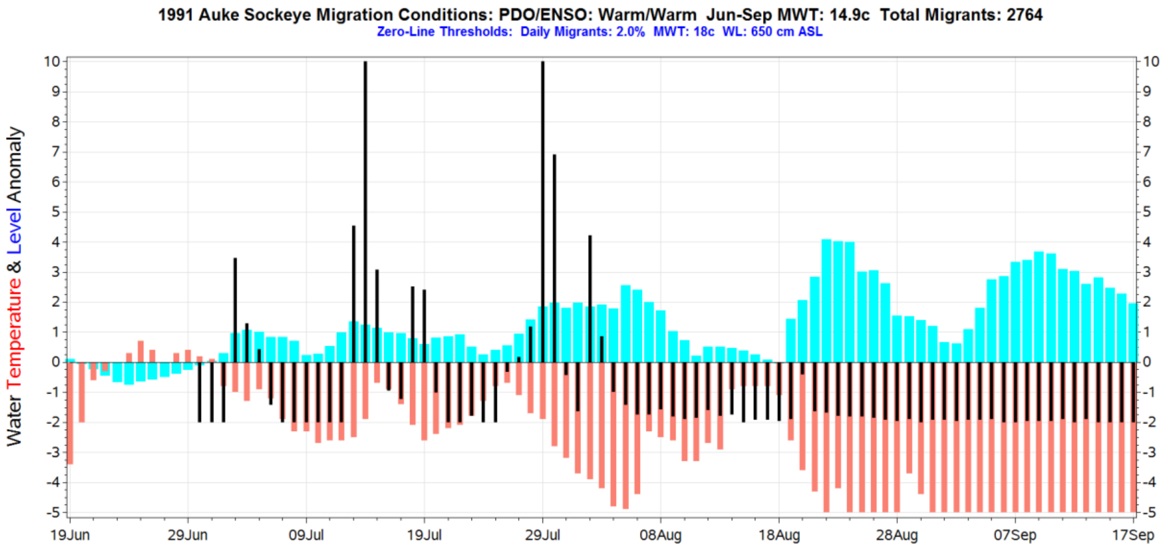
28Aug
07Sep
17Sep


1991 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 14.9c Total Migrants: 2764
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
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29Jun
09Jul
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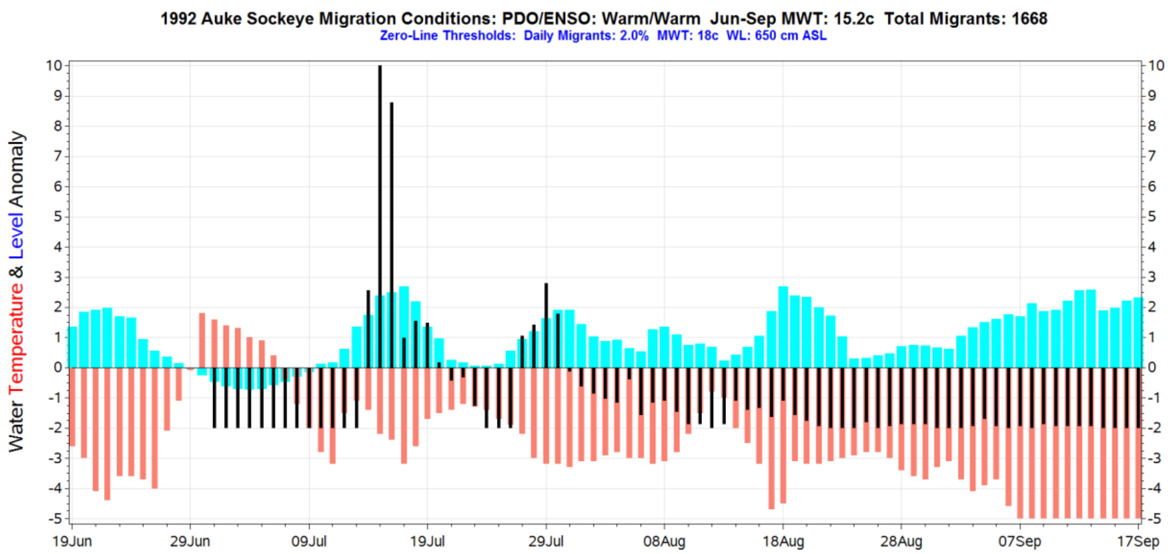
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep


1992 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 15.2c Total Migrants: 1668
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
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29Jun
09Jul
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18Aug
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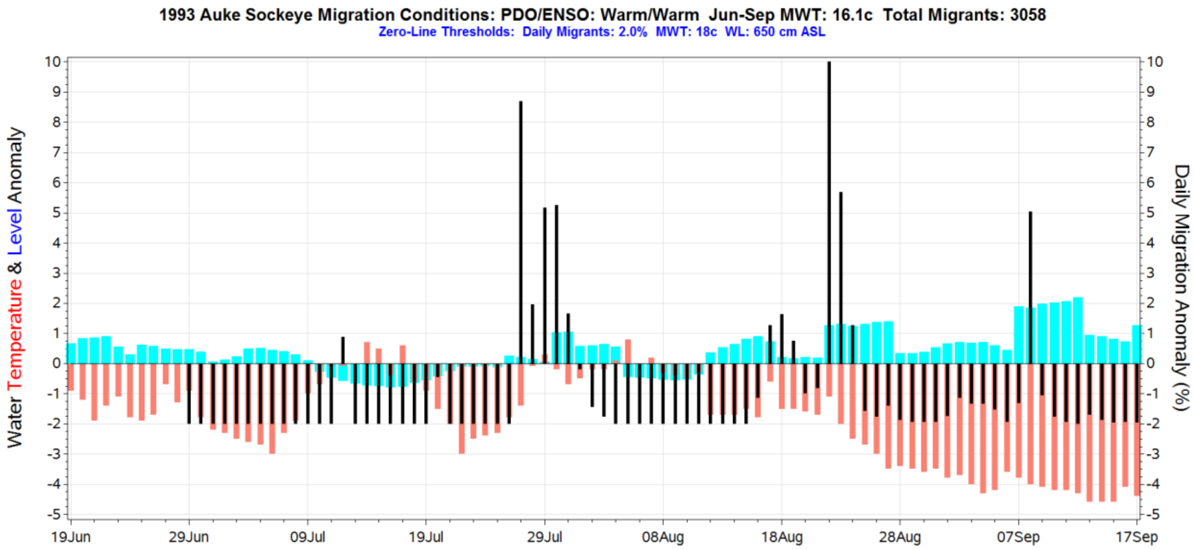
07Sep
17Sep


