JUVENILE SALMON, ESTUARINE, AND FRESHWATER FISH UTILIZATION OF HABITAT ASSOCIATED WITH THE FISHER SLOUGH RESTORATION PROJECT IN 2011

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Small net beach seine round haul at Fisher Slough, photo by Rich Henderson

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Abstract

The Fisher Slough Restoration Project, located in the south fork Skagit River tidal delta near the town of Conway, is intended to help recover the six populations of wild Chinook salmon present within the Skagit River and its natal estuary. We report monitoring results related to Project Element 1 (of 3), which replaced an existing floodgate with a new floodgate. The goal of Project Element 1 was to improve fish passage and tidal inundation to areas upstream of the floodgate and to protect adjacent farmland from flooding. We address monitoring questions related to Project Element 1 for fish with data collected in 2009 (Beamer et al. 2010), in 2010 (Beamer et al. 2011), and in 2011 (this report). The primary question for Project Element 1 and juvenile salmon monitoring is: Does juvenile Chinook salmon use increase in habitat upstream of the floodgate after its replacement occurring between the 2009 and 2010 fish monitoring periods?

The new Fisher Slough floodgate, during the monitoring period covered by this report, was operated according to management periods outlined in its hydraulic permit. Upstream juvenile salmon passage opportunity coincides with non-ebb tidal stage periods when floodgate doors are open and was estimated to occur 46.8% of the time during the 2011 fish monitoring period. This statistic varied little over the three years of monitoring Fisher Slough's floodgate, ranging between 45% and 47%.

In 2011, twelve different species of fish were found in the study area, including five different salmonids and other freshwater and estuarine species. Average monthly juvenile wild Chinook salmon density was higher downstream of the floodgate than upstream of the floodgate in 2011 (year 2 after replacement), but it is not significant at the 0.05 level. In 2009, before floodgate replacement, there was statistically and visually no difference in juvenile wild Chinook salmon density between sites up- and downstream of the floodgate. However, in 2010, there were higher densities of juvenile wild Chinook salmon downstream of the floodgate than upstream of the floodgate. An analysis of juvenile Chinook salmon density and landscape connectivity suggests juvenile Chinook salmon use of Fisher Slough upstream of the floodgate was lower than the normal pattern observed at all other Skagit sites after the floodgate was replaced.

The statistical tests and graphical trends over three years of monitoring indicate that the new floodgate may not be influencing Chinook salmon densities as was originally hypothesized (i.e., juvenile wild Chinook salmon abundance would increase upstream of the floodgate after its replacement). There are factors that may be influencing juvenile Chinook salmon results at Fisher Slough other than floodgate replacement, and we explored six of these: 1) site variability in the local environment, 2) variability in floodgate operation, 3) chance, 4) an unmonitored mechanism, 5) disturbance from restoration construction occurring in 2011, and 6) variability in Skagit River juvenile Chinook salmon outmigration population size. Of these six potential influences, we feel the one most likely to be influencing juvenile Chinook salmon results is variability in floodgate operation, because 2009 had an extended period of gates being held open while years 2010 and 2011 did not.

It is also possible that the original hypothesis for floodgate replacement (i.e., an increase in juvenile wild Chinook salmon density upstream of the floodgate after its replacement) was overstated. The original hypothesis was generated without the benefit of any pre-project monitoring data. Upstream juvenile Chinook salmon passage into Fisher Slough was assumed to be poor with the old floodgates and the one year of pre-floodgate replacement results in 2009 suggest otherwise.

Moving forward with monitoring at Fisher Slough which will include influences from dike setback restoration and its resulting new habitat area for fish, we recommend future monitoring use all monitored independent variables hypothesized to influence juvenile Chinook salmon in an integrated analysis approach.

Background of the Fisher Slough Restoration Project and study area

The Fisher Slough Restoration Project, located in the south fork Skagit River tidal delta near the town of Conway (Figure 1), was included in the Skagit Chinook Recovery Plan (SRSC and WDFW 2005, page 172) as a necessary restoration action to help recover the six populations of wild Chinook salmon (*Oncorhynchus tshawytscha*) present within the Skagit River and its natal estuary. The project was envisioned conceptually to restore 50 to 80 acres of historic riverine tidal zone, previously in agricultural use, to a variety of channel, estuarine wetland, and tributary junction habitats.

Since the writing of the Skagit Chinook Recovery Plan, The Nature Conservancy (TNC) and its partners have acquired agriculture lands in the project area and designed specific restoration actions for the study area that were be phased in their implementation, over several years, in three Project Elements. The goal of Project Element 1 is to improve fish passage and tidal inundation to areas upstream of the floodgate and to protect adjacent farmland from flooding by replacing an existing floodgate with a new floodgate within Fisher Slough at the Pioneer Highway crossing.

Project Element 2 resolved a drainage conflict preventing implementation of the final restoration Project Element. Project Element 2 relocates the Big Ditch siphon culvert, which was located underneath Fisher Slough within the dike setback area. The siphon was located at the edge of the project footprint for dike setback in order to accommodate drainage issues for adjacent and upstream land owners while allowing for full dike setback.

The third Project Element was a dike setback in order to allow more of the agricultural area to be inundated by tidal and freshwater hydrology. The new tidal habitat area, following implementation of Project Element 3, is approximately 60 acres.

Project Element 1 was completed in the fall of 2009. Project Element 2 was started in the summer of 2010. Construction continued through the end of October 2011 when the floodgates were re-engaged and operated for the criteria set forth for the Fall/Winter Flood Control Period. The construction for Project Element 2 was completed in 2011 (after the fish monitoring period covered in this report). Project Element 3 was completed in 2011, also after the fish monitoring time period of this report (Figure 2).

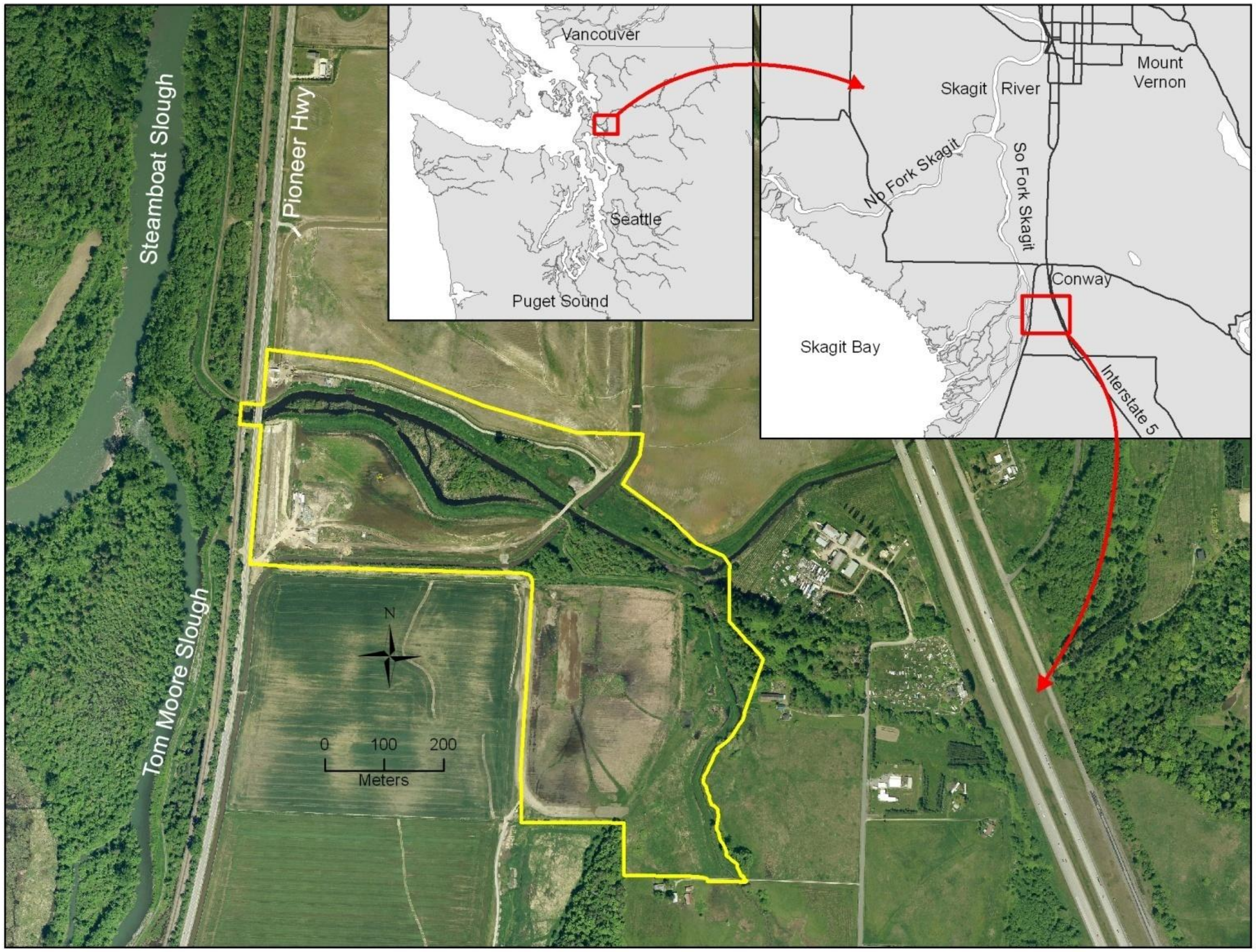


Figure 1. Location of study area and sites sampled at Fisher Slough, WA, during 2011.

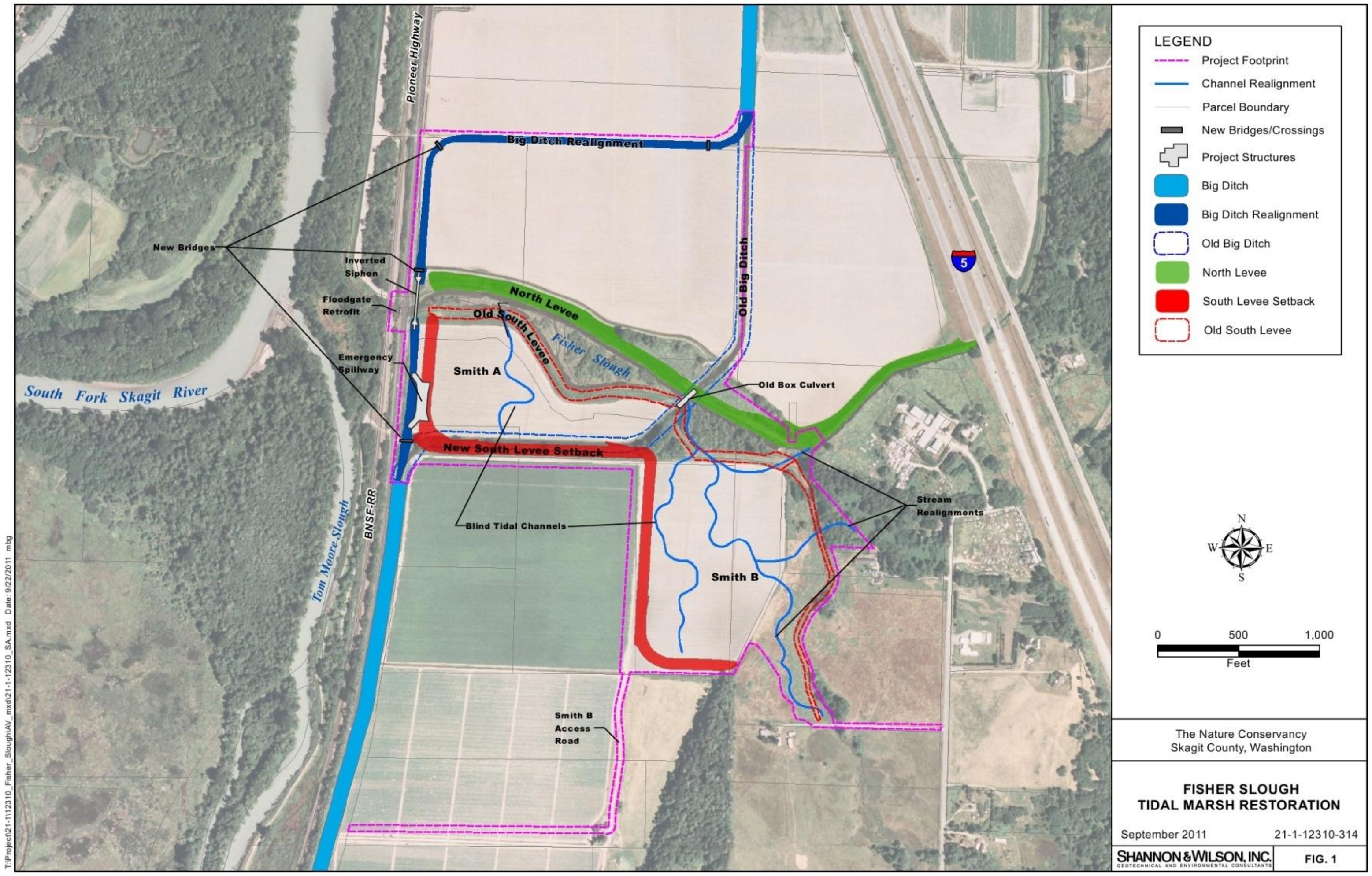


Figure 2. Post-restoration figure provided by TNC. Project Element 3 (dike setback and channel relocation) was completed after fish monitoring in 2011.

Purpose and monitoring framework of 2011 report

The Fisher Slough Tidal Marsh Restoration: Monitoring and Adaptive Management Plan (Parametrix 2010) states: the goal of restoration monitoring at Fisher Slough is to document changes between existing and restored estuarine habitats following reintroduction of tidal hydrology and reconnection of stream floodplains within the restoration site. Specifically, the monitoring program is designed to track progress toward the following primary project objectives:

1. Restore the ecological processes and structure to support and maintain a functional freshwater tidal wetland that supports target species, such as Chinook salmon;
2. Restore and improve freshwater tidal rearing habitat for Chinook salmon;
3. Restore fish passage for coho (*Oncorhynchus kisutch*) and chum (*Oncorhynchus keta*) salmon spawning access; and
4. Improve flood storage to protect agricultural uses of adjacent properties.

The monitoring program is based upon a conceptual model linking ecosystem processes to structural conditions and biological responses to those conditions. This annual monitoring report is the third in a series that focuses on results related to Objective 2 above – creating freshwater tidal rearing habitat for Chinook salmon; however, monitoring results are reported more broadly to include other fish species rearing within the Fisher Slough project area, not just juvenile Chinook salmon.

Juvenile salmon and other tidal delta fishes are hypothesized to re-colonize habitat restored by the Fisher Slough Restoration Project. Because the sources of salmon (e.g., natal or non-natal relative to Fisher Slough and its watersheds) and life stages of salmon vary, fish passage through the floodgate at Fisher Slough must adequately allow up- and downstream migration for juvenile salmon and upstream migration for adult salmon. After implementation of Project Element 1 (i.e., floodgate replacement), an increase in tidal delta juvenile salmon abundance was expected because it was assumed that existing channel areas upstream of the tidegate in Fisher Slough would become tidally influenced (or more tidally influenced) and would be more available to juvenile salmon originating from areas outside of the Fisher Slough watersheds, through improved access.

Project Element 3 of the Fisher Slough Restoration project (i.e., the dike setback) is intended to increase fish carrying capacity. Juvenile Chinook salmon carrying capacity of the restored area is a function of habitat area, its type and quality as well as its landscape connectivity. The dike setback is expected to increase habitat area available for fish rearing within the project area. Thus, future monitoring of the project area may require additional or different fish sampling sites than those selected for Project Element 1.

The Fisher Slough Restoration Project is expected to achieve two juvenile Chinook salmon related objectives: (1) increase the amount of tidal delta habitat area for juvenile rearing and (2) improve juvenile access to that habitat. Our fish-use monitoring is primarily a pre- and post-treatment restoration design. We expect changes in fish use within the treatment (restored) area following completion of Project Element 3.

We address monitoring questions related to Project Element 1 with data collected in 2009 (Beamer et al. 2010), in 2010 (Beamer et al. 2011), and in 2011 (this report). The primary question for Project Element 1 and juvenile salmon monitoring is whether juvenile Chinook salmon use increases in habitat upstream of the new gate over usage upstream of the old gate. For example, we hypothesize juvenile Chinook salmon density should increase after floodgate replacement because floodgate doors should be open more of the time after restoration than before restoration, allowing increased fish passage opportunity. We answer this question by comparing fish use at sampling sites downstream and upstream of the floodgate (Figure 1) using data collected in years before and after installation of the new gate. Data collected in 2009, representing the baseline values of fish utilization before floodgate replacement, is reported in Beamer et al. (2010). The floodgate replacement occurred in late August 2009, and data collected in 2010, representing values of fish utilization in year one after floodgate replacement, is reported in Beamer et al. (2011). This document gives the values of fish utilization in year two after the floodgate replacement.

The monitoring framework also looks at juvenile Chinook salmon results from Fisher Slough within a landscape context compared to other long-term monitoring sites within the Skagit River tidal delta.

Description of floodgate

The floodgate structure at Fisher Slough during the 2011 fish monitoring period consisted of self-regulating floodgate system manufactured by Nehalem Marine Manufacturing that had been installed on an existing concrete headwall in August 2009. The existing headwall had three openings measuring 8’9” tall and 11’ wide. New aluminum floodgate doors (one per opening) replaced the old set of paired wooden, side-hinged doors. The bottom edge of the openings in the concrete headwall (the sill) for both the new self-regulated floodgate doors and the old doors is at an elevation of 4.3 ft NAVD88. The floodgate openings remain the same.

As in 2009 (i.e., before floodgate replacement), two smaller openings in the concrete headwall beneath the floodgates remain. These openings are covered with flapgates and are centered under the middle and south floodgates. Each opening measures 24 inches by 24 inches. The opening under the middle floodgate door is covered with a top hinged flapgate and operates as a traditional floodgate; it opens or closes based on whether water flow is coming downstream (gate open), is slack (gate closed) or the tide is pushing upstream (gate closed). The flapgate under the south floodgate door is controlled by an adjustment arm so it can be propped open or held closed depending on floodgate management periods.

Methods

Sample timing

A combination of beach seine and fyke trapping methods was used to collect fish at sites within the study area on nine sampling days between February 10 and June 20, 2011 to coincide with the known juvenile rearing period for Chinook salmon in the Skagit River estuary (Beamer et al. 2010).

Sampling was conducted twice per month from 2009 through 2011 to be consistent with the design of long term juvenile Chinook salmon monitoring in the Skagit River estuary (Greene and Beamer 2006). Seven environmental variables were collected at each site on each sampling date: water temperature, salinity, Dissolved Oxygen (DO), velocity, vegetation, substrate, and the depth of the water sampled. Fish sampling was scheduled for February 25 but was not conducted due to an arctic blast and one to two feet of snow blanketing the area, making it impossible to sample.

Fish sampling ended in June 2011 due to in-stream construction occurring upstream of the floodgate as part of Project Elements 2 and 3 of the Restoration Plan. Monitoring of temperature, salinity, and dissolved oxygen continued until July 8, 2011.

Site selection

Sites for fish monitoring were systematically selected downstream and upstream of the floodgate to represent the habitat types and spatial diversity found within the project area (Figure 3). The locations of sampling sites were selected in order to compare the fish assemblage above and below the floodgate. The same sites were sampled in 2011 as in 2009 and 2010. See Beamer et al. (2010) for details on site selection methods.

The site location for the data loggers measuring DO, water surface elevation (WSE), water temperature and floodgate door openness had been established by TNC and were continued at the same locations in 2011 (Figure 3).

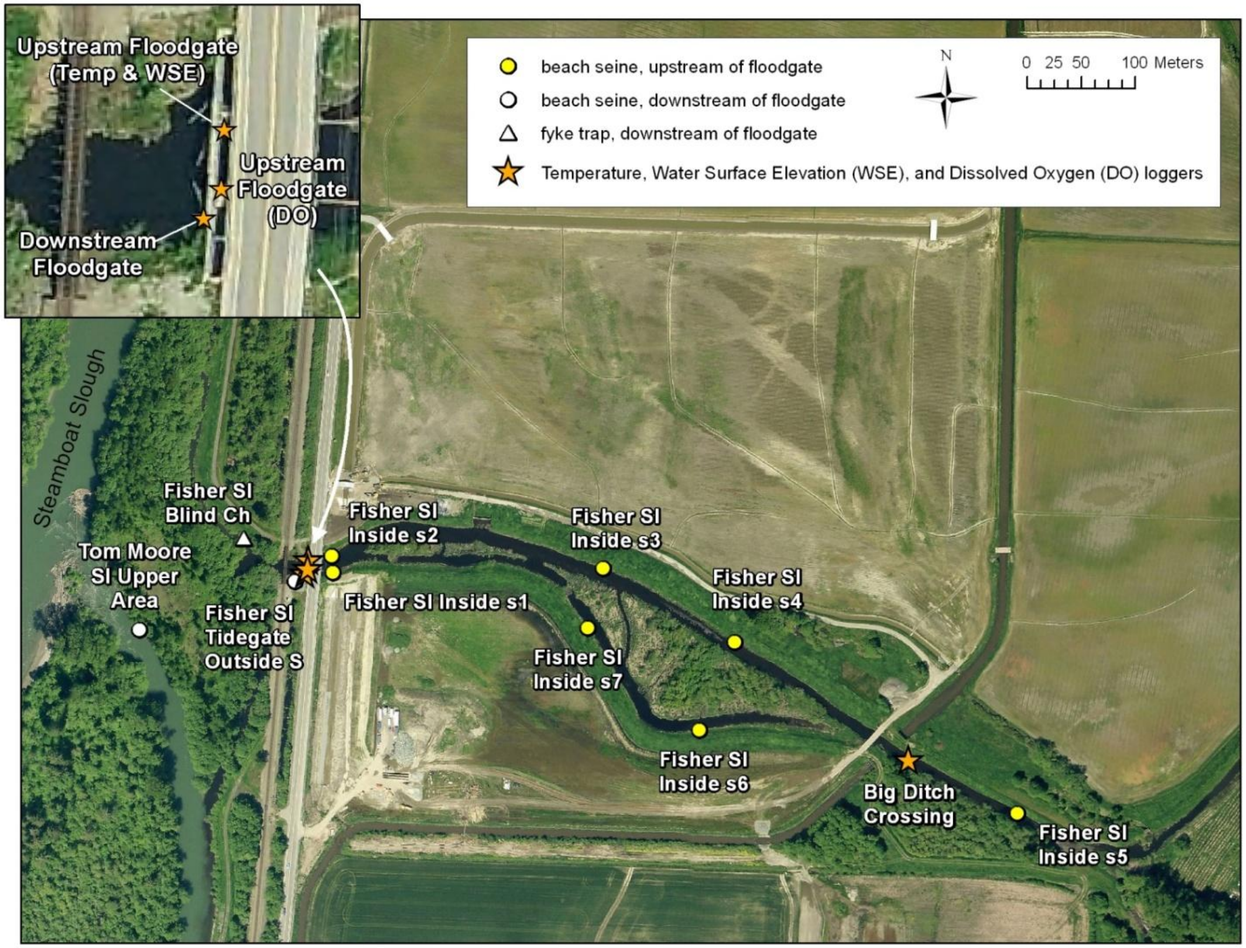


Figure 3. Location of fish monitoring sites and data loggers at Fisher Slough in 2011. In addition to the data loggers shown on the map, inclinometers were used to measure door openness for each of the three floodgate doors. See Table 1 for strata designation of each site and data logger.

Fish sampling methods

Beach seine

Small net beach seine method was used to sample inside Fisher Slough as well as at the adjacent site downstream of the floodgate at Tom Moore Slough Upper Area (Figure 3). Small net beach seine methodology uses an 80-ft (24.4 m) by 6-ft (1.8 m) by 1/8-inch (0.3 cm) mesh knotless nylon net. The net is set in “round haul” fashion by fixing one end of the net on the beach, while the other end is deployed by setting the net “upstream” against the water current, if present, and then returning to the shoreline in a half circle. Both ends of the net are then retrieved, yielding a catch. The small net beach seine is usually deployed from a floating tub that is pulled while wading along the shoreline, but because of the greater water depth at Fisher Slough, a small skiff was used to pull the tub while setting the net at most of the sites. The average beach seine set area was 96 square meters.

Beach seine sampling occurred at high slack tide and the first half of the ebb tide starting with the downstream sites and working upstream. This was done consistently from 2009 through 2011.

For each set, the catch was identified and counted fish by species, and measured individual fish lengths by species. When one set contained 20 individuals or less of one species, all individual fish were measured at each site/date combination. For sets larger than 20 individuals of one species, 20 individuals were randomly selected for length samples. All the fish were returned alive to the slough, with the exception of hatchery-origin salmon with coded-wire tags embedded in their snouts. These fish were sacrificed in order to read the tags. Freshwater mussels were counted as they are suggested biomonitors, an indicator species for clean water (Nedeau et al. 2009).

The time and date of each set was recorded as was the percent of set area (the area that the net covers compared to setting in a perfect half circle), and all environmental variables were measured (see next section) with the exception of WSE.

Fyke trap

As in 2009 and 2010, we used a fyke trap to sample a blind channel that enters Fisher Slough approximately 55 meters downstream of the floodgate on the right bank (Figure 3). The fyke trap is constructed of 1/8-inch (0.3 cm) mesh knotless nylon net with a 2-ft (0.6m) by 9-ft (2.7m) cone sewn into the opening to collect fish draining out of the blind channel site. This trap is set in place at high tide and fished through the ebb tide, yielding a catch. Fish were identified and counted and environmental data were collected as for beach seine sets (see above).

Beach seine and fyke trap efforts are shown in Table 1.

Table 1. Beach seine and fyke trap sampling effort, by site and strata at the Fisher Slough study area, 2011.

Strata	Location/Site	Number of beach seine or fyke trap sets per sampling date
Upstream floodgate	Fisher Sl Inside s1	1
	Fisher Sl Inside s2	1
	Fisher Sl Inside s3	1
	Fisher Sl Inside s4	1
	Fisher Sl Inside s5	1
	Fisher Sl Inside s6	1
	Fisher Sl Inside s7	1
Downstream floodgate	Fisher Sl Tidegate Outside S	1
	Tom Moore Sl Upper Area	2
	Fisher Sl Blind Ch	1

Environmental variables

Differences in local environment might influence fish use between sites upstream and downstream of the floodgate independent of how the floodgate operates for fish passage. Thus, we measured selected environmental variables at each site at the time of beach seining or fyke trapping to assess their potential influence on fish results (e.g., presence, density, seasonality) across sites in the study area. Based on recommendations in the 2009 report, the sampling protocol was updated to include environmental sampling at both high and low tide as well as during beach seine or fyke trap sampling events. This was implemented in 2010 and continued during the sampling in 2011. In addition, data loggers continuously recorded water surface level, water temperature and/or dissolved oxygen at three sites, both up and downstream of the floodgate.

Salinity

Water surface salinity (in parts per thousand, or ppt) was measured using a YSI Professional Plus Model meter. The meter measures the conductivity of the water and then calculates and displays this value as salinity. Spot measurements were taken at each beach seine or fyke trap site at high tide and at low tide. One measurement of salinity was taken at the top and bottom of the water column within each beach seine or fyke trap set area. On low tide conditions, when the depth of the water column at the sample site was less than 30 cm, only a surface sample was taken.

