

JUVENILE SALMON, ESTUARINE, AND FRESHWATER FISH UTILIZATION OF HABITAT ASSOCIATED WITH THE FISHER SLOUGH RESTORATION PROJECT IN 2012

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May 2013

Prepared for The Nature Conservancy
(contract # WAFO-136-020410)



Fisher Slough Blind Channel 1, January 2013, looking east on a frosty morning from the top of the dike. Photo by Rich Henderson.

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Recommended Citation

Beamer, E, R Henderson, and K Wolf. 2013. Juvenile salmon, estuarine, and freshwater fish utilization of habitat associated with the Fisher Slough Restoration Project in 2012. Report prepared for The Nature Conservancy, Washington.

Acknowledgements

The authors wish to thank the following people and organizations for their help with this study:

- Skagit River System Cooperative field sampling crew - Bruce Brown, Jason Boome, Jeremy Cayou, Len Rodriguez, Josh Demma, and Ric Haase.
- The Nature Conservancy - funding and help from Jenny Baker, Joelene Boyd, and Kris Knight with study design, description of floodgate structures, assistance with site access, and environmental data (water surface elevation and water temperature).
- Casey Rice of NOAA Fisheries for analysis methods.
- Dave Olson of Dike District 3 for site access.
- Report reviewers Joelene Boyd, Jenny Baker, Roger Fuller and Liane Davis of TNC; Polly Hicks of NOAA Fisheries.
- Funding for this report was provided by WDFW through the Estuary and Salmon Restoration Program.

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. The restoration project was phased in three parts. Project Element 1 was 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 3 was a dike setback in order to allow more of the agricultural area to be inundated by tidal and freshwater hydrology, increasing fish carrying capacity. The new tidal habitat area, following implementation of Project Element 3, increased from 9.8 acres to 55.7 acres. All three phases were completed before monitoring in 2012. The monitoring results related to Project Elements 1 and 3 are presented in this report.

The new Fisher Slough floodgate, during the 2012 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 37.6% of the time during the 2012 fish monitoring period. This statistic varied little over the previous three years (2009 – 2011) of monitoring Fisher Slough's floodgate, ranging between 45% and 47%.

In 2012, 19 different species of fish were found in the study area, including six different salmonids and other freshwater and estuarine species. Average monthly juvenile wild Chinook salmon density was higher upstream of the floodgate than downstream of the floodgate in 2012 (year 3 after replacement and year 1 after dike setback), but it is not significant at the 0.05 level. In contrast with the two previous years, an analysis of juvenile Chinook salmon density and landscape connectivity shows that values from Fisher Slough are within the normal pattern observed at all other Skagit River delta sites, suggesting there was no disruption at the site of the floodgate in 2012 after completion of dike setback restoration. Updated juvenile Chinook salmon carrying capacity predicted tidal habitat upstream of the floodgate has the capacity to support 38,773 or 23,935 tidal delta-rearing Chinook salmon smolts annually, depending on which landscape connectivity value is used. Juvenile wild Chinook salmon population size in tidal habitat of Fisher Slough upstream of the floodgate in 2012 was equivalent to the higher of the updated carrying capacity estimates.

Our limited statistical tests and graphical trends over four years of monitoring support two tentative conclusions: (1) The new floodgate alone did not influence juvenile wild Chinook salmon as hypothesized (i.e., juvenile wild Chinook salmon abundance would increase upstream of the floodgate after its replacement) in 2010 and 2011, and (2) juvenile Chinook salmon responded as hypothesized to dike setback restoration (along with the new floodgate) in 2012. Dike setback restoration was hypothesized to increase fish carrying capacity by increasing available habitat. Our best estimate of increased carrying capacity as a result of Fisher Slough restoration is 21,823 juvenile Chinook annually as of 2012. However this estimate only takes into consideration one year of post-restoration results and is subject to change as more information becomes available from future years of fish monitoring. The results could change based on: 1) how fish find the area each year (i.e., fluctuations in habitat connectivity) and 2) how channel/impounded areas change over time within the restoration project area.

The conclusions are tentative because there is uncertainty in them due to the short length of the monitoring record after dike setback (1 year) and the potential for floodgate operation to improve now that all restoration and construction has been completed. Additionally, initial response by fish to the newly available habitat within the dike setback area may be different than later response, especially as the habitat adjusts in size and quality over time. 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, which had been put into 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 phased in their implementation, over several years, in three Project Elements. 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 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 relocated the Big Ditch siphon culvert, which is located underneath Fisher Slough within the future dike setback area. The siphon was located at the edge of the project footprint 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, increased from 9.8 acres to 55.7 acres (Beamer et al. 2013b, Hypothesis 3).

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 by the criteria set forth for the Fall/Winter Flood Control Period. The construction was completed in 2011. Project Element 3 was completed in 2011 (Table 1).

Table 1. Timeline of Project Element events, fish sampling periods, and floodgate management periods at Fisher Slough from 2009 to 2012

YR	Month	Project Element 1	Project Element 2	Project Element 3	Fish Monitoring	Floodgate Management Period	
2009	Jan				2/27/09 to 8/12/09	Fall/Winter Flood Control Period	
	Feb						
	Mar					Spring Juvenile Chinook Migration Period	
	Apr						
	May						
	June						
	July					Summer Irrigation Period	
	Aug						
	Sept	New floodgate installed 9/24/09 to 11/25/09					
	Oct						
	Nov						
	Dec					Fall/Winter Flood Control Period	
2010	Jan				2/5/10 to 7/13/10		
	Feb						
	Mar					Spring Juvenile Chinook Migration Period	
	Apr						
	May						
	June		Out of water work 6/14/10 to 7/21/10				
	July		Floodgate disengaged and in-water work 7/21/10 to 10/21/10				Summer Irrigation Period
	Aug						
	Sept						
	Oct		Out of water work continued 7/21/10 to 11/24/10				
	Nov					Fall/Winter Flood Control Period	
	Dec						
2011	Jan				2/10/11 to 6/20/11		
	Feb						
	Mar					Spring Juvenile Chinook Migration Period	
	Apr		Out of water work 4/12/11 to 6/27/11, work related to both Project Elements 2 and 3				
	May						
	June		Floodgate disengaged and in-water work 6/27/11to 10/31/11, work related to both Project Elements 2 and 3				Summer Irrigation Period
	July						
	Aug						
	Sept						
	Oct						
	Nov					Fall/Winter Flood Control Period	
	Dec						
2012	Jan				2/14/2012 to 7/24/2012		
	Feb						
	Mar					Spring Juvenile Chinook Migration Period	
	Apr						
	May						
	June						
	July						
	Aug			Floodgate disengaged 8/3/12 to 8/20/12 ¹		Summer Irrigation Period	
				Out of water work during August and September			
	Sept						
	Oct						
	Nov					Fall/Winter Flood Control Period	
Dec							

¹ Fish exclusion nets were in place periodically from 7/16/12 to 8/2/12 between the downstream side of the floodgate and the railroad trestle during a BNSF bridge replacement project.