1993 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 16.1c Total Migrants: 3058
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
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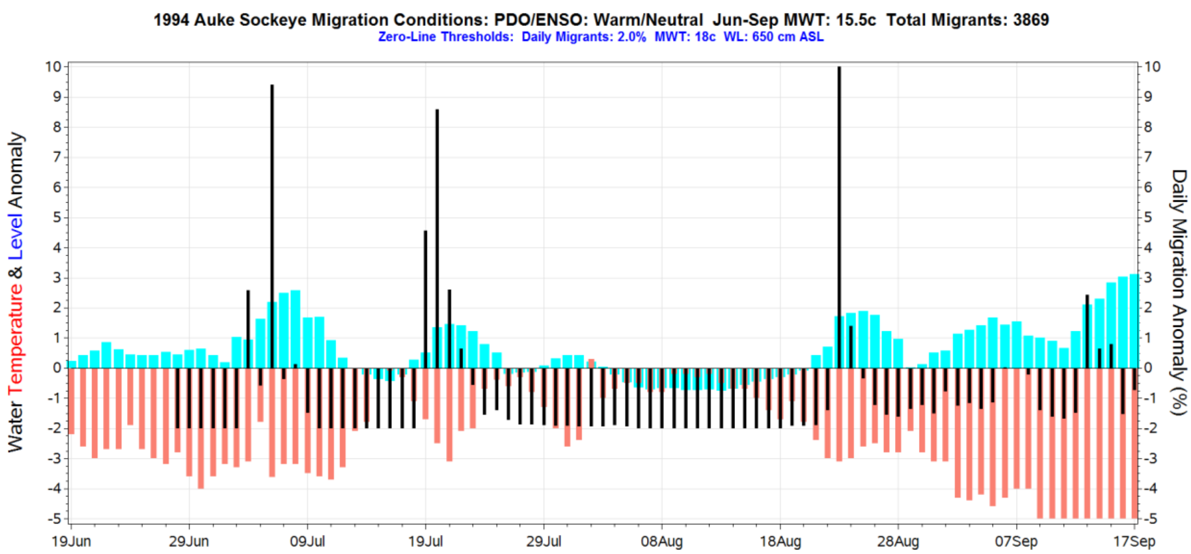
17Sep


1994 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jun-Sep MWT: 15.5c Total Migrants: 3869
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
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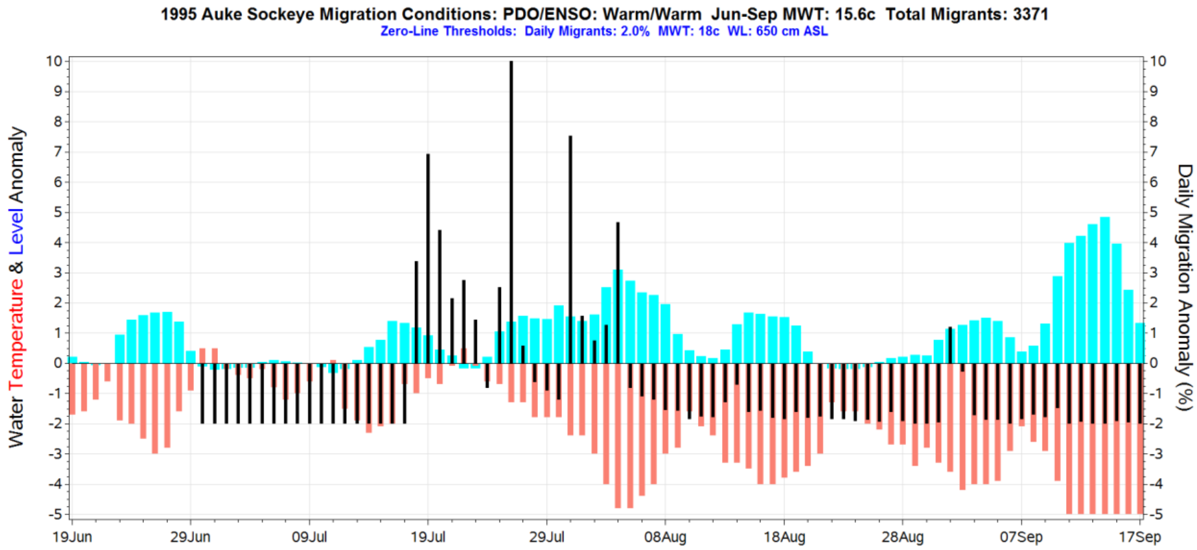
07Sep
17Sep


1995 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 15.6c Total Migrants: 3371
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
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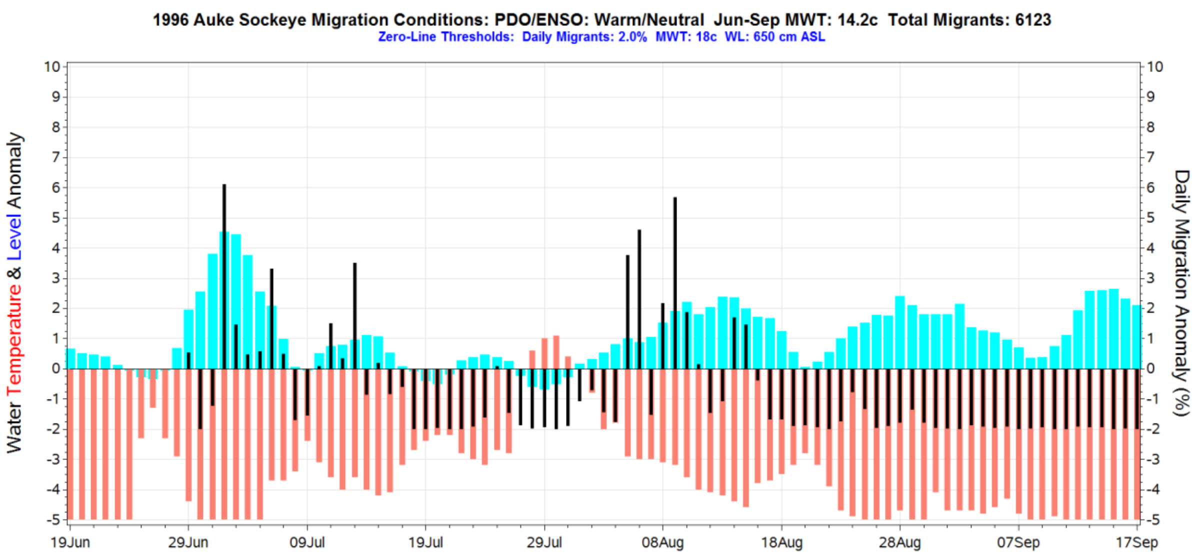
08Aug
18Aug
28Aug
07Sep
17Sep