The salinity was measured at high and low tide stage, as well as during fish sampling, in order to observe the range in variability in salinity over the tidal cycle.

Water temperature

Water temperature was measured by both continual monitoring (data logger) and spot measurement methods. Spot measurements were taken at each beach seine or fyke trap site at high tide, during sampling and at low tide using a YSI Professional Plus Model meter. Two readings were taken just under the surface and at the bottom of the water column within the set area. On low tide conditions, when the depth of the water column at the sample site was less than 30 cm, only a surface sample was taken.

Continual monitoring was done utilizing two different types of data loggers. A Model 3001 Levelogger Gold data logger made by Solinst Canada Ltd was placed in standpipes at two sites, one upstream of the floodgate near the Big Ditch Crossing and one downstream of the floodgate (Downstream Floodgate) on the floodgate headwall structure (Figure 3). Water temperature was taken at the bottom of the water column. The data logger at Big Ditch Crossing is at an elevation of 4.10 ft NAVD88; the one at Downstream Floodgate is at 0.25 ft NAVD88. An INW (formerly known as Instrumentation Northwest) data logger, model AquiStar® PS9805, is located on the upstream face (Upstream Floodgate) of the floodgate headwall (Figure 1). A Campbell Scientific data monitor, model CR1000 with software communication software version PC200W, was used to store and download data. The data logger at the upstream side of the floodgate headwall is at 1.0 ft NAVD88 and takes temperature readings from the bottom of the water column.

All Solinst loggers were set to automatically record the temperature at 15-minute intervals, seven days per week. The INW logger is set to record data at 1-minute intervals and gave a summary report for a 15 minute time period. The daily range (maximum and minimum values) in degrees Celsius is reported in order to compare the spot measurements taken at the time of sampling to those taken by the continual monitoring results from the Solinst data loggers and the INW AquiStar data logger.

Water temperature results from data loggers were compared to water temperature results from spot measurements by pairing data from the logger with data from the spot measurement. Only spot measurements taken at the bottom of the water column were compared to logger results because loggers are located in the bottom of the water column. Site comparisons are according to Table 2 and water temperature measurements were paired by time and date (see Figure 3 for site locations.)

Table 2. Site comparisons for spot measurements and data logger measurements.

Comparison	Spot measurement site(s)	Logger measurement site
downstream of floodgate	Fisher Sl Floodgate Outside S Fisher Sl Blind Ch	Downstream Floodgate
upstream of floodgate	Fisher Sl Inside s1 Fisher Sl Inside s2	Upstream Floodgate
	Fisher Sl Inside s5	Big Ditch Crossing

Dissolved oxygen

Dissolved oxygen was measured by both continual monitoring and spot measurements methods. A YSI Professional Plus Model meter was used for spot measurement readings of DO levels (mg/L) which were taken at each beach seine or fyke trap site at high tide, during sampling and at low tide. Two readings were taken at the surface and at the bottom of the water column of the areas seined and at the fyke trap site. The average value of DO at the surface and at the bottom is reported for each site and tidal stage. The YSI Professional Plus DO meter was calibrated each day prior to use.

Continual monitoring was done using a model AquiStar® Dissolved Oxygen Sensor with a GDL datalogger made by INW. The DO loggers were placed in standpipes at three sites, one at Big Ditch Crossing, one upstream of the floodgate (Upstream Floodgate) secured to a highway bridge piling and one downstream of the floodgate (Downstream Floodgate) secured to the floodgate headwall. The DO loggers at Downstream Floodgate and at Big Ditch Crossing were installed on April 22, 2011 and the logger at Upstream Floodgate was installed on May 2, 2011 (Figure 3). Dissolved oxygen readings were taken at the bottom of the water column. The AquiStar DO loggers record the DO content as parts per million (ppm). This is the equivalent of mg/L values recorded by the YSI loggers used for spot measurements. We report the DO values as mg/L for the comparisons of the two methods.

The DO data logger at Downstream Floodgate is at 0.17 ft NAVD88, the one at Upstream Floodgate is at 0.15 ft NAVD88, and the data logger at Big Ditch Crossing is at an elevation of 4.10 ft NAVD88. Loggers were set to automatically record DO at 15-minute intervals, 7 days per week. We report the daily range (maximum and minimum values) in mg/L, in order to compare the spot measurements taken at the time of sampling to those taken by the continual monitoring results from the Solinst data loggers. The DO loggers at Downstream Floodgate and Upstream Floodgate were removed on July 8, 2011. Since the floodgate doors were disengaged at the end of June for restoration construction activities, only data collected before that time is reported. At the Big Ditch Crossing site there was a malfunction with the DO probe, rendering it inoperable after April 9. This was due to the DO probe being buried in pond weed in the channel; therefore DO results past May 8 were not reliable. Negative values are the error code for the DO data loggers and were removed from the data set prior to analysis. Negative DO values are not possible in water and indicate a malfunction with the data logger (e.g., probe is buried or there is a loss of communication between the probe and data logger).

The DO results were compared from the data loggers to DO results from the spot measurements by pairing data from the logger with data from the spot measurement taken at the bottom of the water column for nearest site, time, and date during the time period fish sampling was being conducted. The site comparisons are the same site pairings as listed in the temperature section above.

Water depth

The maximum water depth at each beach seine set was measured in meters using a calibrated measuring rod. The maximum depth at the fyke trap (Figure 3) was taken from the relative WSE staff gauge, located just upstream of the fyke trap, at the time the trap was deployed each sampling day.

Water velocity

Velocity was measured in feet per second at each beach seine site using a Swoffer Model 2100 flow meter. Four measurements were taken across the area seined after the set was made. These values were then converted to meters per second and the average value of these readings was reported for each site/date combination.

Substrate and vegetation

Substrate at each site was recorded based on visual inspection of the site where fish were captured (i.e., set area) according to ten possible substrate criteria described in SSC (2003) after Dethier (1990). The only two we observed at Fisher Slough were:

- Mixed fines = Fine sand, silt, and clay comprise 75% of the surface area, with no one size class being dominant. May contain gravel (<15%). Cobbles and boulders make up <6%. Easy to walk on without sinking.
- Sand = Grains in a size class of 0.06 to 2 mm in diameter cover over 75% of the surface area.

Vegetation at each site was recorded based on visual inspection of the site where fish were captured (i.e., set area) according to nine possible vegetation criteria described in SSC (2003) after Dethier (1990). For vegetation at least 25% of a set area must be covered by vegetation in order to be classified as vegetated (SSC 2003). Vegetation types present at Fisher Slough sites were defined as follows:

- Unvegetated = <25% of area is vegetated.
- Freshwater aquatic plant cover = >25% of area is live, floating, non-woody vascular plant cover (not emergent marsh plants).

Analysis methods

Site-scale environmental impacts

Differences in environment at the site level might influence juvenile Chinook salmon densities at sites upstream and downstream of the floodgate independent of how the floodgate operates for fish passage. Field measurements of salinity, temperature, velocity, depth, and DO were compared graphically or using a Generalized Linear Model (GLM), using strata (up- or downstream of the floodgate, shown in Table 1 and Figure 3), site (sampling stations), and date as independent variables. We used Scheffé pair-wise testing to compare between groups. GLM was selected to accommodate unbalanced sampling effort at some sites. Statistical analysis was done with the software package SYSTAT 13.

For selected environmental variables, data were compared for site and date results to known or hypothesized relationships for juvenile Chinook salmon presence in order to understand whether site level environmental conditions during the monitoring period were influencing juvenile Chinook salmon results. The environmental relationships for juvenile Chinook salmon are summarized below.

- Young of the year Chinook salmon are sensitive to salinity stress and will seek low salinity microhabitats to reduce stress and to acclimate. Salinity stress may not occur until salinity exceeds 4.5 ppt (Macdonald et al. 1987).
- Water temperature in excess of 15 degrees C is postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).
- Water temperature in excess of 24.8 degrees C is postulated as lethal to juvenile Chinook salmon in estuaries (McCullaugh 1999).
- The water quality standard in Washington State for DO in freshwater bodies with salmonid rearing and migration is 6.5 mg/L or higher.
- The minimum water depth threshold for juvenile Chinook salmon is 0.20 meters (shown in Beamer et al. 2005, Figure D.II.2, page 57).
- The preferred maximum water velocity threshold for juvenile Chinook salmon
- is 0.20 meters per second (shown in Beamer et al. 2005, Figure D.II.3, page 58).
- The maximum water velocity threshold for juvenile Chinook salmon presence is 0.38 meters per second (shown in Beamer et al. 2005, Figure D.II.3, page 58).

Fish density estimates

For juvenile Chinook salmon sampled by beach seines, we calculated the density of juveniles for each set (the number of fish divided by set area).

For the fyke trap site, juvenile Chinook salmon catch numbers were adjusted by trap recovery efficiency (RE) estimates derived from three mark-recapture experiments using a known number of marked fish released upstream of the trap at high tide. Recovery efficiency estimates are unique to each site and are related to hydraulic characteristics of the site during trapping. At this site, the change in WSE during trapping (a measurement of how well the channel drains) explained the RE results, which varied between 1.3 and 41 percent in 2011. RE results were used to convert the “raw” juvenile Chinook salmon catch to an estimated population size within the channel network upstream of the fyke trap on any sampling day. The RE-adjusted Chinook salmon catch was divided by the bankfull channel area of the blind channel network upstream of the trap to calculate a juvenile Chinook salmon density. The extent of the blind channel network upstream of the trap was determined in the field. To calculate bankfull channel area, we digitized a channel polygon using high resolution orthophotos. The bankfull channel area associated with the fyke trap site is 1,367 m^2.

The same fish density calculation methods were used to estimate fish density of other fish species for a graphical presentation of the fish assemblage.

Graphic analysis of fork length for juvenile wild Chinook salmon is provided to show seasonal changes in growth and to compare differences in growth between the fish found in the treatment areas upstream and downstream of the floodgate.

Statistical analysis of Chinook salmon density

Comparing Chinook salmon density by treatment and strata

Juvenile Chinook salmon density data from all three years, 2009, 2010 and 2011, are combined in order to test for treatment (years before/after floodgate replacement) and strata significance.

A two-way ANOVA was used to reveal treatment and strata differences in juvenile Chinook salmon density. Scheffé pair-wise testing was used to compare between treatment/strata groups. Statistical analysis was done with the software package SYSTAT 13.

To reduce the effects of non-normal data distribution, zeros, and unequal variance, Chinook salmon densities were log (x+1) transformed. Normality in ANOVA test residuals from transformed and untransformed Chinook salmon density was tested. Residuals of untransformed data were not normally distributed, while the residuals of transformed data were normally distributed.

Comparing Chinook salmon density in Fisher Slough to other sites within the Skagit River tidal delta

Landscape connectivity, or large-scale connectivity, refers to the relative distances and pathways that salmon must travel to find habitat over a very large area. As we apply this concept in the Skagit River delta, landscape connectivity is a function of both the distance and complexity of the pathway that salmon must follow to specific habitat areas (e.g., sites within Fisher Slough). Connectivity decreases as complexity of the route the fish must swim increases and the distance the fish must swim increases. Within the delta, the complexity of the route fish must take to find habitat is measured by the distributary bifurcation order and distance traveled. Habitat that is less connected to the source of fish has lower densities of fish. By determining landscape connectivity to various sites, we can compare juvenile Chinook salmon usage results from Fisher Slough with that of other sites throughout the Skagit River tidal delta in order to determine whether Fisher Slough is functioning consistently with the rest of the Skagit River delta.

The season-long density of juvenile Chinook salmon at all Fisher Slough monitoring sites and at nine other long-term monitoring sites located throughout the Skagit River tidal delta was estimated. We termed this fish density statistic *cumulative Chinook salmon density*. Cumulative Chinook salmon density was estimated for the periods February 1 through August 15 for tidal curves of juvenile Chinook salmon in Skagit River tidal delta habitat. Cumulative Chinook salmon density (C) (fish*days*ha^{-1}) was calculated as:

$$C = \sum_{m=F}^{L} D_m n_m$$

where D_m is the average monthly density, n_m is the number of days in the month, and F and L are the first and last months (m) sampled, respectively. In years when the full monitoring period was not implemented at Fisher Slough, fishdays were calculated for

Fisher Slough sites and the Skagit long term monitoring sites based on the Fisher Slough monitoring period.

The cumulative Chinook salmon density by landscape connectivity was plotted to graphically determine whether juvenile Chinook salmon are using the habitat up- and downstream of the floodgate in Fisher Slough at different densities than at natural tidal channel sites within the Skagit tidal delta.

Landscape connectivity (C) for each site is calculated:

$$C = \frac{1}{\sum_{j=1}^{j_{end}} (O_j * D_j)}$$

where O_j = distributary channel order for channel segment j, D_j = distance along segment j of order O_j, j = count $(1...j_{end})$ of distributary channel segments, and j_{end} = total number of channel segments at destination or sample point.

Results

Floodgate operation in 2011

Floodgate operation for this project was specified in Washington Department of Fish and Wildlife's Hydraulic Project Approval (HPA) Permit No. 114361-5, which defines three management periods with criteria designed to meet fish passage, tidal exchange and flood protection objectives. Floodgate operation results for Water Year (WY) 2011 are reported in Beamer and Henderson (2012) and summarized in Table 3. In WY 2011 floodgate operation nuances are as follows: During the Summer Irrigation Period starting June 1, instead of the floodgate doors remaining open 100% of the time, the floodgates continued to operate under the criteria set for the Spring Juvenile Chinook Migration Period through June 27, with the gates set to close when WSE exceeded 9.5 ft NAVD88. From June 28 to September 30, 2011 the floodgates were operated as a gravity system while Fisher Slough restoration construction occurred. In this report we are concerned about floodgate operation effects on fish passage coinciding with our fish monitoring period: February 10, 2011 through June 20, 2011.

Table 3. Summary of Fisher Slough floodgates and their operational criteria for WY 2011 (from Beamer and Henderson 2012).

Floodgate Operation Period	**Were criteria met in WY 2011?**			
	Gate opening		**Water velocity**	**Water depth**
	% of time gates shall be open	**Minimum gate closure elevation**		
Fall/Winter Flood Control (Oct. 1- Feb 28/29)	Does not apply	Yes. Floodgates were never closed when WSE was less than the minimum closure setting of +7.5 ft NAVD88 during normal operational periods	Does not apply	Does not apply
Spring Juvenile Chinook Migration (March 1-May 31)	Yes. Floodgates were open greater than 90% of the time during normal operational periods	Yes. Floodgates were open >99% of the time when WSE was less than the minimum closure setting of +9.5 ft NAVD88 during normal operational periods	Likely yes, based on spot measurement of velocity	Yes. Water depth exceeded minimum depth criterion 100% of the time
Summer Irrigation (Jun. 1-Sept. 30)	Does not apply. The 100% gate open criterion does not apply this year due to construction activities at the site per WDFW approval. Floodgates were open 14-16% of the time (depending on door)	Does not apply	Does not apply	Does not apply

Fish site level environmental variables

In this section of the results, we report site and date variation of selected environmental variables known, or hypothesized, to influence juvenile Chinook salmon presence in order to characterize the monitoring area in 2011 and potentially exclude some site and date combinations from the juvenile Chinook salmon analysis. In the comparisons of environmental data taken during the strata of high tide, low tide, and during fish sampling, the data taken at Tom Moore Sl Upper Area was not included. Data from this site were only taken sporadically at the high and low tide periods and therefore was not used in the downstream floodgate data set. Data were included this site when comparing the combined upstream sites to the combined downstream sites on the fish sampling days.

Salinity

Throughout the monitoring period, salinity at sites both upstream and downstream of the floodgate was much lower than is hypothesized to be stressful for juvenile Chinook salmon (> 4.5 ppt). In fact, salinity was generally less than 0.1 ppt (Appendix A Tables 1 and 2; Figures 4 and 5). Overall, salinity at high and low tides remained very low (< 0.1 ppt, Figure 5). Salinity results during fish sampling tended to be similar to or lower than salinity results for both low and high tides. Fisher Slough is essentially a freshwater tidal system throughout the monitoring area, and therefore the influence of salinity by site or date was not tested.

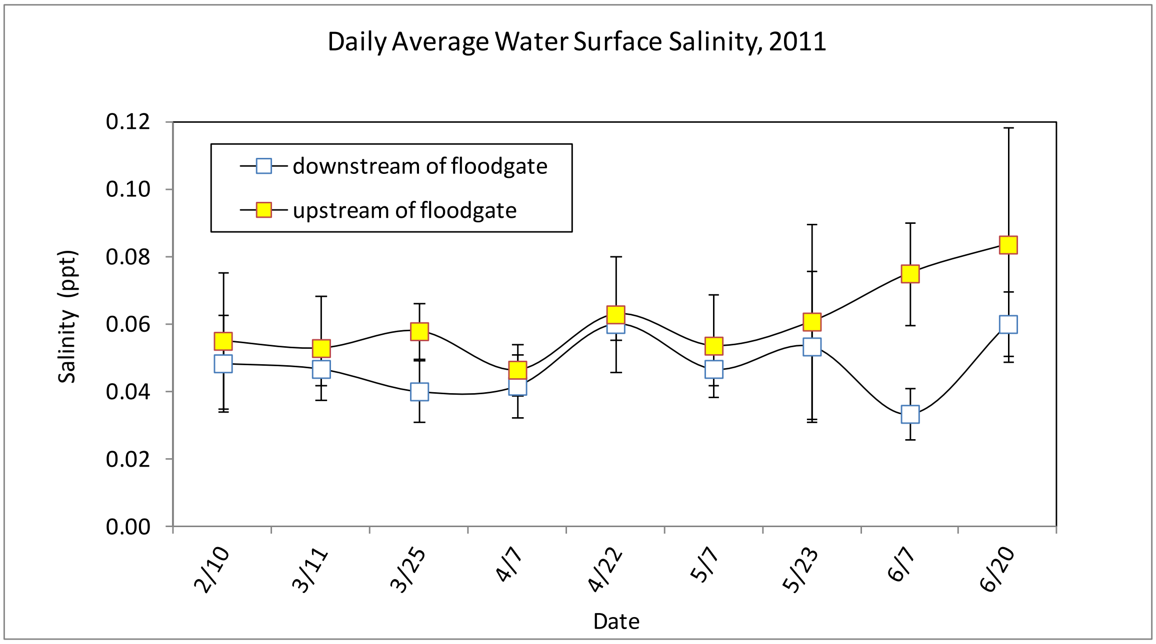


Figure 4. Comparison of daily average water surface salinity in parts per thousand for combined upstream and combined downstream sites during the fish sampling time at Fisher Slough in 2011. Error bars are one standard deviation.

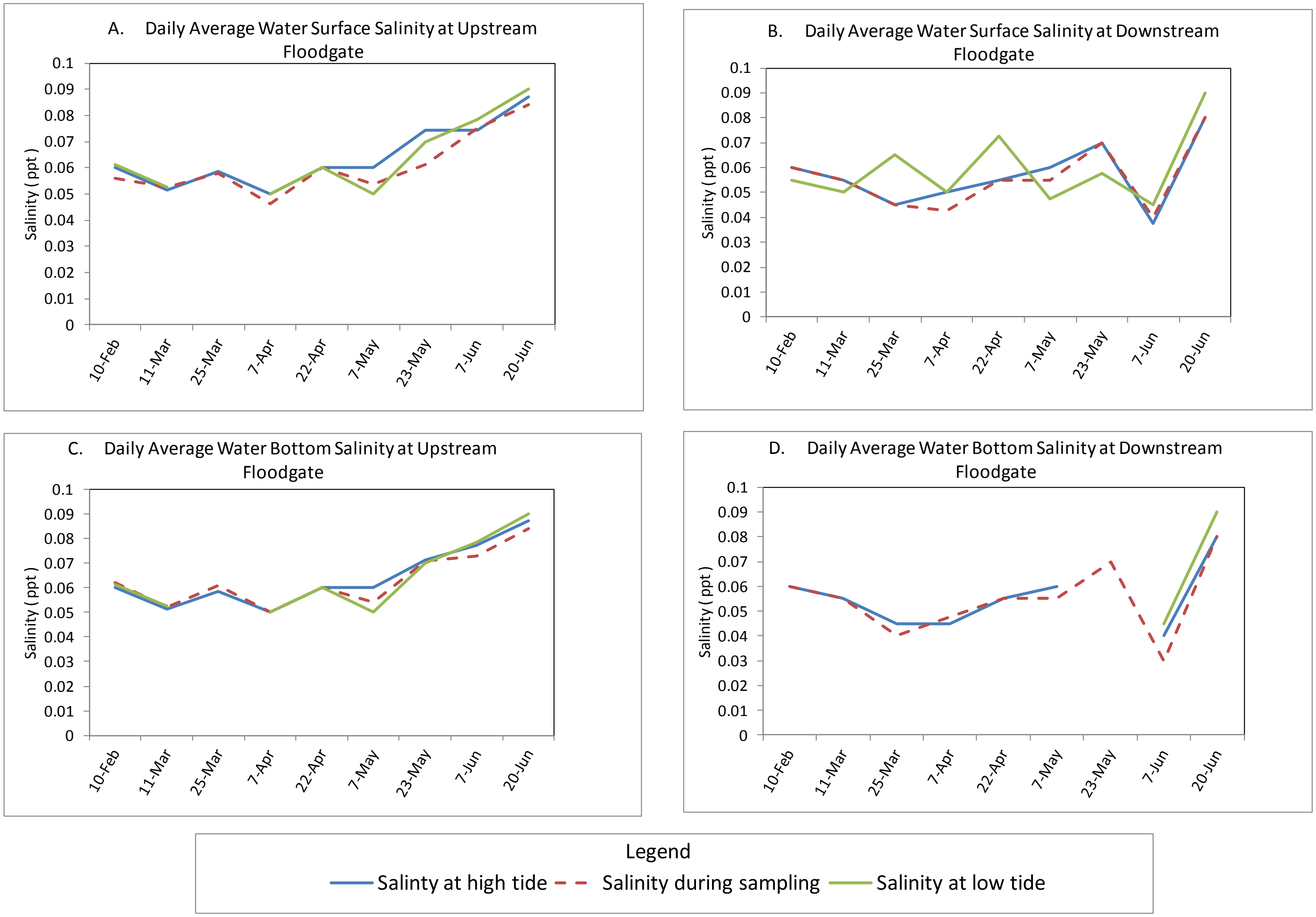


Figure 5. Comparison of daily average water surface and bottom salinity in parts per thousand for combined upstream and combined downstream sites by sampling day and tidal strata at Fisher Slough in 2011. The downstream floodgate sites do not include Tom Moore Sl Upper Area. Measurements were not taken at the bottom of the water column when the depth was less than 0.30 meters.

Water temperature

Water temperature values are shown in Appendix A Tables 3 and 4.

Comparison of collection methods

Water temperature results are available from two methodologies: (1) spot measurements taken at high and low tide and during beach seine sampling, and (2) continual sampling from data loggers. Spot measurements are limited compared to the data logger results in temporal coverage (one time per site per tide or sampling stage on nine different sampling days compared to 15-minute readings for five months with the loggers), but stronger than the data loggers in spatial coverage (eleven spot measurement sites compared to three for the data loggers).

There is strong consistency in water temperature between spot and continual measurements. The overall trend in water temperature between the two different methods is not significantly different (i.e., the regression results are not different than the 1:1 line shown in each graph, Figure 6). Individual water temperature measurements between spot measurements and data logger methods were off by as much as 1.1 °C at Upstream Floodgate (Figure 6, panel B) and by 1.6 °C on one date at Big Ditch Crossing site (Figure 6, panel C). However, average differences in water temperature between the two methods were less than 0.45 °C at Downstream Floodgate (Figure 6, panel A), 0.38 °C at Upstream Floodgate, and 0.32 °C at Big Ditch Crossing.

Comparison of average temperature to continuously monitored extremes

Both temperature measurement methods show a seasonal increase in temperature. Daily fluctuations in temperature existed throughout the monitoring period, but the largest fluctuations occurred in the summer during June, where fluctuations regularly exceeded 5 °C per day at the sites downstream and immediately upstream of the floodgate. At Big Ditch Crossing the daily fluctuations were 0.4 to 4.8 °C during this time period (Figures 7, 8 and 9). The largest daily fluctuation for Downstream Floodgate was 7.4 °C on June 9; for Upstream Floodgate it was 6.6 °C on June 4; and for Big Ditch Crossing it was 4.8 °C on June 17.

Comparison of temperature by strata and date

Tests were done to determine whether surface or bottom water temperature was influenced by strata and/or sampling date over the sampling season. Statistical analysis reveals a strong ($p<0.001$) date and strata influence on water temperature values (Appendix A Tables 5-7). The date influence is visible in Figures 7, 8 and 9 as temperatures generally increase over the season. Note a decrease in water temperature at the end of February due to sub-freezing weather in the area. The strata influence is visible in Figure 10, which shows sites upstream of the floodgate were higher in temperature than sites downstream of the floodgate.

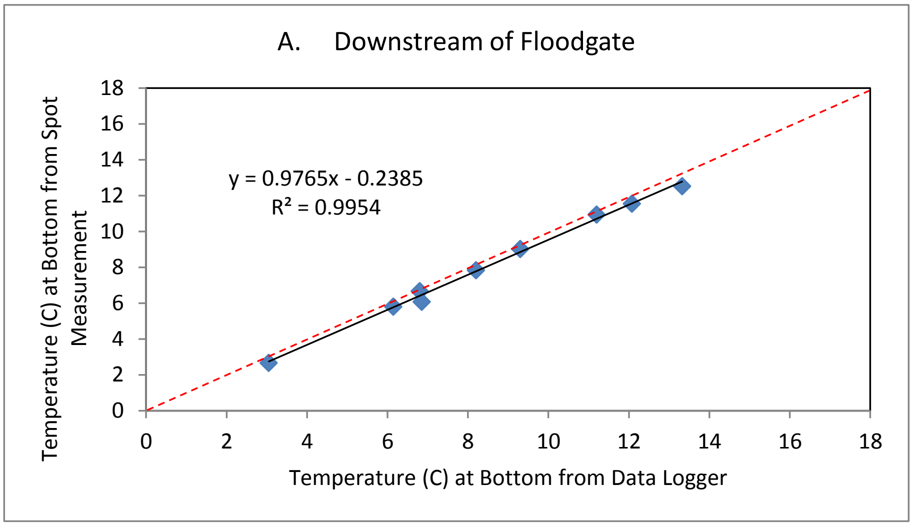
Comparison of temperature by tidal stage

The water temperature at high tide usually matched water temperatures taken during fish sampling for both surface and bottom water column readings (Figure 11). Water temperature was generally lower at high tide than at low tide.