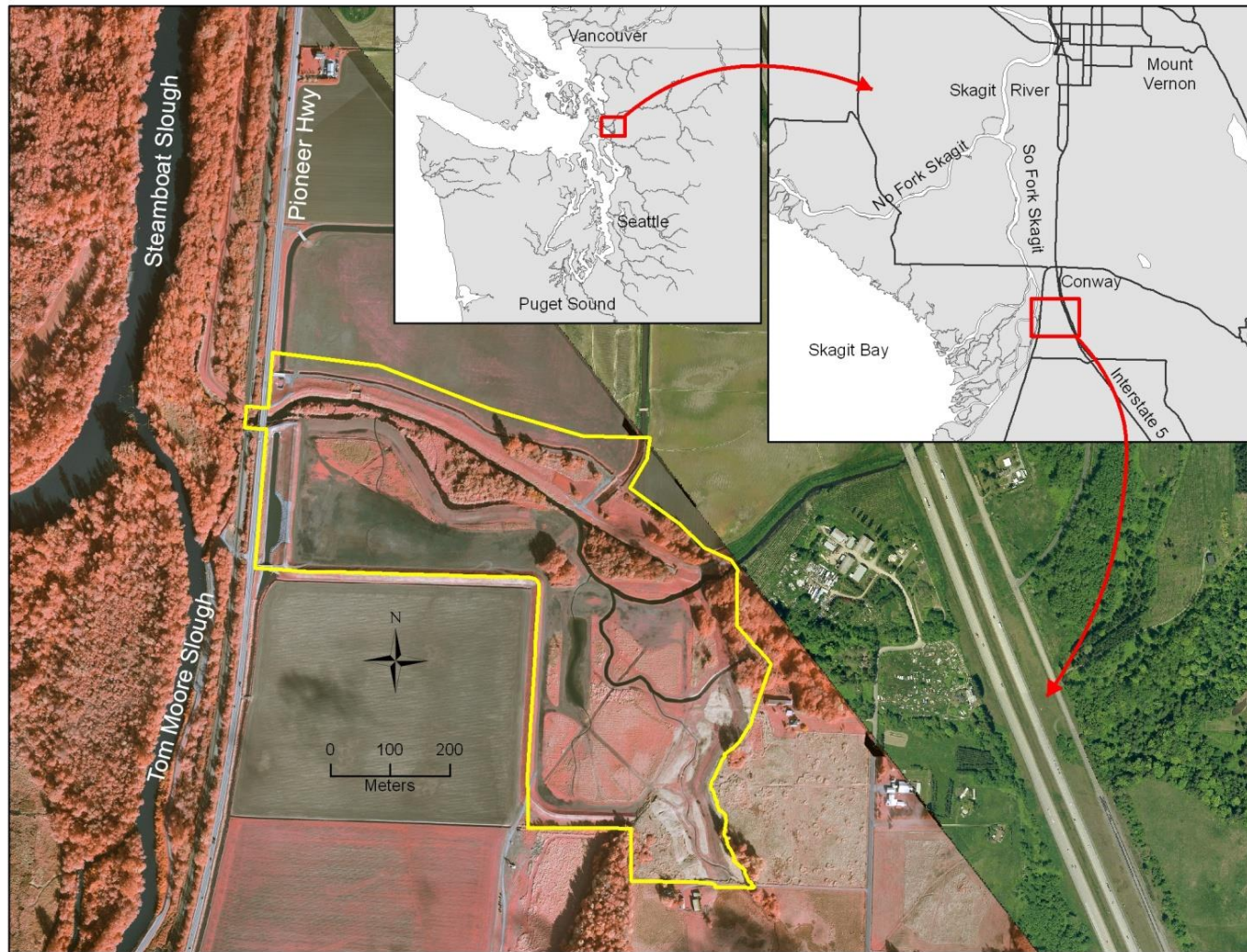


Figure 1. Location of Fisher Slough. Study area is outlined in yellow. Color-infrared photo is post-restoration from October 2011.

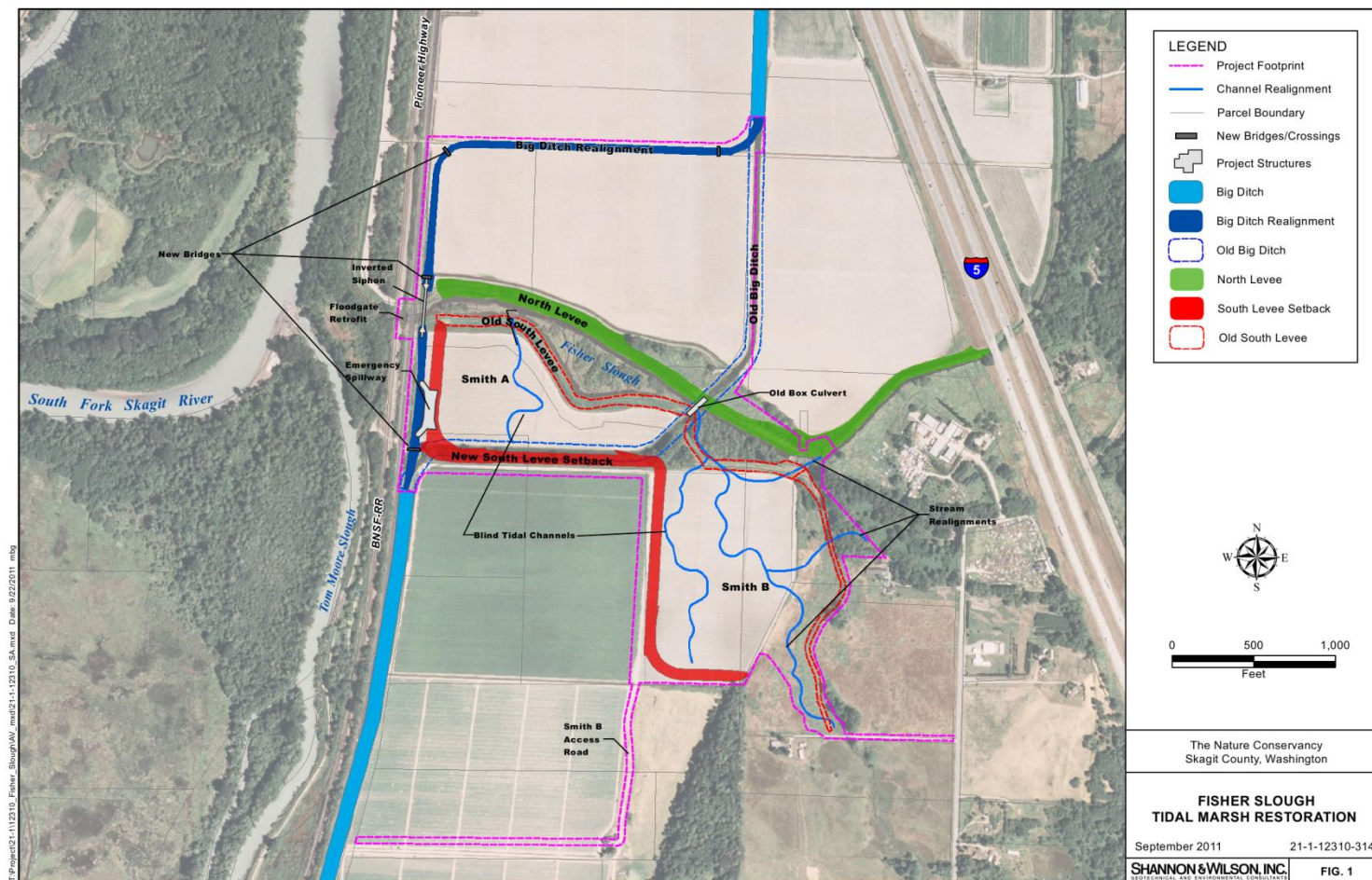


Figure 2. Restoration map of Fisher Slough provided by TNC.