1996 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jun-Sep MWT: 14.2c Total Migrants: 6123
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
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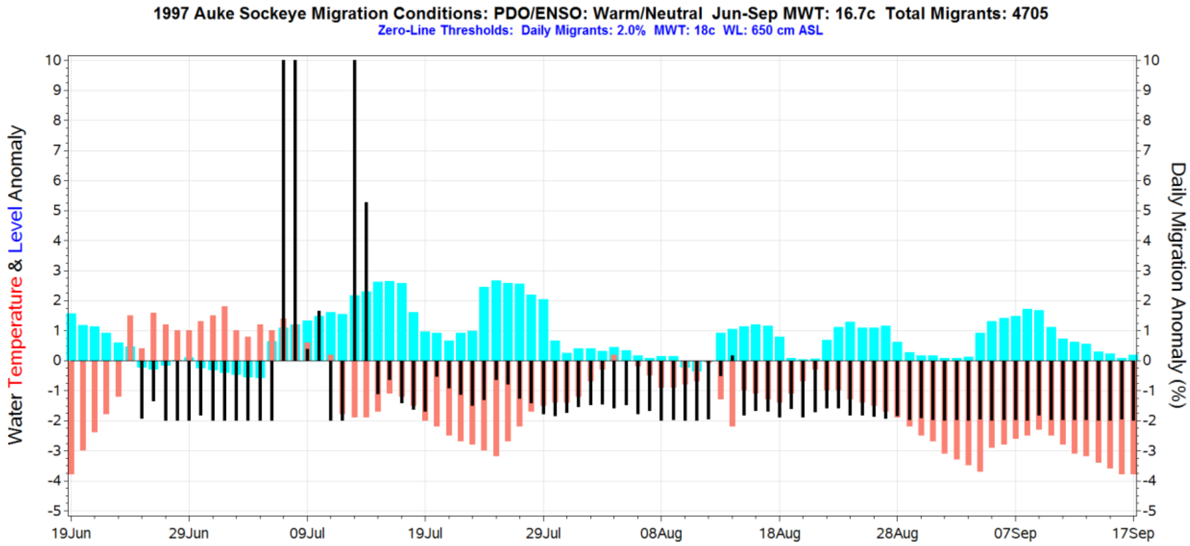
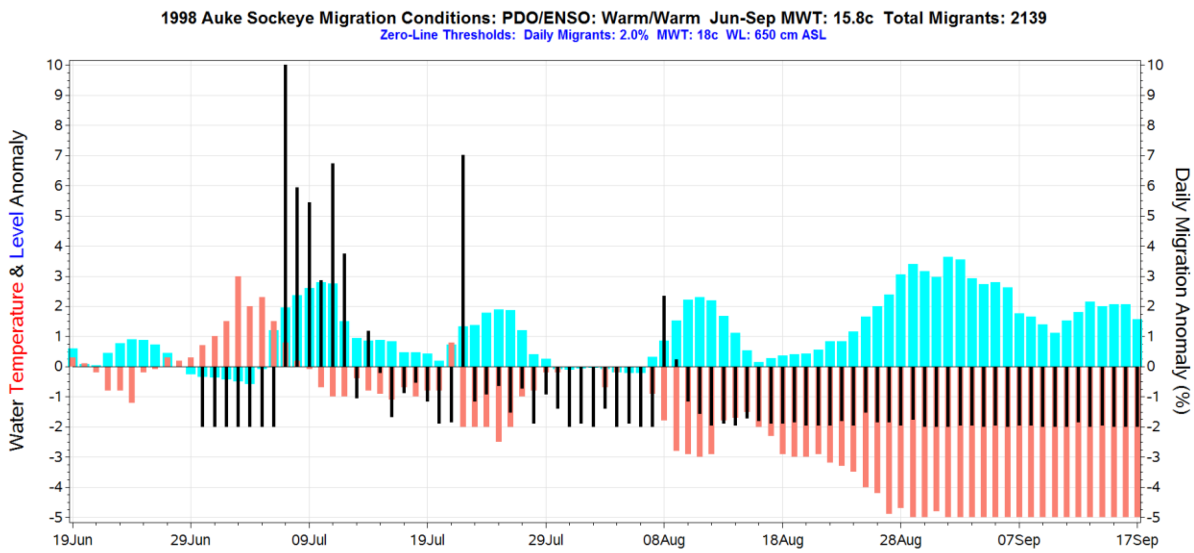
07Sep
17Sep


1997 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Neutral Jun-Sep MWT: 16.7c Total Migrants: 4705
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep


1998 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 15.8c Total Migrants: 2139
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
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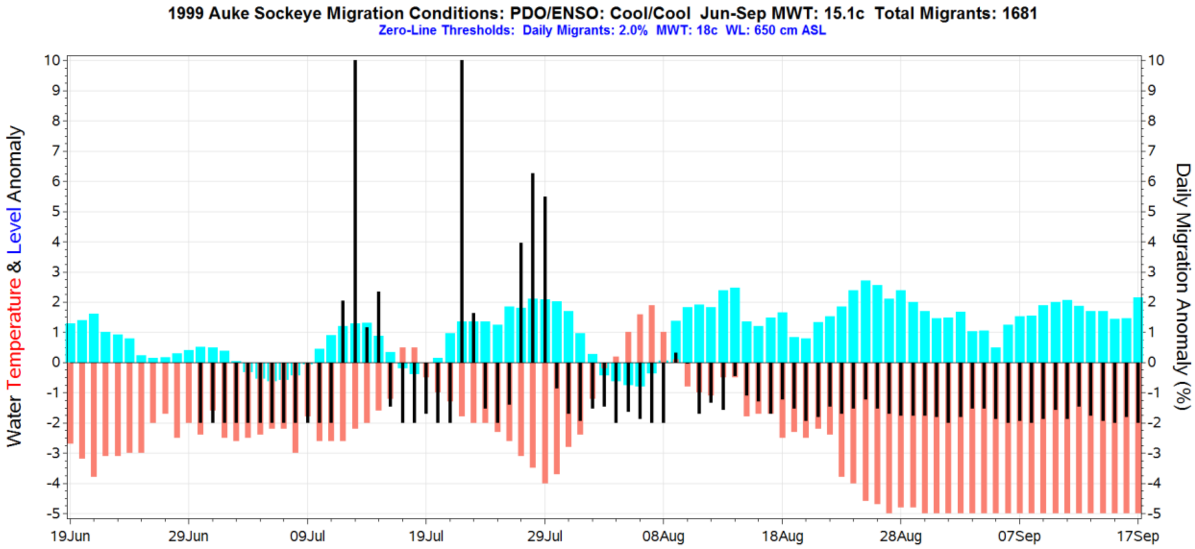
07Sep
17Sep