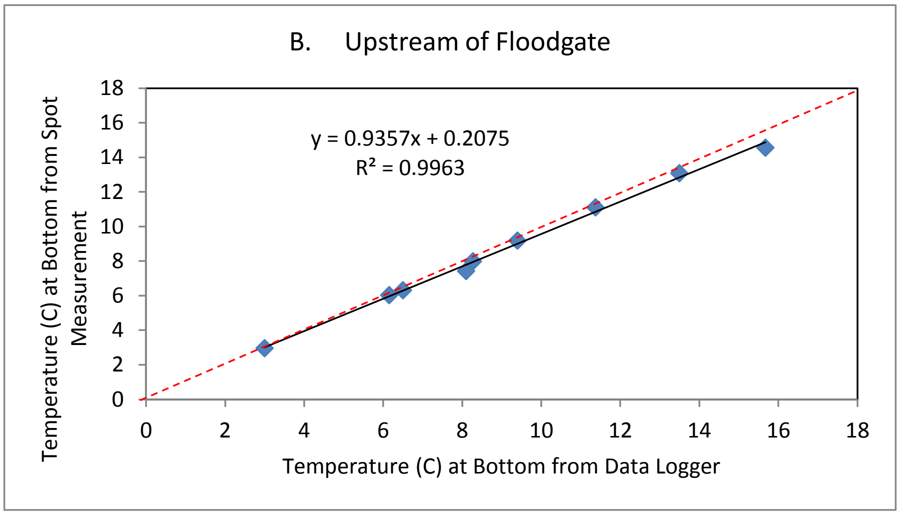
Comparison of temperature to temperature thresholds

Water temperature never exceeded the 24.8 °C lethal temperature for juvenile Chinook salmon during our monitoring period in 2011. Average surface and bottom water temperature exceeded the 15 °C threshold postulated as stressful to juvenile Chinook salmon in estuaries on only one fish sampling date (June 7) and only for the upstream of floodgate stratum (16.16 °C, Figure 10).

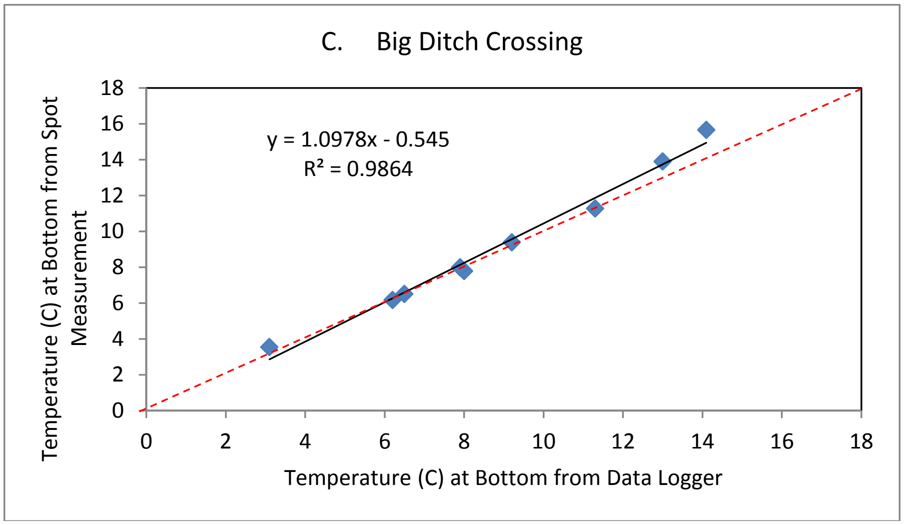
On June 20, individual (as opposed to daily average) surface or bottom water temperatures exceeded 15 °C at about a third of the sampling sites (Appendix A Tables 3 and 4). In addition, water temperature at low tide exceeded 15 °C at one site (Fisher Sl s6) on April 22 and May 23. Fisher Sl s6 is a side channel site that is susceptible to heating/cooling by air temperature because it is usually quite shallow and cut off from surface flow during low tide. Water temperature was lower than 15 °C during some part of each day over our entire fish sampling period (Figures 7-9).



A. Downstream of Floodgate



B. Upstream of Floodgate



C. Big Ditch Crossing

Figure 6. Comparison of water temperature from continuously reading data loggers (shown on x axis) and spot measurements taken during the time of beach seining in Fisher Slough, 2011 (shown on y axis). The 1:1 line is shown as a dashed line in each figure.

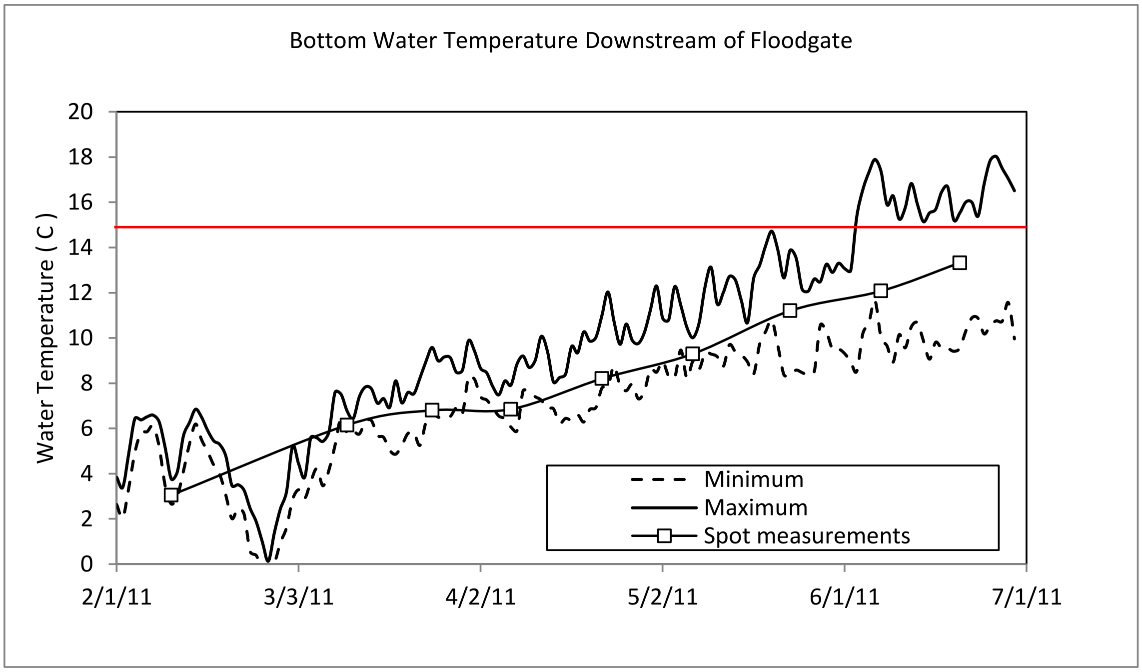


Figure 7. . Maximum and minimum of temperature from the data logger at Downstream Floodgate and daily average bottom temperature at sites Fisher Sl Outside Tidegate S and Fisher Sl Blind Ch (spot measurements) averaged together during the fish sampling time period in Fisher Slough, 2011. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

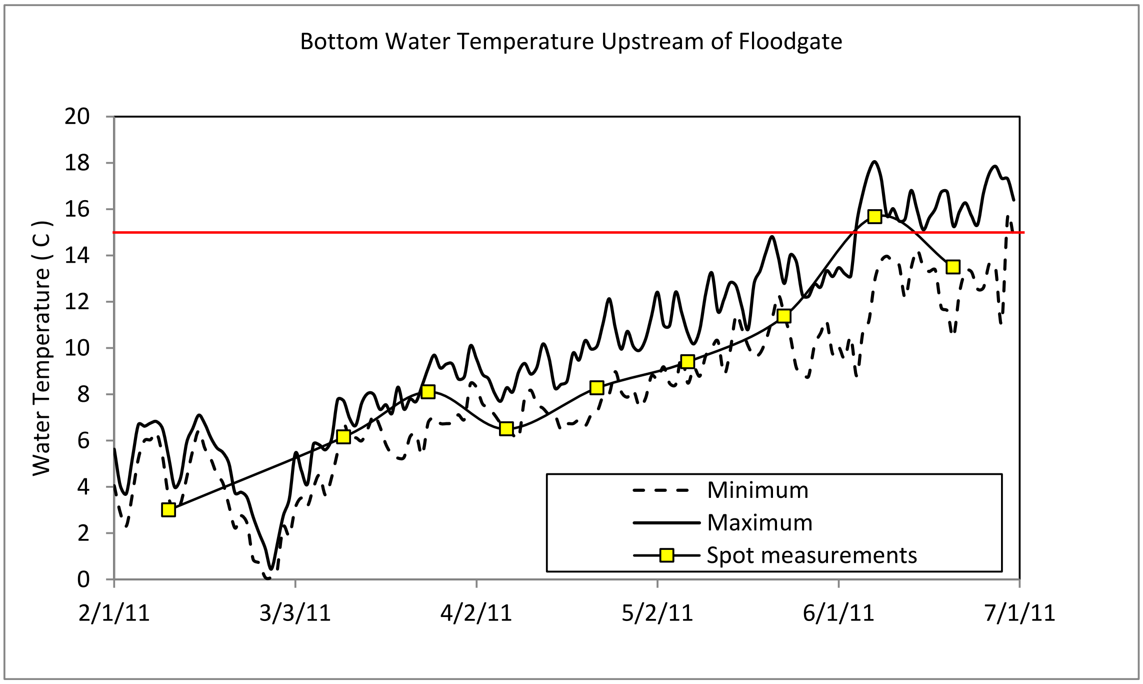


Figure 8. Maximum and minimum of temperature from the data logger at Upstream Floodgate and daily average bottom temperature at sites Fisher Sl Inside s1 and s2, (spot measurements) averaged together during the fish sampling time period in Fisher Slough, 2011. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

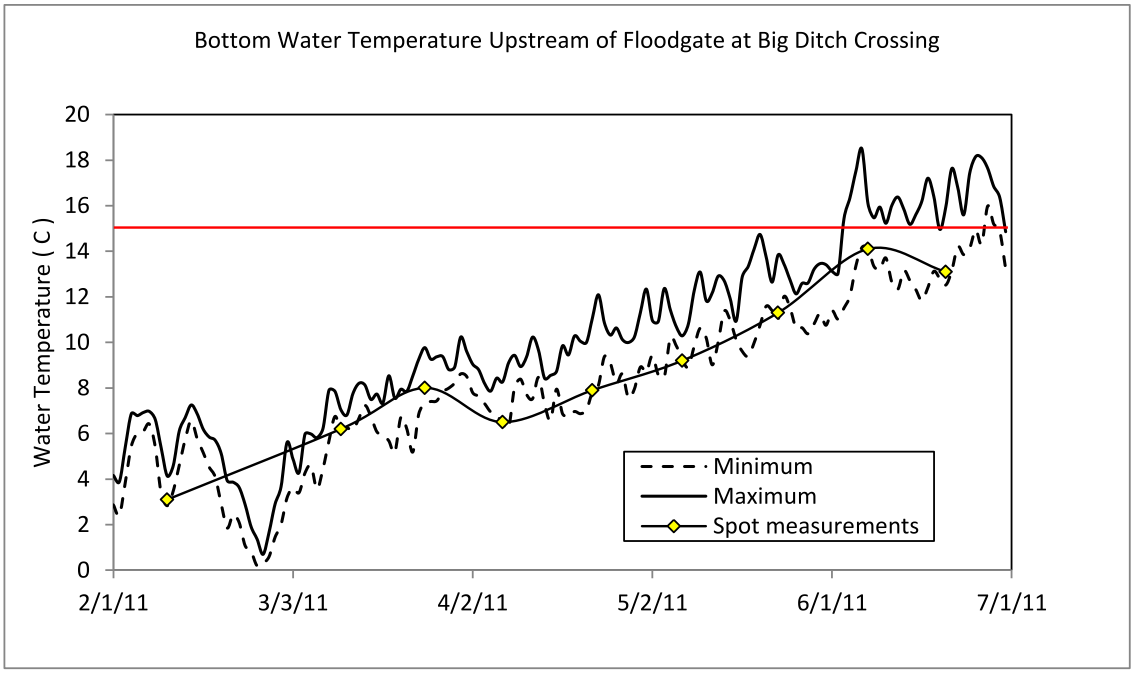


Figure 9. Maximum and minimum of temperature from the data logger at Big Ditch Crossing and daily average bottom temperature at site Fisher Sl Inside s5, (spot measurements) during the fish sampling time period in Fisher Slough, 2011. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

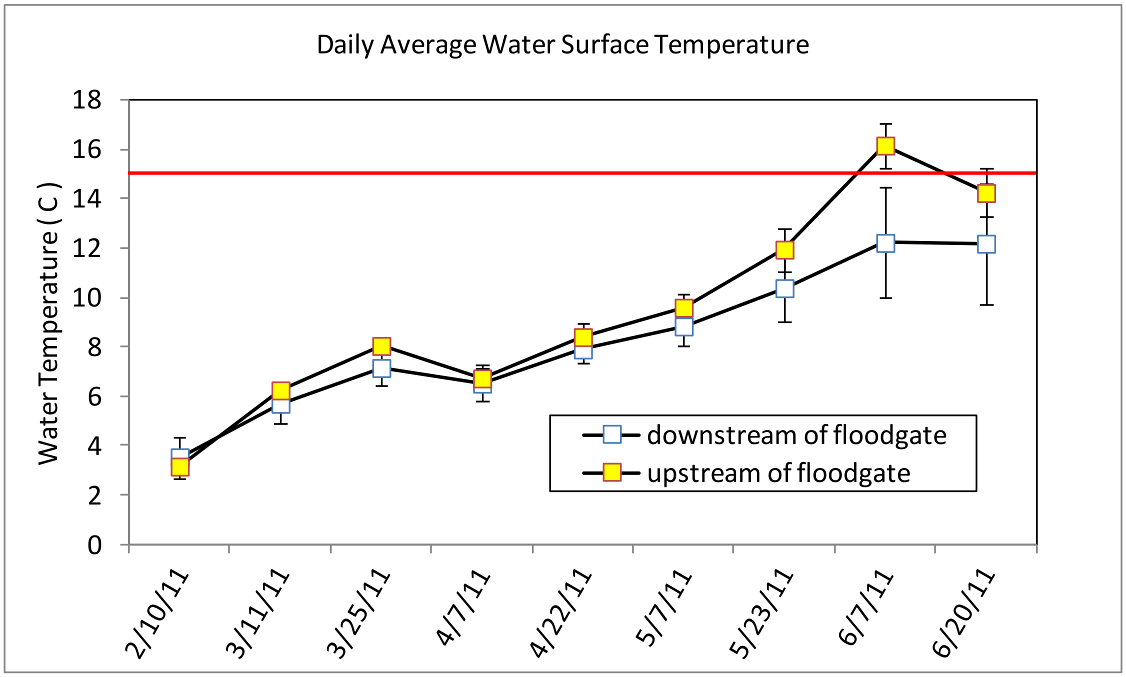


Figure 10. Comparison of daily average water surface temperature for combined upstream and combined downstream sites by sampling day at Fisher Slough in 2011. Error bars are one standard deviation. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

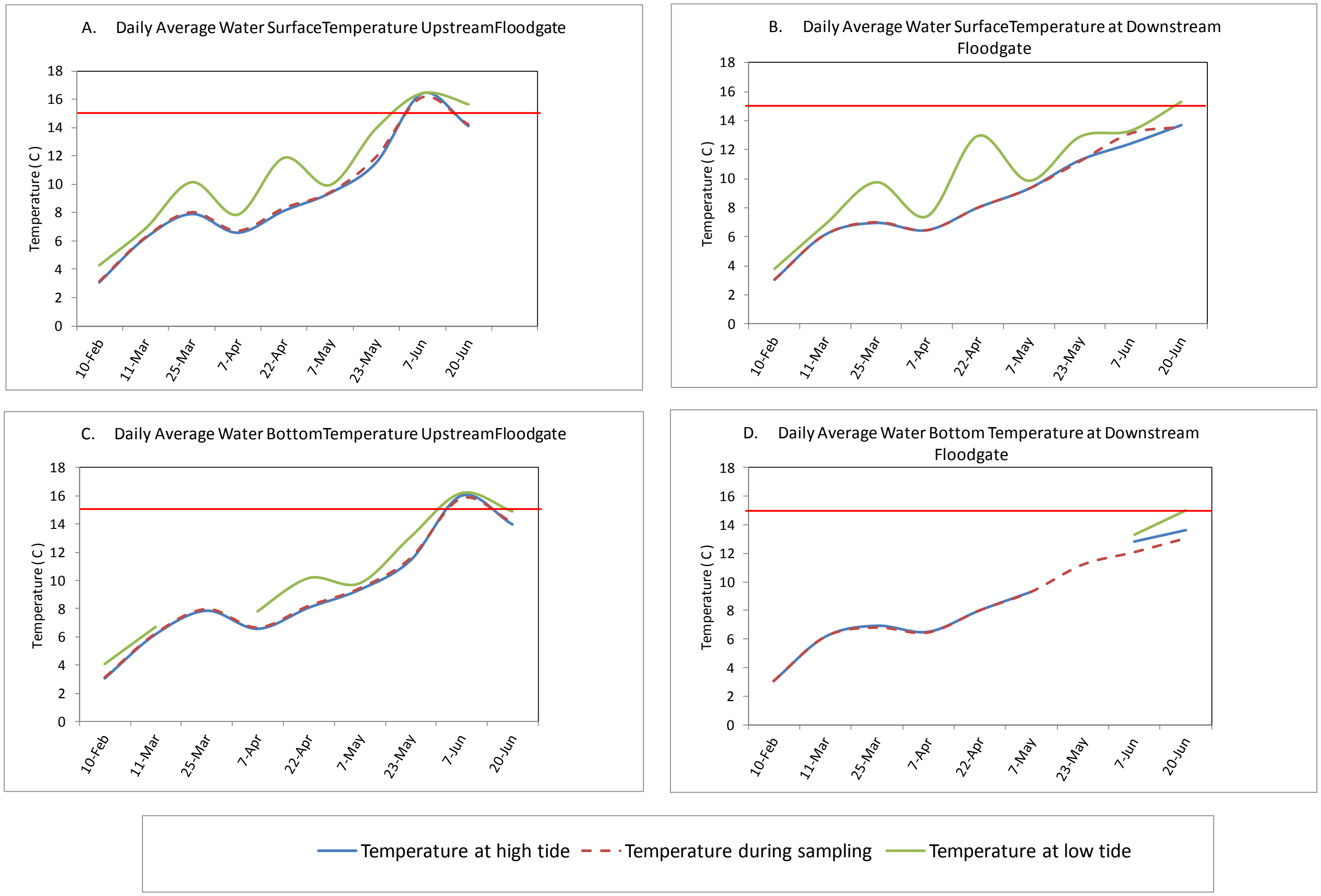


Figure 11. Comparison of daily average surface and bottom water temperature in degrees Celsius for combined upstream and combined downstream sites by sampling strata and day at Fisher Slough in 2011. The downstream sites do not include Tom Moore Sl Upper Area. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006). Measurements were not taken when the depth was less than 0.30 meters, hence the disconnected lines in panels C and D.

Dissolved oxygen

Water DO data are shown in Appendix A Tables 8 and 9.

Comparison of DO collection methods

Dissolved oxygen level results are available from two methodologies: (1) spot measurements taken at high and low tide and during beach seine sampling, and (2) continual sampling from data loggers. Spot measurements are limited compared to the data logger results in temporal coverage (one time per site per tide or sampling stage on nine different sampling days compared to 15-minute readings for five months with the loggers), but stronger than the data loggers in spatial coverage (eleven sites compared to three for the loggers).

There was consistency in measured DO levels between both measurement methods at two of the three comparison sites (Figure 12). Spot-measured DO at Downstream Floodgate and Upstream Floodgate were correlated (Figures 12, panels A and B), but spot measurements were consistently higher than logger measurements. The site Big Ditch Crossing only had two comparison observations (Figure 12, panel C). Both observations showed the spot-measured DO was higher than the logger data.

Individual spot and data logger DO measurements were off by as much as 1.5 mg/L at Downstream Floodgate and by 1.7 mg/L at Upstream Floodgate. At the Big Ditch Crossing site, there was one sampling that was off by 5.0 mg/L. Average differences in DO levels between the two methods were less than 0.75 mg/L at Downstream Floodgate, 0.48 mg/L Upstream Floodgate, and 2.9 mg/L at Big Ditch Crossing.

Statistical comparison of DO level by strata and date

Tests were done to determine whether our spot measurements of DO collected at the time of fish sampling were influenced by strata or by date. Statistical analysis reveals a strong ($p<0.001$) strata and date influence for DO taken at the surface of the water column (Appendix A, Tables 10-12) The main conclusions are:

1. The downstream strata had higher DO values than the combined upstream strata.
2. The difference in DO between the strata increased as the season progressed.
3. Both strata had a seasonal decrease in DO.

Each of these findings is shown in the results sections below.

Temporal variation in DO

Both DO measurement methods show a seasonal decrease in DO levels (Figures 13-17). Continuous-measuring loggers showed daily fluctuations in DO levels throughout the monitoring period. The largest fluctuations began in June at the sites immediately up- and downstream of the floodgate (Figures 13 and 14). In June, daily fluctuations regularly exceeded 4 or 5 mg/L per day at the sites immediately up- and downstream of the floodgate. At Big Ditch Crossing, the DO logger was only in place for 17 days in the spring, and the daily fluctuations exceeded 2.5 mg/L on five of those days. The maximum daily fluctuation was 6.3 mg/L on May 7, 2011 (Figure 15).

Comparison of DO results to Washington State water quality standards

Results from data loggers show that the DO levels fell below the 6.5 mg/L threshold level for waters with salmonid rearing and migrating at the site Downstream Floodgate for 135.75 hours (8.2% of the time), at the Upstream Floodgate site for 346.25 hours (24.3% of the time), and at the Big Ditch Crossing site for 16.0 hours (4.1% of the time) when the loggers were in place and operating correctly (Figures 13, 14 and 15; Appendix A Tables 9 and 10).

Data from the spot measurements during fish sampling show that the DO levels fell below the 6.5 mg/L threshold level on one of the nine days of sampling (11.1% of the spot measurements) for both the surface and bottom of the water column for the sites upstream of the floodgate (Figures 16 and 17; Appendix A, Tables 9 and 10). Spot-measured DO levels at the sites downstream of the floodgate never fell below 6.5 mg/L.

Comparison of DO by tidal stage and day/night patterns

Figures 13-15 show that our spot measurements of DO generally reflect the high daily DO values from the continuously-measuring DO data loggers. Dissolved oxygen was measured at high and low tides on the days of fish sampling in order to determine how our measurements of DO during fish sampling compared with DO levels at tidal extremes on the same day. DO levels at high and low tides generally tracked with DO levels taken during fish sampling for both surface and bottom water column readings (Figure 18). Dissolved oxygen results from data loggers during June (when daily fluctuations in DO were most extreme) visually correlate with tidal cycles rather than day/night cycles (Figure 19).

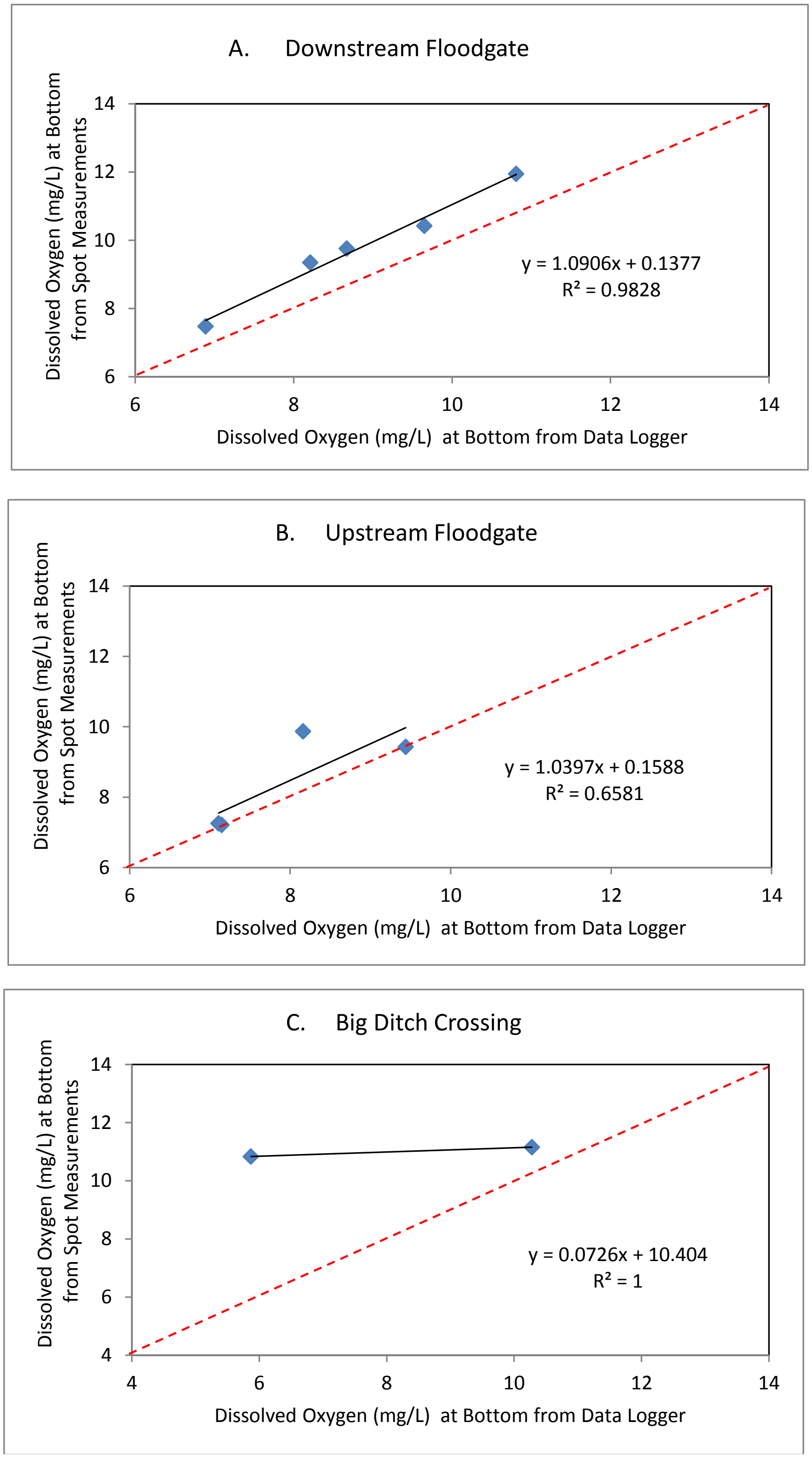


Figure 12. Comparison of dissolved oxygen levels from continuously reading data loggers (shown on x axis) and spot measurements taken during the time of beach seining in Fisher Slough, 2011 (shown on y axis). The 1:1 line is shown as a dashed line in each figure. In Panel C there are only two comparisons due to a data recording malfunction from the logger being surrounded by pond weed vegetation after May 9, 2011. Also note the different axis in Panel C.

