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2017 Auke Creek Research Station Report: Data Summary and Historical Trends from 1980 to 2017

S. C. Vulstek, J. R. Russell, J. E. Joyce, and A. K. Gray

May 2022

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National Oceanic and Atmospheric Administration
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2017 Auke Creek Research Station Report: Data Summary and Historical Trends from 1980 to 2017

S. C. Vulstek, J. R. Russell, J. E. Joyce, and A. K. Gray

Auke Bay Laboratories
Alaska Fisheries Science Center
National Marine Fisheries Service
17109 Lena Point Loop Road
Juneau, AK 99801

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Abstract

The Auke Creek weir, located in Juneau, Alaska, is a permanent fish counting structure that allows for near complete sampling of downstream and upstream migrant salmonid species. The weir has been in operation in its current configuration since 1980 and has produced a rich long-term series of biological and physical data. Collected data include fish abundance, migration timing, age, length, and weight, as well as creek temperature, and gauge height. We summarize data collected in 2017 and report historical trends from 1980 to 2017. Since 1980, the temperature of Auke Creek appears to have increased. Coinciding with environmental changes, several biological attributes of Auke Creek salmonids have also been changing, such as migrations occurring earlier. Despite changing biotic and abiotic conditions, the abundance of most species and populations of Auke Creek salmonids has remained stable.

Contents

Introduction

The two main objectives of all physical and biological sampling efforts at Auke Creek Research Station are to: (1) provide indices of salmon productivity to inform salmon management in Southeast Alaska and (2) understand the impact of climate variability on critical periods of Pacific salmon life cycles by linking their freshwater and marine ecology. The complete enumeration of juvenile and returning adult coho, pink, and sockeye salmon provide indices of productivity that help inform science and management of those species in Southeast Alaska. Additionally, data collected at Auke Creek provide linkages to the nearshore and Gulf of Alaska marine environments and, when combined with marine surveys, allow for a more thorough examination of these larger ecosystem processes. The data collected between 1980 and 2017 provide 38 consecutive years of continuous, comparable data. Due to the volume of data encompassed by this report, analyses were limited in order to investigate as many basic historical trends as possible. While there are many interesting and more complex analyses to be done, we have focused on the relationship of fish abundance, size, age, and migration timing with year in order to construct a baseline reference for past, present, and future research regarding more specific topics.

Study Site and Weir Operation

Auke Creek Research Station is located approximately 16 km northwest of downtown Juneau, Alaska (Fig 1; Latitude: [58.38072 N] Longitude: [134.64187 W]). A fish collection weir intersects Auke Creek just above average high tide level. A fish tagging/incubating/rearing facility is adjacent to the weir. The current weir was built in 1979 and consists of a permanent structure that can be changed to either a downstream or upstream capture configuration. The steel framework of the weir is tied to a concrete pad on the stream floor and a concrete retaining

wall on each side of the creek in order to facilitate the capture of all upstream and downstream migrants, even in periods of high water discharge.

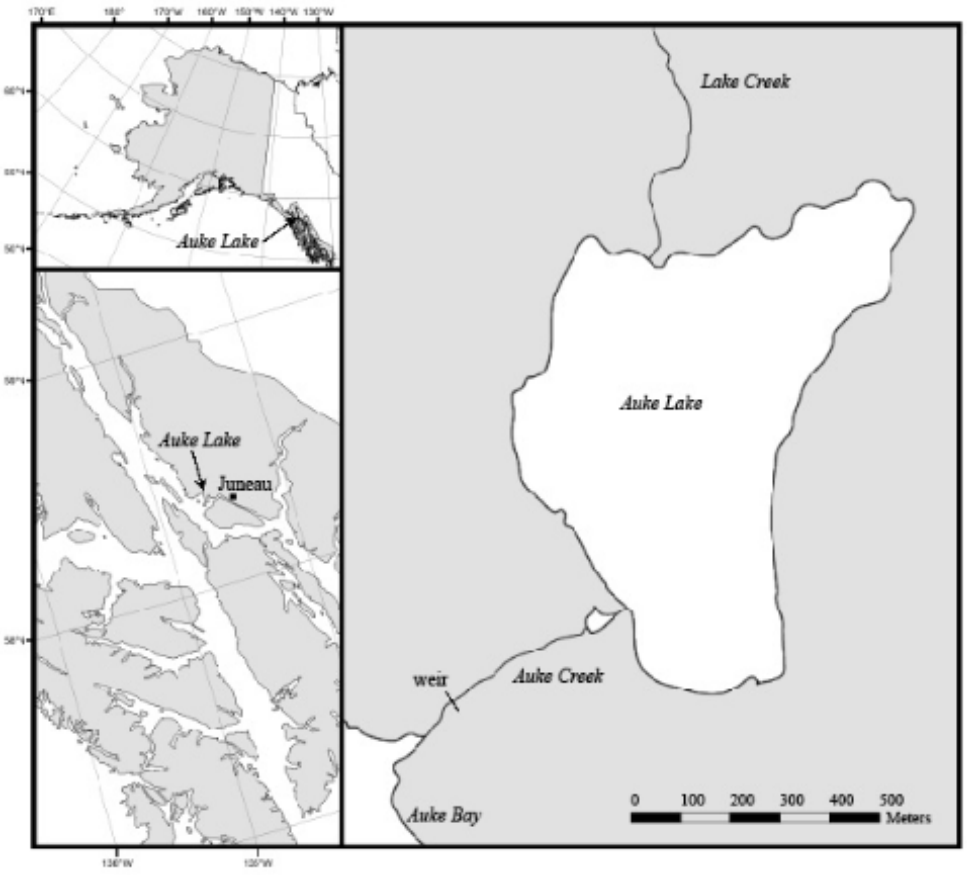

Figure 1. -- Location of Auke Creek Research Station in the Auke Lake System and in Southeast Alaska.

Auke Creek is the 0.65 km outlet of the Auke Lake watershed (Wing and Pella 1998). The watershed has a catchment of 10 km^2. Lake Creek and Lake Two Creek are the main tributaries that feed into Auke Lake. Auke Lake has an area of 0.67 km^2.

Before 1963, the substrate in Auke Creek consisted mainly of small rocks and boulders on bedrock, presumably with limited spawning area for salmon. Spawning channels built in the upper reach of Auke Creek in 1963 provided about 1,000 m^2 of new spawning area. The original

streambed substrate was removed down to bedrock during channel construction. The channels were created using 20 × 20 cm timbers bolted together to form single-wall dams about 1 m high. The timbers were buttressed from the downstream side by concrete-filled sandbags. Each dam was filled with washed rocks, mostly 5-10 cm cobbles, purchased locally. Since 1963, floods have washed large amounts of cobble fill from the channels, and the streambed is reverting to bedrock and small boulder substrate. The streambed downstream from the weir is intertidal, consisting of mainly boulders, broken shale, and smaller gravel on bedrock. The wash-out cobbles continue to move downstream during high flows and can now be found in the intertidal area.

The downstream weir is typically operated from early March through June. The weir captures salmonid species which migrate downstream in the following order: pink salmon (*Oncorhynchus gorbuscha*) fry, Dolly Varden char (*Salvelinus malma*), cutthroat trout (*O. clarkii*), coho salmon (*O. kisutch*) smolts, and sockeye salmon (*O. nerka*) smolts. The downstream weir allows water to spill through five inclined fan-shaped traps and removable vertical aluminum flow divider panels covered with 3-mm perforations. The remaining water from all five fan traps empties into a common trough that feeds a fish-sorting system comprised of two grate-type filters in the bottom of the trough. The first filter allows pink salmon fry to collect in the first of three bins. The second filter allows smolts and small trout and char to collect in the second bin, and large trout and char are separated into the third bin. Due to fluctuations in spring water flow and the small perforations necessary to capture pink salmon fry, the weir must be consistently cleaned and adjusted to maintain proper flow and prevent accumulation of debris to ensure the health of fish captured and held overnight.

The upstream weir is typically operated from late June through October. The weir captures Pacific salmon species which migrate upstream in the following order: sockeye salmon,

pink salmon, and coho salmon. The weir also captures Dolly Varden and cutthroat trout. In addition, chum salmon (*O. keta*), and Chinook salmon (*O. tshawytscha*) are captured at the weir, but they are the result of nearby hatchery production and are not native to the Auke Lake system. The upstream weir consists of vertical-slotted aluminum panels (90 × 178 cm) fitted into steel I-beams which angle upstream. Additional panels can be added during periods of high flow. Fish are unable to pass over the structure and are diverted into a holding trap. Aluminum screens (45 × 90 cm) with lateral slots (1.5 × 10 cm) were used to ensure capture of smaller trout and char during a previous period of intensive research on these species. Due to the heavy accumulation of downstream debris during periods of high water flow, however, the use of these additional finer meshed screens was discontinued in 2007 upon completion of those studies. As a result, while daily counts are made of cutthroat trout and Dolly Varden char, a complete census of upstream fall migrants is not possible.

Data Collection Prior to 1980

Prior to the operation of the current weir beginning in 1980, salmon abundance was collected by a variety of methods and with varying accuracy. Upstream migrant adult salmon abundance was estimated using with low-height, picket-style weirs. Sockeye salmon were captured from 1963 to 1979 and had an average abundance of 7,312. Pink salmon were captured in 1967, 1968, and from 1971 to 1979 and had an average abundance of 3,547 during these years. Coho salmon were captured from 1971 to 1979 with an average abundance of 681 adults and 288 jacks. Chum salmon were captured in 1967, 1968, and from 1971 to 1979 with an average abundance of 20 prior to enhancement experiments that started in 1976. However, the integrity of these picket weirs were often compromised during flood events some unknown level of fish passage likely occurred.

Pink salmon fry estimates were obtained between 1972 and 1979 using hydraulic census techniques. During that period, pink fry abundance was estimated at 131,660. However, hydraulic census techniques can be difficult in the large cobble substrate of Auke Creek. Chum salmon fry were observed in the 1972-76 downstream migrations but were not counted.

Fyke nets were used intermittently between 1961 and 1979 to capture sockeye smolts at the outlet of Auke Lake. From 1964 to 1979, wild sockeye smolt abundance estimates averaged 39,839. Also, pre-1980 adult counts suggest that smolts were significantly more abundant in the 1960s and early 1970s. However, sockeye smolt estimates lack continuity and some estimates are known to be incomplete.

In 1976, 1977, and 1979, coho smolts were captured by fyke net at the outlet of Auke Lake, and a portion of the total migration were adipose fin clipped and tagged with coded wires. For each of those years the total smolt abundance was estimated from the return of jacks and adults from each smolt cohort. The Auke Creek smolt abundance from partial-count years was estimated after determining the number of stray marked and unmarked jacks and adults at the weir, and subtracting them from the total upstream migration. The number of unmarked Auke Creek smolts was estimated from the ratio of marked smolts and marked and unmarked jacks and adults of Auke Creek origin. For the three years with estimates, the average abundance of coho smolts was 12,959.

Data Collection 1980 to Present

The present Auke Creek weir was built in 1979 and data collection at the present weir began in 1980. Methods and materials have remained consistent since, so we focus on data collected from 1980 onward.

Baseline physical data associated with Auke Creek are collected daily every year. Average daily stream temperature is calculated year-round using a thermograph that records stream temperature every hour. Water level is recorded each day throughout the downstream and upstream weir seasons. Since many salmonid populations overwinter in Auke Lake, ice conditions on Auke Lake can also influence migration. Ice-up is defined as the date on which 50% or more of the surface of Auke Lake is covered with ice, and ice-out is defined as the date on which less than 50% of the surface is covered with ice. These dates are recorded each fall and spring, respectively, in order to investigate relationships between ice coverage and salmonid population processes.

The downstream weir was operated from 24 February through 19 June in 2017. At minimum, all downstream migrants were identified and counted prior to release. Additional size and/or age data were collected for all species. Frequency of these additional data collections was based on availability of fish with the intent to collect a representative sample of the run for both size and age information. As downstream migration is strongly correlated with flow, temperature, and time of year, these sampling efforts were not evenly distributed throughout the downstream season. Fifty pink salmon fry were collected approximately once per week, anesthetized in a tricaine methanesulfonate (MS-222) solution, weighed to the nearest 0.001 g, and measured to the nearest 1 mm fork length. All coho smolt were anesthetized, injected with a coded wire tag (CWT), and marked by adipose-fin excision. Individuals from a random subsample of coho smolt were weighed to the nearest 0.01 g, and measured to the nearest 1 mm fork length. Additionally, scales were collected (4-8) to be aged at a later time. With the exception of CWT injection, sockeye smolts were sampled in the same manner as coho. All downstream migrant cutthroat trout and steelhead juveniles were counted and measured to the nearest 1 mm fork length. All downstream migrant Dolly Varden were also counted daily, and a

minimum of 1 in 10 Dolly Varden were randomly chosen to be measured to the nearest 5 mm fork length.

The upstream weir was operated from 19 June through 27 October in 2017. At minimum, all upstream migrants were identified and counted prior to release. Sex was determined for sockeye salmon, pink salmon, and coho salmon adults. Additionally, adult (age x.1) and jack (age x.0) coho salmon were examined for external marks prior to upstream release and enumerated by mark type. Additional length and scale data were collected at a frequency similar to that employed during the downstream season. Individuals from a random subsample (including jacks) of the coho and sockeye populations were measured to the nearest 1 mm fork length and 1 (sockeye) or 4 (coho) scales were collected and placed on gummed cards. Scales were later pressed onto acetate and aged. Again, the current weir configuration may allow the two-way passage of smaller cutthroat, steelhead, and Dolly Varden through the weir panels. Therefore, while trout and char captured in the adult trap were counted, size data were not collected and the censuses are assumed to be incomplete.

The primary goal of these baseline physical and biological sampling efforts at Auke Creek is to continue to monitor historical trends and to assess the health and productivity of the populations in the face of shifting freshwater and marine environments and fishery exploitation patterns. Data collected at Auke Creek also provide linkages to the nearshore and Gulf of Alaska marine environments and, when combined with marine surveys, allow for a more thorough examination of these larger ecosystem processes. The data collected between 1980 and 2017 provide 38 consecutive years of continuous, comparable data. Due to the volume of data encompassed by this report, analyses were limited in order to investigate as many basic historical trends as possible. While there are many interesting and more complex analyses to be done, we have focused on the relationship of fish abundance, size, age, and migration timing with year in

order to construct a baseline reference for past, present, and future research regarding more specific topics.