Purpose and monitoring framework of 2012 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 forth 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 their life stages 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 of the project (i.e., floodgate replacement), an increase in tidal delta juvenile salmon abundance was expected. 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.

The Fisher Slough Restoration Project was 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. The fish-use monitoring is primarily of a pre- and post-treatment restoration design. Changes in fish use were expected within the treatment (restored) area following completion of Project Element 3.

Project Element 1, floodgate replacement, occurred in late August 2009. Data collected in 2009, representing the baseline values of fish utilization before floodgate replacement, are reported in Beamer et al. (2010). Data collected in 2010 and 2011, representing values of fish utilization in years one and two after floodgate replacement, are reported in Beamer et al. (2011) and Beamer et al. (2013a). Project Element 3, dike setback and channel relocation, was completed prior to the 2012 fish sampling period. This document,

reporting fish results for 2012, gives the values of fish utilization in the first year after the dike setback and channel relocation restoration had been completed.

Project Element 3 of the Fisher Slough Restoration project (i.e., the dike setback) was intended to increase fish carrying capacity through increasing available habitat. Juvenile Chinook salmon carrying capacity of the restored area will be a function of habitat area, its type and quality as well as its landscape connectivity. Monitoring of the project area thus required more fish sampling sites than those sampled to evaluate Project Element 1. Juvenile Chinook salmon abundance in 2012 was compared with predicted carrying capacity estimated for the Fisher Slough Restoration Project in the Skagit Chinook Recovery Plan. The monitoring framework 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 in operation at Fisher Slough during the 2012 fish monitoring period consisted of a 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 each measuring 8'9" tall and 11' wide. Three new aluminum floodgates (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 floodgates and the old doors is at an elevation of 4.3 ft NAVD88.

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 is covered with a top-hinge flapgate that opens or closes based on whether water flow is coming downstream (gate open) or tide is pushing upstream (gate closed). The flapgate under the south floodgate is controlled by an adjustment arm so it can be propped open or held closed depending on floodgate management period.

Methods

Sample timing

A combination of beach seine and fyke trapping methods were used to collect fish at sites within the study area on 19 sampling days between February 14 and July 24, 2012 to coincide with the known juvenile rearing period for Chinook in the Skagit estuary (Beamer et al. 2010). Sampling was consistent across all years (2009-2011)

Sampling was conducted once per month in February and then twice per month (March through the end of the summer to be consistent with the monitoring design of long term juvenile Chinook monitoring in the Skagit estuary (Greene and Beamer 2006). The end date of the fish sampling has varied each year during the last four years of monitoring (2009 through 2012) from June to August according to the restoration construction activities occurring in each year and the floodgate operation related to those activities.

Seven environmental variables were collected at each site on each sampling date: water temperature, salinity, dissolved oxygen, water velocity, vegetation, substrate, and the depth of the water sampled. Beach seining in the blind channel lobes 1 and 2 was scheduled for June 25, but this event was not conducted due to extreme high water.

Fish sampling was stopped for the season at the end of July 2012. The decision was based on two main factors described here. Burlington Northern Santa Fe (BNSF) railroad replaced the trestle and bridge deck just downstream of the floodgate with work starting in July. This project required fish removal and exclusion during the time that in-water construction work was being performed. Fish exclusion nets had been in place periodically from July 16 to August 2, 2011. Dike District 3 had requested that the floodgates be disengaged in order to help accommodate low flows in Hill Ditch upstream of the project area so a maintenance project could be conducted in that area. Permission was granted from Washington Department of Fish and Wildlife. It was decided to stop the fish monitoring as of the end of July and the floodgates were disengaged on August 3 through August 20, 2012 (Appendix B, Table 1).

Site selection

Fish monitoring sites were systematically selected downstream and upstream of the floodgate to represent the habitat types and spatial diversity found within the project area (Figure 2). The locations of fish sampling sites were selected in order to compare the fish assemblage above the floodgate, including the new marsh areas, to that below the floodgate. Sampling in 2012 represents the first year after Restoration Project Element 3 was completed at Fisher Slough. Three blind channel lobes were created from the dike setback and main channel relocation. The existing sites along the main channel of Fisher Slough (upstream/downstream of floodgate), the reference blind channel site, and the site at Tom Moore Sl Upper Area were sampled in the same way (including tidal stage) as in 2009-11 in order to not bias year to year comparisons. See Beamer et al. (2010) for details on site selection methods.

The site location for the data loggers measuring dissolved oxygen (DO), water surface elevation (WSE), water temperature and floodgate door openness had been previously established by TNC and were continued at the same locations in 2012.

Blind channel lobes 1 and 2 (located in the old Smith A and Smith B fields, respectively, Figures 2 and 3) are new habitat as a result of the dike set-back. Sampling transects were designed in each lobe, with transect lines running roughly west to east at 50 meter intervals. Each lobe was further divided into west and east sections, with the new blind channel being the dividing line between them. There were 12 possible sampling areas in Blind Channel 1 and 16 in Blind Channel 2 (Figure 3). Microsoft Excel software random number-generator was used to select three transects to seine in each lobe for each sampling day, with two sets made along each transect line (six sets per lobe per sampling day for a total of 12 sets per day). Blind channel lobes 1 and 2 vary in water surface area by tidal stage, Skagit River discharge, gate closure setting, and tributary discharge. The sampling within these lobes started at low tide on each sampling day, but even at low tide, much of each lobe was flooded beyond the channel margin. Thus, the randomly selected sites included shoreline edge and open water beach seine sets, collecting fish density results from all habitat types (Figures 3 and 4).

Blind Channel 3 resulted from relocating the main channel to the south. This lobe is much smaller, with only three transect lines on a grid of approximately 50 meters. The site Fisher Sl Inside s5, which was sampled in the 2009-2011 monitoring effort, is located in this section and was sampled each time seining was done in this lobe, along with one randomly selected transect area (two sets per sampling day).