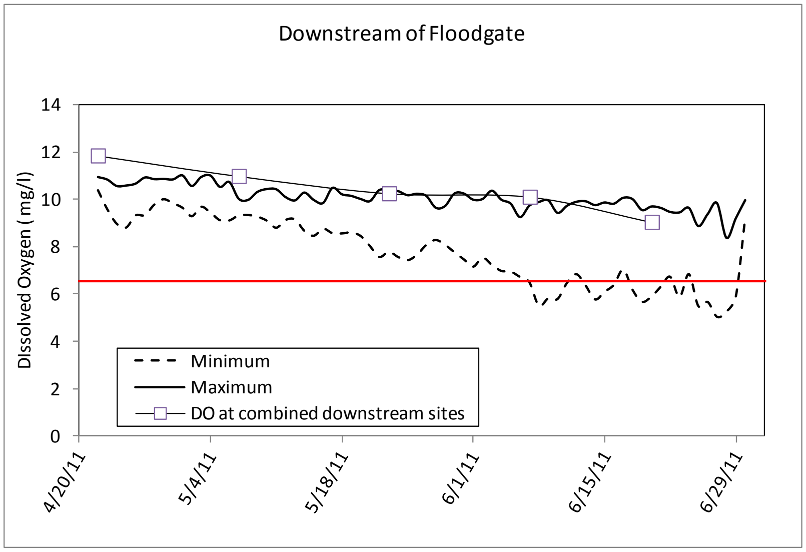


Figure 13. Maximum and minimum from DO data logger at Downstream Floodgate and daily average bottom dissolved oxygen from spot measurements at sites Fisher Sl Outside Tidegate S and Fisher Sl Blind Ch. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migration.

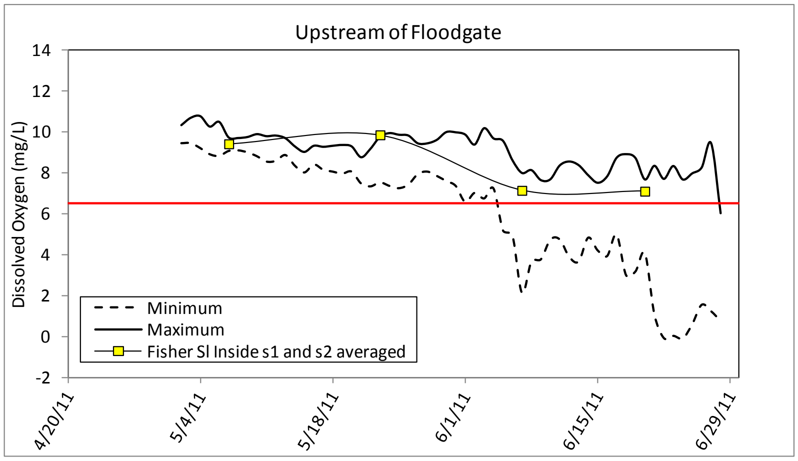


Figure 14. Maximum and minimum from DO data logger at Upstream Floodgate and daily average bottom dissolved oxygen from spot measurements at sites Fisher Sl s1 and s2. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migration.

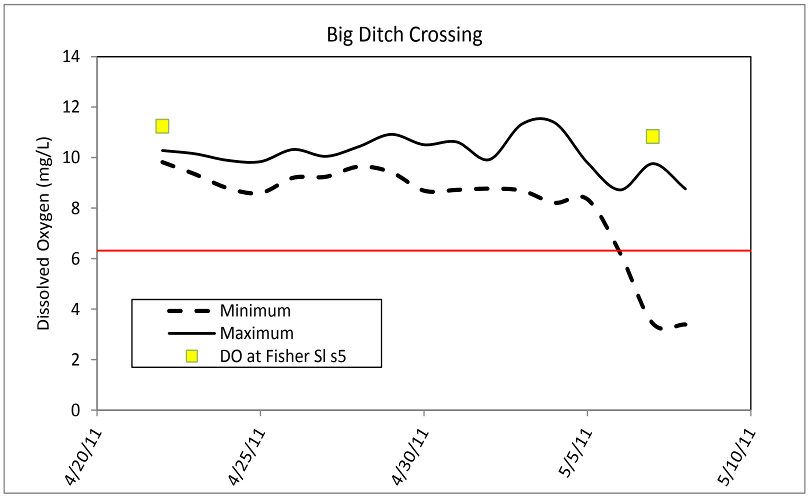


Figure 15. Maximum and minimum from DO data logger at Big Ditch Crossing and daily average bottom dissolved oxygen from spot measurements at site Fisher Sl s5. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels for DO levels in waters with salmonid rearing and migration. The AquiStar DO logger became buried by pond weed on May 9, resulting in inaccurate data after that time.

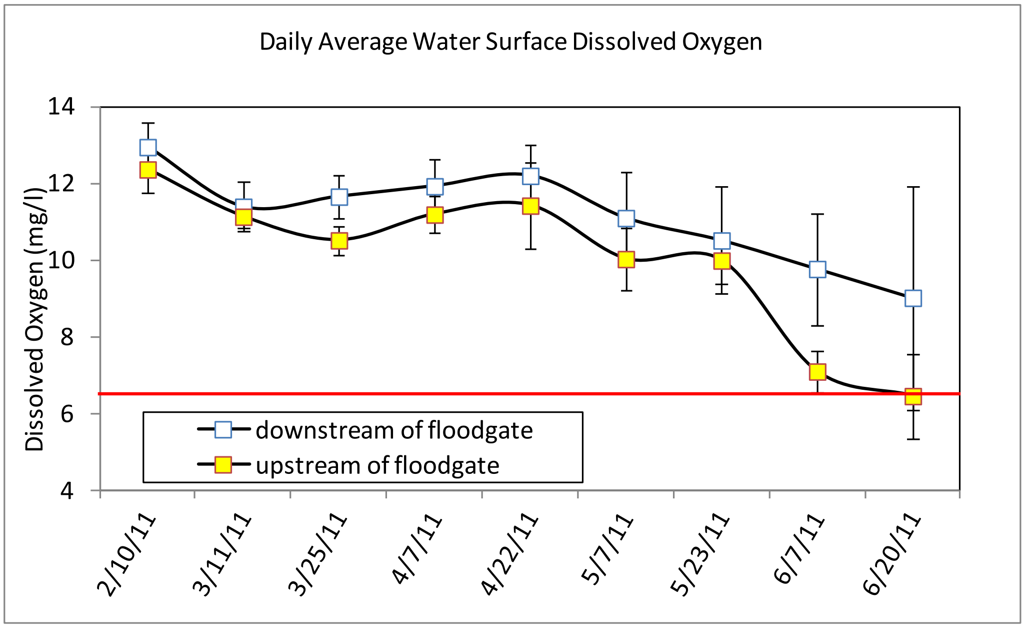


Figure 16. Comparison of daily average water surface dissolved oxygen level in mg/L for combined upstream and combined downstream sites by sampling day at Fisher Slough in 2011. Error bars are one standard deviation. Data from the site at Tom Moore Sl Upper Area is included in the downstream of floodgate data set. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migrating.

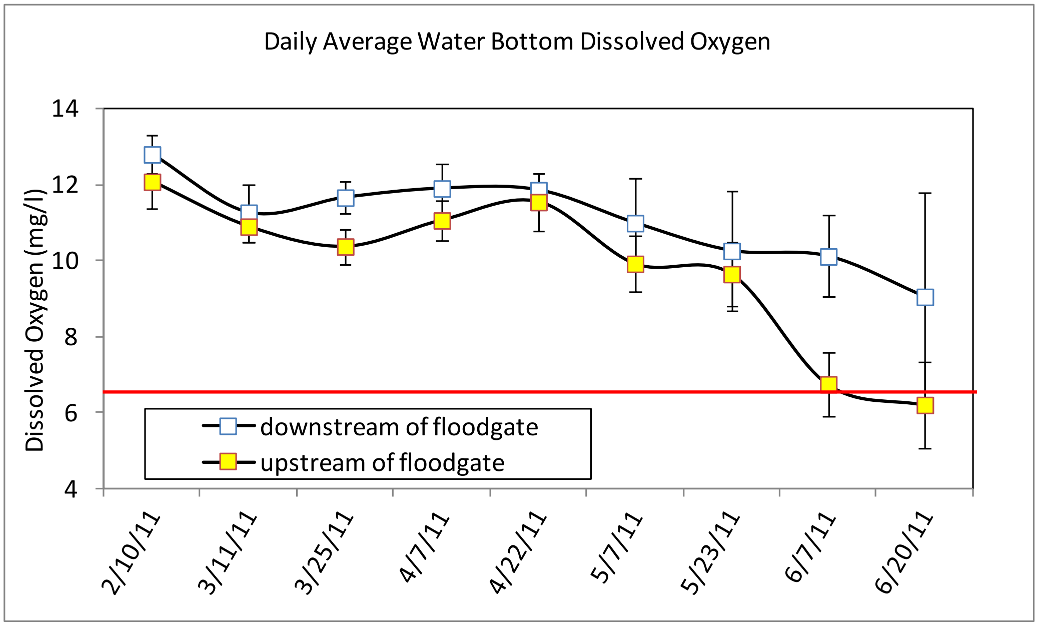


Figure 17. Comparison of daily average water bottom dissolved oxygen level in mg/L for combined upstream and combined downstream sites by sampling day at Fisher Slough in 2011. Error bars are one standard deviation. Data from the site at Tom Moore Sl Upper Area is included in the downstream of floodgate data set. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migrating.

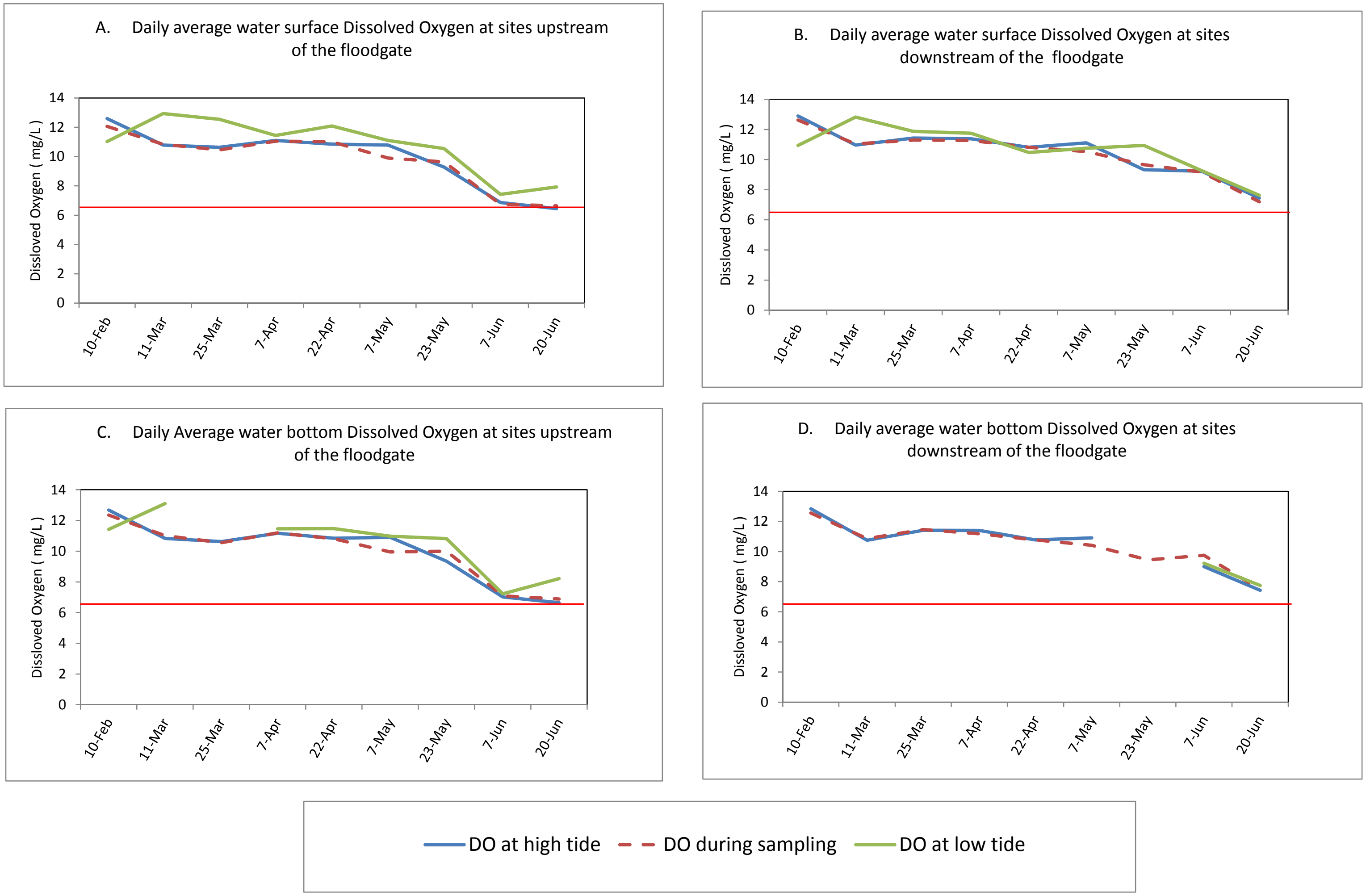


Figure 18. Comparison of daily average water surface and bottom dissolved oxygen levels in mg/L for upstream and downstream combined sites by sampling day and by tidal stage strata at Fisher Slough in 2011. The downstream sites do not include Tom Moore Sl Upper Area. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migrating. Measurements were not taken when the depth was less than 0.30 meters, hence the disconnected lines in panel C and D.

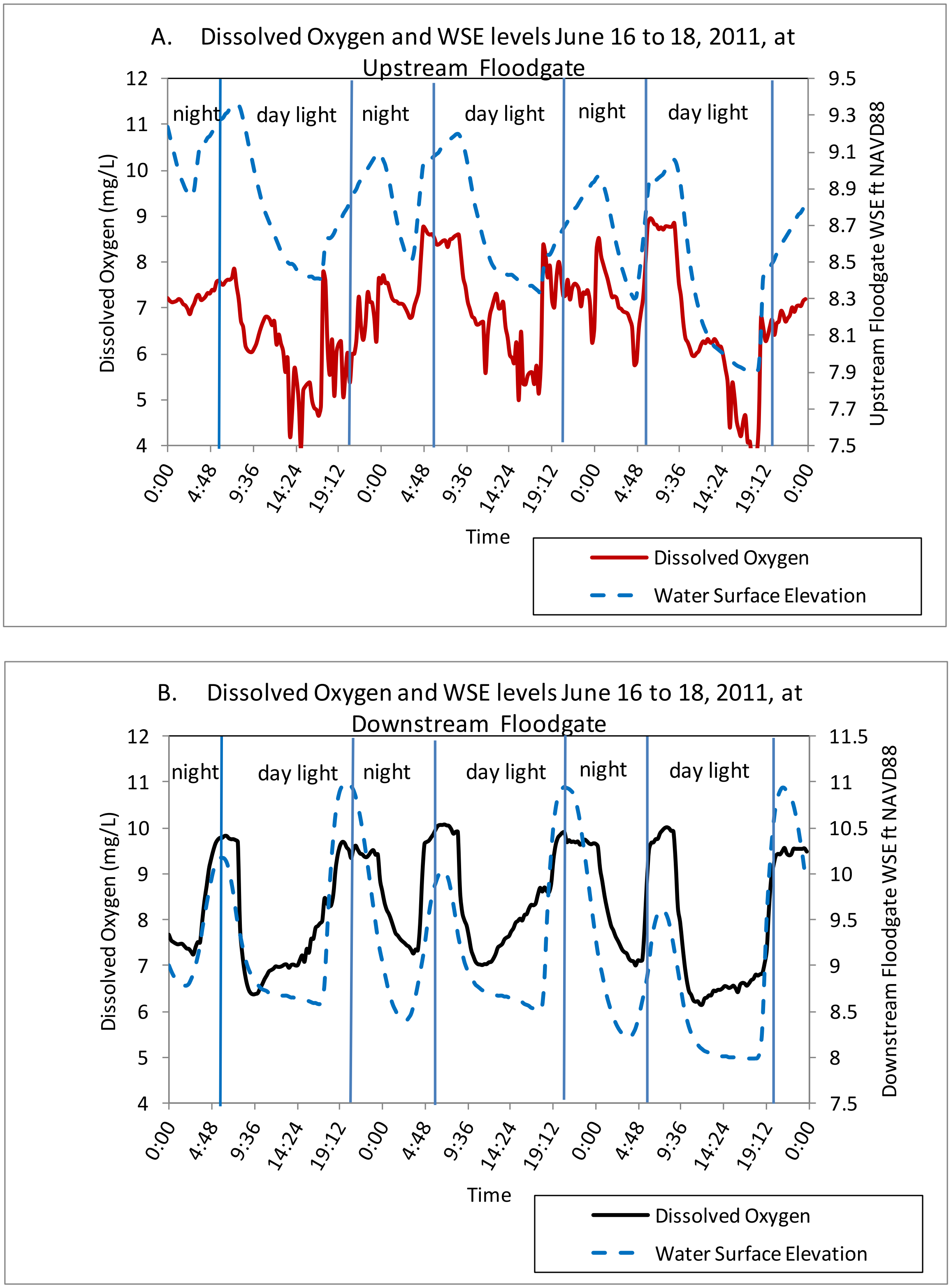


Figure 19. Dissolved oxygen levels at Upstream Flodgate (panel A) and Downstream Floodgate (panel B) of the Fisher Slough floodgate over a three-day period, June 16-18, 2011. Note different scale on the secondary Y axis.

Water depth

Water depth at each site met minimum water depth threshold (0.20 meters) for juvenile Chinook salmon rearing on all sample dates (Table 4).

Table 4. Maximum water depth (m) for sites at Fisher Slough in 2011.

Location / Site		Date in 2011								
		2/10	3/11	3/25	4/7	4/22	5/7	5/23	6/7	6/20
Upstream of floodgate	Fisher Sl Inside s1	2.00	1.30	1.80	1.80	1.85	2.00	1.90	1.50	1.46
	Fisher Sl Inside s2	2.10	2.40	2.40	1.80	1.96	2.10	1.78	2.00	2.10
	Fisher Sl Inside s3	1.70	1.60	1.70	1.80	1.45	1.45	1.25	1.80	1.42
	Fisher Sl Inside s4	1.30	1.45	1.50	1.35	1.18	1.25	1.06	1.50	1.34
	Fisher Sl Inside s5	1.20	1.30	1.30	1.15	0.80	1.05	0.83	1.30	1.17
	Fisher Sl Inside s6	1.40	1.35	1.60	1.35	1.12	1.90	1.05	1.70	1.34
	Fisher Sl Inside s7	1.30	1.90	1.50	1.50	1.15	1.22	1.25	1.50	1.23
Downstream of floodgate	Fisher Sl Tidegate Outside S	2.80	3.00	3.25	3.80	3.80	2.80	3.00	3.50	3.10
	Tom Moore Sl Upper Area	2.30	2.10	1.70	1.50	1.73	1.80	2.00	1.80	1.45
	Fisher Sl Blind Ch	1.47	1.57	1.65	1.57	1.33	1.34	1.07	1.59	1.36

Water velocity

For the sites upstream of the floodgate, the velocity threshold for juvenile Chinook salmon preference (0.20 m/s) was exceeded at 12.7% of the 2011 sampling occurrences (7.8% in 2010 and 4% in 2009). For the sites downstream of the floodgate, the velocity threshold was exceeded at 18.5% of the sampling occurrences (7.7% in 2010 and 8% in 2009). However, velocity exceeded the threshold for juvenile Chinook presence (as opposed to preference) (0.38 m/s) only one time upstream (Fisher Sl Inside s5 on April 7) and once downstream (Tom Moore Sl Upper Area on February 10) of the floodgate (Table 5).

Table 5. Average water velocity (m/s) at sites in Fisher Slough in 2011. Values that exceed juvenile Chinook salmon preference, as established in Beamer et al. (2005), are shown in bold.

Location / Site		Date in 2011								
		2/10	3/11	3/25	4/7	4/22	5/7	5/23	6/7	6/20
Upstream of floodgate	Fisher Sl Inside s1	0.00	0.03	0.00	0.04	0.00	0.01	0.00	0.00	0.00
	Fisher Sl Inside s2	0.04	0.14	0.05	**0.33**	0.08	0.11	0.07	0.00	0.01
	Fisher Sl Inside s3	0.04	0.18	0.11	**0.34**	0.13	0.09	0.09	0.00	0.04
	Fisher Sl Inside s4	0.05	0.14	0.06	0.18	0.13	0.13	0.06	0.00	0.02
	Fisher Sl Inside s5	0.18	**0.27**	**0.24**	**0.46**	**0.25**	**0.34**	**0.21**	0.10	0.04
	Fisher Sl Inside s6	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fisher Sl Inside s7	0.00	0.05	0.00	0.00	0.03	0.02	0.02	0.00	0.00
Downstream of floodgate	Fisher Sl Tidegate Outside S	0.00	0.07	0.00	0.14	0.00	0.05	0.01	0.00	0.00
	Tom Moore Sl Upper Area	**0.44**	0.13	0.13	**0.25**	0.12	0.10	**0.28**	**0.21**	**0.24**
	Fisher Sl Blind Ch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Substrate and vegetation

The substrate classification at all sites upstream of the floodgate (except Inside s5) and at the two sites directly below the floodgate was mixed fines. The substrate at Tom Moore Sl Upper Area and Fisher Sl Inside s5 was sand.

Vegetation at the sites upstream of the floodgate changed seasonally. At the start of the season all sites were considered unvegetated. By March 11 the vegetation within the channel grew so that all sites were classified as fresh water aquatic plants, made up primarily of pondweed. By the end of sampling on June 20, beach seine set areas at each site were approximately 75% covered by pondweed. We did not identify the pondweed species.

All of the beach seine sites downstream of the floodgate were classified as unvegetated throughout the sampling season. The vegetation at the fyke trap site was a combination of fresh water grasses and fresh water aquatic plants.

Fish assemblage

There were 2,736 fish representing 13 fish species found in the sampling at Fisher Slough from February 9 to June 20, 2011. In addition to the fish species, two non-fish species: rough-skinned newts and freshwater mussels were identified and counted. The catch for all species is shown in Table 6. A seasonal view of fish assemblage is shown in Figure 20.

Table 6. Total catch by species at Fisher Slough sites in 2011. Mean catch per beach seine set or per fyke trap daily catch is in parentheses.

	Upstream of floodgate	**Downstream of floodgate**	
Salmonid species:	beach seine	beach seine	fyke trap
Chinook salmon, unmarked subyearling *Oncorhynchus tshawytscha*	134 (2.13)	347 (12.85)	286 (31.78)
Chinook salmon, hatchery origin, all marks and ages combined *Oncorhynchus tshawytscha*	1 (0.02)	4 (0.15)	1 (0.11)
Coho salmon, unmarked subyearling *Oncorhynchus kisutch*	553 (8.78)	66 (2.44)	152 (16.89)
Coho salmon, unmarked yearling *Oncorhynchus kisutch*	52 (0.83)	3 (0.11)	44 (4.89)
Chum salmon subyearling *Oncorhynchus keta*	1 (0.02)	45 (1.67)	32 (3.56)
Cutthroat trout, all ages *Oncorhynchus clarki*	49 (0.77)	1 (0.04)	8 (0.89)
Unidentified trout, subyearling *Oncorhynchus mykiss or clarki*	3 (0.05)	1 (0.04)	0 (0.00)
Whitefish, all ages *Prosopium williamsoni*	1 (0.02)	1 (0.04)	0 (0.00)
Total salmonids:	**794**	**468**	**523**
Other fish species:			
Three-spine stickleback *Gasterosteus aculeatus*	663 (10.52)	12 (0.44)	78 (8.67)
Peamouth chub *Mylocheilus caurinus*	20 (0.32)	3 (0.11)	34 (3.78)
Prickly sculpin *Cottus asper*	50 (0.79)	11 (0.41)	41 (4.56)
Starry flounder *Platichthys stellatus*	5 (0.08)	7 (0.26)	2 (0.22)
Yellow perch *Perca flavescens*	9 (0.14)	0 (0.00)	0 (0.00)
Pumpkinseed *Lepomis gibbosus*	1 (0.02)	0 (0.00)	0 (0.00)
Large scale sucker *Catosmus macrocheilus*	14 (0.22)	1 (0.04)	0 (0.00)
Total other fish species:	**762**	**34**	**155**
Total fish catch:	**1,556**	**502**	**678**
Other non-fish species:			
Roughskin newt *Taricha granulosa*	35 (0.56)	0 (0.00)	2 (0.22)
Freshwater mussel *Anodonta spp.*	564 (8.95)	0 (0.00)	1 (0.11)
Total other non-fish species:	**599**	**0**	**3**
Total catch:	**2,155**	**502**	**681**

Upstream of the floodgate

The sampling effort at the sites upstream of the floodgate caught 1,556 fish of 13 different species (Table 5). All juvenile salmon species combined represented 51.03% of the total fish catch above the floodgate. Wild sub-yearling (young of the year) Chinook salmon comprised 16.88% of the juvenile salmon catch in 2011. The wild sub-yearling coho salmon comprised 69.65% of the juvenile salmon group. Cutthroat trout accounted for 6.17% of the juvenile salmon catch. Chum salmon fry and hatchery Chinook salmon were a minor part of the juvenile salmon catch upstream of the floodgate. There were three trout fry that were too small to be identified to species. There was one mountain whitefish captured in 2011.

Three-spined stickleback was the predominant species caught, accounting for 42.61% of the fish caught above the floodgate. They were caught on every sampling day and were caught at each site. The remainder of the fish catch upstream of the floodgate was comprised of peamouth chub (1.29%), prickly sculpin (3.21%), pumpkinseed sunfish (0.06%), starry flounder (0.32%), large scale sucker (0.90%) and yellow perch (0.58%). Red-sided shiners were caught in 2010 but not 2011. Shiner perch and lamprey were caught in 2009, but not in 2010 or 2011.

Downstream of the floodgate

The sampling effort at the sites downstream of the floodgate caught 1,180 fish of 10 different species (Table 5). All juvenile salmon species combined represented 83.98% of the total fish catch below the floodgate. Wild sub-yearling Chinook salmon comprised 63.87% of the combined salmon group catch in 2011. Wild sub-yearling coho salmon comprised 22.00% of the salmon caught. The remainder of the salmonid catch, minor in their percentages, included hatchery-origin Chinook salmon, wild yearling coho salmon, chum salmon fry, cutthroat trout and mountain whitefish. There was one trout fry that was too small to be identified to species.

Three-spined stickleback accounted for 7.83% of the fish caught below the floodgate. Peamouth chub accounted for 3.14% and prickly sculpin 4.41% of the fish catch below the floodgate. The remainder of the catch included starry flounder (0.76%) and large scale sucker (0.08%). Pumpkinseed sunfish, yellow perch, red-sided shiner and surf smelt were caught in 2010 but not 2011. English sole and lamprey were caught in 2009, but not in 2010 or 2011.