Climate Observation

The average temperature of Auke Creek in 2017 (7.6° C) was cooler than the 1980-2016 average (7.8° C). Temperature during the 2017 downstream migration period (March-June) was below the 1980-2016 average by 0.1° C (Fig. 2). However, temperatures during the 2017 upstream migration period (July-October) were generally near the 1980-2016 average. The ice-out date of Auke Lake in 2017 (17 April) was one day later than the 1980-2016 average (16 April; Fig. 3).

The average annual temperature of Auke Creek has increased over the last 36 years (0.03° C yr^{-1}, R2 = 0.19, P = 0.01; Fig. 4). Temperatures increased during both the downstream (0.03° C yr^{-1}, R2 = 0.07, P = 0.11) and upstream migration periods (0.02° C yr^{-1}, R2 = 0.12, P = 0.03; Fig. 5). Furthermore, average and maximum temperatures had positive temporal trends for all months from 1980 to 2016. In addition to warming, creek temperatures appear to have become more variable from May through September, months in which much of annual migrations occur.

The average gauge height in Auke Creek during 2017 (21.75 ft) was near the 2006-2016 average (21.72 ft).

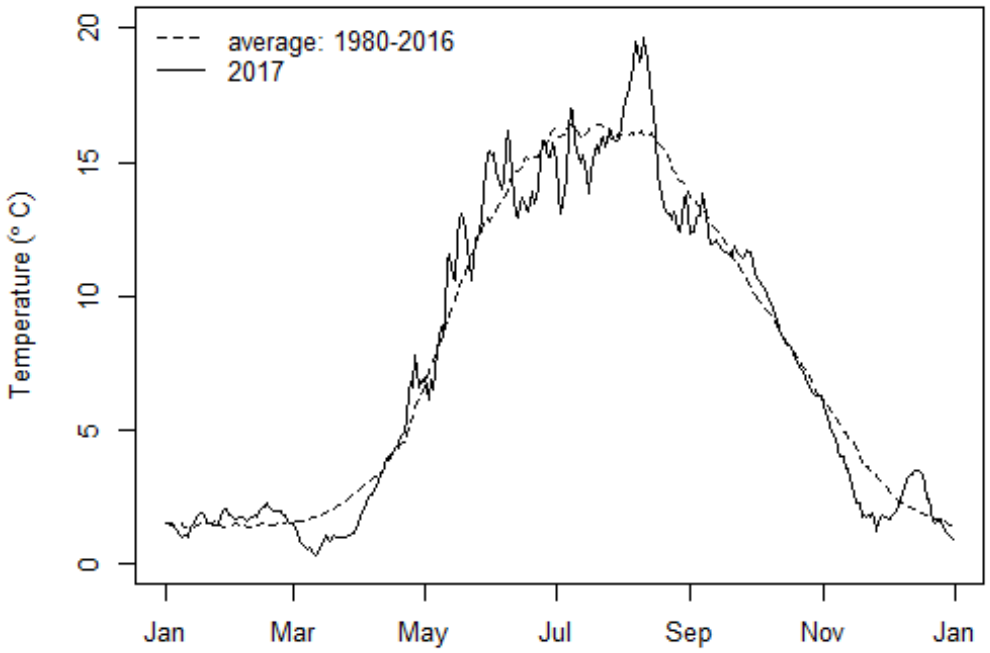

Figure 2. -- Average daily Auke Creek temperatures (°C) against date for 2017 and the 1980-2016 average.

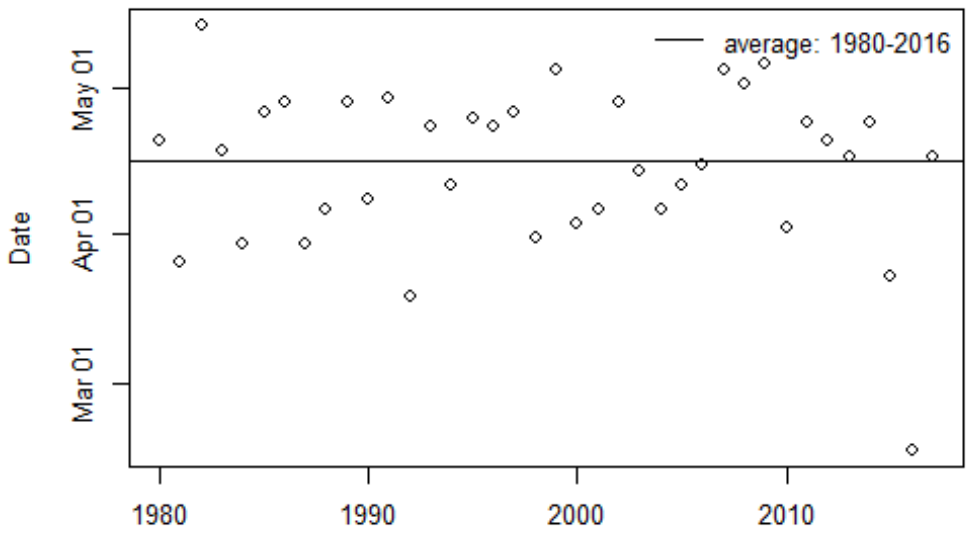

Figure 3. -- Dates of Auke Lake ice-out against year, 1980-2017.

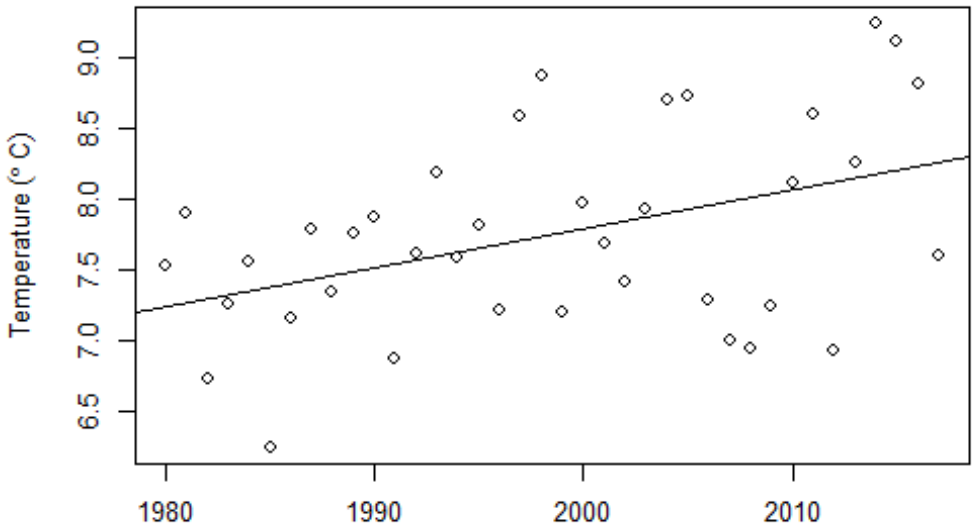

Figure 4. -- Average yearly temperature against year for Auke Creek and temporal trend, 1980-2015.

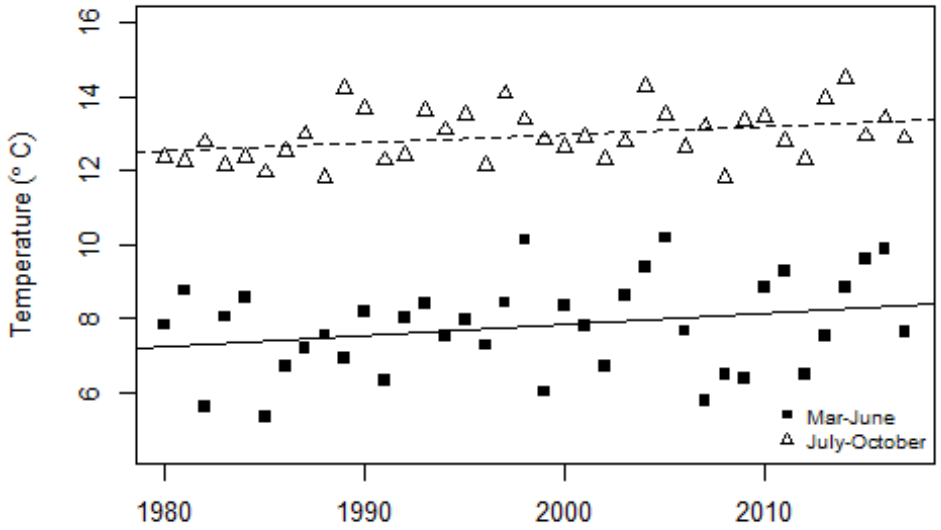

Figure 5. -- Average temperature during downstream (1 Mar. – 30 Jun.) and upstream migration periods (1 Jul. – 31 Oct.) against year for Auke Creek and temporal trends, 1980-2017. The trend line is solid for downstream migration and broken for upstream migration.

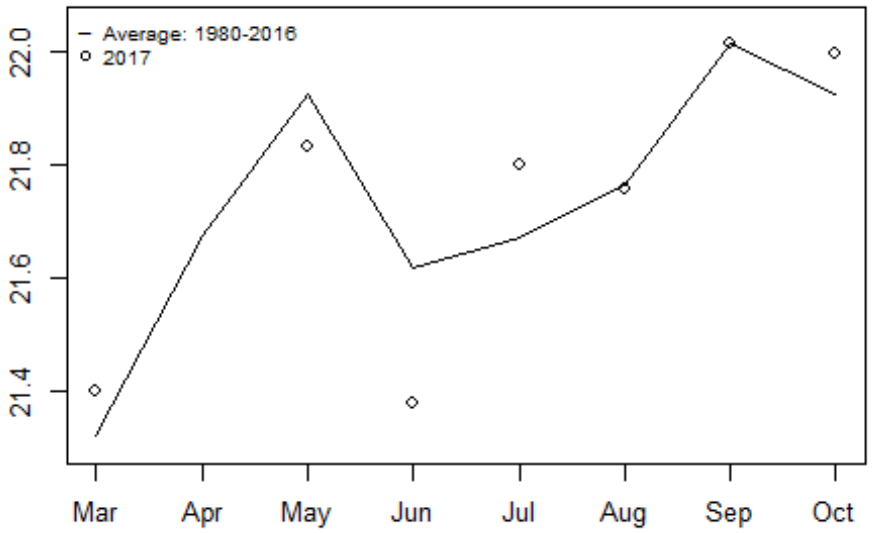

Figure 6. -- Average monthly gage height against month in Auke Creek for 2017 and the 1980-2016 average.

Pink Salmon

Background

Pink salmon spawn mainly in Auke Creek, and to a lesser degree, in the tributaries to Auke Lake. A small portion of pink salmon also spawn in the intertidal area downstream from the weir. Pink salmon have genetically isolated even and odd-year populations, resulting from strict 2-year life cycles. Additionally, Auke Creek pink salmon have historically consisted of distinct early and late runs. However, it is becoming increasingly difficult to differentiate early-run pink salmon from late-run pink salmon based on the sex ratio, general appearance of the fish, and daily abundance.

Current Status and Trends

In 2017, the abundance of Auke Creek pink salmon fry (18,105) was above the 1980-2016 average (95,407; Figs. 7 and 8; Appendix Table A-1). A total of 311 fry migrated

downstream in February, 1,164 migrated in March, 16,567 migrated in April, 60 migrated in May, and 3 migrated in June. Wild pink fry production had a negative temporal trend between 1980 and 2015 for even-year broods (-3,491.91 fry-yr, R2 = 0.35, P = 0.01). Odd-year brood abundance has remained stable since 1980 (R2 = 0.02, P = 0.56).

The 2017 Auke Creek fry downstream migration was one of the earliest on record (Fig. 9). The midpoint of migration in 2017 (09 April) was 8 days earlier than the long-term average midpoint (17 April). Pink salmon fry had a trend towards earlier migration midpoints from 1980 to 2017 for both even (-0.45 days-yr, R2 = 0.31, P = 0.01) and odd-year broods (-0.34 days-yr, R2 = 0.18, P = 0.07).

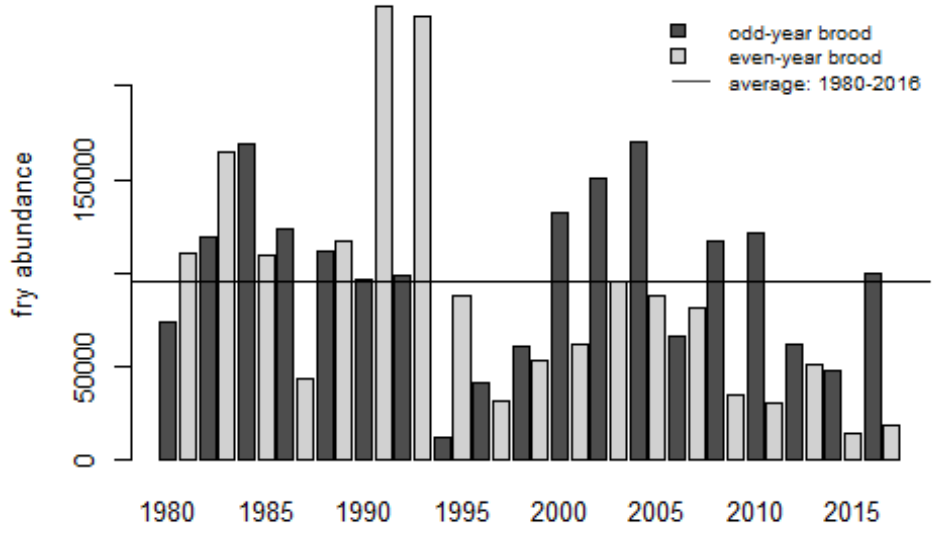

Figure 7. -- Yearly pink salmon fry downstream migration abundance against year for even- and odd-year broods at Auke Creek, 1980-2017.