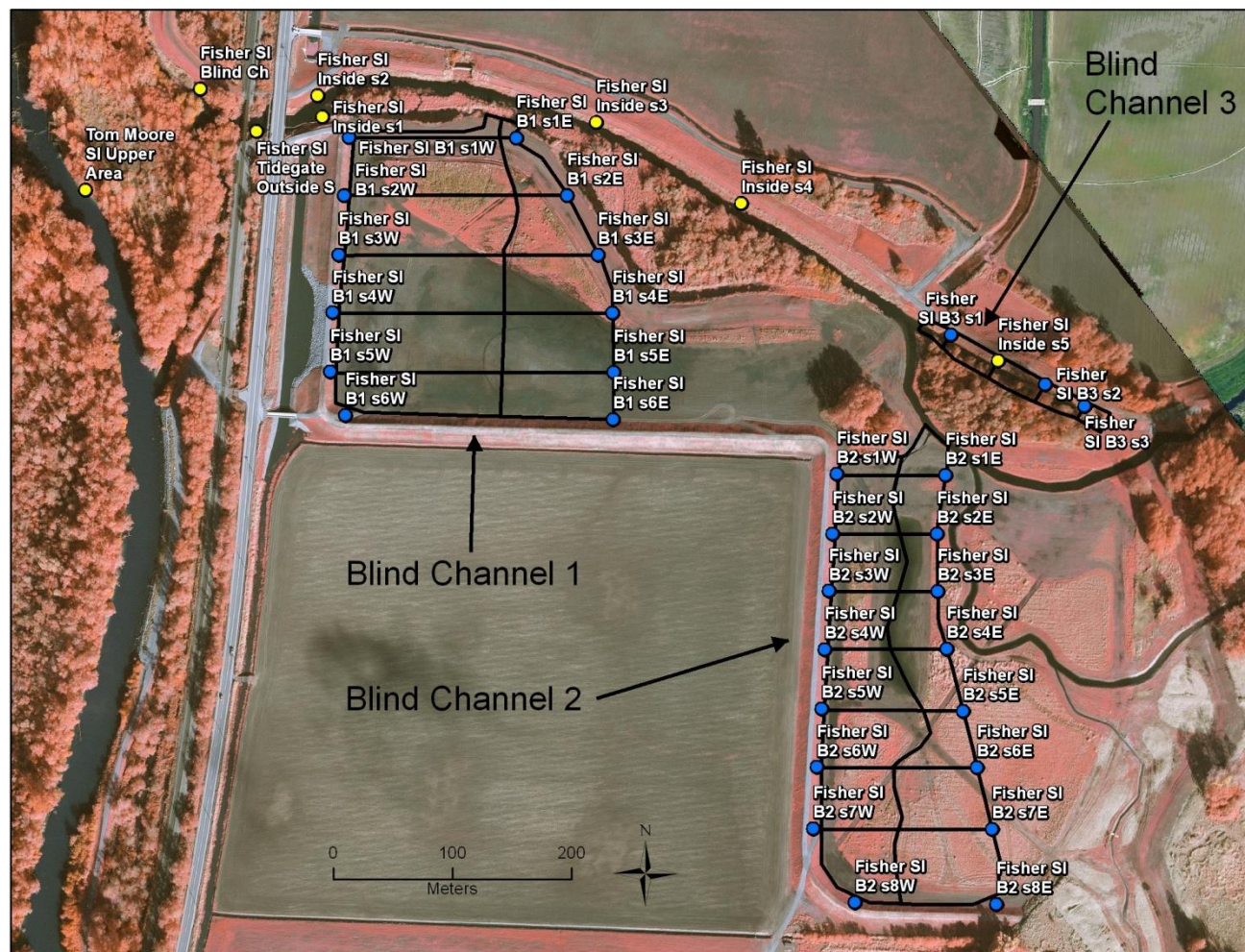


Figure 3. Location of fish monitoring sites (yellow dots are sites sampled 2009 through 2012) and blind channel sampling transects (black lines with blue dots at either end) at Fisher Slough, 2012.

Fish sampling methods

Each fish sampling event took two days to complete because of the varied tides necessary to complete sampling at each site. The first day sampling was in the main channel sites up- and downstream of the floodgate, including the reference blind channel site and Tom Moore Sl Upper Area. Beach seine sampling occurred at high slack tide and the first half of the ebb tide starting with the downstream sites and working upstream. The timing of sampling by tidal stage is consistent with other years, 2009 through 2011. The second sampling day was in the new Blind Channels 1 and 2, with sampling occurring at low slack tide and the first portion of the flood tide.

Beach seine

Beach seining in the main channel areas - Small net beach seine methodology 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 the Fisher Slough main channel areas, a small skiff was used to pull the tub while setting the net at most of the sites along the main channel. The average beach seine set area was 96 square meters.

Beach seining in the new blind channel areas – Sampling in the new habitat area in the Blind Channel 1 and 2 was conducted along the randomly selected transect lines (as described in the Site Selection above). Two styles of the small net methodology were used while sampling. The edge of the lobe along the perimeter dike was sampled according the methods described above for the main channel areas. The net was deployed from the tub by wading along the shoreline. The average beach seine set area was 96 square meters. While sampling the open water area in the middle of the blind channel lobe, the net was deployed from the tub while wading through the water, setting the net in a semi-circle and then both ends of the nets were brought together and the net “pursed up” yielding the catch. The average beach seine set area in the open water sets was 125 square meters. An example of each method is shown in the pictures below. The location of the beach seine sets made on each sampling day in Blind Channel 1 and 2 are shown in Figure 4.



Small net beach seine along the shoreline edge at Fisher Slough Blind Channel 2.



Small net beach seine open water round haul at Fisher Slough Blind Channel 1.

For each set, the fish were identified and counted 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. The catch data collected during the six random beach seine sets in each blind channel lobe were totaled for the day and reported. Freshwater mussels were counted as they are suggested biomonitors, an indicator species for clean water (Nedean 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 water surface elevation.