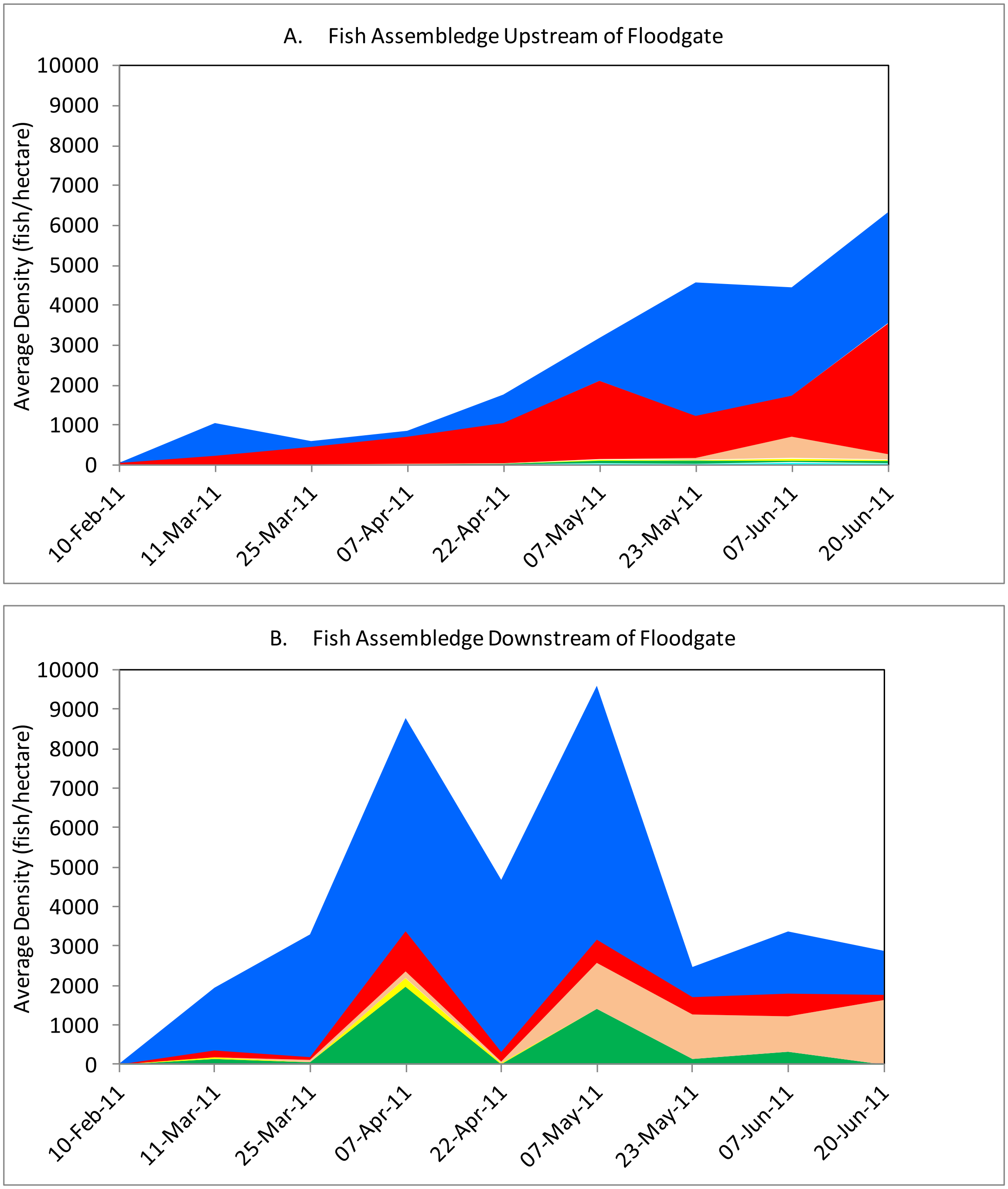


Figure 20. Fish assemblage in Fisher Slough in 2011. Panel A is for the combined sites upstream of the floodgate. Panel B is the for the combined sites downstream of the floodgate.

Juvenile Chinook salmon density

Comparison of juvenile Chinook salmon density by site and date in 2011

Upstream of the floodgate

Juvenile wild Chinook salmon were first present upstream of the floodgate in Fisher Slough starting March 11, 2011 (our second sampling date). Two density peaks of juvenile wild Chinook salmon occurred upstream of the floodgate in 2011, on March 11 and May 23 (Figure 21). Juvenile Chinook salmon were still present upstream of the floodgate at the end of the fish monitoring on June 20, 2011.

Downstream of the floodgate

Juvenile wild Chinook salmon were present downstream of the floodgate in Fisher Slough when monitoring started in February 2011. Two peaks of juvenile wild Chinook salmon density occurred downstream of the floodgate in 2011, on April 22 and June 7 (Figure 21). Juvenile Chinook salmon were still present downstream of the floodgate at the end of the fish monitoring period. By visual analysis, density of juvenile Chinook salmon was higher downstream of the floodgate than upstream.

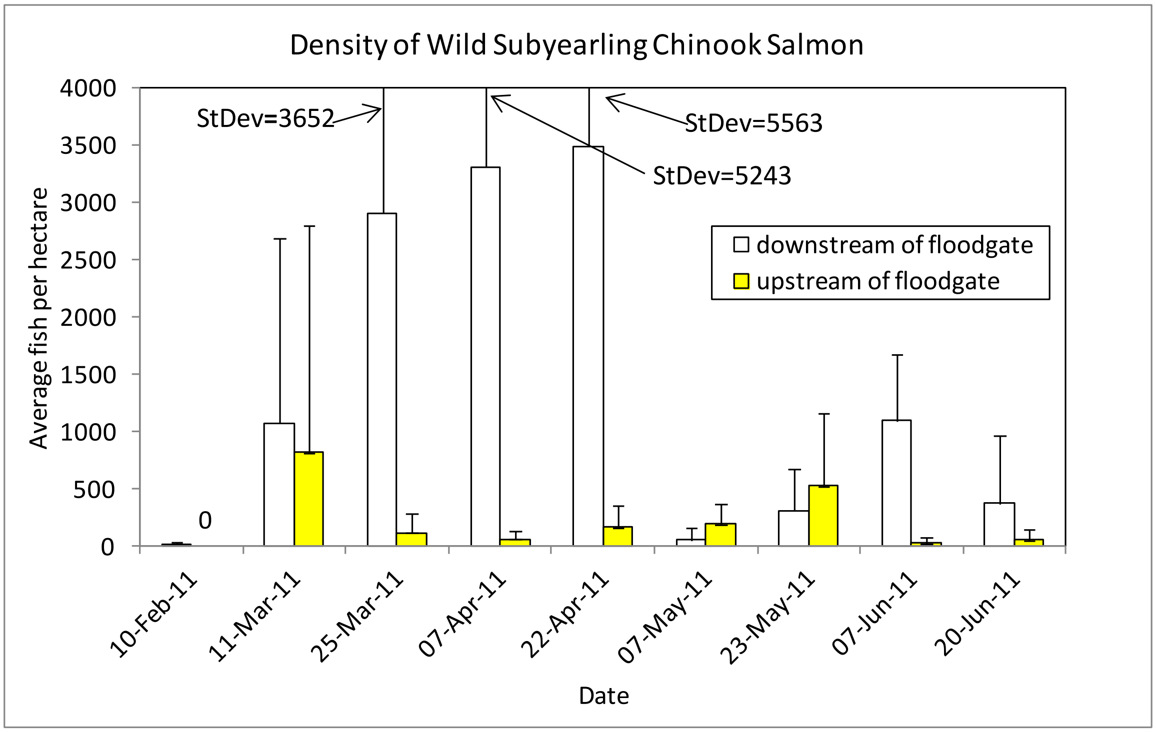


Figure 21. Comparison of average density of wild subyearling Chinook salmon for combined upstream and combined downstream sites by sampling day at Fisher Slough, 2011. Error bars are one standard deviation.

Comparison of juvenile Chinook salmon density by treatment and strata

Statistical analysis reveals log transformed Chinook salmon density was influenced by treatment, strata, and an interaction between these two factors (Table 7). Comparison of treatment/strata groups reveals whether differences between groups in wild Chinook salmon density are significant (Table 8). Wild juvenile Chinook salmon density was higher downstream of the floodgate than upstream of the floodgate in 2010 (year 1 after replacement), which is in contrast to 2009 (before replacement) where there was no statistical difference. Chinook salmon density was also higher downstream of the floodgate than upstream of the floodgate in 2011 (year 2 after replacement, Figure 21), but it is not significant at the 0.05 level.

Densities of wild juvenile Chinook salmon upstream of the floodgate were higher before floodgate replacement than in either year after floodgate replacement. This was not the case for downstream sites, where Chinook salmon densities were similar all three years ($p < 0.0001$ both years). Graphical results illustrate differences in wild Chinook salmon density by site (Figure 22) and season (Figure 23) for the different treatment years and strata.

Table 7. Two-Way Analysis of Variance results for log transformed wild juvenile Chinook salmon density at Fisher Slough, 2009, 2010, and 2011.

Source	**Sum of Squares**	**Degrees of freedom**	**Mean Squares**	**F**	**p**
Factor A Treatment influence (before and after floodgate replacement – there are 2 years of "after" floodgate replacement: Yr1 is 2010, Yr2 is 2011.)	44.769	2	22.384	13.605	**0.000**
Factor B Strata influence (upstream and downstream of the floodgate)	20.480	1	20.480	12.447	**0.000**
Interaction between Factors A&B	10.158	2	5.079	3.087	**0.047**
Error	478.779	291	1.645		

Table 8. Group comparisons using Scheffé Test. Treatments are "before" or "after" floodgate replacement. There are two years of "after" floodgate replacement: Yr1 is 2010, Yr2 is 2011. Strata are "upstream" or "downstream" of the floodgate.

Groups	**Difference**	**p**
AfterYr1*downstream vs. AfterYr1*upstream	0.904	**0.047**
AfterYr1*downstream vs. AfterYr2*downstream	0.106	1.000
AfterYr1*downstream vs. Before*downstream	-0.403	0.879
AfterYr1*upstream vs. AfterYr2*upstream	-0.076	1.000
AfterYr1*upstream vs. Before*upstream	-1.294	**0.000**
AfterYr2*downstream vs. AfterYr2*upstream	0.721	0.207
AfterYr2*downstream vs. Before*downstream	-0.509	0.725
AfterYr2*upstream vs. Before*upstream	-1.218	**0.000**
Before*downstream vs. Before*upstream	0.013	1.000

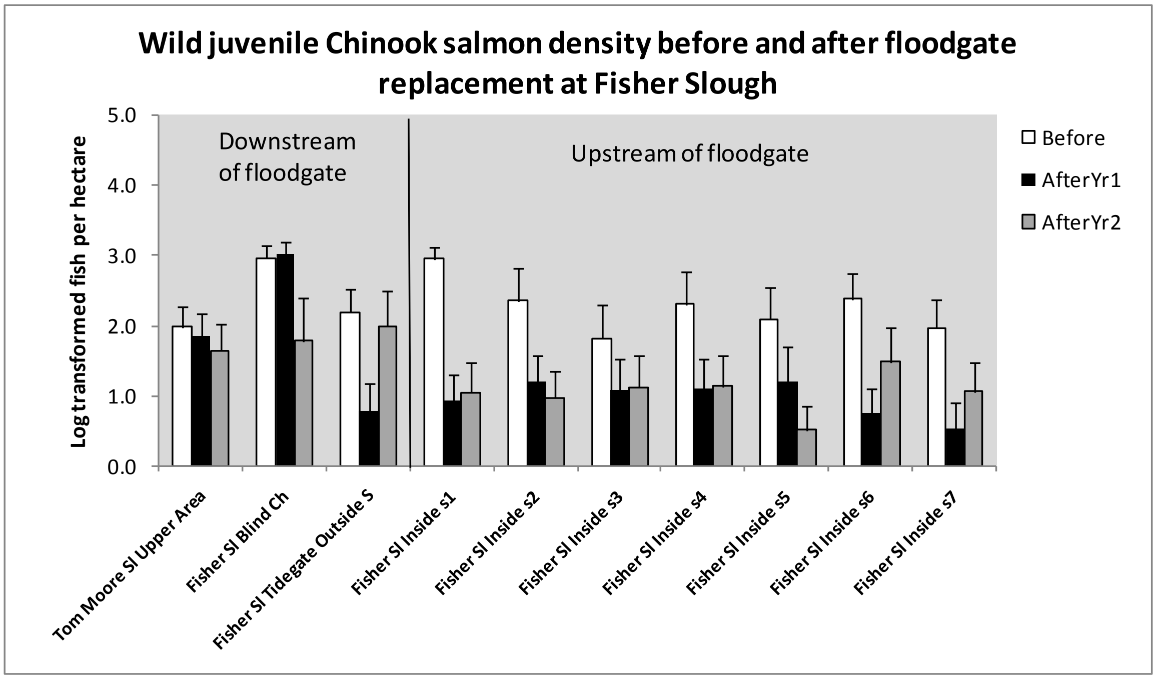


Figure 22. Comparison of mean log transformed wild juvenile Chinook salmon density by treatment, strata, and site. Treatments are “before” or “after” floodgate replacement. Strata are “upstream” or “downstream” of the floodgate. Error bars are standard error.

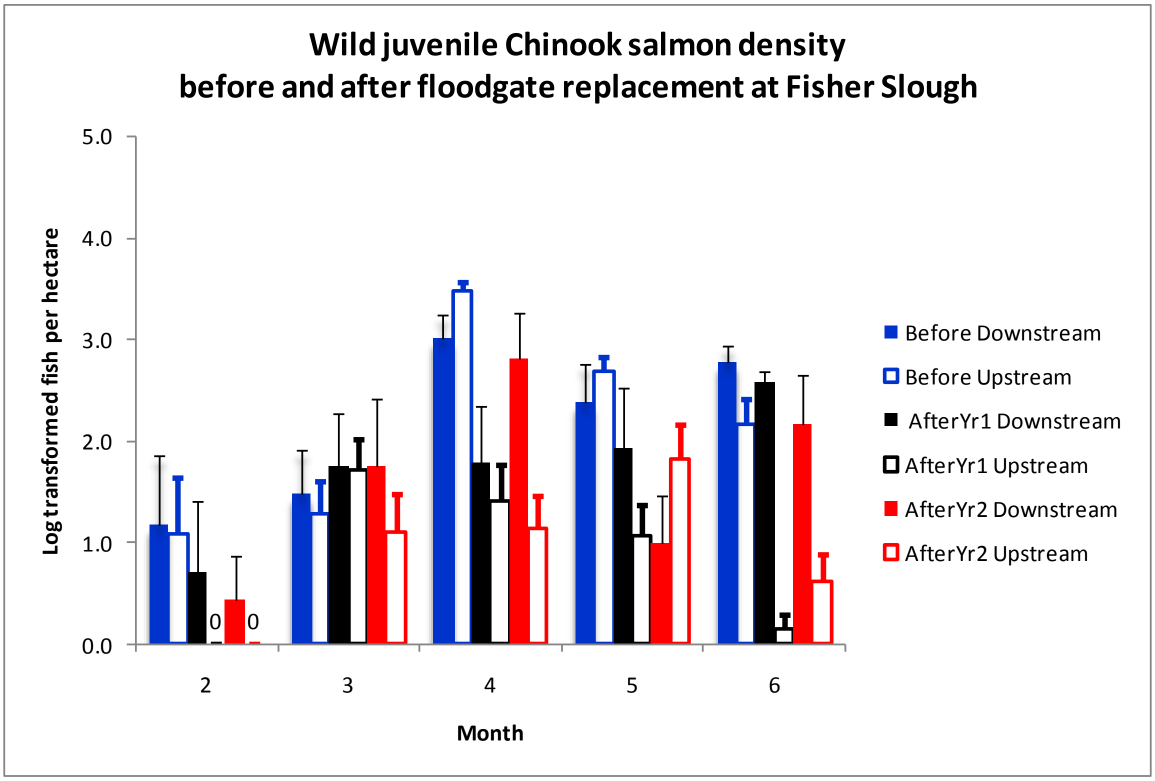


Figure 23. Comparison of mean log transformed wild juvenile Chinook salmon density by treatment, strata, and month. Treatments are “before” or “after” floodgate replacement. Strata are “upstream” or “downstream” of the floodgate. Error bars are standard error.

Comparison of juvenile Chinook salmon density to other sites within the Skagit River tidal delta

This section reports 1) juvenile Chinook salmon density at Fisher Slough monitoring sites compared to the long term Skagit River delta monitoring sites and 2) differences in wild Chinook salmon outmigration population estimates for the three years of Fisher Slough monitoring to date: 2009 through 2011.

Landscape connectivity and Chinook salmon seasonal density:

There is a strong positive relationship between seasonal wild juvenile Chinook salmon density and landscape connectivity for the long term monitoring sites throughout the Skagit River delta for each of the three years when Fisher Slough monitoring has occurred (Figure 24). Depending on the year, landscape connectivity explains 58% to 74% of the variation in seasonal juvenile Chinook salmon density at Skagit River delta long-term monitoring sites. Before floodgate replacement (year 2009) the Fisher Slough monitoring sites generally clustered within the scatter of the Skagit River long term monitoring sites (Figure 24, panel A). In both years after floodgate replacement, most Fisher Slough sites upstream of the floodgate fell outside (lower) of the scatter of the Skagit River long term monitoring sites (Figure 24, panels B and C). In contrast, the Fisher Slough sites located downstream of the floodgate are clustered within the scatter of the Skagit River long term monitoring sites.

Wild juvenile Chinook salmon outmigration population:

WDFW operates a downstream migrant trap in the lower Skagit River near the town of Burlington to estimate the population size of outmigrating juvenile Chinook salmon each year. The point estimate for the wild juvenile Chinook salmon outmigration is 2.8 million fish in 2009, 1.6 million fish in 2010, and 3.7 million fish in 2011 (C. Kinsel, WDFW, personal communication).

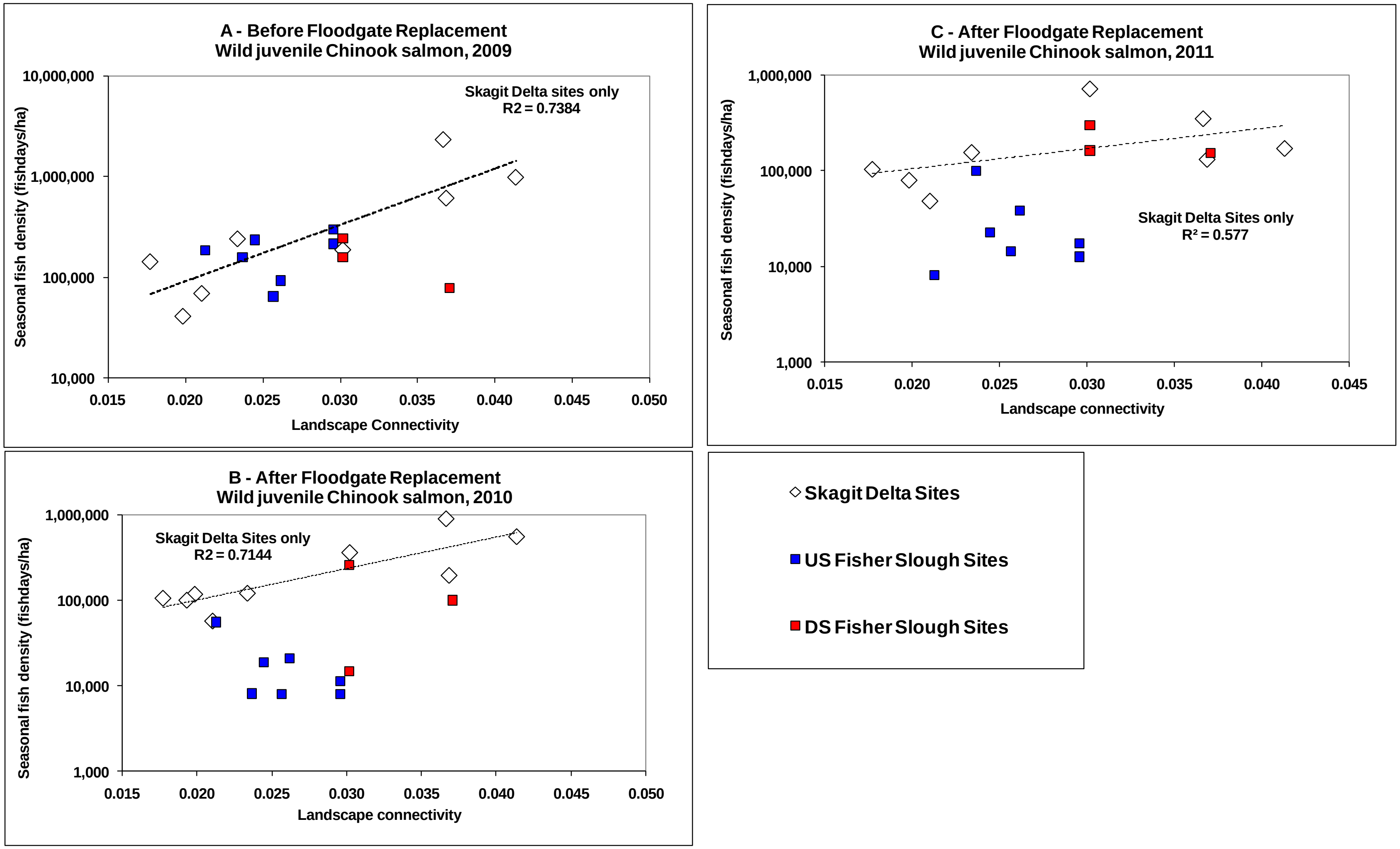


Figure 24. Relationship between landscape connectivity and seasonal Chinook salmon density for Skagit River delta long-term monitoring sites and Fisher Slough monitoring sites in 2009 through 2011. All panels show connectivity calculated to Fisher Slough sites based on fish migration pathways using the downstream end of Tom Moore Slough. Panel A shows results for 2009 (before floodgate replacement). Panel B shows results for 2010 (year 1 after floodgate replacement). Panel C shows results for 2011 (year 2 after floodgate replacement).

Juvenile Chinook salmon size

Chinook length up- and downstream of the floodgate prior to and including the date of peak juvenile Chinook salmon density (March 11 upstream and April 22 downstream) was small and showed no strong increasing or decreasing trend for this period (Figure 25). During this early period, the average juvenile Chinook salmon fork length ranged from 41.9 to 44.7 mm, similar to lengths observed in 2009 and 2010. Increased fish size was seen starting with the sampling on May 7.

Fish found downstream of the floodgate increased on average 7.4 mm in length for each two-week period starting in May, then increased on average 1.9 mm in June for each two-week period. The average Chinook salmon length was 59.6 mm at the end of June.

Upstream of the floodgate, fish size increased on average 8.3 mm in length for each two-week period starting in May. There was a 16.9 mm average size increase at the start of June for the two Chinook salmon that were caught and measured (compared to the average size at the end of May); at the end of June the average length was 68.3 mm. June's record of fish size is based on a limited sample size; only six fish were caught the entire month (Figure 25).

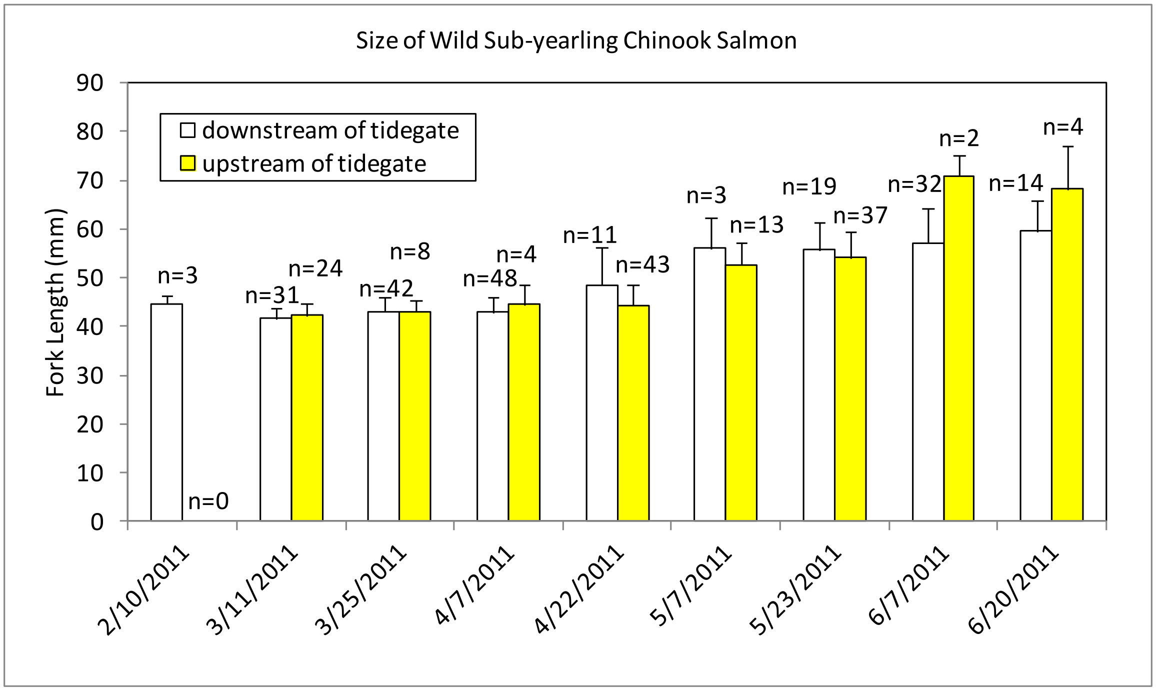


Figure 25. Comparison of average size of wild subyearling Chinook salmon for combined upstream and combined downstream sites by sampling day at Fisher Slough, 2011. Error bars are one standard deviation. The sample size of fish measured each date is shown above the bar for each group (upstream and downstream of floodgate).

Other salmon

Yearling coho salmon

Upstream of the floodgate

Yearling coho salmon were present in Fisher Slough upstream of the floodgate starting on March 25 with an average density of 15 fish per hectare (Figure 26, panel A). The density increased as the coho salmon smolt outmigration continued, with an average peak density of 490 fish per hectare seen on May 23. Yearling coho salmon were not found upstream of the floodgate on the last sampling date of June 20.

Downstream of the floodgate

Yearling coho salmon were only found on May 7 and June 7 at the sites downstream of the floodgate. The peak density was 6,101 fish per hectare on May 7, while the density was 141 fish per hectare on June 7 (Figure 26, panel A).

Sub-yearling coho salmon

Upstream of the floodgate

Coho salmon fry were first encountered at our upstream beach seine catches starting on April 7 (Figure 26, panel B). The density steadily increased with the peak seen on June 20 (the last sampling day) with an average of 2,534 fish per hectare.

Downstream of the floodgate

Subyearling coho salmon were found starting on April 7 at the sites downstream of the floodgate. The peak density of 439 fish per hectare of area sampled was on April 22. During April there were more sub-yearling Coho at the sites downstream than upstream of the floodgate. After April, there were lower density levels at the downstream sites than at the upstream sites through our last sampling event of June 20 (Figure 26, panel B).

Juvenile chum salmon

Juvenile chum salmon were observed at Fisher Slough in 2011 primarily downstream of the floodgate. The peak density of chum salmon at the sites downstream of the floodgate was on April 7 with an average of 1,639 fish per hectare (Figure 26, panel C). Upstream of the floodgate, chum salmon were only caught on April 7 with an average of 15 fish per hectare of area sampled. Juvenile chum salmon were caught on 3% of sets made upstream of the floodgate and 31% of sets made downstream of the floodgate suggests that juvenile chum salmon were not progeny from adult chum salmon that spawned in tributaries upstream of the floodgate. No chum salmon were caught at any site after May 23.

Juvenile pink salmon

Juvenile pink salmon were not caught at Fisher Slough in 2011. We did not expect any juvenile pink salmon at Fisher Slough this year because, in the Skagit River basin, pink salmon are predominantly odd-year spawning adults with even-year progeny.