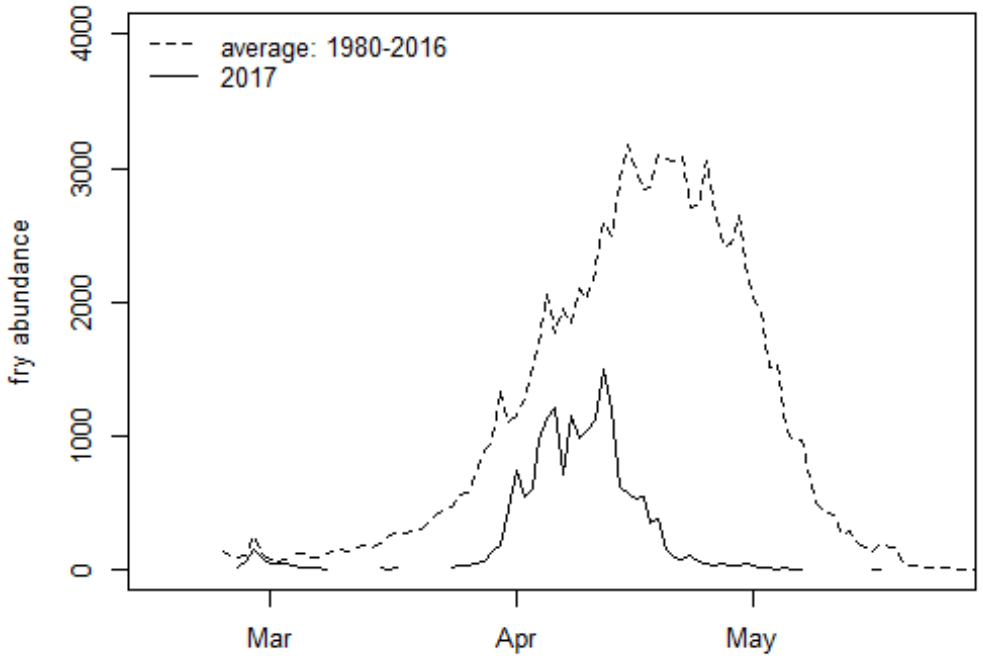

Figure 8. -- Daily pink salmon fry downstream migration abundance against date at Auke Creek for 2017 and the 1980-2016 average.

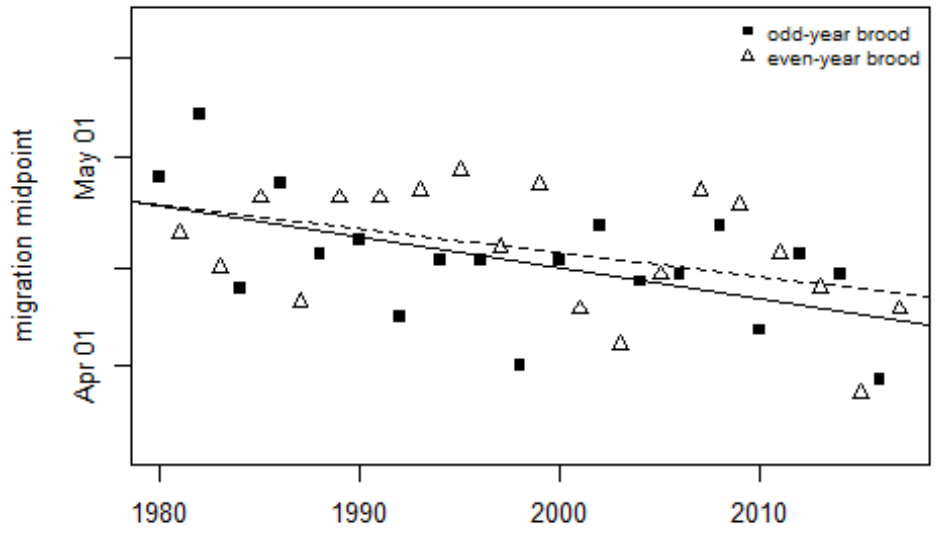

Figure 9. -- Yearly pink salmon fry downstream migration midpoint dates against year at Auke Creek for even- and odd-year broods and temporal trends, 1980-2017. The trend line is solid for even-year broods and broken for odd-year broods.

Marine survival of the 2015 brood (10.69%) was below the long-term average (11.29%). Pink salmon marine survival did not have temporal trends for either the even (R2 = 0.06, P = 0.31) or odd-year broods (R2 = 0.01, P = 0.78).

The abundance of upstream migrant pink salmon adults in 2017 (10,711) was above the long-term average (9,800; Fig. 10; Appendix Table A-1). A total of 60 adult pink salmon migrated in July, 8,662 migrated in August, and 1989 migrated in September. Abundance of adult pink salmon did not have a temporal trend for either the even (R2 = 0.01, P = 0.68) or odd-year broods (R2 = 0.2, P = 0.06).

The midpoint of the 2017 wild adult upstream migration (19 August; Fig. 11) was earlier than the 1980-2016 average (25 August). As with pink salmon fry, pink salmon adults had a trend towards earlier migration midpoints for both even (-0.25 days-yr, R2 = 0.21, P = 0.05) and odd-year broods (-0.09 days-yr, R2 = 0.01, P = 0.65).

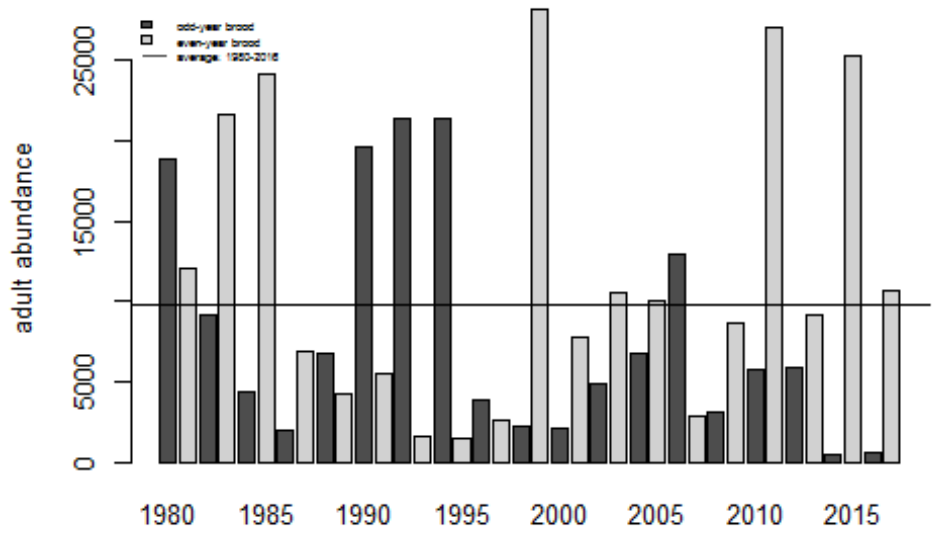

Figure 10. -- Yearly adult pink salmon upstream migration abundance against year for even- and odd-year broods at Auke Creek, 1980-2017.

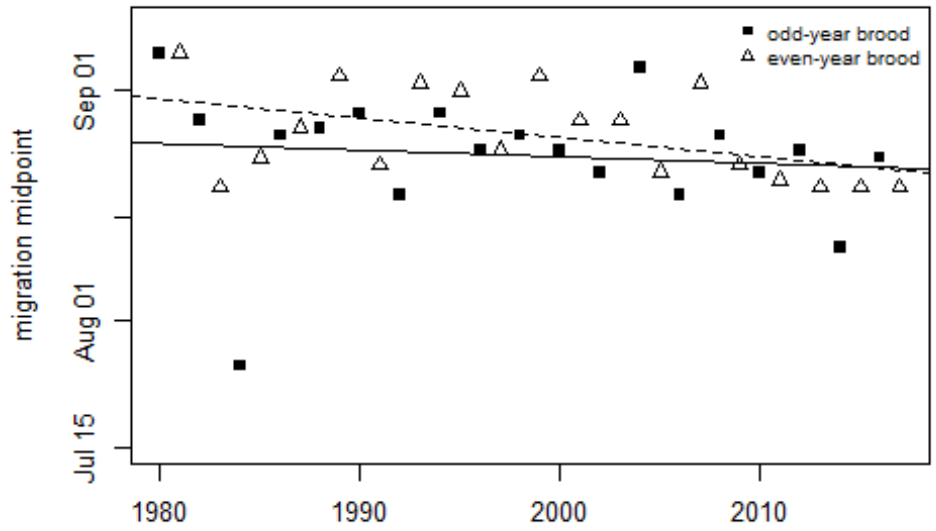

Figure 11. -- Yearly adult pink salmon upstream migration midpoint dates against year for even and odd-year broods at Auke Creek, 1980-2017. The trend line is solid for even-year broods and broken for odd-year broods.

Sockeye Salmon

Background

A sharp decline in abundance was observed in sockeye salmon during the late 1970s and early 1980s until enhancement research boosted subsequent escapements. Multiple enhancement and hatchery projects have been conducted on sockeye salmon at the Auke Creek Research Station. Hatchery-reared sockeye juveniles stocked in Auke Lake in 1974-75 and 1987-89 contributed to smolt downstream migrations in 1975-77 and 1988-91. Sockeye enhancement from 1988 to 1992 included the release of age-0 (under-yearling) smolts reared in the Auke Creek hatchery and in seawater net pens in Auke Bay. Age-0 sockeye reared in the hatchery were released into Auke Lake in 2012-2014, began their downstream migration in 2013, and finished in 2016.

Auke Creek sockeye salmon spawn in tributaries to Auke Lake and on submerged gravel beds in Auke Lake. Juvenile rearing likely occurs mainly in Auke Lake. Distinct size

differentiation allows for visual identification of age-1 and age-2 smolts (Figs. 16 and 17). When compared to scale ageing, this technique has proven to be fairly accurate, and scale samples are taken several times each year to confirm that size differentiation persists. Before 1980, it was estimated that age-2 smolts represented < 5% of the production, and some broods produced no age-2 smolts.

Current Status and Trends

The abundance of downstream migrant sockeye salmon smolt during 2017 (13,665) was below the 1980-2016 average (17,071; Fig. 12, Appendix Table A-2). A total of 11,691 smolt migrated downstream in May, and 1974 migrated in June. The 2017 year class consisted of approximately 9,655 age-1 smolts (2015 brood) and 4,010 age-2 smolts (2014 brood). The 2014 brood has completed the downstream migration. The total production for the 2014 brood (12,904) was below the 1978-2013 brood average (17,290; Fig. 13). Abundance of sockeye smolt did not have a linear temporal trend for either year class ($R^2 = 0.02$, $P = 0.43$) or brood year ($R^2 = 0$, $P = 0.75$).

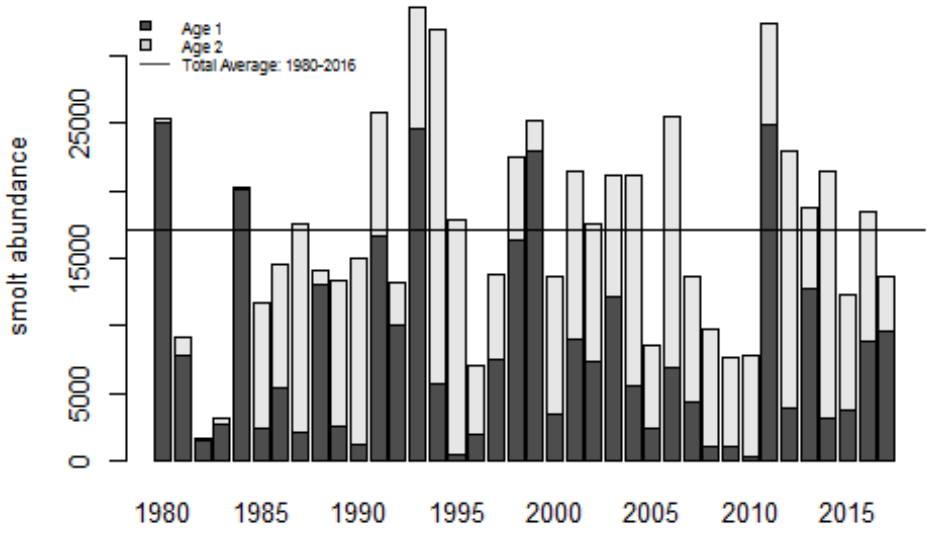

Figure 12. -- Yearly sockeye salmon smolt downstream migration abundance against year for age-1 and age-2 smolts at Auke Creek, 1980-2017.

The proportion of age-1 smolts has varied between 3.66% and 98.02% with an average of 44.98% for the 1978 to 2013 broods. The 2014 brood stock consisted of 68.92% age-1 smolts. Since 1978, sockeye smolts have shown a trend towards a lower proportion age-1 (-0.01-yr, R2 = 0.18, P = 0.01; Fig. 13).

Age-2 smolts migrated slightly earlier than did age-1 fish, with median dates of 24 May and 29 May, respectively (Fig. 14). The overall migration midpoint in 2017 (28 May) was later than the 1980-2016 average (24 May). The migration midpoints of sockeye smolts did not have a temporal trend (R2 = 0, P = 0.84; Fig. 15).