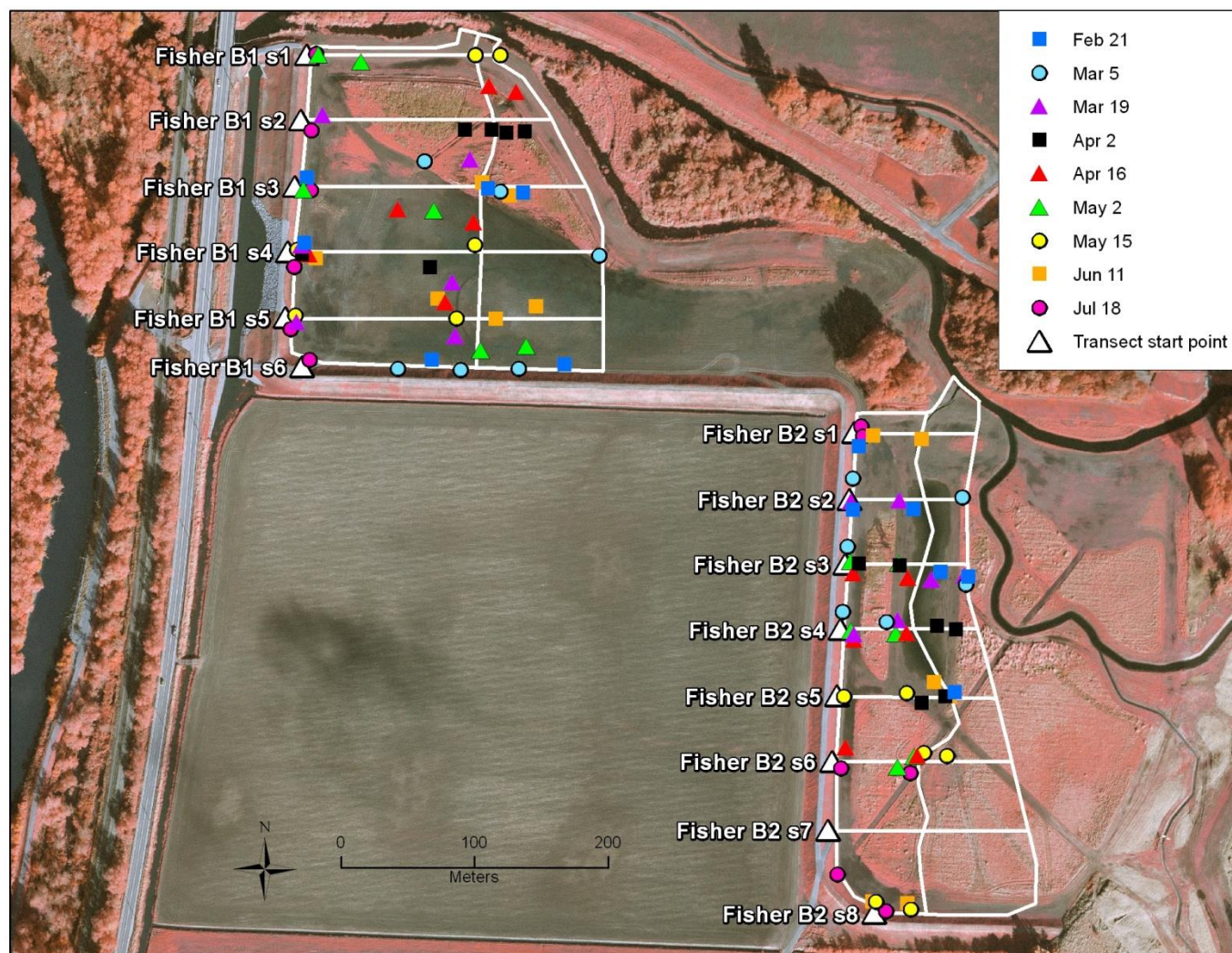


Figure 4. Location of beach seine sets made in Fisher Slough Blind Channel 1 (B1) and 2 (B2) during fish monitoring in 2012.

Fyke trap

As in 2009 through 2011, a fyke trap was used 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. The fish were identified and counted, and environmental data were collected, as was done for beach seine sets (see above). Beach seine and fyke trap efforts are shown in Table 2.

Table 2. Beach seine and fyke trap sampling effort, by site, strata (up- or downstream of the floodgate), and strata2 (subgroups of sites up- or downstream of the floodgate) at the Fisher Slough study area, 2012.

Strata	Strata2	Location/Site	Number of beach seine or fyke trap sets per sampling date
Upstream of floodgate	US FG Main Channel	Fisher Sl Inside s1	1
		Fisher Sl Inside s2	1
		Fisher Sl Inside s3	1
		Fisher Sl Inside s4	1
	US FG Blind 1	Fisher Sl B1 (all random)	6
	US FG Blind 2	Fisher Sl B2 (all random)	6
	US FG Blind 3	Fisher Sl B3 (Fisher Sl Inside s5, non- random)	1
		Fisher Sl B3 (random)	1
Downstream of floodgate	DS FG Main Channel	Fisher Sl Tidegate Outside S	1
		Tom Moore Sl Upper Area	2
	DS FG Ref Blind	Fisher Sl Blind Ch	1

Environmental variables

Differences in local environment might influence fish use between strata (sites upstream and downstream of the floodgate) independent of how the floodgate operates for fish passage. Thus, selected environmental variables were measured at each site at the time of beach seining or fyke trapping in order to assess their potential influence on fish results (e.g., presence, density, seasonality) across sites in the study area. Data loggers continuously recorded water surface level, water temperature and/or dissolved oxygen at the bottom of the water column at six sites, both up and downstream of the floodgate. The location of the continuous-read data loggers is shown in Figure 5. The environmental data collected during the six random beach seine sets in each blind channel lobe were averaged for the day and reported.

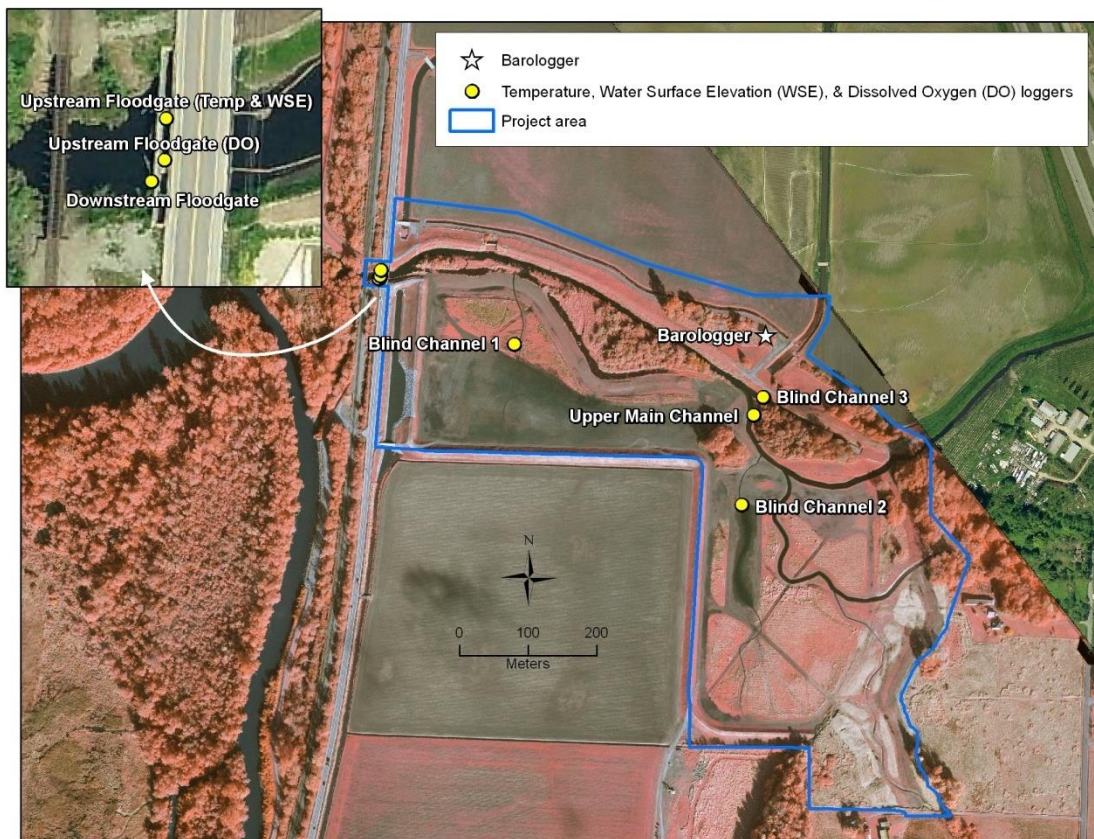


Figure 5. Data logger locations at Fisher Slough in 2012. In addition to the data loggers shown in the photo, inclinometers were used to measure door openness on each of the three floodgate doors.