Cutthroat trout

Cutthroat trout were present in catches both upstream and downstream of the floodgate every month during sampling in 2011 except February (Figure 26, panel D). The peak catch upstream was on May 23 with an average density of 221 fish per hectare of area seined. The peak catch downstream was on June 20, at 281 fish per hectare.

Hatchery-origin salmon

There were six hatchery-origin Chinook salmon caught at Fisher Slough in 2011. All were sacrificed in order to read the tags located in their snouts. All tags came from the WDFW hatchery at Marblemount on the Skagit River. Five of the hatchery Chinook salmon were caught downstream of the floodgate, on April 7 (n=1) and June 20 (n=4). One hatchery Chinook salmon was caught upstream of the floodgate, on June 20. In 2010 there were five hatchery-origin fish caught; in 2009 there were 46.

Steelhead

Juvenile steelhead were not caught during sampling at Fisher Slough in 2011, nor in 2010. One juvenile steelhead was caught in 2009, upstream of the floodgate

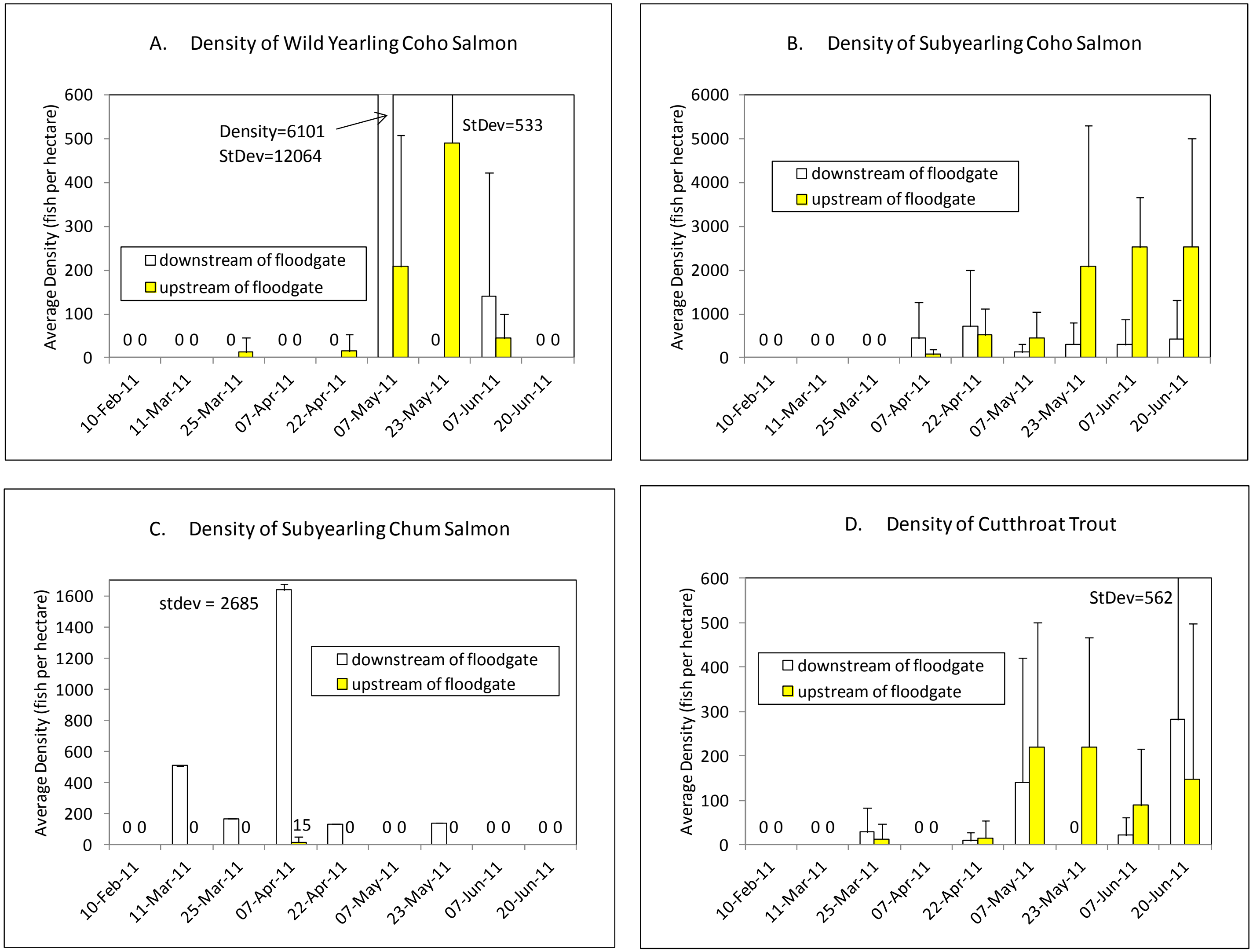


Figure 26. Comparison of the average density of coho salmon, chum salmon and cutthroat trout for combined upstream and combined downstream sites by sampling day at Fisher Slough in 2011. Error bars are one standard deviation. Note the different scales on the y axis.

Non-fish biota

Rough-skinned newts

There were thirty-seven rough-skinned newts caught during sampling at Fisher Slough; all except two were caught upstream of the floodgate. The thirty-five newts caught upstream of the floodgate came from Fisher Sl Inside s6 (n=27) and Fisher Sl Inside s7 (n=8). Both of these sites are located in the side channel area of Fisher Slough, characterized by slow-moving water. The peak catch of the newts was May 7 (n=26), accounting for 74.3% of the newt catch upstream of the floodgate. The newts were found every sampling day except March 11 and June 20. The two newts found downstream of the floodgate were caught at the Fisher Sl Blind Ch fyke trap site on April 7 and June 20 (one each day).

Mid-spring to early summer is when the rough-skinned newts move from their preferred habitat in forested, partially-wooded areas to stream backwaters in order to breed (Corkran and Thoms, 1996). The catch of newts in 2011 was similar to the number caught in 2010, but half that of 2009 (n=68 in 2009).

Rough-skinned newt.

Freshwater mussels

There were 565 freshwater mussels counted in our beach seine samples in 2011 (986 in 2010). All except one was found upstream of the floodgate; 98.7% were caught in the side channel area at Fisher Sl Inside s6 (n=375) and Fisher Sl Inside s7 (n=182). Five mussels were caught at Fisher Sl Inside s2, two at Fisher Sl Inside s4, and one downstream at the Fisher Sl Blind Ch fyke trap site. The mussels were encountered starting April 22 and were caught every sampling day after that. The peak catch was 292 mussels on June 20. The catch of freshwater mussels in 2011 was roughly half the number caught in 2010, and just over a quarter the catch of 2009 (n= 2,044 in 2009).

Discussion and conclusions

Upstream juvenile salmon fish passage opportunity at the floodgate

Fisher Slough floodgate monitoring results for 2011 are presented in Beamer and Henderson (2012). Floodgate door opening characteristics thought to equate to juvenile salmon upstream passage opportunity are discussed in that paper. In this section we reiterate these characteristics and present results for each of the three years of fish monitoring at Fisher Slough.

On one end of the spectrum, juvenile Chinook salmon cannot move upstream through the floodgate structure when its doors are closed. This condition occurred about 7% of the time in 2011, during the fish sampling which was the least amount of time of all three years of monitoring done at Fisher Slough (Table 9). On the other end of the spectrum, juvenile Chinook salmon can move upstream through the floodgate structure when its doors are open and water flow either: a) is moving upstream, or b) has a downstream velocity through the floodgate low enough to allow upstream fish movement. This condition coincides with non-ebb tidal stage periods when doors are open. This condition did not vary much over the three years of monitoring at Fisher Slough and was estimated to occur approximately 45% to 47% of the time (Table 9). We believe the statistic "percentage of time floodgates are open during non-ebb flow periods" may be a good indicator of upstream juvenile salmon passage opportunity at the Fisher Slough floodgates because young fry-sized salmon are not likely to migrate against ebb flows.

Table 9. Summary of floodgate door results for each year of Fisher Slough fish monitoring.

Year	% of time doors closed	% of time doors open	% of time doors open during tide ebb	% of time doors open during non-ebb flow
2009[A]	28.3	71.7	26.2	45.5
2010[B]	10.0	90.0	45.0	45.0
2011[C]	7.0	93.0	46.2	46.8

[A] Results for year 2009 presented in Table 9 are an update to those reported in Beamer et al. (2010), reflecting a difference in the time period examined. The 2009 report (Beamer et al. 2010) examined a subsample of days within the Juvenile Chinook Spring Migration Period, while Table 9 reports values derived from the entire fish monitoring period.

[B] We repeated the methods used in 2009 to obtain results for 2010.

[C] The values shown are summarized for the fish monitoring period and are not necessarily the values reported by Beamer and Henderson (2012), which are presented by HPA-defined floodgate management period. The fish monitoring period spans each of the three HPA-defined floodgate management periods.

Influence of site level environmental variability on juvenile Chinook salmon density

Because fish respond to their local environment (salinity, temperature, DO, velocity, depth, and substrate/vegetation) and the environment changes seasonally and spatially, we need to consider how much the local environment is influencing our observed fish patterns up- and downstream of the floodgate.

Salinity

The very low salinity values (< 0.1 ppt) found at all sites throughout Fisher Slough means salinity is not likely influencing juvenile Chinook salmon monitoring results between strata because measured values are well below the 4.5 ppt threshold value hypothesized to be stressful for juvenile Chinook salmon.

A caveat to our salinity results is created by the instrument used to measure salinity. The YSI Model Professional Plus meter actually measures water temperature and conductivity and then displays a calculated value of salinity based on those two measurements. One of the assumptions made by this instrument (and other hand-held meters) is that the conductivity of the water is caused by sea salt. To confirm the conductive ions in the water are actually from sea salt, a chemical analysis of the water must be performed. We did not conduct this test for this study because the salinity values measured by the YSI instrument were very low. It is likely that the YSI was measuring conductivity from ions other than sea salt because salinity values throughout the study area were generally very low, and because the higher of these values were located upstream of the floodgate (i.e., more distant from the source of sea salt). Conductive ions can be present in freshwater systems due to certain types of geology, wetland organic matter, and practices from adjacent land use. Regardless of the source of conductive ions, Fisher Slough is essentially a freshwater tidal system.

Water temperature

Comparison of collection methods – We conclude that data logger results help our understanding of temporal variation in water temperature (e.g., complete seasonal or daily fluctuations) at Fisher Slough, whereas our spot measurements of water temperature collected during beach seining help our understanding of spatial variation in water temperature within Fisher Slough. We recommend these data continue to be collected.

Fluctuations in water temperature – Both temperature measurement methods (spot and logger) show a seasonal increase in temperature, which is logical due to the general warming pattern that occurs from late winter into summer months. Fluctuations of average water temperature within the season were also observed, on the order of a few days to longer than a week, and we suggest they are due to fluctuations in short term weather patterns and/or river flow. Differences in maximum and minimum daily temperature also exist and were greater later in the season. Tidal cycle plays a role in daily fluctuation of temperature. Water temperature was generally lower at high tide than at low tide, likely because inflowing Skagit River water is cooler than water flowing into Fisher Slough from its surrounding lowland tributary watersheds. It is important to understand how much water temperature fluctuates daily to determine whether temperature refuge exists for juvenile Chinook salmon on a daily basis when average water temperature is above our threshold for stress.

Comparison to temperature thresholds – We adopted two water temperature threshold values: 1) > 15 °C (stressful to salmon in estuarine habitat) and 2) > 24.8 °C (lethal to salmon) to determine whether water temperature is influencing juvenile Chinook salmon monitoring results between strata. The rationale for each threshold is explained in the 2009 Fisher Slough fish monitoring report (Beamer et al. 2010).

Site differences in temperature within Fisher Slough were detected in statistical results for the monitoring period. The upstream sites were warmer than downstream sites and only on June 7 was average water temperature greater than 15 °C. Logger data shows that water cooler than 15 °C was available each day for both strata through our last sampling date. Maximum water temperature did not exceed 24.8 °C at the logger sites in either stratum. Therefore, we conclude that site differences in water temperature are likely not influencing juvenile Chinook monitoring results between strata in 2011.

Dissolved oxygen

In 2011 DO was consistently above the minimum threshold of 6.5 mg/L for waters with salmon rearing and migration from February until late spring or early summer at Fisher Slough (Figures 13 and 14). As the season progressed, mean and minimum daily DO at all sites upstream of the floodgate dipped below the minimum threshold level (Figures 13 and 14). Daily DO variability increased from ~1 mg/L in February to 4-8 mg/L by late June 2011. It makes sense that DO would fluctuate more dramatically later in our monitoring season as water temperature and plant/algae growth increases seasonally. Dissolved oxygen should increase during daylight hours as a result of photosynthesis and decrease at night as a result of respiration. We expected to observe a day/night signal in DO variation based on this hypothesis and our observation of consistently higher DO levels from our spot measurements (all in daylight) compared to the minimum and maximum DO measurements from the loggers (Figures 13 – 15). However, late in the season when DO was lowest and most variable, it fluctuated by the tidal cycle and not by the day/night cycle (Figure 19). We found that DO decreased on ebbing tides and increased on flooding tides both up- and downstream of the floodgate. Also, the downstream sites had higher overall DO levels. This suggests the tidal cycle is moving water masses with dramatically different DO levels into the Fisher Slough monitoring area. Figure 19 suggests the water mass upstream of the floodgate has low DO while the water mass downstream of the floodgate has higher DO. Support for this idea was found by examining results from long term monitoring sites in Skagit County's Water Quality Monitoring Program. One nearby site is located in the South Fork Skagit River (at Conway boat ramp) and represents the water mass downstream of the floodgate. The other nearby site is Carpenter Creek/Hill Ditch (at Cedardale Rd) and represents the water mass upstream of the floodgate. Each site is monitored on two week intervals by Skagit County. Dissolved oxygen varied seasonally at the South Fork site from approximately 8.5 to 13 mg/L, the lowest DO occurring during summer months and the highest during winter months (Water Years 2004 – 2011, Skagit County Public Works 2012). In contrast, while DO also varied seasonally at the Hill Ditch site, the lowest DO levels were much lower, with readings ranging from approximately 2 to 12 mg/L (Water Years 2004 – 2011, Skagit County Public Works 2012). Again, the lowest DO occurred during summer months while highest DO occurred in winter months.

In 2011 the Fisher Slough monitoring sites were exclusively in existing channel area, so factors influencing DO likely were primarily from exterior sources (areas up- or downstream of the restoration project area). Starting with the 2012 fish monitoring period much more habitat area will be available to fish within Fisher Slough because of completion of the dike setback restoration. Therefore, factors influencing habitat conditions will have more potential to originate from within the restoration project area as well as from exterior sources.

Comparison to DO thresholds – We adopted a DO threshold value of < 6.5mg/l (stressful to juvenile salmon rearing and migration) to determine whether DO is likely to influence juvenile Chinook salmon monitoring results between strata. The rationale for this threshold is explained in the 2009 Fisher Slough fish monitoring report (Beamer et al. 2010).

Site differences in DO within Fisher Slough were detected in statistical results for the monitoring period. The upstream sites were lower in DO than the downstream sites. Average DO from spot measurements was lower than the 6.5 mg/l threshold at upstream sites on only one date (June 20, our last sampling date in 2011). Logger data shows that water with DO levels higher than the 6.5 mg/l threshold was available each day for both strata through our last sampling date (Figures 13 – 15). Therefore, we conclude that site differences in DO are likely not influencing juvenile Chinook monitoring results between strata in 2011.

We do acknowledge that DO levels may approach or in some cases exceed conditions less than ideal for juvenile salmon rearing and migration requirements upstream of the floodgate in June (2011 sampling), late June (2010 sampling) and June or later in summer (2009 sampling). If true, this issue could reduce Chinook salmon density or fish size due to habitat quality independent of upstream fish passage efficiency at the floodgate. However, low DO is likely more of a problem for juvenile coho salmon or cutthroat trout, which can rear in Fisher Slough year-round. Coho salmon fry and cutthroat trout catches upstream of the floodgate did not drop off during our two June sampling events in 2011 when DO was lowest (Figure 26, panels B and D).

Adaptive management measures for DO – Low DO is present in Fisher Slough starting in late spring or early summer. This phenomenon has been suspected and confirmed over our three years of monitoring (2009 – 2011). The low DO appears to come from upstream of the restoration project area in Hill Ditch. Tidal dilution is an immediate remedy to improve DO in Fisher Slough, which can be influenced by floodgate operation such as holding the gate open, the normal operational plan for the floodgate's Summer Irrigation management period. Longer-term remedies for low DO might include riparian restoration or addressing nutrient input areas located upstream. With the dike setback restoration completed at Fisher Slough in 2012, the factors influencing DO may become more complex and include factors from within the restoration area in addition to those external.

Use and maintenance of DO logger – We conclude that data logger results help our understanding of temporal variation in DO levels (e.g., complete seasonal or daily fluctuations). However, we have some concern as to whether logger-measured DO results are accurate for the site Big Ditch Crossing due to the probe being buried by pond weed.

Water depth

Water depth exceeded the minimum threshold criteria of 0.20 meters for juvenile Chinook salmon (Beamer et al. 2005, Figure D.II.2, page 57) at all sampling occurrences. We conclude that site differences in water depth are likely not influencing juvenile Chinook salmon monitoring results between sites up- and downstream of floodgate.

Water velocity

In a study describing juvenile Chinook salmon use of tidal channel in the Skagit River delta, few juvenile Chinook salmon were captured in water velocities greater than 0.20 meters per second and essentially none were captured in velocities greater than 0.38 meters per second over a six-month sampling period (Beamer et al. 2005, Figure D.II.3, page 58). When juvenile Chinook salmon were captured in higher velocity habitat, it was later in the year when the fish were larger, suggesting the threshold relationship changes over the season, possibly related to an increased swimming ability of progressively larger fish.

Water velocity at the Fisher Slough sites during fish sampling generally did not exceed the threshold velocity criteria for juvenile Chinook salmon preference or presence at the majority of sites and dates. When preference or presence criteria were exceeded, they were generally exceeded equally in both strata. Most of the incidents of preference threshold exceedance occurred April 7, coinciding with a freshet period for tributary inflow and the Skagit River (Beamer and Henderson 2012, Appendix 2 and 3). Because velocity results compared to preference and presence thresholds were low overall in frequency and balanced between strata, we conclude that site differences in water velocity are likely not influencing juvenile Chinook salmon monitoring results between strata.

Substrate and vegetation

Site differences in substrate are not likely influencing juvenile Chinook salmon monitoring results between strata. While substrates differ between the two areas, all are fine-grained material known to be used by juvenile salmon and should affect fish capture efficiency equally at all sites.

Site differences in vegetation may influence juvenile Chinook salmon monitoring results between strata. More aquatic vegetation is present upstream of the floodgate than downstream, especially later in the season. For this report, we did not analyze whether vegetation significantly influences juvenile Chinook salmon monitoring results because there are no accepted standards for vegetation preference by juvenile Chinook salmon in estuaries. However, future monitoring could investigate whether vegetation characteristics influence juvenile Chinook salmon abundance and sampling gear efficiency.

Juvenile salmon density up- and downstream of the floodgate

It is not surprising to find multiple species of salmonids in abundance upstream of the floodgate because there are known natal populations of coho salmon and cutthroat trout in the upstream watersheds, Due to their larger size, adult salmonids returning to these watersheds more easily pass through the floodgate by swimming against the current when the doors are open. Their progeny were likely observed in our monitoring results, as well as non-natal progeny colonizing the rearing habitat available in Fisher Slough from areas downstream of the floodgate.

Future monitoring of spawners within the watersheds of Fisher Slough would help explain fluctuations in salmonid densities. For example, the large difference in coho salmon fry between years may be explained by Coho salmon spawner data from the Carpenter and Fisher Creek watersheds.

Chinook salmon

Figures 21 and 22 show Chinook salmon density was higher downstream of the floodgate than upstream of the floodgate in 2011 (year 2 after replacement), but it is not significant at the 0.05 level. In 2009 before floodgate replacement, there was statistically no difference in juvenile wild Chinook salmon density between sites upstream and downstream of the floodgates. However in 2010, there were higher densities of juvenile wild Chinook salmon downstream of the floodgate than upstream of the floodgate (Table 7). Our graphical analysis of juvenile Chinook salmon density and landscape connectivity show a disruption in the trend with all Skagit long term monitoring sites at the site of the floodgate (Figure 24). Before floodgate replacement (year 2009) the Fisher Slough monitoring sites generally clustered within the scatter of the Skagit River long term monitoring sites. In both years after floodgate replacement, most Fisher Slough sites located upstream of the floodgate fell outside (lower) of the scatter of the Skagit River long term monitoring sites. In contrast, the Fisher Slough sites located downstream of the floodgate are clustered within the scatter of the Skagit River long term monitoring sites. This graphically-displayed result using the weight of evidence from all the long-term Skagit River delta monitoring sites suggests juvenile Chinook salmon use of Fisher Slough upstream of the floodgate was disrupted from the normal pattern observed at all other Skagit sites after the floodgate was replaced.

We hypothesized that the abundance of Chinook salmon upstream of the floodgates would increase following floodgate replacement as compared with downstream densities, assuming the pre-project condition to be that fish densities upstream of the floodgates would be lower than downstream densities because the old floodgates were limiting fish passage. Our limited statistical tests and graphical trends over three years of monitoring indicate that the new floodgate may not be influencing juvenile Chinook salmon as we hypothesized. The one year of pre-project data we collected indicated the old floodgates were not limiting fish passage, and that densities were similar up- and downstream of the floodgates. There are also factors other than floodgate replacement that may be influencing results at Fisher Slough. The remainder of this discussion is devoted to other factors and limitations of our monitoring.

Other potential influences on juvenile Chinook salmon

There are some possible explanations for why juvenile Chinook salmon results at Fisher Slough did not respond in the expected direction after floodgate replacement other than the treatment effect (floodgate replacement). Six possible explanations are discussed below, although there might be others not considered here.

1-Caused by local environment

Site differences in fish density are not expected at such a small spatial scale as Fisher Slough unless there are 1) significant habitat differences between sites causing fish to avoid, or accumulate in, specific locations, or 2) there is a disruption or blockage in the ability of fish to colonize habitat. Factor 1 was accounted for in our measurements of local environment (e.g., depth, velocity, salinity, temperature, DO, substrate and vegetation). Factor 2 is the floodgate and its operation. Earlier in the discussion section of this report, we concluded that environmental variables were not likely influencing juvenile Chinook salmon monitoring results between strata in 2011. The same was concluded in 2009 (Beamer et al. 2010) and 2010 (Beamer et al. 2011). Thus, the lower density of Chinook salmon upstream of the floodgate in 2010 and the lack of an increase in 2011 may be caused by the new floodgate and/or its operation. Our analysis of environmental factors was simplistic in that we compared environmental results to known or hypothesized relationships for juvenile Chinook salmon preference, presence, or stress. This approach was implemented when data were limited. With a longer data record now available, future analyses should include environmental results as independent variables in an integrated analysis of juvenile Chinook salmon density.

2-Caused by floodgate operation

In addition to floodgate replacement, variability in its operation may be responsible for the lack of an increase in juvenile wild Chinook salmon density upstream of the floodgate after floodgate replacement. Operation of the floodgate before and after its replacement yielded similar results for upstream passage opportunity of juvenile salmon when summarized over the entire monitoring period for each year (Table 8). These results were similar despite a large difference in operation of the floodgate before its replacement in 2009 (gates manually held open for the Summer Irrigation Period), and after its replacement in 2010 and 2011 (gates were operated to accommodate habitat restoration and construction occurring upstream of the floodgate site and generally not held open). This difference of “within-year” operation between pre- and post-floodgate replacement, though not creating differences in fish passage opportunity summarized for the year, may be responsible for much of the difference in Chinook salmon density results because juvenile Chinook salmon abundance is not uniform over the monitoring period each year due to their migratory nature. Thus, within-year differences in floodgate operation may help explain fish results. We recommend future analyses integrate within-year floodgate operation results as an independent variable into the analysis of Chinook salmon density. Potential variables include those described in annual floodgate operation reports for the Fisher Slough floodgate (Beamer and Henderson 2012 & 2013). Unfortunately, we cannot test floodgate operation as an isolated factor after 2011 because fish will also respond to the dike setback treatment (completion of Project Element 3 in 2012). With completion of Project Element 3 operation of the floodgate can resume its HPA management period operational criteria, which includes holding the floodgates open starting June 1.

3-Caused by chance

Juvenile Chinook salmon density results up- and downstream of the floodgate are spurious, i.e. occurred by chance, possibly because there are only three years of data (and only one year of pre-floodgate replacement data). However, our statistical tests (Tables 6 and 7 in Beamer et al. 2011; Tables 7 and 8 in this report) and graphical trends (Figure 24) consistently show there is a low probability (<0.1%) that the relatively high densities of juvenile Chinook salmon occurring upstream of the floodgate in the first year and the lower densities upstream after restoration is due to chance fluctuations in juvenile Chinook salmon numbers.

4-Caused by an unmonitored mechanism

Juvenile Chinook salmon density results up- and downstream of the floodgate are the result of other mechanisms unrelated to Fisher Slough restoration and not indicated in any of our monitoring data. A hypothetical example would be that a pair of kingfishers set up residence upstream of the floodgate after installation, dining on Chinook salmon locally and thereby lowering their density upstream of the floodgate compared to downstream and compared to the reference sites. We generally reject this type of explanation because monitoring at Fisher Slough is comprehensive, including physical and biological components within a Skagit River delta context. However, we have recommended future analysis use a more integrated approach, including using environmental and floodgate operation results as independent variables more years of data are available. Our simplistic analysis approach for this report may not be detecting responses of variables already measured.

5-Caused by restoration construction activities

We explored whether difference among years in juvenile Chinook salmon density up- and downstream of the floodgate is due to changes related to the restoration activities but not to the installation or operation of the floodgate per se.

During the fish monitoring period in 2011, the aquatic habitats within our monitoring sites were not directly involved with construction activities occurring for Elements 2 and 3 of the Fisher Slough Restoration Project. However, heavy construction equipment was on site and indirect effects of construction might have influenced fish results in 2011. Indirect impacts may be caused by noise or earth vibrations caused by construction equipment. We were only able to evaluate whether sound exposure associated with restoration construction activities might influence the distribution and abundance of fish upstream of the floodgate beyond any influence of floodgate operation. No literature was found about vibration of heavy equipment and impacts of nearby fish. A construction activity log was provided by TNC to give a chronology of specific construction activities by location within the Fisher Slough restoration project area during the 2011 fish monitoring period (Appendix B). We distilled the construction activities log into Table 10 and added three fields: 1] nearest fish sampling site, 2] distance of construction activity to nearest fish sampling site and 3] estimated noise emission level. We then compared results in Table 10 to noise levels and from the noise source thought to adversely influence fish. Unfortunately, we found few studies on the effects of construction noise on salmon. Most of what exists are studies relating to the effects of "in-water" construction (usually pile driving) on fish physiology rather than on behavior.