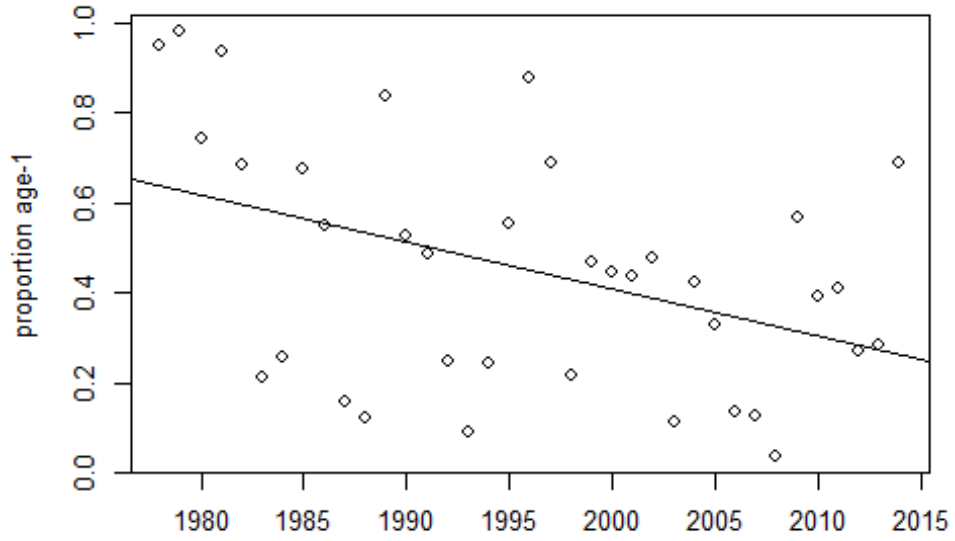

Figure 13. -- Yearly proportion of downstream migrant age-1 sockeye smolts (by brood year) against year and temporal trend, 1978-2014.

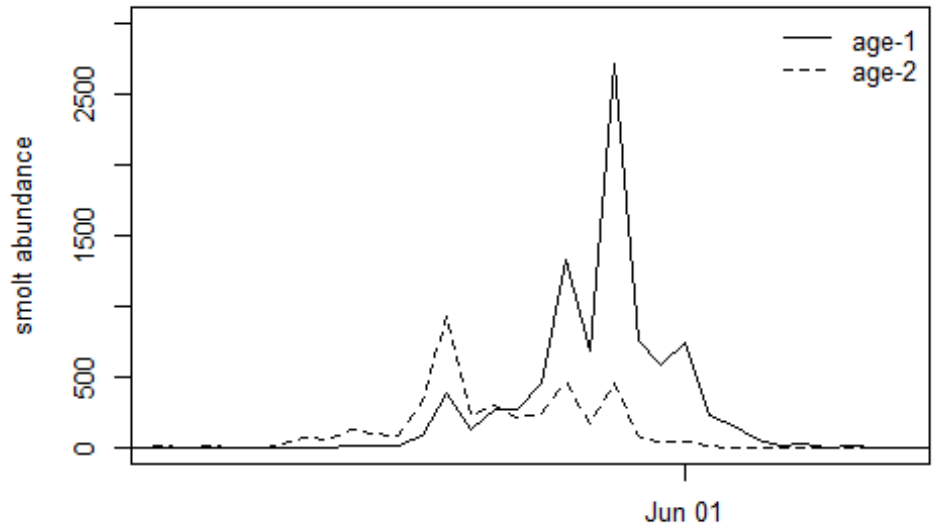

Figure 14. -- Daily sockeye salmon smolt downstream migration abundance against date for age-1 and age-2 smolts at Auke Creek in 2017.

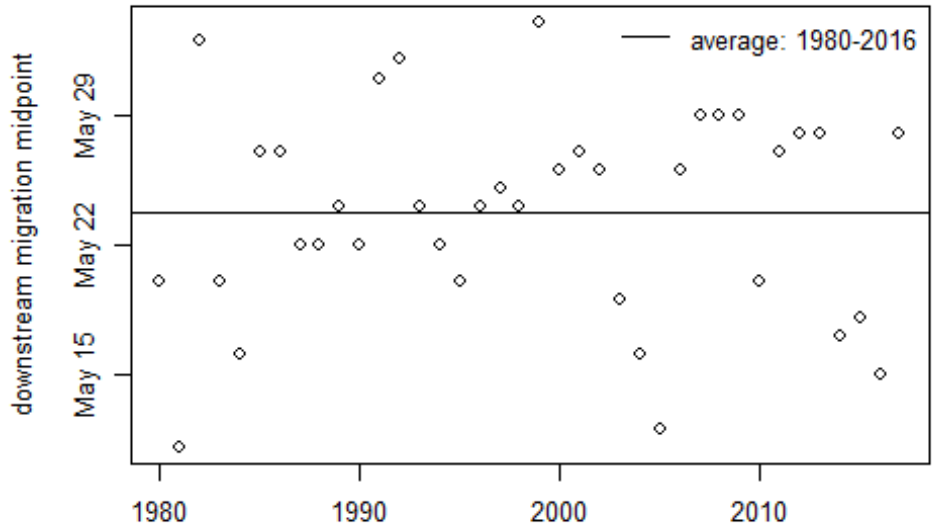

Figure 15. -- Annual sockeye salmon smolt downstream migration midpoint dates against year at Auke Creek, 1980-2017.

In 2017, the average length and weight of both age-1 (83 mm, 5 gm) and age-2 (140 mm, 25 gm) smolts were substantially above the 1980-2016 average for age-1 smolts (80 mm, 4 gm) and age-2 smolts (116 mm, 14 gm; Figs. 16 and 17). Age-2 smolts had a significant increase in

both length (0.74 mm-yr, R2 = 0.32, P ≤ 0.01) and weight (0.04 gm-yr, R 2= 0.11, P = 0.05) between 1980 and 2017. Age-1 smolts also had a trend toward greater length (0.23 mm-yr, R2 = 0.13, P = 0.03; Fig. 18) and weight (0.04 gm-yr, R2 = 0.11, P = 0.05; Fig. 19) since 1980.

The total biomass (total weight of all smolts in a migration year) of sockeye smolts in 2017 (149 kg; Fig. 20) was below the 1980-2016 average (157 kg). The annual biomass has a positive temporal trend since 1980 (3.77 kg-yr, R2 = 0.3, P ≤ 0.01).

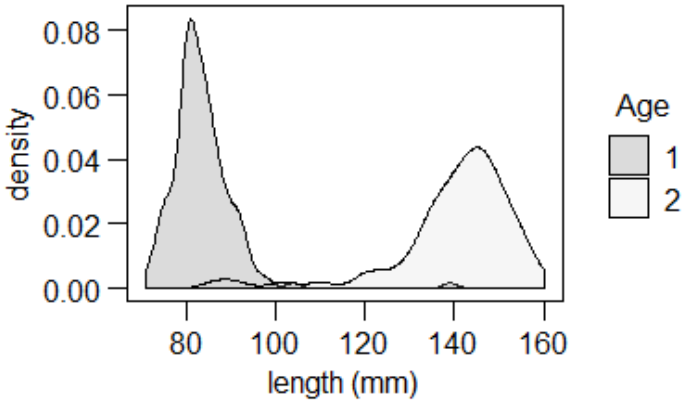

Figure 16. -- Frequency of downstream migrant sockeye salmon smolt lengths (mm) for age-1 and age-2 smolts at Auke Creek in 2017.

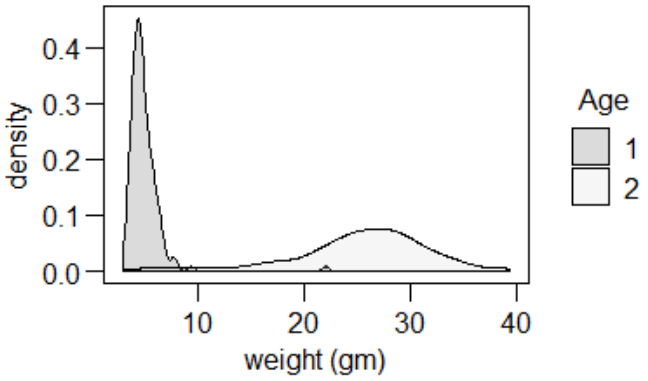

Figure 17. -- Frequency of downstream migrant sockeye salmon smolt weights (gm) for age-1 and age-2 smolts at Auke Creek in 2017.

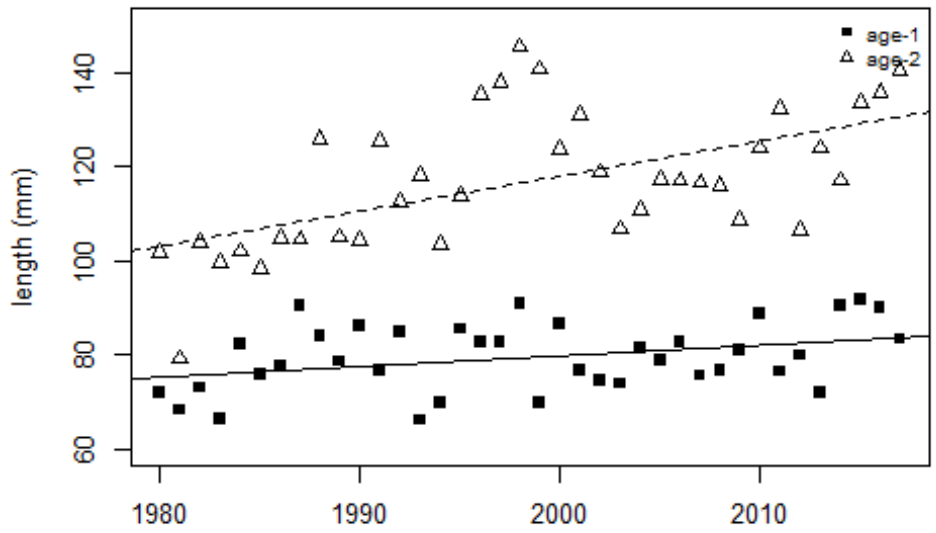

Figure 18. -- Yearly downstream migrant sockeye salmon smolt average length (mm) against year at Auke Creek for age-1 and age-2 smolts and temporal trends, 1980-2017. The trend line is solid for age-1 smolts and broken for age-2 smolts.

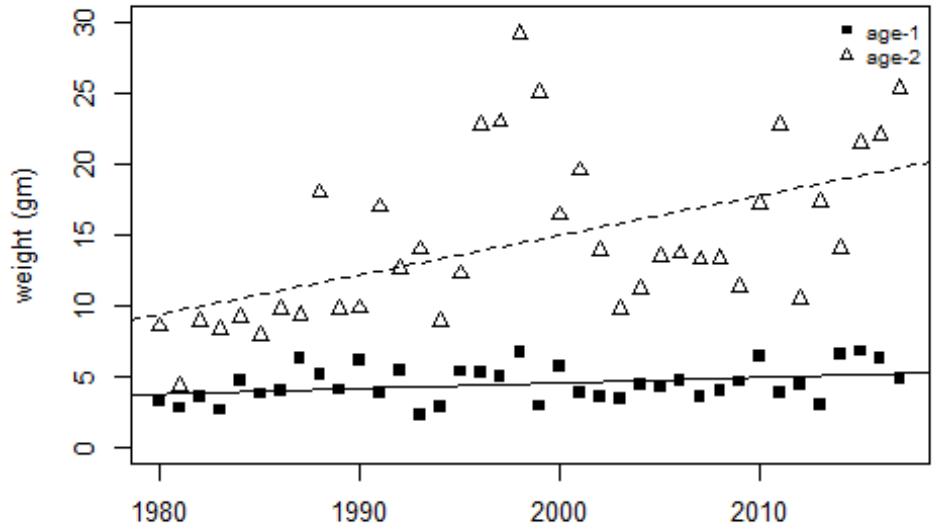

Figure 19. -- Yearly downstream migrant sockeye salmon smolt average weight (gm) against year at Auke Creek for age-1 and age-2 smolts and temporal trends, 1980-2017. The trend line is solid for age-1 smolts and broken for age-2 smolts.

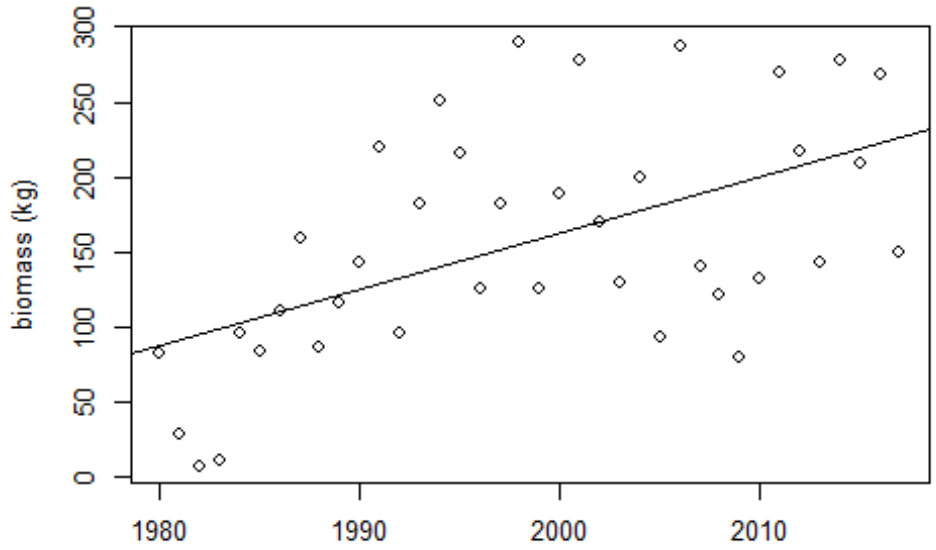

Figure 20. -- Yearly downstream migrant sockeye salmon smolt biomass (kg) against year at Auke Creek and temporal trend, 1980-2017.

A useful measure of freshwater survival is the number of smolts produced per spawner. The 2014 brood produced fewer smolts per spawner (3.86) than the long-term average (8.39; Fig. 21). The 2014 brood produced fewer age-1 smolts per spawner (2.66) than the long-term average (3.56). Additionally, the 2014 brood produced fewer age-2 smolts per spawner (1.2) than the long-term average (4.84).