1999 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jun-Sep MWT: 15.1c Total Migrants: 1681
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
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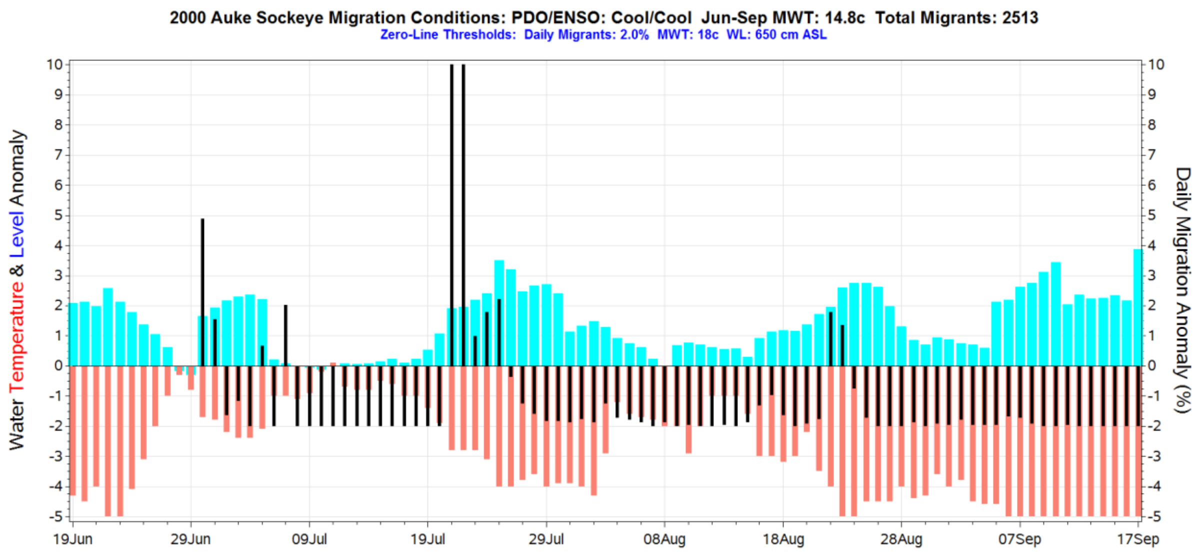
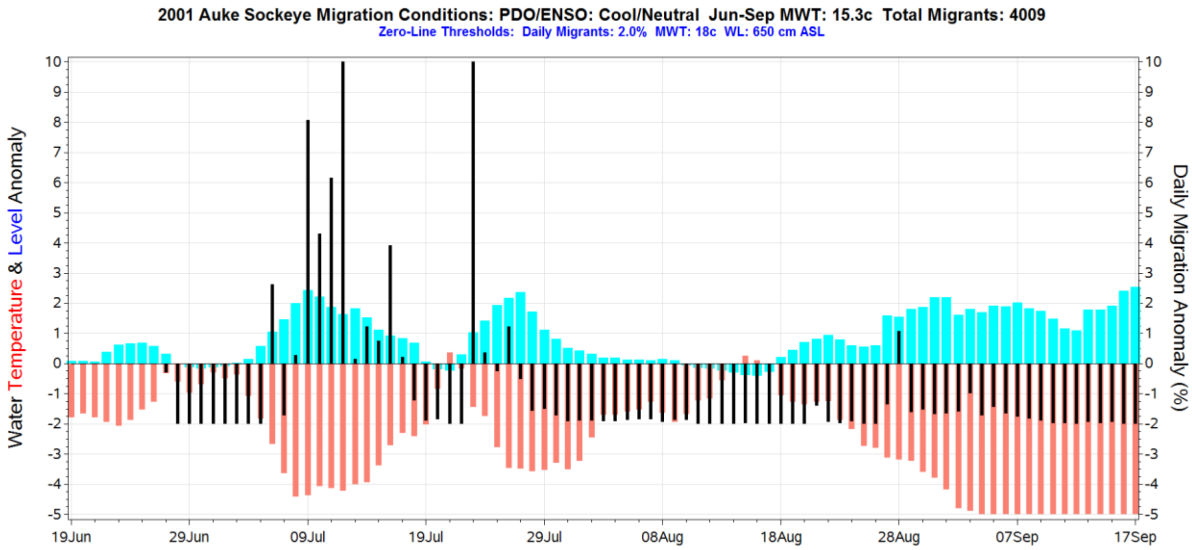
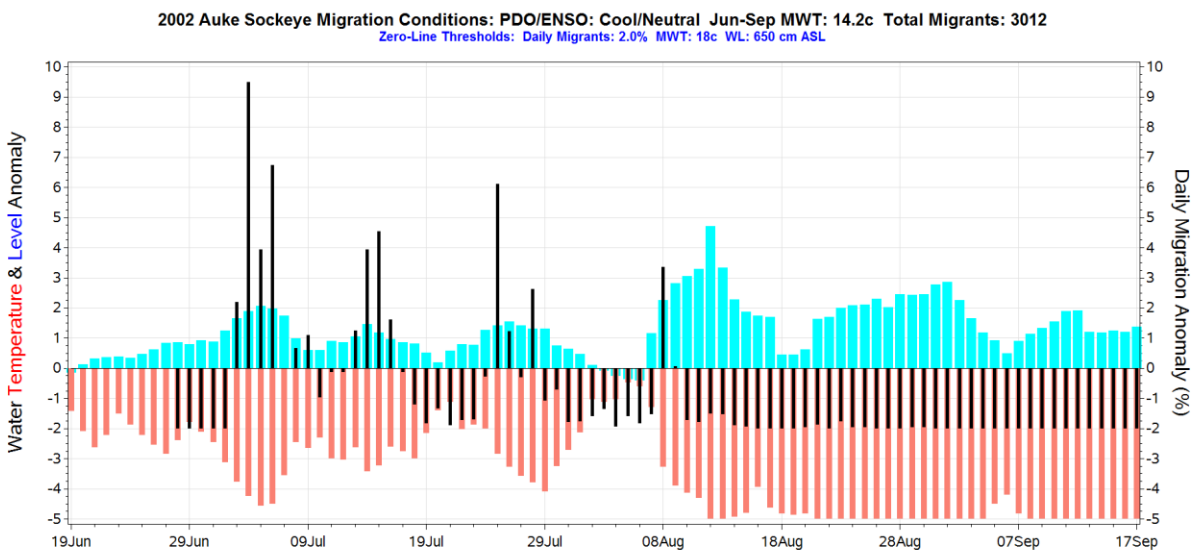
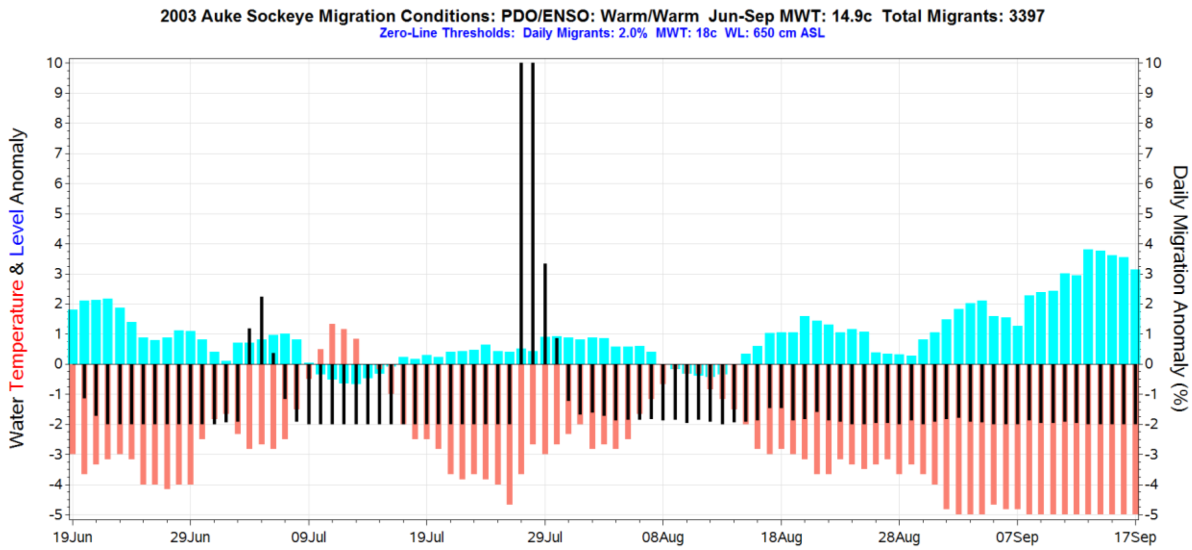
08Aug
18Aug
28Aug
07Sep
17Sep