Feist (1991) found that pile driving operations apparently affected the general behavior and distributions of schools of pink salmon fry in a nearshore marine environment. Nearly twice as many fish schools were found on the construction side of the site on non-pile driving days than on pile driving days. However, Hastings and Popper (2005) discounted the Feist report in their synthesis work on the effects of sound on fish as being "*opportunistic observations of free-swimming fish rather than on animals with known received sound exposures related to pile driving activity. Thus, the results are not quantitative and need to be repeated in some quantitative fashion that allows investigators to relate behavior with known sound levels, distances from sources, etc*." Ruggerone et al. (2008) conducted a study on juvenile coho salmon and their response to pile driving noise near Fisherman's Terminal in Seattle. The pile driving in the test reached a peak of 208 decibels (dB) and no adverse behavior, physiological effects, nor mortalities were found.

The Hastings and Popper (2005) synthesis document used data from an experiment on single explosion sound levels and fish mortality. From these data they suggested noise guidelines for fish based on a regression of fish size (weight) and dB level where 50% mortality of a group of fish was experienced from a single explosion. For juvenile Chinook salmon in Fisher Slough, 50% mortality coincides with single pulse explosive noise levels over 200 dB. Hastings and Popper cautioned use of their guidelines with respect to other noise mechanisms. We could not find reference to studies showing that noise transmitted through the air or ground into water influenced juvenile salmon. For lack of any other guidance on sound level and juvenile salmon effect, we consider that dB levels approaching 200 may influence fish behavior and applied that thought to observations found in Table 10.

On two occasions (April 12 and May 3/4) construction activities were approaching the 200 dB level close to two of our fish sampling sites (125 feet from Fisher Sl Inside s1 and s2). It is interesting that no juvenile Chinook salmon were caught at sites s1 and s2 on the fish sampling day following the first incident (April 22). It should be noted, however, that Chinook salmon were not caught at four of the nine monitoring sites that day, including one site located downstream of the floodgate. On the fish sampling day following the May 3/4 noisy construction event (May 7), juvenile Chinook salmon catches were low at sites s1 and s2 as well as throughout the entire monitoring area. Considering all fish (not just Chinook salmon), 14 fish (all coho salmon fry) were caught at s1 and one fish (coho salmon fry) was caught at s2 on April 22. On May 7, ten fish were caught at s1 (two Chinook salmon) and five fish were caught at s2 (one Chinook salmon). To put these catches in perspective, the average number of fish caught per beach seine set at all Fisher Slough monitoring sites in 2011 was 22.9 (95% CI ±7.3). This means that catches of 14, 10, 5 and 1 fish are below the season average, but not necessarily unusual, as 17 of the 90 beach seine sets made over the entire 2011 monitoring period did not catch any fish.

Overall fish presence rates were lower early in the monitoring period and did not coincide only with the sites Fisher Sl Inside s1 and s2 (Table 11). On May 3 and 4 and again on June 7 construction activities occurred approximately 200 feet away from Fisher Sl Inside s5. However, noise levels for these construction activities were not approaching the 200 dB level. All remaining construction activities shown in Table 10 were more distant from our fish sampling sites (700 to 2,500 feet away).

Regarding noise level and fish impact, it is not clear whether construction activities on April 12 and May 3/4 could have influenced fish in a negative way at Fisher Sl Inside s1 and s2. It is possible, but certainly not conclusive. We do not believe the distant or lower-noise-level construction activities shown in Table 9 had the potential to influence fish distribution results in Fisher Slough. This assessment of potential impacts of construction on juvenile Chinook salmon at Fisher Slough contains uncertainties/assumptions and our monitoring approach was not designed with construction effects in mind.

Table 10. Summary of construction activity at Fisher Slough area in 2011 based on Construction Activity Log (Appendix B, Table 2). Noise emission values are taken from Regan and Grant (1980).

Date	Construction activity	Equipment used	Location	Nearest fish sampling site	Distance from fish sampling site (ft)	Noise emission in dB at 50 ft from source
April 12	excavation	excavator	Smith A	s1, s2	900	170
April 12	excavation	excavator	Jungquist S bridge	s1, s2	125	170
April 12	spillway armoring	front end loader and side dumper	Smith A	s1, s2	750	31 to 96
April 22	filling and compacting	excavator, back hoe w. compactor	Smith A	s1, s2	900	170 to 372
May 3 & 4	excavation	excavator	Smith A	s1, s2	125	170
May 3 & 4	filling and hauling	front end loader and side dumper	Smith B	s5	200	31 to 96
May 24	compacting	back hoe w. compactor	Smith A	s1, s2	900	170
June 7	excavation	excavator	Smith A	s1, s2	750	170
June 7	hauling and dumping	front end loader and side dumper	Smith B	s5	200	31 to 96
June 7	road repair	grader	Smith B	s5	2500	85
June 20	hauling and dumping	front end loader and side dumper	Smith B	s5	1000	31 to 96
June 20	hauling and dumping	front end loader and side dumper	Jungquist E	s4, s5	1000	31 to 96

Table 11. Percentage of beach seine sets made with fish present in the catch by site (left) and by date (right).

Site	% of sets with fish present	Date	% of sets with fish present
Tom Moore Sl Upper Area	78%	10-Feb-11	30%
Fisher Sl Tidegate Outside S	89%	11-Mar-11	50%
Fisher Sl Inside s1	56%	25-Mar-11	70%
Fisher Sl Inside s2	67%	07-Apr-11	80%
Fisher Sl Inside s3	89%	22-Apr-11	100%
Fisher Sl Inside s4	78%	07-May-11	100%
Fisher Sl Inside s5	89%	23-May-11	100%
Fisher Sl Inside s6	89%	07-Jun-11	100%
Fisher Sl Inside s7	100%	20-Jun-11	100%

6-Caused by juvenile Chinook salmon outmigration population size

Another influence on Fisher Slough's juvenile Chinook salmon density results could be differences in overall juvenile Chinook salmon population size within the Skagit River estuary. Years with many fish in the estuary may result in higher densities in upstream habitats through density dependent pressure. As habitat fills up with fish in higher population years, more fish may colonize habitat available further upstream in channel systems such as Fisher Slough.

We do not believe that interannual differences in juvenile Chinook salmon population size in the Skagit River estuary are the cause of the lack of an increase in juvenile wild Chinook salmon density upstream of the floodgate after floodgate replacement. The year before floodgate replacement (2009) had a wild juvenile Chinook salmon outmigration population size of 2.8 million. In 2010 and 2011, the outmigration sizes were 1.6 and 3.7 million, respectively. If overall juvenile Chinook salmon population size was influencing Fisher results, then we'd expect more fish upstream of the floodgate in 2011 than in 2009 or 2010, which we did not observe (Figure 27).

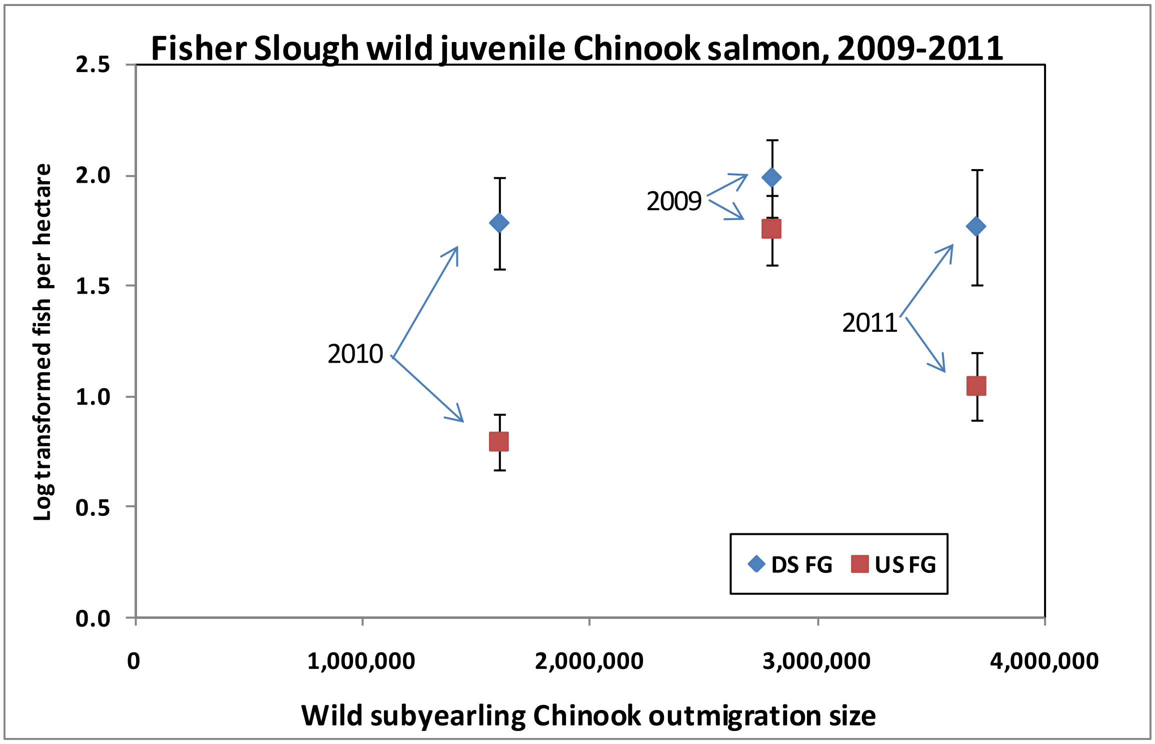


Figure 27. Relationship of wild juvenile Chinook salmon outmigration population size and average wild juvenile Chinook salmon density for combined sites upstream of the floodgate (US FG) and downstream of the floodgate (DS FG). Error bars are standard error.

Recommendations

Data collection

1. Salinity monitoring could be dropped from the scope of work, but dropping it would not reduce field monitoring cost or effort because the same instrument is used for measuring water temperature during fish sampling. Long term salinity results may be helpful at Fisher Slough because predicted sea level rise could move the location of marine water mixing progressively upstream in the Skagit River estuary, possibly reaching Fisher Slough. If this were to occur, salinity may influence fish and certainly would influence tidal vegetation.

2. Discontinue spot measurements of environment (DO, temp, and salinity) at high and low tide but continue spot measurements of environmental factors that are paired with fish sampling. Salinity is not suspected to be a factor in Fisher Slough monitoring, and is adequately documented with the spot measurements collected during fish sampling. Dissolved oxygen and temperature variability are better documented with continuously-operating loggers than with increased spot measurements, which cost more in labor and provide less data.

3. Strategies should be implemented with DO data logger deployment and maintenance to ensure loggers measure accurately.

Adaptive management

1. Dissolved oxygen – Tidal dilution is an immediate remedy to improve DO in Fisher Slough, which can be influenced by floodgate operation such as holding the gate open (the normal operational plan for the floodgate's Summer Irrigation management period). Longer-term remedies for low DO might include riparian restoration or addressing nutrient input areas located upstream.

2. Monitoring design - If future restoration occurs at Fisher Slough at a time when fish monitoring may be influenced by construction, monitoring plans should consider construction disturbance a possible impact to fish. Plans should either be designed to explicitly incorporate monitoring of variables related to construction disturbance (e.g., noise levels) or specify monitoring periods to avoid construction events.

Future analysis

Our simplistic analysis approach for this report may not be detecting responses of variables already measured. The simplistic approach is a statistical comparison of juvenile Chinook salmon densities upstream and downstream of the floodgate. We used the environmental data compared to known standards for juvenile Chinook preference or presence to determine whether environmental conditions at the site level might influence juvenile Chinook salmon densities differentially between sites upstream and downstream of the floodgate. We recommend future monitoring use all monitored independent variables hypothesized to influence juvenile Chinook salmon be used in an integrated analysis approach including variables for 1) local environment (especially temperature, DO, and vegetation), 2) floodgate operation, 3) Skagit River juvenile Chinook salmon outmigration population size, and 4) restoration treatment.

We recommend future analyses use “within year” floodgate operation results as an independent variable into the analysis of Chinook salmon density in addition to annual summaries. Potential variables include those described in annual floodgate operation reports for the Fisher Slough floodgate (e.g., Beamer and Henderson 2012 and 2013). For example, the statistic “percentage of time floodgates are open during non-ebb flow periods” may be a good indicator of upstream juvenile salmon passage opportunity at the Fisher Slough floodgates because young fry-sized salmon are not likely to migrate against ebb flows.

References

Beamer, E., and R. Henderson. 2012. Fisher Slough floodgate report for Water Year 2011. Skagit River System Cooperative, La Conner, WA. Available at www.skagitcoop.org/.

Beamer, E., and R. Henderson. 2013. Fisher Slough Floodgate Report for Water Year 2012. Skagit River System Cooperative, LaConner, WA.

Beamer, E, R. Henderson, and K. Wolf. 2010. Juvenile salmon, estuarine, and freshwater fish utilization of habitat associated with the Fisher Slough Restoration Project, Washington 2009. Unpublished report prepared for The Nature Conservancy, Washington. Available at www.skagitcoop.org/.

Beamer, E., R. Henderson, and K. Wolf. 2011. Juvenile salmon, estuarine, and freshwater fish utilization of habitat associated with the Fisher Slough restoration project in 2010. Skagit River System Cooperative, LaConner, WA. Available at www.skagitcoop.org/.

Beamer, E, A McBride, C Greene, R Henderson, G Hood, K Wolf, K Larsen, C Rice, and K Fresh. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: linking estuary restoration to wild Chinook salmon populations. Appendix to the Skagit Chinook Recovery Plan. Available at www.skagitcoop.org/.

Corkran, C, and C Thoms. 1996. Amphibians of Oregon, Washington and British Columbia. Lone Pine Publishing, Auburn, WA.

Dethier, M. N. 1990. A marine and estuarine habitat classification system for Washington State. Washington Natural Heritage Program, Washington Department of Natural Resources. Olympia WA. 56 pages.

Feist, B.E. 1991. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum *(0. keta*) salmon behavior and distribution. Master’s thesis, University of Washington, Seattle.

Fresh, KL. 2006. Juvenile Pacific Salmon in Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle.

Greene, CM, and EM Beamer. 2006. Monitoring of population responses by Skagit River Chinook salmon to estuary restoration. Northwest Fisheries Science Center, Seattle. Available at www.skagitcoop.org/.

Hastings, M, and A Popper. 2005. Effects of Sound on Fish. Final Report # CA05-0537, Project P476 Noise Thresholds for Endangered Fish. California Department of Transportation, Sacramento.

Macdonald JS, IK Birtwell, and GM Kruzynski. 1987. Food and habitat utilization by juvenile salmonids in the Campbell River estuary. Canadian Journal of Fisheries and Aquatic Science 44:1233-1246.

McCullaugh, DA. 1999. A review and synthesis of effects of alteration to the water temperature regime on freshwater life stages of salmonids, with special reference to Chinook salmon. Published as EPA 910-R-99-010. Prepared for the U.S. Environmental Protection Agency, Region 10, Seattle.

Nedeau, EJ, AK Smith, J Stone, and S Jepsen. 2009. Freshwater Mussels of the Pacific Northwest, Second Edition. The Xerces Society, Portland, OR.

Parametrix. 2010. Fisher Slough Tidal Marsh Restoration: Monitoring and Adaptive Management Plan. Prepared for The Nature Conservancy, October 2010.

Regan, J, and CA Grant. ~1980s. Highway Construction Noise – Measurement, Prediction and Mitigation. US Department of Transportation, Federal Highway Administration Special Report. Available at: http://www.fhwa.dot.gov/environment/noise/construction_noise/special_report/.

Ruggerone, G, S Goodman, and R Miner. 2008. Behavioral Response and Survival of Juvenile Coho Salmon Exposed to Pile Driving Sounds. Natural Recourses Consultants Inc., Report to the Port of Seattle.

Shannon & Wilson, Inc. 2010. Floodgate, Water Quality and Hydrology Monitoring of the Fisher Slough Restoration Project for the Water Year 2009/2010. Prepared for The Nature Conservancy, November 2010.

Skagit County Public Works. 2012. Skagit County Monitoring Program Annual Report - Water Year 2011. Skagit County Public Works, Mount Vernon, WA.

Skagit River System Cooperative and Washington Department of Fish and Wildlife. 2005. Skagit Chinook Recovery Plan. Skagit River System Cooperative, La Conner, WA. Available at www.skagitcoop.org/.

Skagit System Cooperative. 2003. Estuarine fish sampling methods. Skagit River System Cooperative, LaConner, WA. Available at www.skagitcoop.org/.

Appendix A

Appendix A Table 1. Daily average water surface salinity in parts per thousand on sampling days by timing strata at Fisher Slough in 2011.

Location / Site		Date in 2011								
		2/10	3/11	3/25	4/7	4/22	5/7	5/23	6/7	6/20
Upstream of Floodgate	Fisher Sl s1 during sampling	0.06	0.05	0.04	0.05	12.71	0.06	0.01	0.06	0.08
	Fisher Sl s1 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.08	0.07	0.08
	Fisher Sl s1 at low tide sampling	0.06	0.05	0.04	0.05	0.06	0.05	0.08	0.08	0.09
	Fisher Sl s2 during sampling	0.06	0.05	0.06	0.05	12.49	0.05	0.07	0.08	0.08
	Fisher Sl s2 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.08	0.08
	Fisher Sl s2 at low tide sampling	0.06	0.05	0.07	0.05	0.06	0.05	0.07	0.08	0.09
	Fisher Sl s3 during sampling	0.03	0.05	0.06	0.05	4.06	0.05	0.07	0.07	0.09
	Fisher Sl s3 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.07	0.09
	Fisher Sl s3 at low tide sampling	0.06	0.05	0.07	0.05	0.06	0.05	0.07	0.08	0.09
	Fisher Sl s4 during sampling	0.05	0.05	0.06	0.05	0.06	0.05	0.07	0.08	0.09
	Fisher Sl s4 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s4 at low tide sampling	0.06	0.05	0.07	0.05	0.06	0.05	0.07	0.08	0.09
	Fisher Sl s5 during sampling	0.07	0.06	0.07	0.05	0.06	0.05	0.07	0.08	0.07
	Fisher Sl s5 at high tide sampling	0.06	0.06	0.05	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s5 at low tide sampling	0.07	0.06	0.07	0.05	0.06	0.05	0.07	0.08	0.09
	Fisher Sl s6 during sampling	0.06	0.06	0.06	0.03	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s6 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s6 at low tide sampling	0.06	0.06	0.06	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s7 during sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s7 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s7 at low tide sampling	0.06	0.05	0.06	0.05	0.07	0.05	0.07	0.08	0.09
Downstream of Floodgate	Fisher Sl Tidegate Outside S during sampling	0.06	0.05	0.05	0.05	0.07	0.05	0.07	0.05	0.08
	Fisher Sl Tidegate Outside S at high tide sampling	0.06	0.05	0.05	0.05	0.06	0.06	0.07	0.06	0.08
	Fisher Sl Tidegate Outside S at low tide sampling	0.06	0.05	0.07	0.05	0.06	0.05	0.07	0.07	0.09
	Tom Moore Sl Upper Area during sampling	0.03	0.03	0.03	0.04	na	0.03	0.02	0.02	0.02
	Tom Moore Sl Upper Area at high tide sampling	na	0.03	0.04	0.04	na	0.03	0.02	0.02	na
	Tom Moore Sl Upper Area at low tide sampling	0.03	0.03	na	0.04	0.04	0.03	0.02	0.02	0.02
	Fisher Sl Blind Ch during sampling	0.06	0.06	0.04	0.04	7.42	0.06	0.07	0.03	0.08
	Fisher Sl Blind Ch at high tide sampling	0.06	0.06	0.04	0.05	0.05	0.06	0.07	0.02	0.08
	Fisher Sl Blind Ch at low tide sampling	0.05	0.05	0.06	na	0.09	0.05	0.05	0.02	0.09

Appendix A Table 2. Daily average water bottom salinity in parts per thousand on sampling days by timing strata at Fisher Slough in 2011.

Location / Site		Date in 2011								
		2/10	3/11	3/25	4/7	4/22	5/7	5/23	6/7	6/20
Upstream of Floodgate	Fisher Sl s1 during sampling	0.06	0.05	0.06	0.05	na	0.06	0.08	0.06	0.08
	Fisher Sl s1 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.09	0.07	0.08
	Fisher Sl s1 at low tide sampling	0.06	0.05	na	0.05	0.06	na	na	0.07	0.09
	Fisher Sl s2 during sampling	0.06	0.05	0.06	0.05	na	0.05	0.07	0.07	0.08
	Fisher Sl s2 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.07	0.08
	Fisher Sl s2 at low tide sampling	0.06	0.05	na	0.05	0.06	na	na	0.08	0.09
	Fisher Sl s3 during sampling	0.06	0.05	0.06	0.05	0.06	0.05	0.07	0.07	0.09
	Fisher Sl s3 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.07	0.09
	Fisher Sl s3 at low tide sampling	0.06	0.05	na	0.05	na	na	0.07	0.08	na
	Fisher Sl s4 during sampling	0.06	0.05	0.06	0.05	0.06	0.05	0.07	0.08	0.09
	Fisher Sl s4 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	na	0.08	0.09
	Fisher Sl s4 at low tide sampling	na	na	na	0.05	na	na	na	0.08	0.09
	Fisher Sl s5 during sampling	0.07	0.06	0.07	0.05	0.06	0.05	0.07	0.07	0.07
	Fisher Sl s5 at high tide sampling	0.06	0.06	0.05	0.05	0.06	0.06	0.07	0.07	0.09
	Fisher Sl s5 at low tide sampling	0.07	0.06	na	0.05	0.06	0.05	0.07	0.08	0.09
	Fisher Sl s6 during sampling	0.06	0.06	0.06	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s6 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s6 at low tide sampling	na	na	na	0.05	na	na	na	0.08	na
	Fisher Sl s7 during sampling	0.06	0.05	0.06	0.05	0.06	0.06	0.07	0.08	0.09
	Fisher Sl s7 at high tide sampling	0.06	0.05	0.06	0.05	0.06	0.06	na	0.08	0.09
	Fisher Sl s7 at low tide sampling	na	na	na	0.05	na	na	na	0.08	na
Downstream of Floodgate	Fisher Sl Tidegate Outside S during sampling	0.06	0.05	0.04	0.05	na	0.05	0.07	0.04	0.08
	Fisher Sl Tidegate Outside S at high tide sampling	0.06	0.05	0.05	na	0.06	0.06	na	0.06	0.08
	Fisher Sl Tidegate Outside S at low tide sampling	na	0.05	na	0.05	na	na	na	0.07	0.09
	Tom Moore Sl Upper Area during sampling	0.03	0.03	0.03	0.04	na	0.03	0.02	0.02	0.02
	Tom Moore Sl Upper Area at high tide sampling	na	0.05	0.04	0.04	na	0.03	0.02	0.02	na
	Tom Moore Sl Upper Area at low tide sampling	na	na	na	0.04	0.04	na	na	na	0.02
	Fisher Sl Blind Ch during sampling	0.06	0.06	0.04	0.05	0.05	0.06	0.07	0.02	0.08
	Fisher Sl Blind Ch at high tide sampling	0.06	0.06	0.04	0.05	0.05	0.06	na	0.02	0.08
	Fisher Sl Blind Ch at low tide sampling	na	na	na	na	na	na	na	0.02	0.09

Appendix A Table 3. Daily average water surface temperature in degrees Celsius on sampling days by timing strata at Fisher Slough in 2011. Numbers in bold are postulated as stressful to juvenile Chinook salmon in estuaries (>15°C).

Location / Site		Date in 2011								
		2/10	3/11	3/25	4/7	4/22	5/7	5/23	6/7	6/20
Upstream of Floodgate	Fisher Sl s1 during sampling	2.90	6.25	8.00	7.00	na	9.50	12.60	**15.70**	13.05
	Fisher Sl s1 at high tide sampling	3.10	6.20	8.00	6.50	8.20	9.50	11.50	**16.40**	13.70
	Fisher Sl s1 at low tide sampling	4.20	6.80	10.25	8.10	11.35	9.90	13.25	**16.75**	**15.40**
	Fisher Sl s2 during sampling	3.00	6.10	8.10	6.50	na	9.30	11.25	**16.95**	13.80
	Fisher Sl s2 at high tide sampling	3.00	6.10	8.10	6.40	8.15	9.20	11.20	**16.80**	13.75
	Fisher Sl s2 at low tide sampling	4.00	6.70	9.70	7.40	10.25	9.70	13.10	**16.80**	**16.25**
	Fisher Sl s3 during sampling	3.10	6.10	7.90	6.55	8.00	9.20	11.30	**16.00**	14.20
	Fisher Sl s3 at high tide sampling	3.00	6.10	7.90	6.40	8.00	9.20	11.20	**16.20**	14.05
	Fisher Sl s3 at low tide sampling	4.15	6.70	9.60	7.45	10.05	9.80	13.10	**15.65**	**15.00**
	Fisher Sl s4 during sampling	2.90	6.20	7.80	6.45	8.00	9.20	11.20	**15.90**	14.27
	Fisher Sl s4 at high tide sampling	2.90	6.10	7.90	6.40	8.00	9.20	11.30	**15.80**	14.10
	Fisher Sl s4 at low tide sampling	3.95	6.70	9.55	7.40	9.80	9.80	13.30	**15.80**	14.90
	Fisher Sl s5 during sampling	3.20	6.20	8.00	6.50	7.90	9.20	11.30	14.55	13.30
	Fisher Sl s5 at high tide sampling	3.00	6.20	7.30	6.50	7.80	9.20	11.20	**15.50**	13.80
	Fisher Sl s5 at low tide sampling	4.00	6.70	9.50	7.40	9.60	9.80	13.10	**15.70**	14.70
	Fisher Sl s6 during sampling	3.70	6.53	8.30	7.55	9.55	10.20	13.20	**17.20**	**15.70**
	Fisher Sl s6 at high tide sampling	3.45	6.50	8.10	7.25	8.50	10.00	12.80	**17.20**	14.90
	Fisher Sl s6 at low tide sampling	5.40	7.40	11.25	9.10	**17.25**	10.70	**17.20**	**17.05**	**16.80**
	Fisher Sl s7 during sampling	3.30	6.30	8.20	7.10	8.55	9.55	12.80	**16.80**	**15.35**
	Fisher Sl s7 at high tide sampling	3.05	6.20	8.00	6.60	8.20	9.35	11.50	**16.90**	14.55
	Fisher Sl s7 at low tide sampling	4.40	7.20	11.20	8.20	14.75	9.97	14.55	**17.20**	**16.45**
Downstream of Floodgate	Fisher Sl Tidegate Outside S during sampling	3.00	6.10	7.40	6.60	8.20	9.30	11.20	14.65	13.55
	Fisher Sl Tidegate Outside S at high tide sampling	3.00	6.10	7.30	6.40	8.20	9.30	11.30	14.10	13.70
	Fisher Sl Tidegate Outside S at low tide sampling	3.90	6.70	9.60	7.40	10.80	9.70	12.95	**16.10**	**15.35**
	Tom Moore Sl Upper Area during sampling	4.50	4.80	6.60	5.85	na	7.90	8.80	10.30	9.35
	Tom Moore Sl Upper Area at high tide sampling	na	5.50	6.80	6.20	na	8.40	8.35	10.50	na
	Tom Moore Sl Upper Area at low tide sampling	4.55	5.40	na	6.95	10.55	8.60	10.25	10.55	10.15
	Fisher Sl Blind Ch during sampling	3.10	6.20	6.60	6.50	7.80	9.30	11.15	11.55	13.65
	Fisher Sl Blind Ch at high tide sampling	3.10	6.20	6.60	6.50	7.80	9.30	11.20	10.70	13.65
	Fisher Sl Blind Ch at low tide sampling	3.65	7.00	9.90	na	15.10	10.00	12.80	10.50	**15.25**

Appendix A Table 4. Daily average water bottom temperature in degrees Celsius on sampling days by timing strata at Fisher Slough in 2010. Numbers in bold are postulated as stressful to juvenile Chinook salmon in estuaries (>15°C).