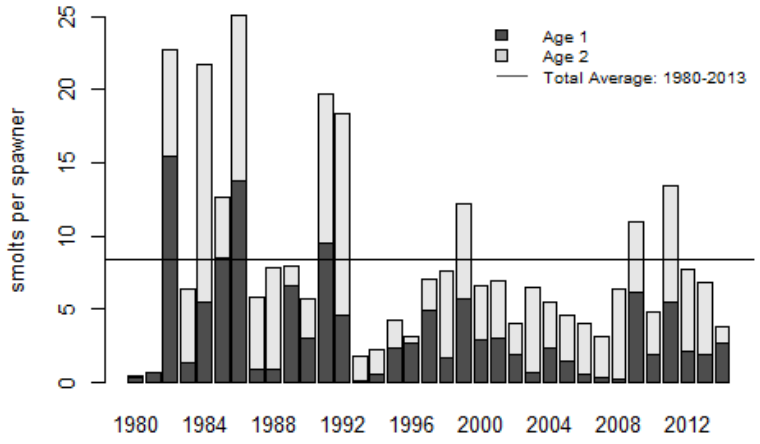

Figure 21. -- Yearly downstream migrant sockeye salmon smolts produced per spawner (by brood year) against year at Auke Creek, 1980-2014.

The 2017 sockeye upstream migration abundance (3,666) was above the 1980-2016 average (2,657; Fig. 24; Appendix Table A-2). The 2017 sockeye run consisted of 3,624 adults and 42 jacks. A total of 265 sockeye migrated in June, 2,668 sockeye migrated in July, 725 migrated in August, and 8 migrated in September. Adult sockeye salmon abundance did not have a temporal trend (R2 = 0.02, P = 0.37). Some of the returning sockeye salmon were hatchery reared. The proportion of hatchery reared fish will be determined using future genetic differentiation.

The upstream migration midpoint of sockeye salmon in 2017 (11 July) was earlier than the long-term average (22 July). Upstream migration midpoint had a trend towards occurring earlier from 1980 to 2016 (-0.29 days-yr, R2 = 0.09, P = 0.07; Fig. 23). Midpoints from 1990 to 1995 include hatchery fish and may not be representative of the midpoint for wild sockeye. However, the exclusion of these years does not affect the significance of the trend.

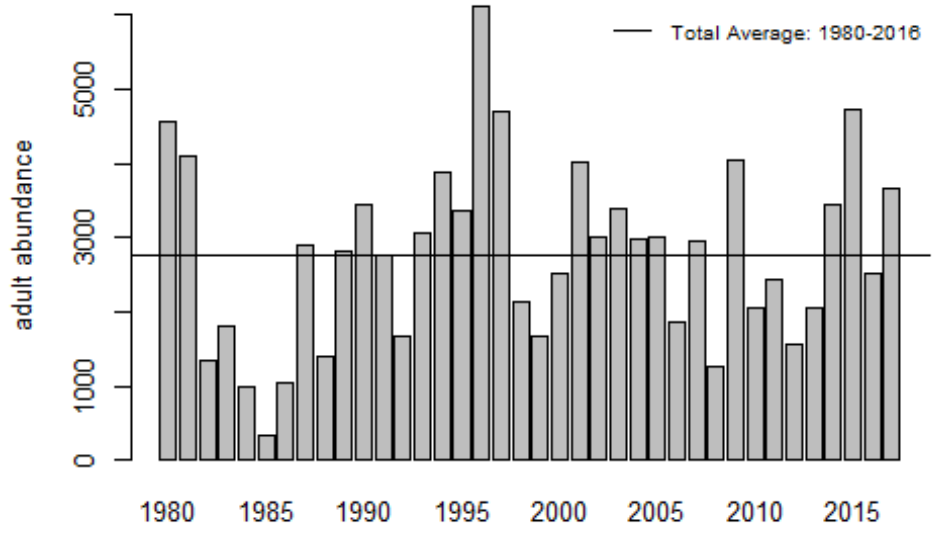

Figure 22. -- Yearly sockeye salmon adult upstream migration abundance against year at Auke Creek for hatchery and wild adults, 1980-2017. Hatchery adults were produced from lake-stocked fry and age-0 smolts.

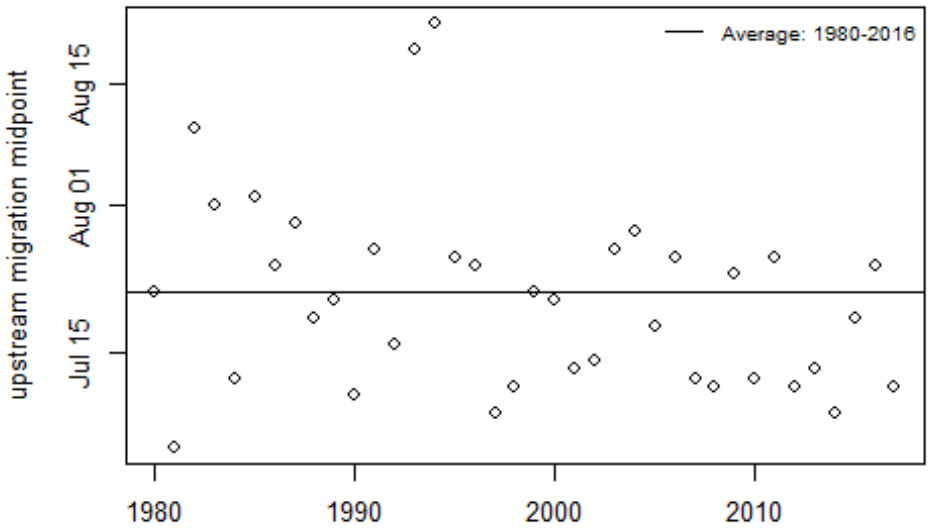

Figure 23. -- Yearly sockeye salmon adult upstream migration midpoint dates against year at Auke Creek 1980-2017. Midpoints from 1990 to 1995 include hatchery releases that may influence migration timing.

Coho Salmon

Background

Coho salmon spawn in the tributaries to Auke Lake and in the upper 100 m of Auke Creek. Juvenile rearing occurs in Auke Lake and probably most of the watershed, although the exact areas are not known.

Coho salmon were spawned for hatchery incubation at Auke Creek in 1978, 1980-84, and 1996-97. All hatchery smolts were tagged with coded wires and marked with an adipose and ventral fin clip to distinguish them from wild fish. All hatchery coho jacks and adults with double fin marks were killed when they returned to Auke Creek. From 1976 to 1980, there were marked and unmarked coho salmon jacks and adults from Auke Creek and from ADFG enhancement projects in the Juneau area. In those years tagged fish (missing the adipose fin) were sampled at different rates at Auke Creek weir to recover wire tags. Those recoveries and

tag release data for hatchery coho released locally were used to estimate the origin of coho in Auke Creek.

As with sockeye smolts, coho migrate downstream as either age-1 or age-2 smolts. When compared to sockeye salmon smolts, age-1 and age-2 coho salmon smolts show considerable overlap in length and weight (Figs. 28 and 29). This overlap occurs every year and makes scale ageing a challenge. Part of the reason for the overlap in size is because of the growth of age-1 smolts in the lake after the age-2 fish migrate. This phenomenon is visible on the scales of later migrants leaving Auke Lake, and in some years reflects rapid growth before the fish leave.

All coho smolts are injected with coded wire tags during downstream migration. Adipose fins are removed to allow for identification of tagged fish. Recovery of coded wire tags in commercial and sport fishery port sampling programs provides an estimate on the harvest of coho salmon from Auke Creek (Clark et al. 1994).

Current Status and Trends

The abundance of coho smolt downstream migrants in 2017 (4,178) was below the 1980-2016 average (6,160; Fig. 24; Appendix Table A-3). A total of 30 coho smolts migrated downstream in March, 30 migrated in April, 3,975 migrated in May, and 173 migrated in June. In 2017, 4,118 smolts were successfully marked by adipose fin clip, tagged with coded wires, and released. The 2017 year class consisted of approximately 2,653 age-1 smolts (2015 brood) and 1,525 age-2 smolts (2014 brood). Coho smolt abundance did not have a temporal trend between 1980 and 2017 by year class ($R2 = 0.03$, $P = 0.3$)

The 2014 brood production (7,217) was above the 1978 to 2013 average (6,025). Coho smolt abundance did not have a linear temporal trend by brood year ($R2 = 0.01$, $P = 0.55$).

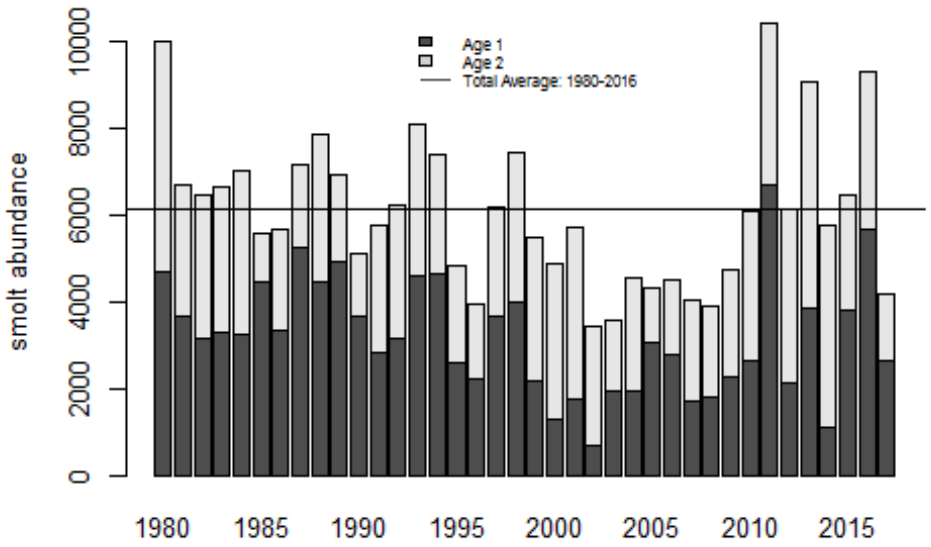

Figure 24. -- Yearly coho salmon smolt downstream migration abundance against year for age-1 and age-2 smolts at Auke Creek, 1980-2017.

The proportion of age-1 smolts has varied between 25.21% and 78.87% with an average of 52.41% for the 1978 to 2013 broods. The 2014 brood stock consisted of 78.87% age-1 smolts. Since 1978, coho smolts have had a trend towards a lower proportion age-1 (0-yr, R2 = 0.14, P = 0.02; Fig. 25).

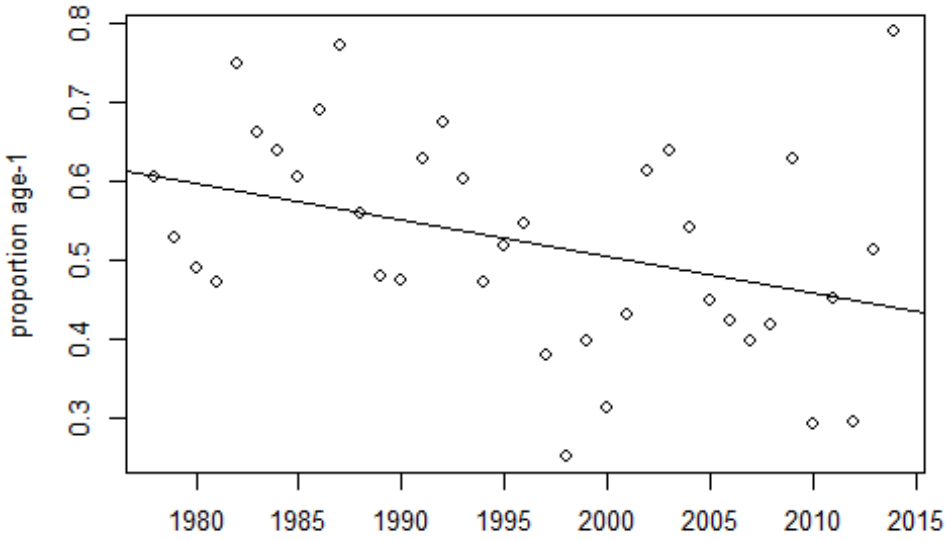

Figure 25. -- Yearly proportion of downstream migrant age-1 coho smolts (by brood year) against year and temporal trend, 1978-2014.

In 2017, the migration midpoint of age-2 smolts (14 May) was earlier than that of age-1 smolts (16 May; Fig. 26). The coho smolt migration midpoint in 2017 (15 May) was earlier than the 1980-2016 average (20 May). Coho smolt had a trend towards earlier migration midpoints since 1980 (-0.18 days-yr, R2 = 0.2, P = 0.01; Fig. 27).

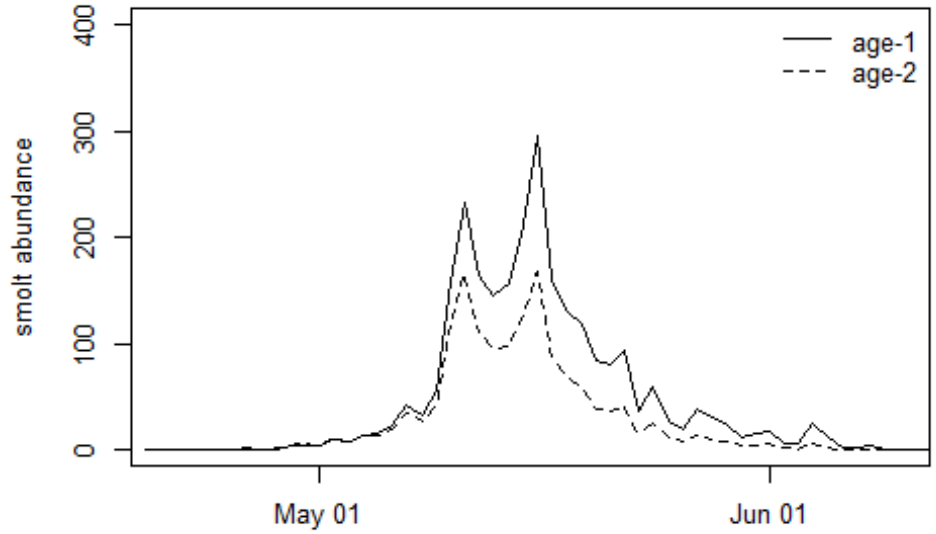

Figure 26. -- Daily coho salmon smolt downstream migration abundance against date for age-1 and age-2 smolts at Auke Creek in 2017.