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 the top and bottom of the water column within each beach seine or fyke trap set area at the start of sampling. Measurements were also taken at the end of the trapping period at the

fyke trap at low tide. 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.

Water temperature

Water temperature was measured by both continual monitoring and spot measurement methods. A YSI Professional Plus Model meter was used for spot measurements, which were taken at each beach seine or fyke trap site during sampling. Two readings were taken, just under the surface and at the bottom of the water column, within the set area.

Continual monitoring was done utilizing two different types of data loggers. Model 3001 Levellogger Gold and/or Model 3001 Edge data loggers made by Solinst Canada Ltd were placed in standpipes at five sites: one downstream of the floodgate on the floodgate headwall structure (Downstream Floodgate), one upstream of the floodgate near the historical Big Ditch Crossing (Blind Channel 3), one in the new main channel upstream of the historical Big Ditch Crossing (Upper Main Channel), and one in each of the two new blind channel lobes (Blind Channel 1 and Blind Channel 2) (Figure 5). Water temperature was taken at the bottom of the water column. The elevation of the data loggers is shown in Table 3.

An INW (formerly known as Instrumentation Northwest) data logger, model Aquistar® PS9805, is located on the upstream face of the floodgate headwall (Figure 5). Data from this logger were used for water temperature comparisons. This data logger, like the Model 3001 Levellogger Gold and/or Model 3001 Edge data loggers, is a combination of a pressure transducer and thermometer. A Campbell Scientific data monitor, model CR1000 with software communication software version PC200W, was used to store and download data. Data were processed within the data logger and the results were converted to the desired units of pressure and temperature. Downloaded data contained values for both water temperature and WSE at the upstream side of the floodgates. The data logger was located at 1.00 ft NAVD88 and takes 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 gives a report of the 15 minute average of data. 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 the data loggers were compared to water temperature results from the spot measurements during fish sampling by pairing data from the data logger with data from the spot measurement. Only spot measurements taken at the bottom of the water column were compared to data logger results because the loggers are located in the bottom of the water column. Site comparisons are according to Table 3 and water temperature measurements were paired by time and date. See Figure 3 for site locations and Figure 5 for data logger locations.

Table 3. Data logger and spot measurement site locations and elevation of the data loggers used for temperature and DO comparisons during fish sampling at Fisher Slough in 2012

Comparison	Spot measurement site(s)	Data Logger measurement site	Data logger elevation (ft NAVD88)
downstream of floodgate	Fisher Sl Floodgate Outside S Fisher Sl Blind Ch	Downstream Floodgate	0.25
upstream of floodgate	Fisher Sl Inside s1 Fisher Sl Inside s2	Upstream Floodgate	1.0
	Fisher Sl Inside s4	Upper Main Channel	4.43
blind channel	random beach seine sets made within Blind Channel 1	Blind Channel 1	4.66
	random beach seine sets made within Blind Channel 2	Blind Channel 2	4.86
	Fisher Sl Inside s5 and the random site within Blind Channel 3	Blind Channel 3	4.10

The Solinst WSE and water temperature loggers, as well as the floodgate data logger are in place year round, but only data collected during the fish monitoring period are reported.

Dissolved oxygen

Dissolved oxygen (DO) was measured by both continual monitoring and spot measurement 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 during sampling. Two readings were taken at the surface and bottom of the water column of the areas seined, and at the fyke trap site. The average value of the DO at the surface and bottom of the water column is reported for each site. 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 data logger made by INW. The DO loggers were placed in perforated PVC standpipes at three sites in the main channel: one downstream of the floodgate (Downstream Floodgate) secured to the floodgate headwall, one upstream of the floodgate (Upstream Floodgate) secured to a highway bridge piling, and one further upstream at the Upper Main Channel site (Figure 5). A fourth DO logger was rotated between the three blind channel areas approximately every two weeks. The DO loggers at Downstream Floodgate, Upper Main Channel and the roving DO logger in Blind Channel 3 were installed on March 29, 2012. The logger at Upstream Floodgate was installed on May 5, 2012. Dissolved oxygen and water temperature readings were taken at the bottom of the water column. The Aquistar DO data loggers record the DO content as parts per million (ppm). This is the equivalent of mg/L values recorded by the YSI loggers. The DO values are reported as mg/L for the comparisons of the two methods.

Loggers were set to automatically record the DO at 15-minute intervals, seven days per week. The daily range (maximum and minimum values) is reported in mg/L, in order to compare the spot measurements taken at the time of fish sampling to those taken by the continual monitoring of the Solinst data loggers. All DO loggers were in place until

September 30, 2012 but here only data collected during the fish monitoring period are reported.

Problems were encountered with all the continual-read DO loggers. All would periodically record a value of negative 90, indicating a communication problem between the sensor probe and the data housing. These -90 values were removed from the data set prior to any statistical analysis. Two of the DO loggers, deployed at the Upper Main Channel site and blind channel lobes, had other problems as well. Both units recorded negative values ranging from -0.01 to -31.3 ppm. This is a physical impossibility in water. The errors in data recorded by the roving DO logger were seen when the logger was deployed in Blind Channel 1 on May 10, on July 6 in Blind Channel 2 and then in Blind Channel 3 from July 21 through 31. The logger located at the Upper Main Channel site did not show the negative values until after the fish monitoring period ended. It had 523 of the -90 data error messages out of 11,268 potential data records (equaling 4.64% of the time) between March 29 and July 24. Each record represented a 15-minute data collection period. The negative value errors occurred primarily after the fish monitoring period but the timeline description is given here to show that there was something problematic with the DO data loggers.

The problem of negative values was discussed with INW (the manufacturer) at the end of the season. They had not previously encountered this problem (other than the -90 data communication error), nor could they reproduce a negative value in their lab (Jerome Gogue, INW, personal communication). One theory was that the logger had gone dry, but this was not the case as the actual WSE at the time ranged from 0.90 to 1.96 meters over the top of the logger. It is most probable that the logger standpipe had become encased with a mass of floating green algae or pondweed, preventing water from circulating around the probe. Again, all negative numbers were removed from the data set prior to analysis.

The DO results were compared by pairing data from the continuous-read data loggers with water bottom data from the spot measurements for nearest site, time, and date during the time period fish sampling was being conducted. The data logger elevations and site pairings are shown in the temperature section above (Table 3).