Location / Site		Date in 2011								
		2/10	3/11	3/25	4/7	4/22	5/7	5/23	6/7	6/20
Upstream of Floodgate	Fisher Sl s1 during sampling	3.00	6.20	8.10	7.00	na	9.50	11.50	**15.00**	13.20
	Fisher Sl s1 at high tide sampling	3.10	6.20	8.00	6.50	8.10	9.50	11.50	**15.80**	13.60
	Fisher Sl s1 at low tide sampling	4.20	6.80	na	8.10	10.60	na	na	**16.30**	**15.00**
	Fisher Sl s2 during sampling	3.00	6.10	8.10	6.50	na	9.30	11.20	**16.35**	13.80
	Fisher Sl s2 at high tide sampling	3.00	6.10	8.00	6.40	8.10	9.20	11.20	**16.18**	13.60
	Fisher Sl s2 at low tide sampling	4.00	6.70	na	7.40	10.30	na	na	**16.55**	14.95
	Fisher Sl s3 during sampling	3.00	6.10	7.90	6.50	8.00	9.20	11.25	**15.90**	14.20
	Fisher Sl s3 at high tide sampling	3.00	6.10	7.90	6.40	8.00	9.20	11.20	**15.65**	14.00
	Fisher Sl s3 at low tide sampling	4.20	6.70	na	7.40	na	na	13.10	**15.50**	na
	Fisher Sl s4 during sampling	3.00	6.20	7.55	6.45	8.00	9.25	11.20	**15.60**	14.10
	Fisher Sl s4 at high tide sampling	2.90	6.15	7.90	6.40	8.00	9.20	na	**15.70**	14.00
	Fisher Sl s4 at low tide sampling	na	na	na	7.40	na	na	na	**15.60**	14.90
	Fisher Sl s5 during sampling	3.10	6.25	8.00	6.50	7.90	9.20	11.30	14.10	13.00
	Fisher Sl s5 at high tide sampling	3.00	6.20	7.30	6.45	7.80	9.20	11.20	14.80	13.70
	Fisher Sl s5 at low tide sampling	4.00	6.70	na	7.40	9.60	9.80	13.05	**15.70**	14.70
	Fisher Sl s6 during sampling	3.70	6.55	8.20	7.30	8.75	10.20	12.80	**16.90**	**15.10**
	Fisher Sl s6 at high tide sampling	3.45	6.50	8.10	7.25	8.40	9.80	12.80	**17.15**	14.80
	Fisher Sl s6 at low tide sampling	na	na	na	9.00	na	na	na	**16.70**	na
	Fisher Sl s7 during sampling	3.15	6.30	8.10	6.95	8.55	9.50	11.80	**16.80**	**15.35**
	Fisher Sl s7 at high tide sampling	3.10	6.20	7.90	6.75	8.20	9.40	na	**16.80**	14.30
	Fisher Sl s7 at low tide sampling	na	na	na	8.05	na	na	na	**16.90**	na
Downstream of Floodgate	Fisher Sl Tidegate Outside S during sampling	3.00	6.10	7.00	6.50	na	9.30	11.20	13.35	13.05
	Fisher Sl Tidegate Outside S at high tide sampling	3.00	6.10	7.25	na	8.20	9.30	na	**15.05**	13.65
	Fisher Sl Tidegate Outside S at low tide sampling	na	6.70	na	7.40	na	na	na	**16.10**	**15.25**
	Tom Moore Sl Upper Area during sampling	4.50	4.80	6.60	5.80	na	7.90	8.80	10.30	9.30
	Tom Moore Sl Upper Area at high tide sampling	na	5.50	6.80	6.10	na	8.40	8.20	10.20	na
	Tom Moore Sl Upper Area at low tide sampling	na	na	na	6.75	10.60	na	na	na	9.90
	Fisher Sl Blind Ch during sampling	3.10	6.20	6.60	6.50	7.80	9.30	11.20	10.80	13.60
	Fisher Sl Blind Ch at high tide sampling	3.10	6.20	6.60	6.50	7.80	9.30	na	10.60	13.60
	Fisher Sl Blind Ch at low tide sampling	na	na	na	na	na	na	na	10.50	14.75

Appendix A Table 5. GLM results for surface temperature in 2011.

Source	Type III sum of squares	Degrees of freedom	Mean squares	F-ratio	p-value
Factor 1: Strata (up or downstream of floodgate)	24.206	1	24.206	32.792	0.000
Factor 2: Sample date	830.782	8	103.848	140.683	0.000
Interaction between factors	27.29	8	3.411	4.621	0.000
Error	53.886	73	0.738		

Appendix A Table 6. Scheffé Test for surface temperature by strata in 2011.

STRATA(i)	STRATA(j)	Difference	p-Value
Downstream of floodgate	Upstream of floodgate	-1.121	0.000

Appendix A Table 7. Scheffé Test for surface temperature by sampling dates in 2011.

SAMPLEDATE(i)	SAMPLEDATE(j)	Difference	p-Value
2/9/2011	3/10/2011	-2.626	0.000
2/9/2011	3/24/2011	-4.251	0.000
2/9/2011	4/6/2011	-3.277	0.000
2/9/2011	4/21/2011	-4.805	0.000
2/9/2011	5/6/2011	-5.868	0.000
2/9/2011	5/22/2011	-7.818	0.000
2/9/2011	6/6/2011	-10.842	0.000
2/9/2011	6/19/2011	-9.865	0.000
3/10/2011	3/24/2011	-1.625	0.051
3/10/2011	4/6/2011	-0.651	0.963
3/10/2011	4/21/2011	-2.179	0.002
3/10/2011	5/6/2011	-3.242	0.000
3/10/2011	5/22/2011	-5.192	0.000
3/10/2011	6/6/2011	-8.215	0.000
3/10/2011	6/19/2011	-7.239	0.000
3/24/2011	4/6/2011	0.974	0.657
3/24/2011	4/21/2011	-0.554	0.982
3/24/2011	5/6/2011	-1.617	0.054
3/24/2011	5/22/2011	-3.567	0.000
3/24/2011	6/6/2011	-6.59	0.000
3/24/2011	6/19/2011	-5.614	0.000
4/6/2011	4/21/2011	-1.527	0.123
4/6/2011	5/6/2011	-2.59	0.000
4/6/2011	5/22/2011	-4.54	0.000
4/6/2011	6/6/2011	-7.564	0.000
4/6/2011	6/19/2011	-6.588	0.000
4/21/2011	5/6/2011	-1.063	0.601
4/21/2011	5/22/2011	-3.013	0.000
4/21/2011	6/6/2011	-6.037	0.000
4/21/2011	6/19/2011	-5.061	0.000
5/6/2011	5/22/2011	-1.95	0.012
5/6/2011	6/6/2011	-4.974	0.000
5/6/2011	6/19/2011	-3.998	0.000
5/22/2011	6/6/2011	-3.024	0.000
5/22/2011	6/19/2011	-2.048	0.006
6/6/2011	6/19/2011	0.976	0.710

Appendix A Table 8. Daily average water surface dissolved oxygen in mg/L on sampling days by timing strata at Fisher Slough in 2011. Bold values are less than Washington State's standard for DO in freshwater bodies with salmonid rearing and migration.

Location / Site		Date in 2011								
		2/10	3/11	3/25	4/7	4/22	5/7	5/23	6/7	6/20
Upstream of Floodgate	Fisher Sl s1 during sampling	12.43	11.05	10.50	11.72	8.48	9.13	10.91	7.29	7.40
	Fisher Sl s1 at high tide sampling	12.80	10.82	10.46	11.39	10.61	10.44	8.75	6.80	7.41
	Fisher Sl s1 at low tide sampling	11.44	13.06	12.33	11.26	12.13	10.73	10.39	6.57	7.27
	Fisher Sl s2 during sampling	12.68	11.36	10.66	11.32	8.14	9.77	9.89	6.88	7.03
	Fisher Sl s2 at high tide sampling	12.86	11.00	10.39	11.40	10.75	11.20	9.70	7.03	7.32
	Fisher Sl s2 at low tide sampling	11.52	13.18	12.28	11.52	11.25	11.05	11.06	6.97	7.57
	Fisher Sl s3 during sampling	12.67	11.33	10.67	11.57	10.03	9.81	10.21	6.77	6.73
	Fisher Sl s3 at high tide sampling	12.96	11.04	10.62	11.54	10.90	11.22	9.78	6.71	7.10
	Fisher Sl s3 at low tide sampling	11.44	13.17	12.31	11.56	11.18	10.99	11.04	7.69	9.30
	Fisher Sl s4 during sampling	12.99	11.36	10.92	11.54	11.05	10.62	10.22	6.74	7.27
	Fisher Sl s4 at high tide sampling	13.23	11.15	10.79	11.40	10.97	11.27	9.95	7.07	7.34
	Fisher Sl s4 at low tide sampling	11.58	13.14	12.31	11.50	11.07	11.01	11.20	7.84	8.90
	Fisher Sl s5 during sampling	12.33	11.15	10.54	11.25	11.24	11.18	10.26	7.91	9.29
	Fisher Sl s5 at high tide sampling	13.03	10.86	11.55	11.06	11.18	11.30	9.71	7.30	7.66
	Fisher Sl s5 at low tide sampling	11.52	13.08	12.24	11.47	11.31	11.00	10.66	8.05	8.94
	Fisher Sl s6 during sampling	11.04	10.38	9.81	10.14	9.59	9.08	9.19	7.69	**4.57**
	Fisher Sl s6 at high tide sampling	11.42	10.19	9.96	10.15	10.56	9.97	7.65	7.85	**4.36**
	Fisher Sl s6 at low tide sampling	9.16	12.31	13.53	11.29	14.37	11.84	8.46	7.07	**6.19**
	Fisher Sl s7 during sampling	12.38	11.08	10.81	11.10	11.36	10.60	9.32	**6.39**	**5.73**
	Fisher Sl s7 at high tide sampling	12.42	10.74	10.61	11.26	10.92	10.89	9.94	6.56	**5.33**
	Fisher Sl s7 at low tide sampling	10.52	12.69	12.84	11.58	13.39	11.15	11.07	7.80	7.39
Downstream of Floodgate	Fisher Sl Tidegate Outside S during sampling	12.35	11.12	10.85	11.39	11.74	9.83	9.78	8.16	7.20
	Fisher Sl Tidegate Outside S at high tide sampling	12.90	10.98	11.12	11.37	10.58	10.99	9.38	8.25	7.44
	Fisher Sl Tidegate Outside S at low tide sampling	11.51	13.15	12.35	11.76	11.19	10.99	10.73	7.24	7.66
	Tom Moore Sl Upper Area during sampling	13.60	12.13	12.18	12.33	na	12.22	12.11	10.97	12.39
	Tom Moore Sl Upper Area at high tide sampling	na	11.93	11.66	12.21	na	10.78	12.50	11.25	na
	Tom Moore Sl Upper Area at low tide sampling	12.32	14.34	na	12.49	11.41	11.90	12.17	11.20	12.02
	Fisher Sl Blind Ch during sampling	12.90	10.95	11.73	11.42	8.80	11.24	9.55	10.18	7.46
	Fisher Sl Blind Ch at high tide sampling	12.90	10.95	11.73	11.39	11.05	11.24	9.27	10.21	7.46
	Fisher Sl Blind Ch at low tide sampling	10.38	12.50	11.39	na	9.74	10.52	11.15	11.30	7.61

Appendix A Table 9. Daily average water bottom dissolved oxygen in mg/L on sampling days by timing strata at Fisher Slough in 2011. Bold values are less than Washington State's standard for DO in freshwater bodies with salmonid rearing and migration.

Location / Site		Date in 2011								
		2/10	3/11	3/25	4/7	4/22	5/7	5/23	6/7	6/20
Upstream of Floodgate	Fisher Sl s1 during sampling	12.07	10.96	10.14	11.29	na	9.15	9.85	7.21	7.25
	Fisher Sl s1 at high tide sampling	12.74	10.82	10.54	11.26	10.71	10.40	8.81	7.07	7.34
	Fisher Sl s1 at low tide sampling	11.34	13.06	na	11.15	11.96	na	na	6.98	7.02
	Fisher Sl s2 during sampling	12.45	11.18	10.51	11.29	na	9.71	9.81	7.09	6.97
	Fisher Sl s2 at high tide sampling	12.82	11.00	10.47	10.94	10.75	11.09	9.68	7.23	7.43
	Fisher Sl s2 at low tide sampling	11.52	13.17	na	11.50	11.27	na	na	6.80	8.22
	Fisher Sl s3 during sampling	12.47	11.12	10.59	11.37	11.05	9.68	10.03	6.53	6.56
	Fisher Sl s3 at high tide sampling	12.92	11.02	10.58	11.41	10.87	11.11	9.75	**6.47**	6.77
	Fisher Sl s3 at low tide sampling	11.37	13.12	na	11.49	na	na	11.02	7.63	na
	Fisher Sl s4 during sampling	12.62	11.17	11.05	11.25	11.05	10.75	10.05	**6.22**	6.77
	Fisher Sl s4 at high tide sampling	13.20	11.09	10.82	11.44	10.98	11.13	na	**6.02**	6.81
	Fisher Sl s4 at low tide sampling	na	na	na	11.44	na	na	na	7.93	8.76
	Fisher Sl s5 during sampling	12.28	10.98	10.31	11.23	11.15	10.83	10.01	8.27	9.15
	Fisher Sl s5 at high tide sampling	12.94	10.85	11.52	11.22	11.13	11.20	9.69	7.94	7.63
	Fisher Sl s5 at low tide sampling	11.48	13.06	na	11.39	11.20	10.98	10.63	8.05	8.88
	Fisher Sl s6 during sampling	10.58	10.09	9.66	9.88	10.79	8.94	7.74	**5.74**	**4.23**
	Fisher Sl s6 at high tide sampling	11.08	10.03	9.87	10.28	10.61	9.96	7.70	7.15	**3.77**
	Fisher Sl s6 at low tide sampling	na	na	na	11.88	na	na	na	**6.39**	na
	Fisher Sl s7 during sampling	12.09	10.83	10.57	11.16	11.64	10.38	10.00	**6.20**	**5.46**
	Fisher Sl s7 at high tide sampling	12.48	10.75	10.66	11.25	10.91	10.68	na	**6.37**	**5.37**
	Fisher Sl s7 at low tide sampling	na	na	na	11.39	na	na	na	6.80	na
Downstream of Floodgate	Fisher Sl Tidegate Outside S during sampling	12.27	11.15	11.21	11.21	na	9.81	9.54	8.88	7.49
	Fisher Sl Tidegate Outside S at high tide sampling	12.85	10.94	11.12	na	10.57	10.80	na	7.80	7.42
	Fisher Sl Tidegate Outside S at low tide sampling	na	13.15	na	11.57	na	na	na	7.22	7.59
	Tom Moore Sl Upper Area during sampling	13.29	12.07	12.05	12.20	na	12.14	12.09	10.84	12.21
	Tom Moore Sl Upper Area at high tide sampling	na	11.16	11.48	12.15	na	10.77	12.24	11.07	na
	Tom Moore Sl Upper Area at low tide sampling	na	na	na	12.21	11.35	na	na	na	11.98
	Fisher Sl Blind Ch during sampling	12.84	10.58	11.73	11.22	10.99	11.03	9.36	10.63	7.45
	Fisher Sl Blind Ch at high tide sampling	12.84	10.58	11.73	11.40	10.99	11.03	na	10.22	7.45
	Fisher Sl Blind Ch at low tide sampling	na	na	na	na	na	na	na	11.25	7.91

Appendix A Table 10. ANOVA results for surface DO in 2011.

Source	Type III sum of squares	Degrees of freedom	Mean squares	F-ratio	p-value
Factor 1: Strata (up or downstream of floodgate)	25.099	1	25.099	30.080	0.000
Factor 2: Sample date	167.468	8	20.934	25.087	0.000
Interaction between factors	12.671	8	1.584	1.898	0.074
Error	59.244	71	0.834		

Appendix A Table 11. Scheffé Test for surface DO by strata in 2011.

STRATA(i)	STRATA(j)	Difference	p-Value
Downstream of floodgate	Upstream of floodgate	1.148	0.000

Appendix A Table 12. Scheffé Test for surface DO by sampling dates in 2011.

SAMPLEDATE(i)	SAMPLEDATE(j)	Difference	p-Value
2/9/2011	3/10/2011	1.394	0.299
2/9/2011	3/24/2011	1.57	0.125
2/9/2011	4/6/2011	1.099	0.639
2/9/2011	4/21/2011	0.847	0.886
2/9/2011	5/6/2011	2.093	0.010
2/9/2011	5/22/2011	2.405	0.001
2/9/2011	6/6/2011	4.223	0.000
2/9/2011	6/19/2011	4.919	0.000
3/10/2011	3/24/2011	0.176	1.000
3/10/2011	4/6/2011	-0.295	1.000
3/10/2011	4/21/2011	-0.547	0.992
3/10/2011	5/6/2011	0.699	0.961
3/10/2011	5/22/2011	1.011	0.738
3/10/2011	6/6/2011	2.829	0.000
3/10/2011	6/19/2011	3.525	0.000
3/24/2011	4/6/2011	-0.471	0.996
3/24/2011	4/21/2011	-0.724	0.942
3/24/2011	5/6/2011	0.523	0.993
3/24/2011	5/22/2011	0.835	0.875
3/24/2011	6/6/2011	2.653	0.000
3/24/2011	6/19/2011	3.349	0.000
4/6/2011	4/21/2011	-0.252	1.000
4/6/2011	5/6/2011	0.994	0.757
4/6/2011	5/22/2011	1.306	0.391
4/6/2011	6/6/2011	3.124	0.000
4/6/2011	6/19/2011	3.82	0.000
4/21/2011	5/6/2011	1.246	0.461
4/21/2011	5/22/2011	1.559	0.163
4/21/2011	6/6/2011	3.376	0.000
4/21/2011	6/19/2011	4.072	0.000
5/6/2011	5/22/2011	0.312	1.000
5/6/2011	6/6/2011	2.13	0.008
5/6/2011	6/19/2011	2.826	0.000
5/22/2011	6/6/2011	1.818	0.049
5/22/2011	6/19/2011	2.514	0.001
6/6/2011	6/19/2011	0.696	0.965

Appendix B

Appendix B Table 1. Fisher Slough floodgate operations log, WY 2011.

Date	Time	Name of person completing work	Change to float setting	Period
10/1/2010			Float disengaged since August 16 to prevent water from entering construction area – preparing for siphon construction	Fall/Winter flood control
10/13/2010		Dave Olson, Kris Knight	Float re-engaged after in-water construction completed and floodgates set to close at 7.5 ft NAVD88, per floodgate operation schedule and HPA permit (floodgates were to be back operating by Oct 15). Checked setting on 10/14/10 at high tide at Noon - water elevation upstream of gates between 7.4 and 7.5 NAVD88.	
12/11/2010	morning	Dave Olson, Darrin Morrison	Float hoisted up for flood protection with forecast of flooding on Skagit - Skagit was above flood stage 12/13/10 at nearly 30 ft.	
1/10/2011	14:30	Dave Olson, Darrin Morrison	Float re-engaged after being raised because of flood threat when river rose above 28 ft. Setting remains where gates will close at or near 7.5 ft NAVD88	
3/1/2011	15:30	Dave Olson and Kris Knight	Changed floodgate setting for Spring Chinook Migration Operational Setting so gates close at ~9.5 ft NAVD88.	Spring juvenile Chinook migration
3/2/2011	20:30	Kris Knight	Lowered gate setting since the setting appeared to be too high when gates were observed propped open by arms at a water elevation at 10.5 the afternoon of 3/2/11	
3/5/2011	05:15	Kris Knight	Lowered gate setting since gates were still open at a 10.4 high tide. North gate much farther open than middle and south gates which where held open by arms	
3/7/2011	06:15	Kris Knight	Lowered gate setting again because gates still open at 10.4 high tide. After adjustment south and middle gates 0.5 degrees open but north gate still 50 degrees open	
3/8/2011	06:30	Kris Knight	Lowered gate setting 5 turns because south and middle gates were closed at upstream elevation of 9.8 ft NAVD88 (but north gate was still held open slightly - measuring 1.8 degrees open)	
3/18/2011	15:30	Kris Knight	Lowered gate setting since it still appears they are not closing soon enough	
3/29/2011	15:45	Kris Knight	Lowered gate setting since it still appeared gates were not closing soon enough	
5/16/2011	12:25	Kris Knight	Raised gate setting 4 turns after recently observing gates closing at water surface elevation upstream of gates at approximately 9.1 - 9.5 ft NAVD88	
6/27/2011	Between 13:00 and 15:00	Dave Olson	Float/gates were disengaged due to construction activities. They began taking down south levee and a 22 ft river was forecasted at Mt. Vernon. Per our agreement with WDFW, we were allowed to disengage gates in this situation.	Summer irrigation
9/30/2011			Float remained disengaged due to construction related activities	

Appendix B Table 2. Fisher construction activity log (provided by The Nature Conservancy). Note: the text in black indicates activities on fish sampling days. Text in blue indicates activities on non-fish sampling days.

Fish Sampling day	Non-fish Sampling day	Location of Activity	Construction Activity Report Notes for fish sampling date
10-Feb-11			no construction activity report
11-Mar-11			no construction activity report
25-Mar-11			no construction activity report
7-Apr-11			no construction activity report
	12-Apr-11		April 12, 2011 - (first Construction Activity Report in 2011) Bridge footing subgrade test pit was excavated at Smith A bridge. Two additional test pits were excavated for proposed Jungquist South bridge. Importing of spillway embankment rock material using side-dump trucks.
22-Apr-11		Jungquist S. Bridge, West Footing Subgrade Installation	I visited the site to observe the installation of the footing subgrade for the west abutment of the Smith A Bridge. The over-excavation was backfilled with 1-1/4” minus crushed rock with a Deere 135 excavator (Figure 1). The fill was then compacted with an excavator mounted hoepack vibrating compactor (Figure 2). The surface was trimmed and leveled and compacted with a WP1550 compactor to a depth of 6” (Figure 3). I probed the compacted fill with a ½-inch-diameter steel Tbar. The probe generally had less than 3 inches of penetration, and appeared to be properly compacted.
	May 3 and 4, 2011		May 3 & 4, 2011 - Foundation Subgrade preparation, inverted siphon sediment basin. Stockpiling of excavation spoils near the existing Big Ditch concrete culvert.
7-May-11			no construction activity report
23-May-11			no construction activity report
	24-May-11	West footing foundation subgrade preparation of Smith A bridge	ICI informed me that geotextile fabric (10 feet x 11.5 feet) was placed on the over-excavated subgrade and 2 feet of 1¼ inch minus crushed rock was placed over the fabric in the area shown in Photo 1. In the area where there was not over-excavation or geotextile fabric, ICI placed 0.5 feet of 1¼ inch minus crushed rock. At the time of my arrival, ICI was compacting the crushed rock with an excavator mounted hoepack. I evaluated the compacted rock using a ½-inch steel T-bar probe and observed penetrations of approximately 1inch, indicating that the material had been compacted to a dense and unyielding condition.

Fish Sampling day	Non-fish Sampling day	Location of Activity	Construction Activity Report Notes for fish sampling date
7-Jun-11		Big Ditch excavation in Smith A, Smith B access road repair, guardrail installation Smith A Bridge, Asphalt debris off-site hauling Smith A	ICI continued to excavate the proposed Big Ditch Realignment spillway along the top rock toe line at elevation 0 feet. After the spillway excavation was completed, ICI continued to excavate the Big Ditch realignment southward, and stopped north of the Smith A Bridge. The excavation spoils were being hauled to the east end of Smith A near the existing concrete box culvert, and stockpiled for future levee fill placement. ICI also repaired a portion (about 100 feet long) of Smith B access road near the southwest corner of Smith B. The road subgrade began pumping and settling under the heavy truck load. ICI removed the pumping subgrade and placed about 10 inches of 8” minus quarry spall. Per the trucking tickets, a total of 59.12 tons (three truck loads) of 8” minus rock was hauled in and used. ICI was hauling and stockpiling spillway bedding material (4” minus rock). The material was being imported from Martin Marietta Materials. After the spillway rock was unloaded, the trucks were then hauling offsite the asphalt debris that was encountered during Big Ditch excavation at Smith A Bridge.
20-Jun-11		Levee fill placement, south levee setback, Smith B	ICI continued to haul and place the imported levee fill (Conway Pit material) on the south levee setback in Smith B. A total of 3,616 tons (approximately 1,954 cubic yards) of the material was imported today. The hauling started at 7 am and stopped at 5 pm. There were 8 trucks that were transporting the fill material. As of today, a total of 32,654 tons (approximately 17,651 cubic yards) of Conway Pit material has been imported. The levee fill was placed between Stations 44+00 and 49+00 from approximate elevation 10.5’ to 12’. The fill was placed in about 6-inch lifts and compacted with a 10-ton vibrating roller. A representative from GeoTest visited the site this morning and performed in place density tests on the fill that was previously placed on 6/16/2011 and 6/17/11. The test results indicated that the fill had been compacted to the required 95% of maximum dry density (Standard Proctor). According to ICI, the fill that was placed today will be tested at a later date.

Fish Sampling day	**Non-fish Sampling day**	**Location of Activity**	**Construction Activity Report Notes for fish sampling date**
20-Jun-11		Big Ditch U/S Plug Construction, Jungquist NE	This morning, ICI removed the D/S steel sheet cofferdam that was placed north of Smith A Bridge and connected the Big Ditch Realignment with the existing Big Ditch. ICI then began to install U/S steel plate cofferdams for the construction of the Big Ditch U/S plug near the northeast corner of the Jungquist field. One cofferdam had been previously installed in the Big Ditch Realignment. ICI installed two additional cofferdams in the existing Big Ditch and tried to isolate a triangle area for dewatering. ICI used a large pump to pump the water out of the triangle area and into the Big Ditch Realignment. However, ICI later realized that this setup was not working well because too much water was leaking through the U/S cofferdam due to the high water head pressure on the U/S cofferdam. ICI then decided to rearrange the cofferdams and isolate a dewater area inside the existing Big Ditch only. ICI removed the cofferdam from the Big Ditch Realignment and reinstalled it in the D/S Big Ditch. Another cofferdam was installed about 90 feet apart from the first one. When the water was lowered, ICI began to muck out the ditch bottom. The very soft sediments appeared to be relatively deep (3ft – 4ft). During the weekly meeting it was decided that the use of geogrid and geotextile to stabilize the ditch bottom for structural fill placement. ICI was still having problem to prevent the water from leaking below the steel sheets. ICI will try to minimize the leak and continue to install the plug tomorrow.