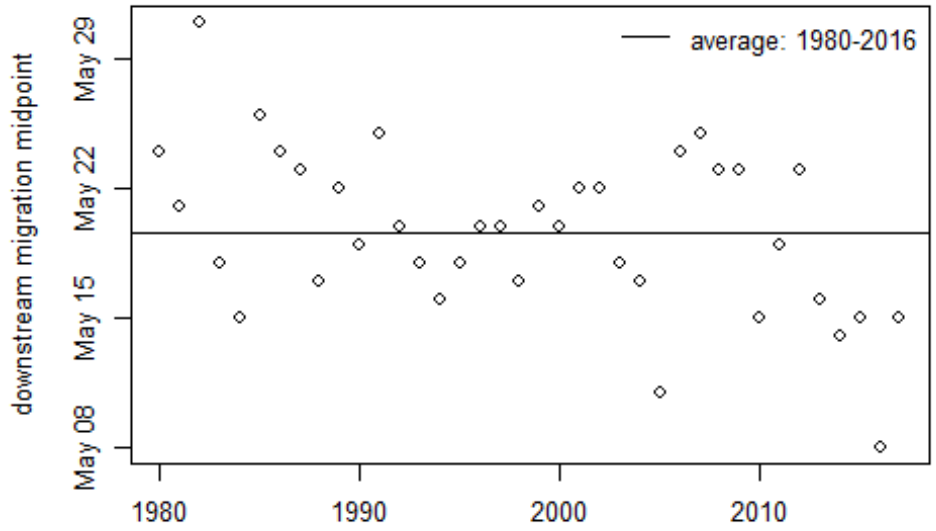

Figure 27. -- Yearly coho salmon smolt downstream migration midpoint dates against year at Auke Creek, 1980-2017.

In 2017, the average length and weight of both age-1 (105 mm, 11 gm) and age-2 (127 mm, 19 gm) smolts were near the 1980-2016 average for age-1 smolts (106 mm, 11 gm) and age-2 smolts (126 mm, 18 gm; Figs. 28 and 29). Age-2 smolts had no significant change in both length (R2 = 0, P = 0.74) and weight (R2 = 0.02, P = 0.37) between 1980 and 2017. Age-1 smolts also had no trends in length (R2 = 0.01, P = 0.54; Fig. 30) and weight (R2 = 0.02, P = 0.37; Fig. 31) since 1980.

The total biomass of coho smolts in 2017 (58 kg) was above the long-term average (90 kg). Biomass did not have a temporal trend between 1980 and 2015 (R2 = 0.01, P = 0.54; Fig. 32). However, biomass appears to have increased over the last decade.

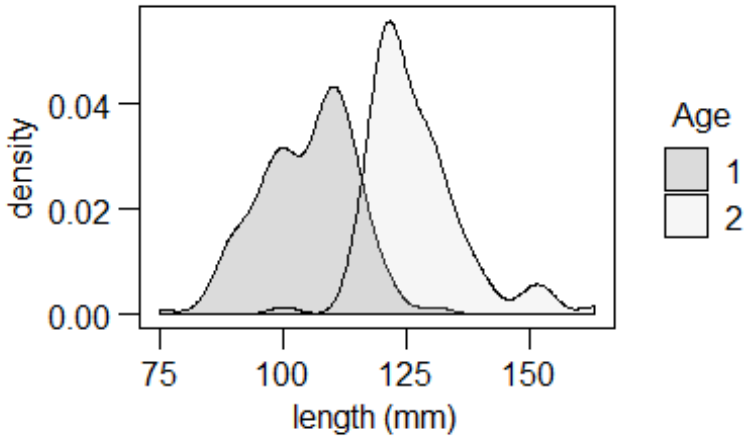

Figure 28. -- Frequency of downstream migrant coho salmon smolt lengths (mm) for age-1 and age-2 smolts at Auke Creek in 2017.

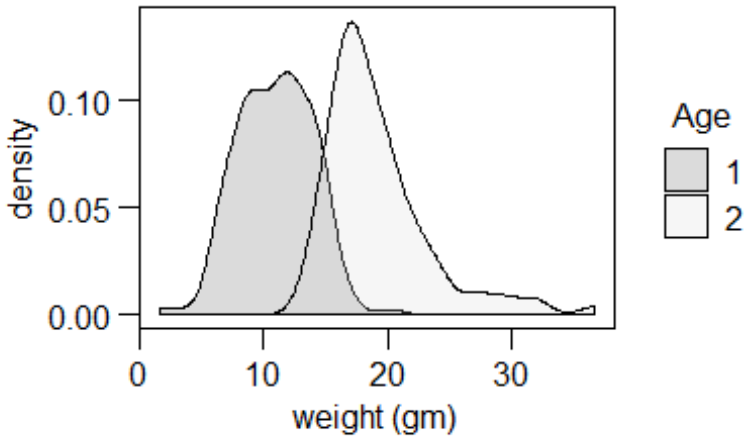

Figure 29. -- Frequency of downstream migrant coho salmon smolt weights (gm) for age-1 and age-2 smolts at Auke Creek in 2017.

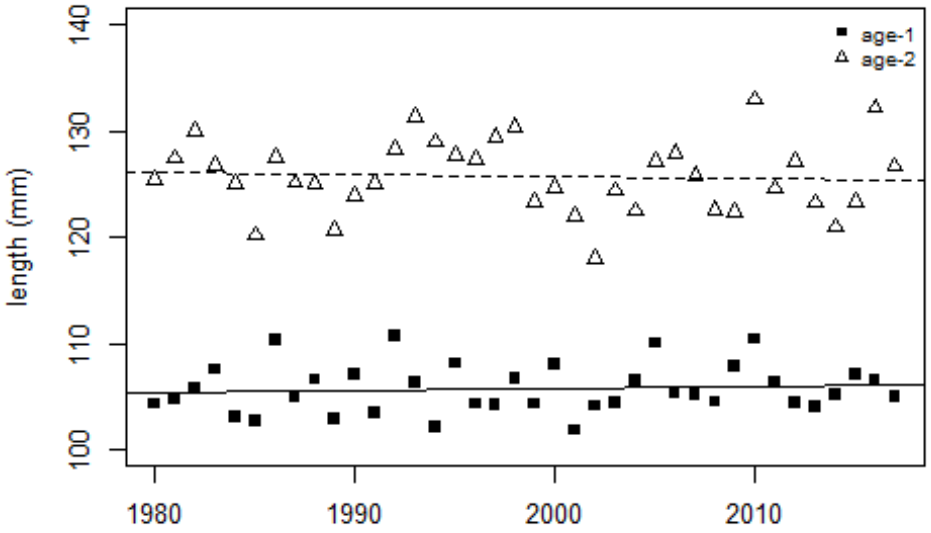

Figure 30. -- Yearly downstream migrant coho salmon smolt average length (mm) against year at Auke Creek for age-1 and age-2 smolts and temporal trends, 1980-2017. The trend line is solid for age-1 smolts and broken for age-2 smolts.

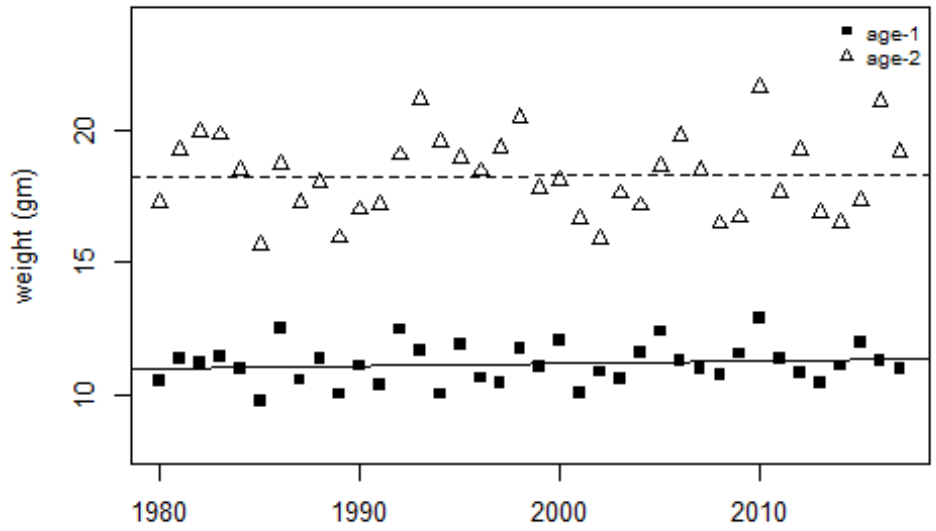

Figure 31. -- Yearly downstream migrant coho salmon smolt average weight (mm) against year at Auke Creek for age-1 and age-2 smolts and temporal trends, 1980-2017. The trend line is solid for age-1 smolts and broken for age-2 smolts.

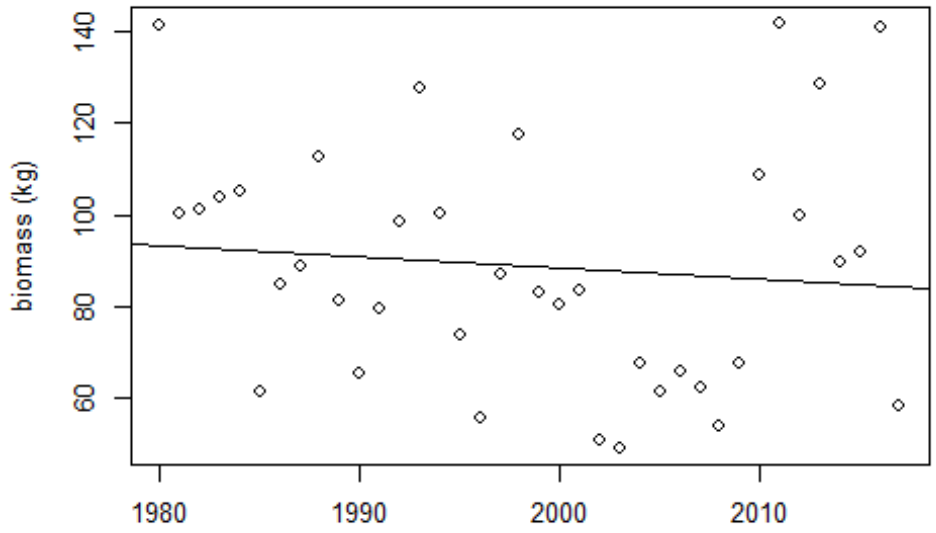

Figure 32. -- Yearly downstream migrant coho salmon smolt biomass (kg) against year at Auke Creek, 1980-2017.

The 2014 brood produced smolts per spawner (4.71) below the long-term average (10.01; Fig. 33). The 2014 brood produced fewer age-1 smolts per spawner (3.71) than the long-term average (5.21). Additionally, the 2014 brood produced more age-2 smolts per spawner (0.99) than the long-term average (4.8).

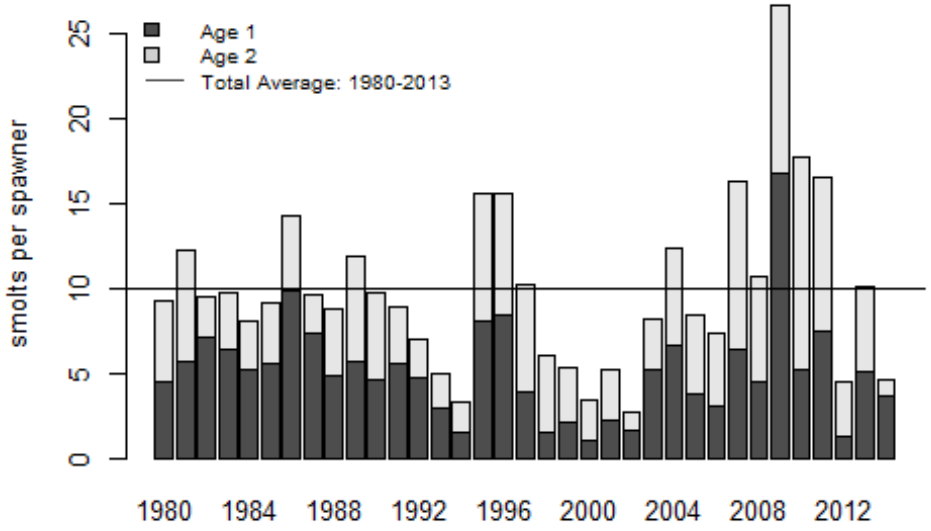

Figure 33. -- Yearly downstream migrant coho salmon smolts produced per spawner (by brood year) against year at Auke Creek, 1980-2014.

The abundance of upstream migrant adult coho salmon in 2017 (304) was lower than the 1980-1980-2016 average (683; Appendix Table A-3). In 2017, a total of 14 coho adults migrated upstream in August, 265 migrated in September, and 25 migrated in October. The yearly abundance of upstream migrant coho salmon did not have a significant temporal trend from 1980 to 2017 ($R2 = 0.05$, $P = 0.16$).

The upstream migration midpoint for adult coho in 2017 (11 September) was earlier than the 1980-2016 average (21 September). Coho adults have a significant trend towards earlier migration midpoints between 1980 and 2017 (-0.43 days-yr, $R2 = 0.73$, $P \leq 0.01$; Fig. 34).

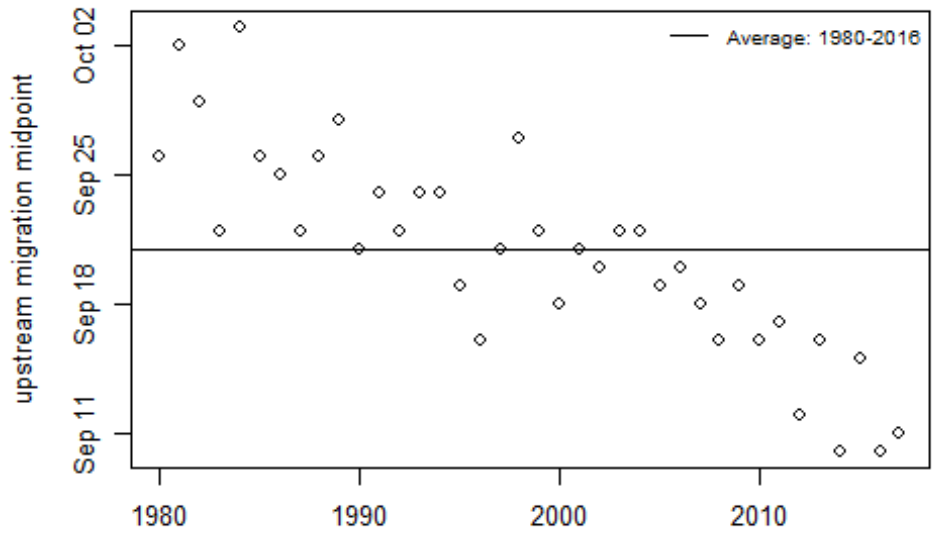

Figure 34. -- Yearly coho salmon adult upstream migration midpoint dates against year at Auke Creek and temporal trend, 1980-2017.