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 was taken from the relative water surface elevation staff gage, located just upstream of the fyke trap (Figure 3), 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 Swiffer Model 2100 flow meter. Four measurements were taken near the surface of the water across the area seined after the set was made. These values were 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 were 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). 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 dissolved oxygen were compared graphically or using ANOVA to reveal strata (up- or downstream of the floodgate, shown in Table 2 and Figure 5), site, or date differences in each of the environmental variables. Scheffé pair-wise testing was used to compare between groups. Statistical analysis was done with the software package SYSTAT 13.

For selected environmental variables, comparisons of site and season results to known or hypothesized relationships for juvenile Chinook salmon presence were made 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 dissolved oxygen 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, the density of juveniles for each set (the number of fish divided by set area) was calculated.

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 water surface elevation during trapping (a measurement of how well the channel drains) explained the RE results, which varied between 2.3 and 9.4 percent in 2012. The 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, the channel polygon was digitized using high resolution orthophotos and used GIS to calculate the area of the polygon. The bankfull channel area associated with the fyke trap site is 1,367 m².

Juvenile Chinook salmon density results up- and downstream of the Fisher Slough floodgate were statistically compared. 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 four years, 2009 through 2012, were combined in order to test for treatment (years before/after floodgate replacement) and strata or strata2 significance. Strata are “downstream of floodgate” and “upstream of floodgate.” Strata2 consists of six sub-groupings of sites within strata and were broken out based on their uniqueness in habitat type (blind channel versus main channel) or the need to sample with different methods (fyke versus beach seine versus open water beach seine). The sites in each strata and strata2 are shown in Table 2.

A two-way ANOVA is used to reveal treatment and strata or strata2 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 this concept is applied 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, comparisons of juvenile Chinook salmon usage results from Fisher Slough with that of other sites throughout the Skagit River tidal delta can be made 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. This is termed 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 (LC) for each site is calculated:

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

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.

Fish abundance estimates

Juvenile wild Chinook salmon abundance estimates were made to determine the number of fish that reared in habitat upstream of the floodgate in 2012 compared to model-generated carrying capacity estimates for juvenile Chinook salmon. Fish abundance was calculated as: fish density multiplied by the wetted area of strata2 during the time of sampling.

Fish abundance was calculated for each set on each sampling date because wetted area and juvenile Chinook salmon catches varied by strata2 and sampling date. Blind channel lobes 1 and 2 vary in water surface area by tidal stage, Skagit River discharge, gate closure setting, and tributary discharge. Each fish sampling day the wetted area of blind channel lobes 1 and 2 was estimated in order to estimate the fish population size that used each lobe over the monitoring season. Wetted area was calculated using water surface elevation (WSE) during the time of fish sampling, along with the as-built topography. A WSE-to-wetted area relationship was developed for both blind channel lobes and can be found in Appendix D. Wetted area for blind channel lobe 3 and main channels upstream of the floodgate were always within bankfull area during the time of fish sampling, so we used channel area for these strata2 to expand fish density to fish abundance. Channel area for blind channel lobe 3 and main channels upstream of the floodgate are 0.104 and 1.359 hectares, respectively.

Individual fish abundance estimates were averaged by strata2, resulting in average daily juvenile Chinook salmon abundance for the entire monitoring period (154 days). Average juvenile Chinook salmon abundance was multiplied by the 154-day period, yielding an estimate of fishdays, then divided by the average resident time (35 days) of individual juvenile Chinook salmon rearing in Skagit River tidal delta habitat (Beamer et al. 2000). This calculation procedure is an estimate of the population of juvenile Chinook salmon that used each strata2 habitat area during the 2012 monitoring period.

Results

Floodgate operation in 2012

Floodgate operation for this project was specified in Washington Department of Fish and Wildlife's Hydraulic Project Approval (HPA) Permit No. 114361-5, which defined three management periods designed to meet fish passage, tidal exchange and flood protection. The permit includes fish passage criteria along with estimates of juvenile salmon passage conditions (Table 4). The complete floodgate operation results for Water Year (WY) 2012 are found in Beamer and Henderson (2013) and summarized in Table 4. In WY 2011 floodgate operation nuances are as follows:

Restoration construction for Project Element 3 was completed on October 31, 2011 during the Fall/Winter Flood Control Period. At that time the floodgate was set to operate normally and continued without further deviation to the operating criteria with all criteria being met. During the Spring Juvenile Chinook Migration Period the floodgate was operated normally without deviation to the operating criteria, but two of the four fish passage criteria were not successfully met. This was due in part to challenges in getting the floodgate door closure elevation set accurately, altered hydraulics due to the implementation of Project Element 3 (the dike setback) and a broken mechanism in the self-regulating system. The floodgate (at least one door) is supposed to be open more than 90% of the time but was only open 85.48% of the time. Sixty-five percent of the floodgate closures occurred when WSE was lower than the required minimum closure criterion of 9.5 ft NAVD88. The Summer Irrigation Period, which starts on June 1, requires the floodgate doors to remain open 100% of the time. The floodgates were operated normally during this period in 2012 except for a two-and-a-half-week period from August 3 through August 20, for maintenance activities by Dike District 3 upstream of the Fisher Slough restoration area. During maintenance activities the floodgate was disengaged and was operated as a gravity system. Prior to the floodgates being disengaged the floodgate was open 100% of the time. In this report only the floodgate operation effects on fish passage coinciding with the fish monitoring period February 14 through July 24, 2012 are of concern; therefore the change in operations during the Summer Irrigation Period did not affect this report.

Table 4. Summary of Fisher Slough floodgates and their operational criteria for WY 2012 (from WDFW Hydraulic Project Approval Permit No. 114361-5).

Floodgate Operation Period	Were criteria met in WY 2012?			
	Gate opening		Water velocity	Water depth
	% of time gates shall be open ^{A/}	Minimum gate closure elevation		
Fall/Winter Flood Control (Oct. 1- Feb 28/29)	Does not apply	Yes. All (100%) of the floodgate closures occurred when WSE was greater than the required minimum closure criterion (7.5 ft NAVD88).	Does not apply	Does not apply
Spring Juvenile Chinook Migration (March 1-May 31)	No. Floodgates were not open more than 90% of the time during normal operational periods. They were open 85.48% of the period.	No. Sixty-five percent (65%) of the floodgate closures occurred when WSE was lower than the required minimum closure criterion (9.5 ft NAVD88).	Yes . Water velocity never exceeded the maximum criterion (8 ft /sec), based on continuous monitoring of velocity for 15 tidal cycles.	Yes. Water depth exceeded minimum depth criterion (0.5 ft) 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 upstream of the site by Dike District 3 per WDFW approval. Floodgates were open 86-87% of the time (depending on door)	Does not apply	Does not apply	Does not apply

^{A/} Except during those instances when the NOAA Hydrologic Prediction Service web-page shows that the predicted flood flow in the Skagit River at the Mount Vernon Gage is above 28 feet. Under these conditions, the floodgate can be set to close at lower elevations.

Fish site level environmental variables

In this section of the results, the site and season variation of selected environmental variables known, or hypothesized, to influence juvenile Chinook salmon presence in order to characterize the monitoring area in 2012 is reported.