2000 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jun-Sep MWT: 14.8c Total Migrants: 2513
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep


2001 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jun-Sep MWT: 15.3c Total Migrants: 4009
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep


2002 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jun-Sep MWT: 14.2c Total Migrants: 3012
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep


2003 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 14.9c Total Migrants: 3397
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
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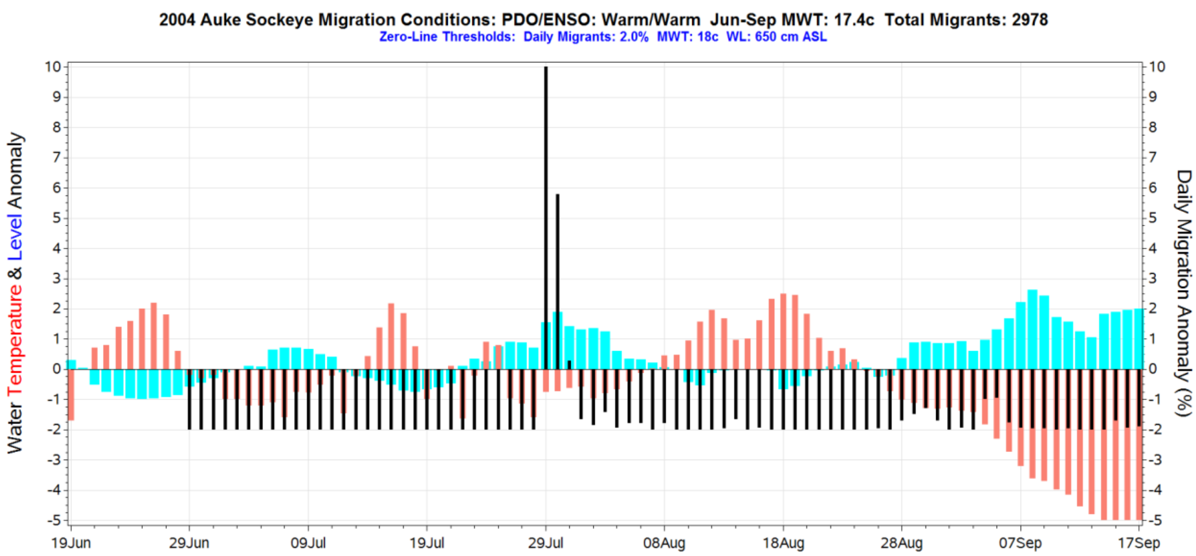
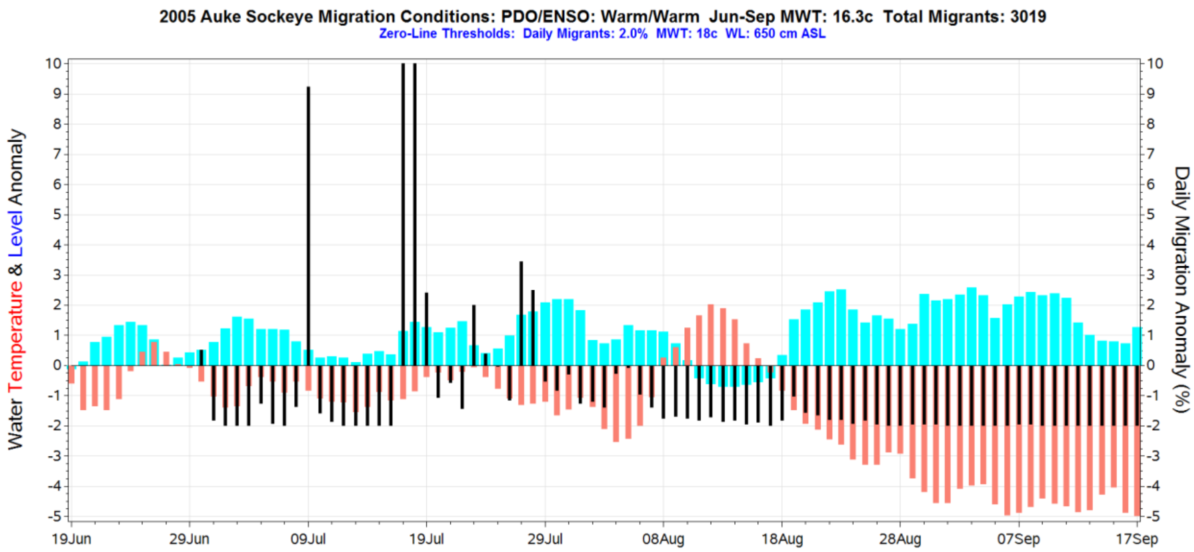
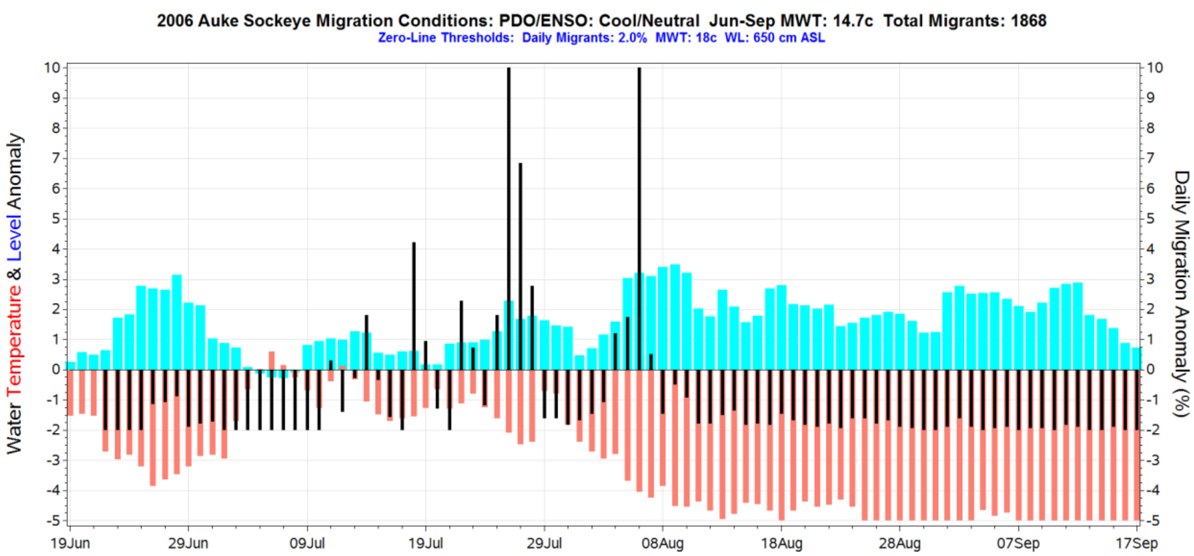
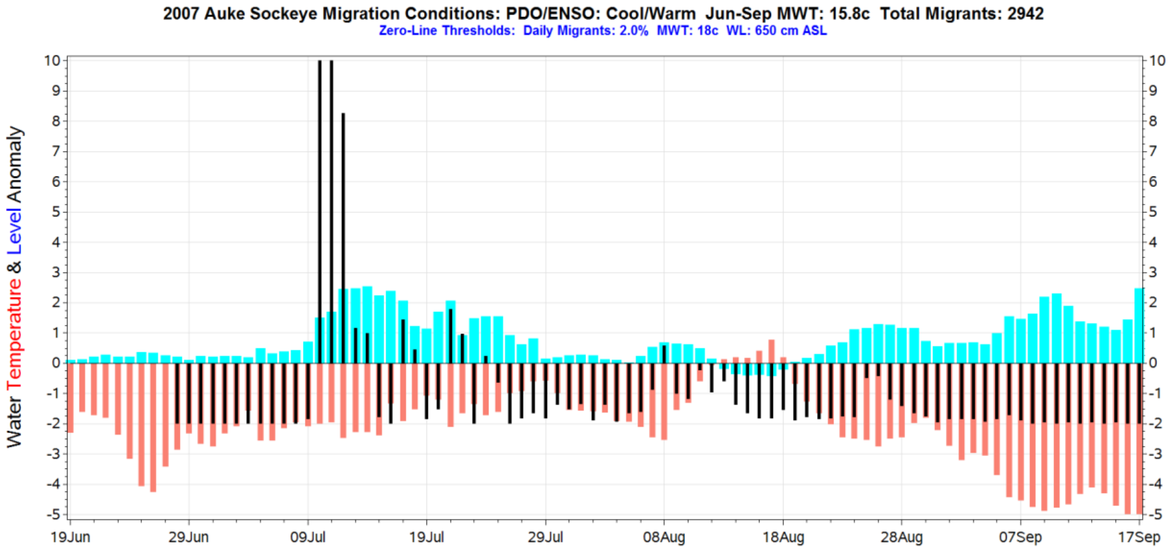
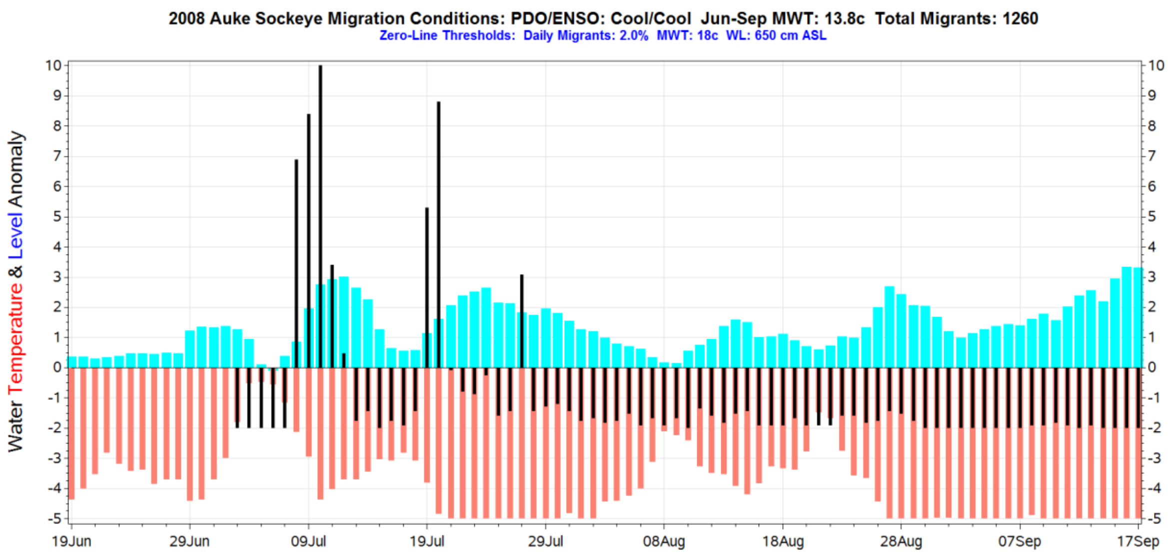
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep


2004 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 17.4c Total Migrants: 2978
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep

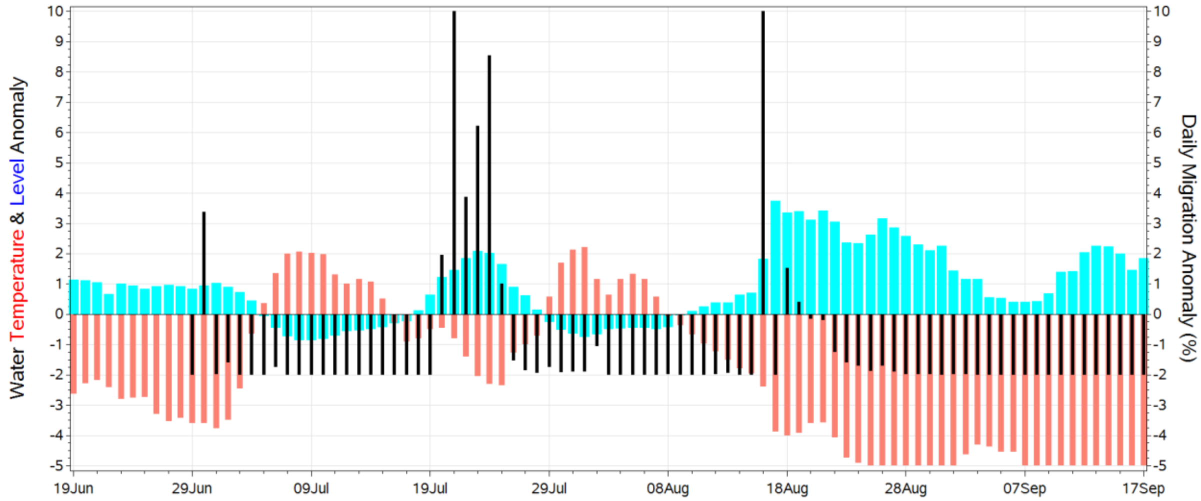

2005 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 16.3c Total Migrants: 3019
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep


2006 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jun-Sep MWT: 14.7c Total Migrants: 1868
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun 29Jun 09Jul 19Jul 29Jul 08Aug 18Aug 28Aug 07Sep 17Sep

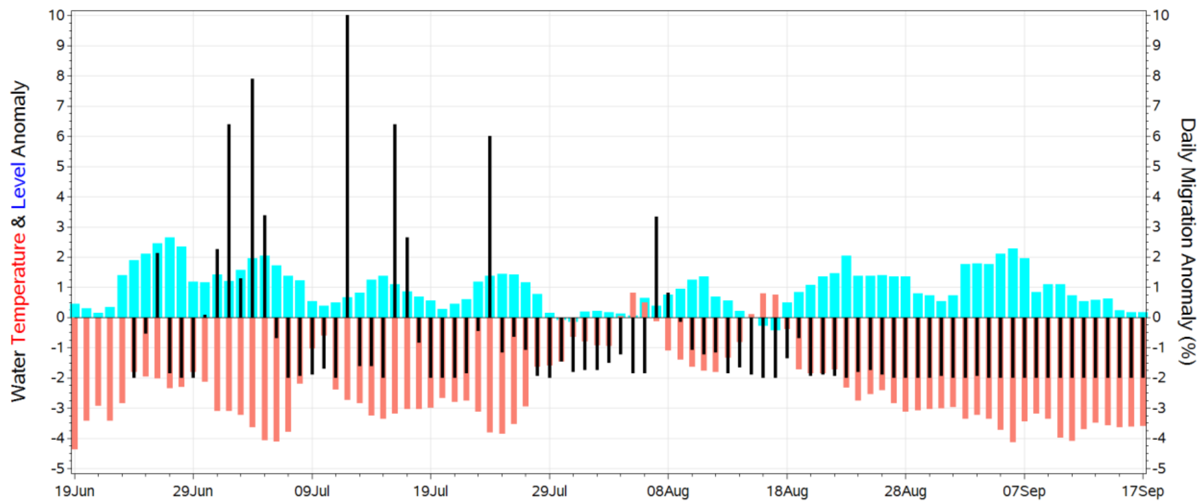

2007 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Warm Jun-Sep MWT: 15.8c Total Migrants: 2942
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep


2008 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jun-Sep MWT: 13.8c Total Migrants: 1260
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep

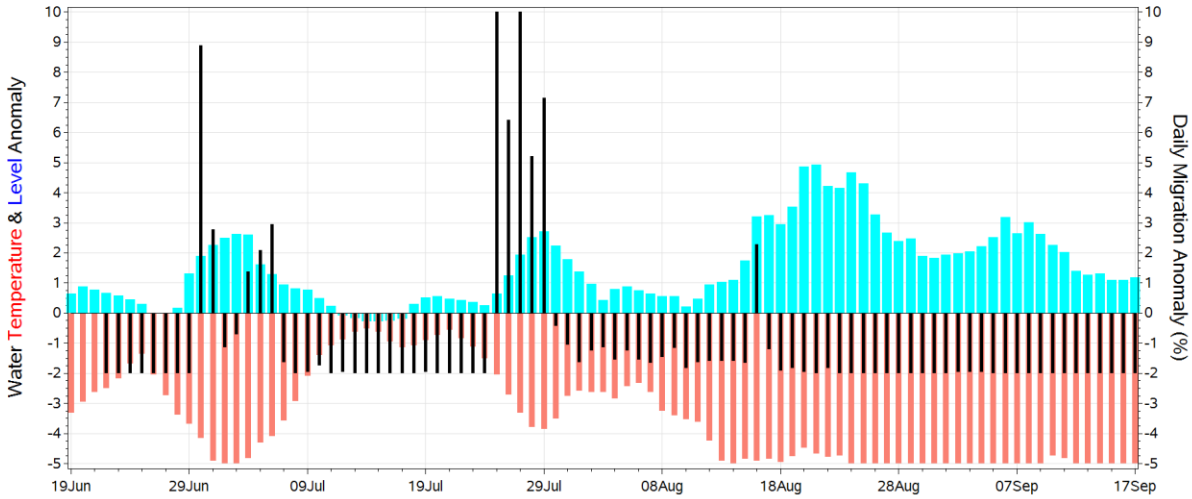
2009 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jun-Sep MWT: 15.8c Total Migrants: 4048
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL



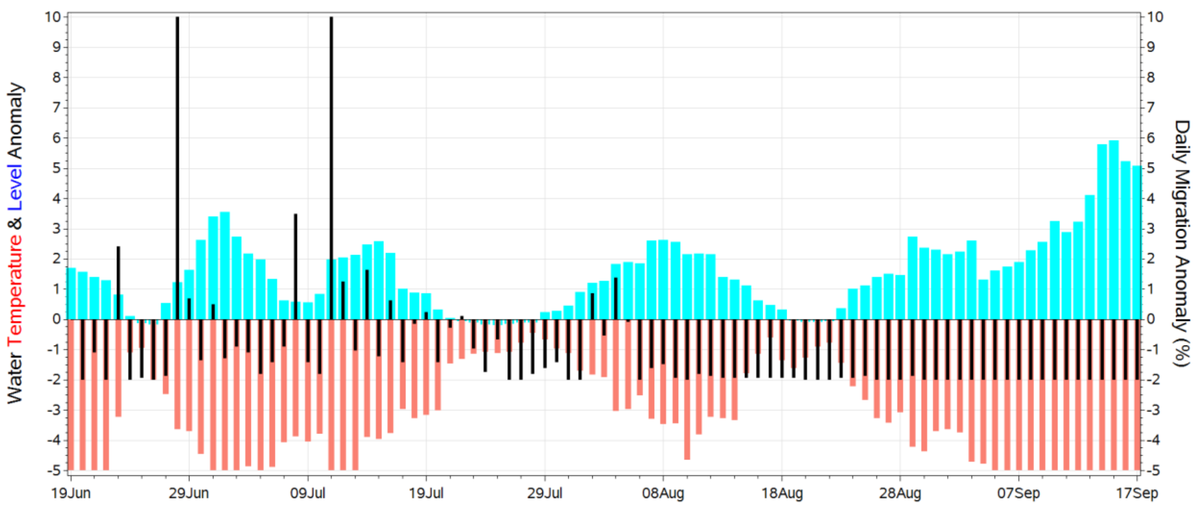
2010 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 15.6c Total Migrants: 2063
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL



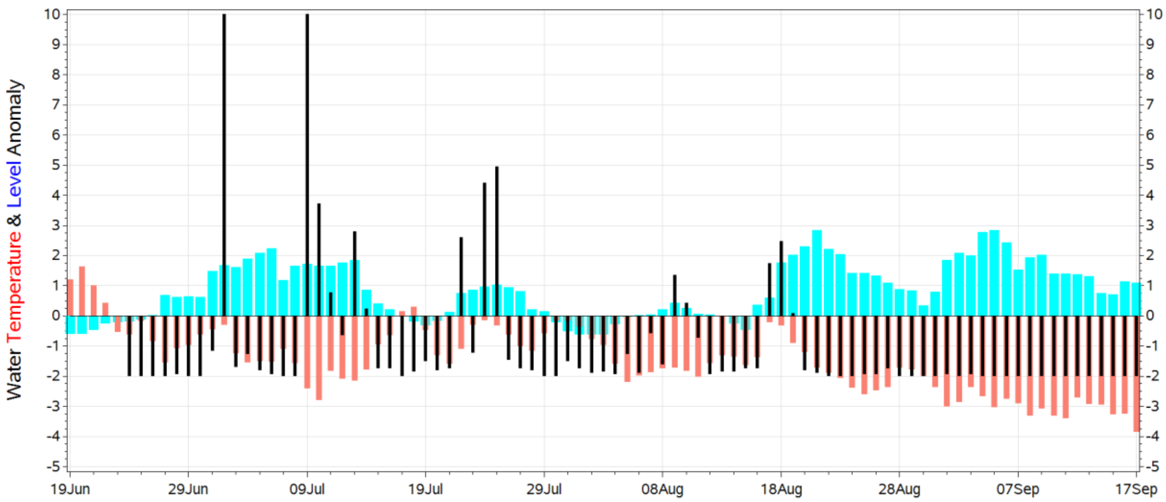
2011 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jun-Sep MWT: .c Total Migrants: 2426
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL



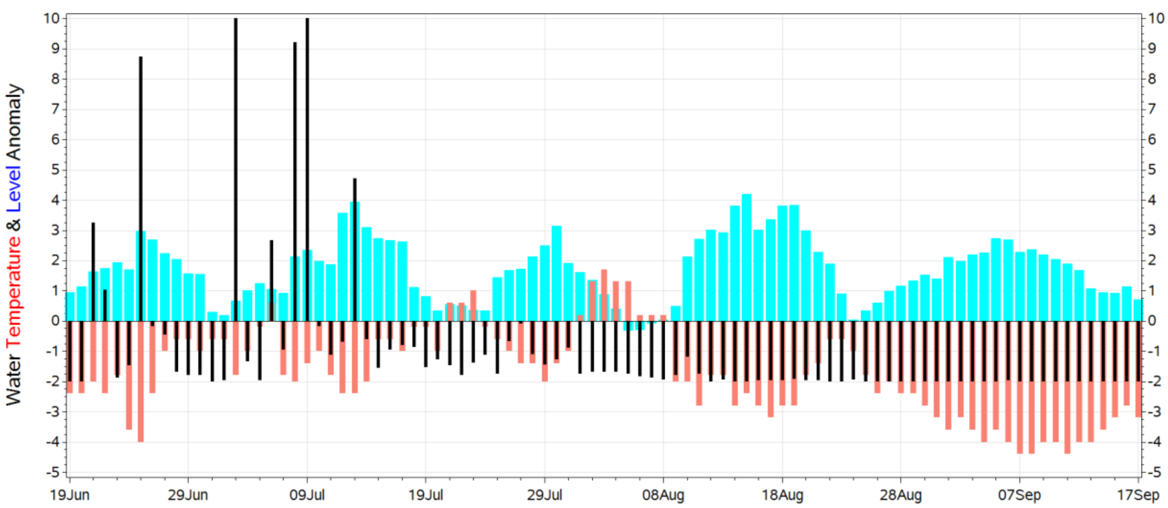
2012 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Cool Jun-Sep MWT: 14.4c Total Migrants: 1569
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL

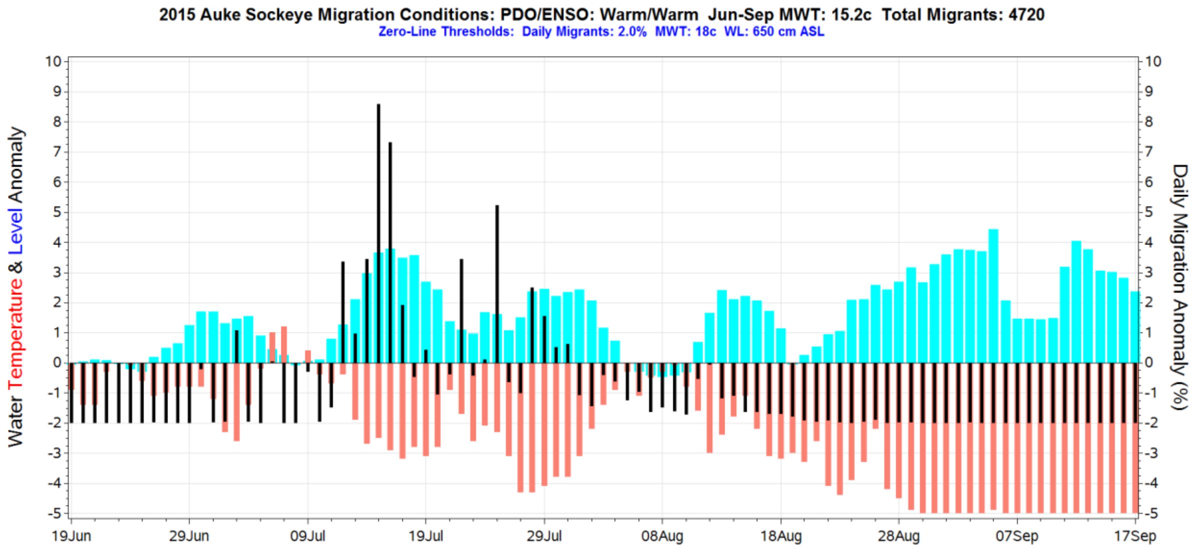


2013 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jun-Sep MWT: 16.5c Total Migrants: 2060
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL

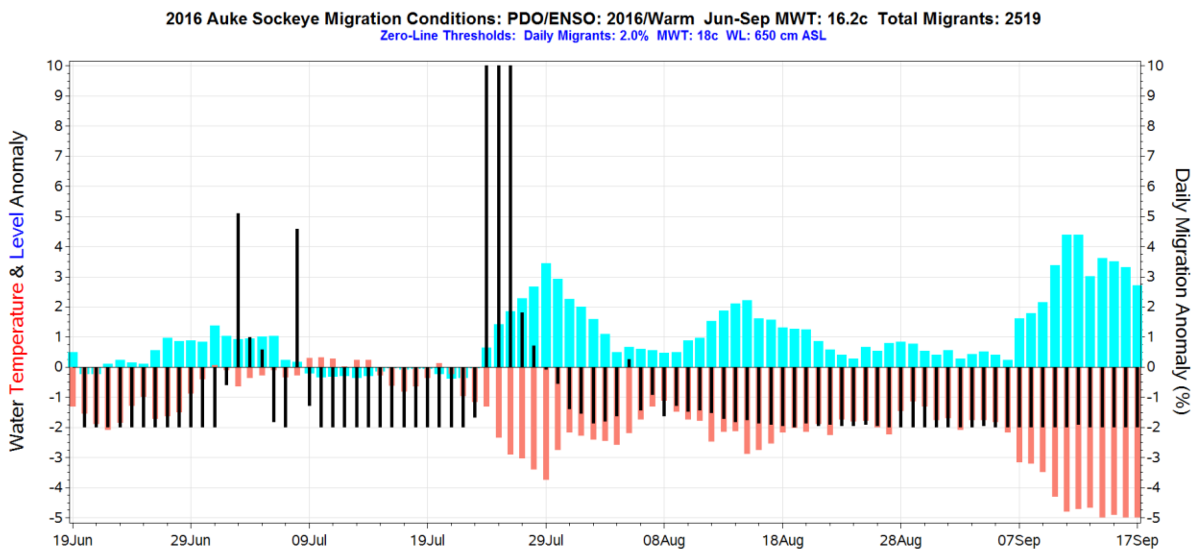


2014 Auke Sockeye Migration Conditions: PDO/ENSO: Cool/Neutral Jun-Sep MWT: 16.2c Total Migrants: 3443
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL





2015 Auke Sockeye Migration Conditions: PDO/ENSO: Warm/Warm Jun-Sep MWT: 15.2c Total Migrants: 4720
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep



2016 Auke Sockeye Migration Conditions: PDO/ENSO: 2016/Warm Jun-Sep MWT: 16.2c Total Migrants: 2519
Zero-Line Thresholds: Daily Migrants: 2.0% MWT: 18c WL: 650 cm ASL
Water Temperature & Level Anomaly
Daily Migration Anomaly (%)
19Jun
29Jun
09Jul
19Jul
29Jul
08Aug
18Aug
28Aug
07Sep
17Sep