The estimated harvest of Auke Creek coho salmon in 2017 (41; Fig. 35; Appendix Table A-4) was lower than the 1980-2016 average (424). Likewise, the estimated harvest rate of Auke Creek coho salmon in 2017 (7.12%) was below the long-term average (30.74%). For 2017 returns, marine survival (6.18%) was below 1980-2016 average (23.02%).

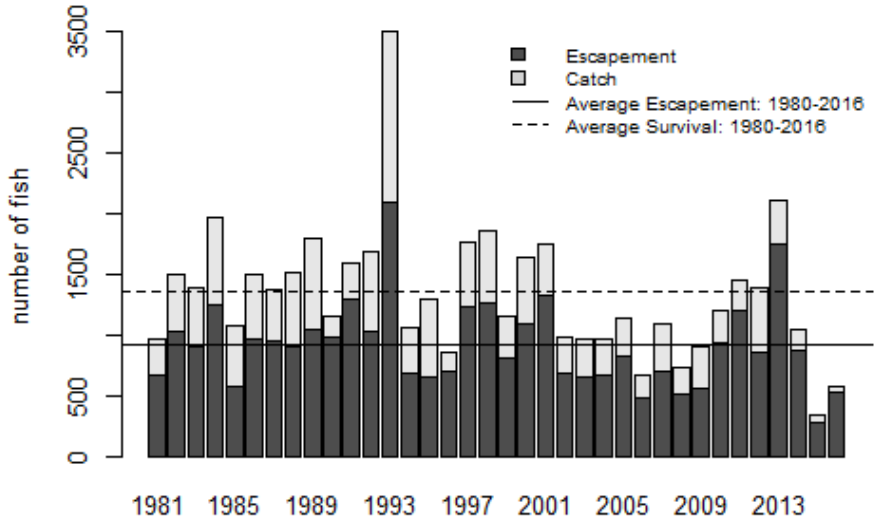

Figure 35. -- Yearly coho salmon smolt marine survival (returning adult abundance; by year of smolt migration) against year, including both catch (harvested adults) and escapement (weir captured adults), for coho salmon native to Auke Creek, 1981-2017.

Chum Salmon

It is not known if chum salmon are native to Auke Creek or strays from other local systems. Probably few chum salmon were ever produced in the Auke Lake system, although adults were observed in all spawning areas, including the intertidal. From 1976 to 1985, NMFS conducted chum salmon enhancement projects, and examined the use of a small population for brood stock development, marine survival of juveniles, and age heritability. Hatchery chum salmon fry were released in 1977-84 and 1986. All hatchery fry, except in 1984, were marked by ventral fin clip or adipose fin clip and coded wire tag. No adults were released in Auke Creek from 1976 to 1983. In those years all chum adults were captured and spawned for hatchery incubation, thus, no wild fry were captured at Auke Creek from 1977 to 1984. Chum salmon adults seen at Auke Creek since 1994 are most likely strays from releases of Macaulay hatchery juveniles at Amalga Harbor and other release sites.

In 2017, the abundance of adult chum salmon was 1,396. Based on run timing and chum salmon adult abundance, it is suspected that most of the adults were strays from Macaulay hatchery releases. Before 1994, chum salmon in Auke Creek typically migrated after during the last week of August of early September, were much smaller in size, and exhibited far greater body condition than the suspected strays that currently migrate earlier in the year. It is presumed that these chum salmon, if any, are endemic to Auke Creek. In an effort to minimize the impact of such a large number of strays, only fish believed to be endemic to Auke Creek were allowed to spawn in 2016. Therefore, very few fry were seen in the spring of 2017 (127). Also, due to the confusion surrounding adult chum salmon in Auke Creek, historical averages have little meaning. Wild and hatchery adults are differentiated as accurately as possible; September upstream migrants are typically counted as wild.

Chinook Salmon

Chinook salmon are not native to the Auke Lake system. Chinook captured at Auke Creek are hatchery fish from releases of juveniles in the Juneau area, including Auke Bay near Auke Creek. Those releases began as a 3-year cooperative study in 1986 to examine survival, homing, and straying of hatchery Chinook. The original study plan and fish transport permit required that all Chinook be killed when they entered Auke Creek. This was to prevent the intentional release of Chinook in the Auke Lake system as well as the potential transport of infectious hematopoietic necrosis (IHN) virus. The project continues under an arrangement between Sport Fish Division, ADFG, and Douglas Island Pink and Chum Incorporated. Juveniles were released near Auke Creek in spring 2017.

At Auke Creek, Chinook are captured at the weir and classed as mini-jacks or adults based on length. All mini-jacks are precocious males < 250 mm fork length that mature and return to fresh water the same year they are released. Adults are > 250 mm and remain at large for 1 year or more. Chinook captured in 2015 were sampled for size and tags if they had an adipose fin clip. In 2017, Chinook mini-jacks numbered 263 and adult Chinook numbered 309 (Fig. 36; Appendix Table A-5).

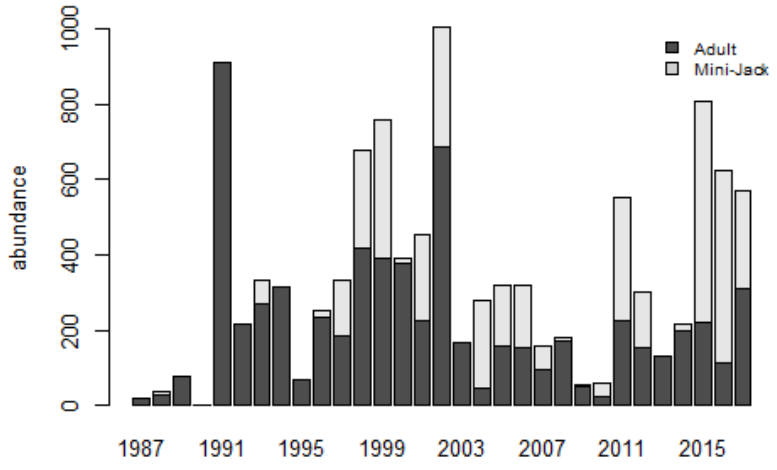

Figure 36. -- Yearly Chinook salmon immigration abundance against year for mini-jacks and adults at Auke Creek, 1987-2017.

Dolly Varden Char

The Auke Lake system is important for spawning, rearing, and over-wintering Dolly Varden in the Juneau area. Dolly Varden spawner numbers and smolt production in the Auke Lake watershed are not known. Since the reconfiguration of the upstream weir in 2007, the smallest Dolly Varden may have been able to pass the weir undetected during upstream migration, and censuses are not considered complete. Thus, we only present data for the downstream migration of Dolly Varden here.

The Dolly Varden downstream migration abundance in 2017 (5,756) was below the 1980-2016 average (5,990; Fig. 38; Appendix Table A-6). A total of 2,221 Dolly Varden migrated downstream in March, 2,221 migrated in April, 3521 migrated in May, and 14 migrated in June. Dolly Varden downstream abundance did not have a linear trend between 1980 and 2017 (R2 = 0.01, P = 0.61). The Dolly Varden downstream migration midpoint in 2017 (5 May) was earlier than the long-term average (8 May; Fig. 38). Downstream migration midpoints did not have a temporal trend between 1980 and 2017 (R2 = 0.03, P = 0.27).

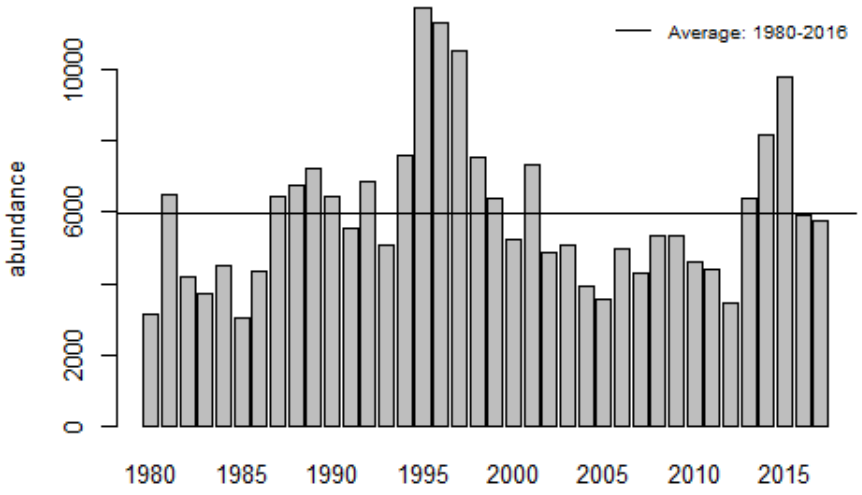

Figure 37. -- Yearly Dolly Varden downstream migration abundance against year at Auke Creek, 1980-2017.

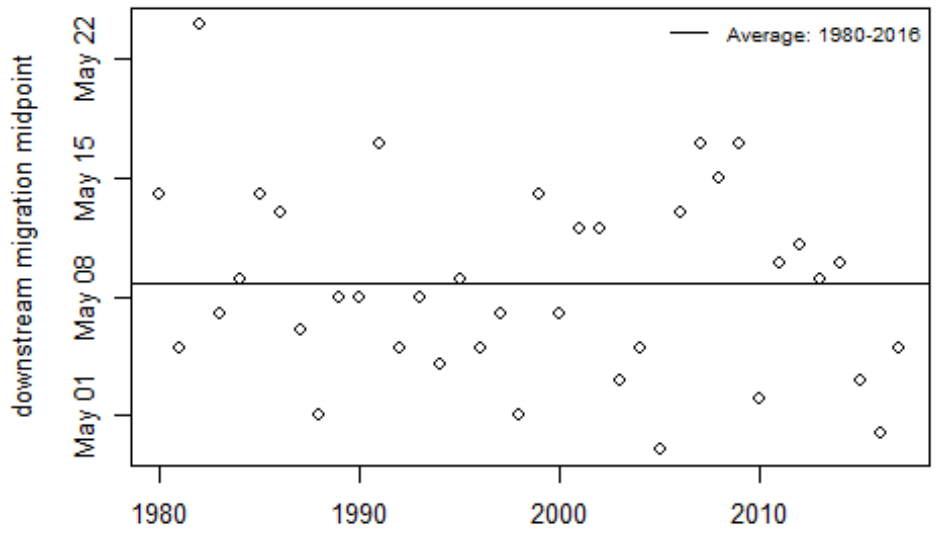

Figure 38. -- Yearly Dolly Varden downstream migration midpoint dates against year at Auke Creek, 1980-2017.

Cutthroat Trout

Little was known about the life history of cutthroat trout in the Auke Lake system before the start of tagging programs in 1994 and lake population estimates in 1998 (Lum and Taylor 2006). These projects and concurrent weir operations show that Auke Lake cutthroat have a complex life history involving anadromous components, freshwater residency, and use of other lake and stream systems in the nearby area. Upstream migration was fully enumerated from 1997 to 2006. Mature downstream migrants were spawned for hatchery incubation in 1981-82, 1985-86, 1991, and 1993. The resulting progeny were fin marked, released in Auke Lake, and migrants were captured at the weir in subsequent downstream migrations. None of the cutthroat captured during the 2015 downstream migration were fin marked and had a detectable passive integrated transponder (PIT) tag that was implanted during the 2006 downstream season. Tagging of downstream migrant cutthroat trout has not been done since 2006.

The wild downstream migrant cutthroat count in 2017 (518) was the above the 1980-2016 average (338) (Appendix Table A-7). A total of 225 migrated in April, 274 migrated in May, and 19 migrated in June. Cutthroat trout abundance shows an increasing trend between 1980 and 2017 (2.66 total-yr, R2 = 0.03, P = 0.34; Fig. 40).

The downstream migration midpoint of cutthroat trout in 2017 (08 May) was earlier than the long-term average (15 May). Cutthroat trout downstream migration shows no significant temporal trends since 1980 (R2 = 0.1, P = 0.05; Fig. 44).

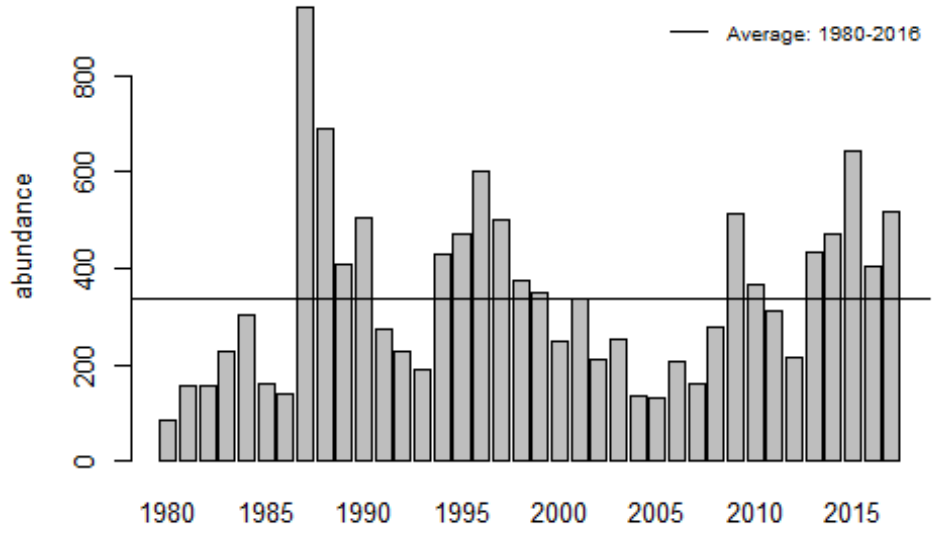

Figure 39. -- Yearly cutthroat trout downstream migration abundance against year at Auke Creek, 1980-2017.

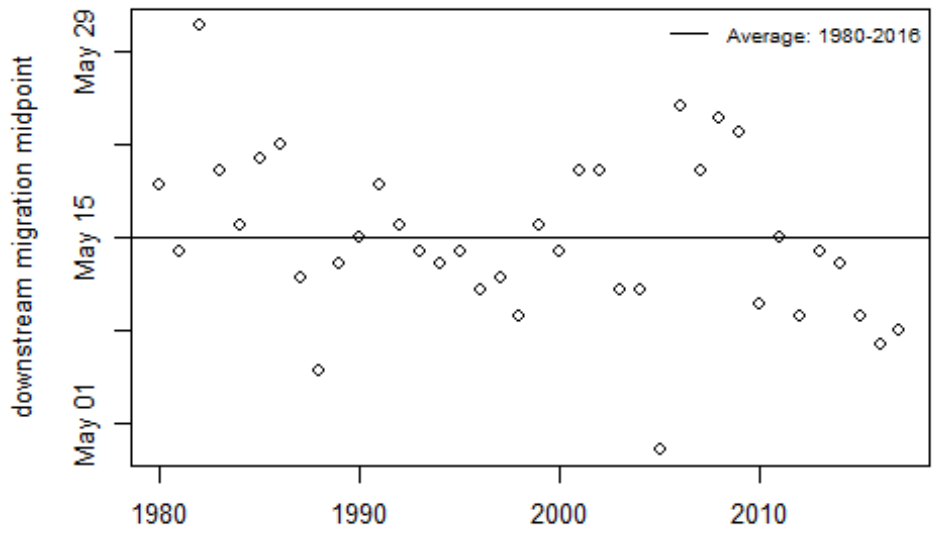

Figure 40. -- Yearly cutthroat trout downstream migration midpoint dates against year at Auke Creek, 1980-2017.

Discussion

Rising temperatures in Auke Creek over the last 38 years appear to have had numerous influences on salmonids. Trends towards earlier migration midpoints have been reported previously across multiple species during both upstream and downstream migration in Auke Creek (Taylor 2008, Kovach et al. 2013). This trend has continued during recent years with 2017 again having some of the earliest migrations on record. Adult sockeye salmon were the only species and life history stage that was reported to be occurring significantly later (Kovach et al. 2013). However, over the last several years adult sockeye salmon have been migrating upstream earlier than average, and sockeye adults now also appear to have a trend towards earlier migration.

Additionally, trends toward higher proportion age-2 smolts and larger smolt sizes have been documented for both coho and sockeye salmon (Kovach et al. 2014). Data in recent years, including 2017, are consistent with these trends, though a higher proportion of age-1 coho smolts was seen in 2017. In 2017, lengths and weights were above average for sockeye and coho. The

higher proportion age-2 and large size of smolts has also increased biomass for sockeye salmon. Although coho biomass does not have a strong temporal trend since 1980, coho biomass has been above average for the last 7 years. Adult pink returns during the 2017 season were the second lowest on record.

Although warming conditions in Auke Creek have been associated with changing biological conditions, the abundance of almost all species as remained stable since 1980, the only exception being even-year brood pink fry which appear to have decreased in abundance. Salmon populations in Auke Creek thus appear to have been resilient to the changing environmental conditions. Resiliency of Auke Creek salmon may be due to intra-specific and inter-specific diversity of salmon, as well as habitat diversity in the Auke Lake system. Continued monitoring of Auke Creek salmon will be necessary to understand whether populations will remain resilient during future warming.

Citations

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Appendices

Appendix Table A-1. -- Yearly abundance of pink salmon downstream migrant fry and upstream migrant adults at Auke Creek, 1980-2017.

Year	Fry	Adults
1980	74047	18875
1981	110552	12047
1982	119548	9232
1983	164784	21563
1984	169552	4437
1985	110001	24118
1986	123887	2007
1987	43502	6922
1988	111932	6787
1989	116873	4299
1990	96654	19589
1991	242771	5566
1992	98449	21319
1993	237073	1637
1994	11603	21312
1995	88197	1548
1996	41359	3858
1997	31092	2666
1998	60785	2267
1999	53535	28127
2000	132075	2180
2001	61504	7857
2002	150149	4923
2003	95132	10576
2004	169568	6798
2005	87928	10004
2006	65889	12895
2007	81899	2930
2008	117591	3133
2009	34847	8698
2010	121639	5835
2011	30924	26995
2012	61802	5890
2013	51191	9211
2014	47350	584
2015	14178	25235
2016	100198	667
2017	18105	10711
Average	**93373**	**9824**

Appendix Table A-2. -- Yearly abundance of sockeye salmon downstream migrant smolts and upstream migrant adults at Auke Creek, 1980-2017.

Year	Age-1 smolt	Age-2 smolt	Total smolts	Adults	Jacks	Total adults
1980	24988	311	25299	4553	17	4570
1981	7870	1313	9183	4021	68	4089
1982	1460	159	1619	1295	39	1334
1983	2674	507	3181	1800	5	1805
1984	20067	184	20251	964	11	975
1985	2438	9309	11747	240	85	325
1986	5353	9150	14503	952	81	1033
1987	2051	15547	17598	2829	67	2896
1988	13088	983	14071	1338	54	1392
1989	2626	10806	13432	2508	299	2807
1990	1282	13773	15055	3297	155	3452
1991	16683	9174	25857	2587	177	2764
1992	10008	3240	13248	1260	408	1668
1993	24648	8968	33616	2989	69	3058
1994	5796	26213	32009	3699	170	3869
1995	499	17358	17857	3224	147	3371
1996	2013	5056	7069	5998	125	6123
1997	7590	6258	13848	4671	34	4705
1998	16404	6092	22496	2068	71	2139
1999	22952	2297	25249	1572	109	1681
2000	3423	10276	13699	2480	33	2513
2001	8993	12435	21428	3963	46	4009
2002	7318	10276	17594	2882	130	3012
2003	12103	9051	21154	3239	158	3397
2004	5582	15524	21106	2958	20	2978
2005	2395	6118	8513	2879	140	3019
2006	6903	18612	25515	1848	20	1868
2007	4344	9372	13716	2754	188	2942
2008	1011	8827	9838	1223	37	1260
2009	1105	6535	7640	4001	47	4048
2010	288	7505	7793	2018	45	2063
2011	24860	7585	32445	2308	118	2426
2012	3853	19084	22937	1516	53	1569
2013	12811	5998	18809	1953	107	2060
2014	3164	18293	21457	3345	98	3443
2015	3795	8519	12314	4589	131	4720
2016	8894	9592	18486	2501	18	2519
2017	9655	4010	13665	3624	42	3666
Average	**8184**	**8798**	**16982**	**2683**	**95**	**2778**

Appendix Table A-3, -- Yearly abundance of coho salmon downstream migrant smolts and upstream migrant adults at Auke Creek, 1980-2017.

Year	Age-1 smolt	Age-2 smolt	Total smolts	Adults	Jacks	Total adults
1980	4714	5308	10022	698	266	964
1981	3667	3061	6728	578	217	795
1982	3176	3279	6455	462	339	801
1983	3325	3316	6641	694	261	955
1984	3282	3730	7012	651	315	966
1985	4494	1107	5601	942	123	1065
1986	3378	2288	5666	453	307	760
1987	5262	1917	7179	661	204	865
1988	4468	3420	7888	744	405	1149
1989	4921	2012	6933	501	369	870
1990	3678	1454	5132	680	163	843
1991	2859	2905	5764	818	314	1132
1992	3154	3108	6262	988	169	1157
1993	4611	3492	8103	859	662	1521
1994	4683	2730	7413	1437	229	1666
1995	2611	2258	4869	459	185	644
1996	2237	1725	3962	469	144	613
1997	3696	2511	6207	558	375	933
1998	3993	3437	7430	862	422	1284
1999	2179	3312	5491	844	150	994
2000	1331	3560	4891	669	227	896
2001	1794	3948	5742	865	155	1020
2002	726	2708	3434	1168	103	1271
2003	1982	1592	3574	584	244	828
2004	1979	2602	4581	415	222	637
2005	3067	1251	4318	450	256	706
2006	2794	1738	4532	581	141	722
2007	1713	2358	4071	352	106	458
2008	1802	2095	3897	599	110	709
2009	2284	2458	4742	401	150	551
2010	2681	3439	6120	418	419	837
2011	6714	3721	10435	516	376	892
2012	2168	3975	6143	835	121	956
2013	3855	5222	9077	736	214	950
2014	1119	4674	5793	1533	301	1834
2015	3811	2671	6482	576	78	654
2016	5692	3628	9320	204	252	456
2017	2653	1525	4178	283	21	304
Average	**3225**	**2882**	**6108**	**672**	**240**	**912**

Appendix Table A-4. -- Yearly marine survival of coho salmon smolts tagged with coded wires at Auke Creek by year of smolt migration, 1981-2016.

Year	Smolts	Adults	Jacks	Escapement	Catch	Total return	Percent catch	Marine survival
1981	6728	462	217	679	290	969	29.9	14.40
1982	6455	694	339	1033	473	1506	31.4	23.33
1983	6641	651	261	912	488	1400	34.9	21.08
1984	7012	942	315	1257	710	1967	36.1	28.05
1985	5601	453	123	576	498	1074	46.4	19.18
1986	5666	661	307	968	531	1499	35.4	26.46
1987	7178	744	204	948	433	1381	31.4	19.24
1988	7888	501	405	906	616	1522	40.5	19.30
1989	6933	680	369	1049	750	1799	41.7	25.95
1990	5132	818	163	981	183	1164	15.7	22.68
1991	5764	988	314	1302	296	1598	18.5	27.72
1992	6262	859	169	1028	654	1682	38.9	26.86
1993	8103	1437	662	2099	1403	3502	40.1	43.22
1994	7413	459	229	688	369	1057	34.9	14.26
1995	4869	469	185	654	638	1292	49.4	26.54
1996	3962	558	144	702	162	864	18.8	21.81
1997	6207	862	375	1237	533	1770	30.1	28.52
1998	7430	844	422	1266	600	1866	32.1	25.11
1999	5491	669	150	819	334	1153	29.0	21.00
2000	4891	865	227	1092	553	1645	33.6	33.63
2001	5742	1168	155	1323	425	1748	24.3	30.44
2002	3434	584	103	687	302	989	30.5	28.80
2003	3574	415	244	659	315	974	32.3	27.25
2004	4581	450	222	672	299	971	30.8	21.20
2005	4318	581	256	837	298	1135	26.3	26.29
2006	4532	352	141	493	184	677	27.2	14.94
2007	4071	599	106	705	394	1099	35.9	27.00
2008	3897	401	110	511	233	744	31.3	19.09
2009	4742	418	150	568	346	914	37.9	19.27
2010	6120	516	419	935	277	1212	22.9	19.80
2011	10435	835	376	1211	244	1455	16.8	13.94
2012	6143	736	121	857	531	1388	38.3	22.59
2013	9077	1533	214	1747	370	2117	17.5	23.32
2014	5793	576	301	877	173	1050	16.5	18.13
2015	6482	204	78	282	66	348	19.0	5.37
2016	9320	283	252	535	41	576	7.1	6.18
Average	**6052**	**674**	**245**	**919**	**417**	**1336**	**30.0**	**23.00**

Appendix Table A-5. -- Yearly Chinook salmon upstream migration abundance at Auke Creek, 1987-2017. Mini-jacks returned the same year of smolt release, adults returned 1 or more years later.

Year	Mini jacks	Adults
1987	0	18
1988	9	27
1989	0	77
1990	0	0
1991	0	912
1992	0	214
1993	62	272
1994	2	314
1995	0	68
1996	15	236
1997	149	183
1998	264	416
1999	367	392
2000	15	377
2001	228	224
2002	319	687
2003	0	165
2004	232	46
2005	162	158
2006	165	152
2007	63	96
2008	8	173
2009	2	52
2010	36	22
2011	329	225
2012	148	155
2013	1	132
2014	18	198
2015	589	219
2016	508	115
2017	263	309
Average	**128**	**214**

Appendix Table A-6. -- Yearly Dolly Varden downstream migration abundance at Auke Creek, 1980-2017.

Year	Total
1980	3132
1981	6472
1982	4172
1983	3718
1984	4512
1985	3052
1986	4358
1987	6443
1988	6770
1989	7230
1990	6426
1991	5559
1992	6839
1993	5075
1994	7604
1995	11732
1996	11323
1997	10506
1998	7532
1999	6393
2000	5254
2001	7356
2002	4858
2003	5067
2004	3955
2005	3544
2006	4975
2007	4300
2008	5364
2009	5319
2010	4625
2011	4382
2012	3472
2013	6405
2014	8187
2015	9805
2016	5899
2017	5756
Average	**5983**

Appendix Table A-7. -- Yearly cutthroat trout downstream migration abundance at Auke Creek, 1980-2017.

Year	Total
1980	85
1981	157
1982	157
1983	228
1984	304
1985	161
1986	138
1987	942
1988	690
1989	410
1990	506
1991	273
1992	227
1993	190
1994	431
1995	470
1996	601
1997	500
1998	374
1999	351
2000	250
2001	337
2002	210
2003	254
2004	136
2005	133
2006	208
2007	162
2008	276
2009	515
2010	364
2011	312
2012	217
2013	434
2014	470
2015	645
2016	405
2017	518
Average	**343**

U.S. Secretary of Commerce
Gina M. Raimondo

Under Secretary of Commerce for Oceans and Atmosphere
Dr. Richard W. Spinrad

Assistant Administrator, National Marine Fisheries Service. Also serving as Acting Assistant Secretary of Commerce for Oceans and Atmosphere, and Deputy NOAA Administrator
Janet Coit

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