Salinity

Water salinity values are shown in Appendix A, Tables 1 and 2.

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 always less than 0.1 ppt (Figure 6, Appendix A Tables 1 and 2) 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.

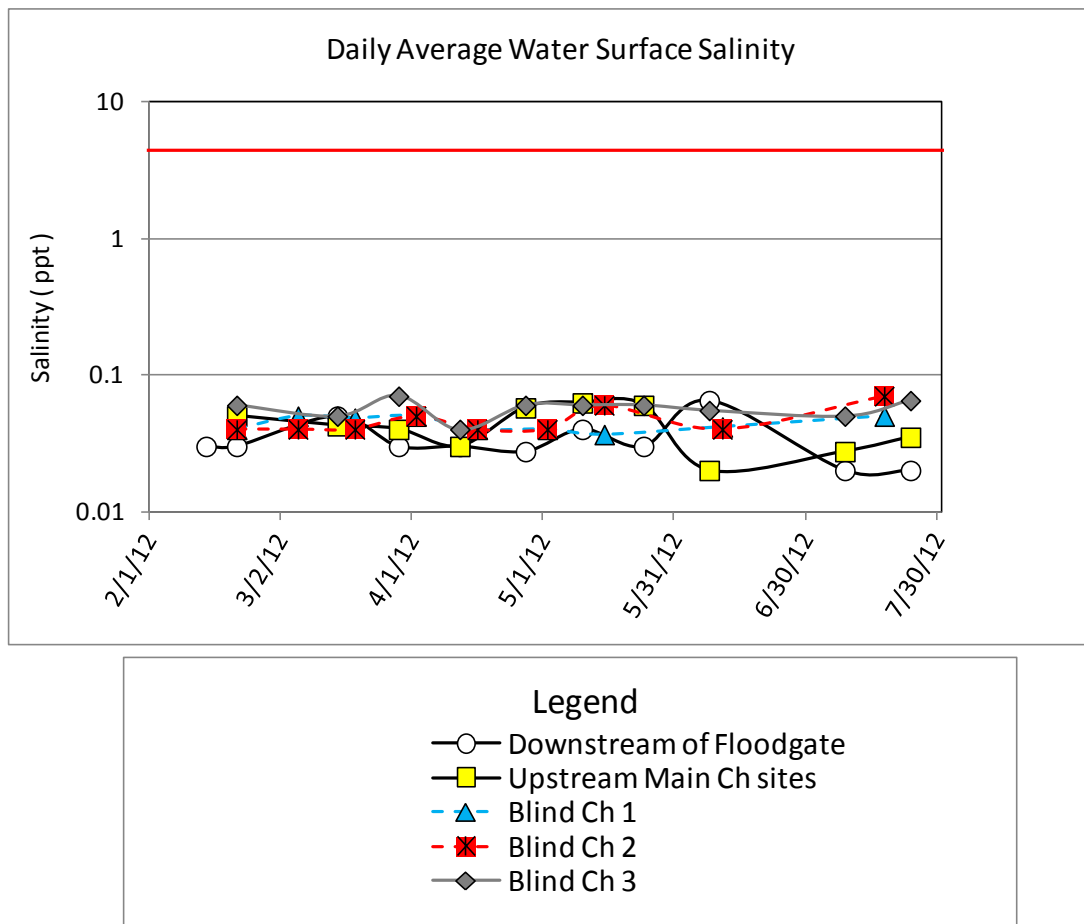


Figure 6. Comparison of daily average water surface salinity in parts per thousand from spot measurements for combined upstream main channel sites, combined downstream sites and Blind Channel 1, 2 and 3 sites during the fish sampling time at Fisher Slough in 2012. Y axis is shown in logarithmic scale. Horizontal line at 4.5 ppt shows the salinity level postulated as stressful to juvenile Chinook salmon (Macdonald et al, 1987).

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 methodological sources: (1) spot measurements taken at the time of beach seine sampling and (2) continuous-read data loggers. Spot measurements are limited compared to the data logger results in temporal coverage (one time per site on 19 different sampling days compared to 15-minute readings for five months with the loggers), but stronger than the data loggers in spatial coverage (ten sites compared to six for the loggers).

There is strong consistency in water temperature between measurement methods at four of the six comparison sites. The overall trend in water temperature between the two methods is not significantly different, i.e., the regression results are not different than the 1:1 line shown in each graph 1 (Figures 7 and 8). There was good correlation in all three of the channel sites and in Blind Channel 1 (Figures 7 and 8, panel A). At two of the blind channel lobes (numbers 2 and 3), the correlation was not strong at higher temperatures, with the temperature taken during spot measurements being higher than the data logger values (Figure 8, panels B and C).

The timing of the spot measurements taken during fish monitoring is evident when the comparison the spot measurement to the minimum and maximum daily temperatures from the continuous-recording data logger is made. The sampling in the channel areas up- and downstream of the floodgate and in Blind Channel 3 started near high tide, which usually was early in the morning. The values recorded during this time tended to coincide with the minimum daily temperatures (Figures 9-11 and Figure 14). Fish monitoring in Blind Channel 1 and 2 was conducted starting at low tide (shallower water), and therefore the spot measurements tended to coincide with the daily maximum temperatures (Figures 12 and 13).

Individual spot measured and data logger water temperatures were off by as much as 2.4 °C at the Downstream Floodgate site (Figure 7, panel A), 1.0 °C at the Upstream Floodgate site (Figure 7, panel B) and by 2.0 °C on one date at the Upper Main Channel site (Figure 7, panel C). In the blind channel lobes the daily difference was 1.0 °C in Blind Channel 1 (Figure 8, panel A), 4.3 °C in Blind Channel 2 (Figure 8, panel B), and 1.8 °C in Blind Channel 3 (Figure 8, panel C). However, average differences in water temperature between the two methods were less than 0.8 °C at Downstream Floodgate site, 0.3 °C for Upstream Floodgate site, and 0.6 °C for the Upper Main Channel site. In the blind channel lobes the average difference was 0.5 °C in Blind Channel 1, 2.4 °C in Blind Channel 2, and 1.0 °C in Blind Channel 3.

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 and July,

The maximum daily fluctuation for the Downstream Floodgate site was 12.4 °C on July 24; for Upstream Floodgate it was 12.3 °C on July 26; for the Upper Main Channel site it was 11.8 °C on July 25 (Figures 10 and 11). In the blind channel lobes the greatest daily fluctuation varied in timing from those in the main channel area. The maximum daily fluctuation was 12.4 °C on July 25 in Blind Channel 1; in Blind Channel 2 it was 12.6 °C on May 12; in Blind Channel 3 it was 6.5 °C on June 11 (Figures 12-14).

Seasonal fluctuations of water temperatures were observed and it is suggested that they are likely due to short term weather patterns, tidal cycles, and river flow cycles.

Comparison of temperature by site and date

Tests were made to determine whether surface water temperature was influenced by site, strata and/or sampling date over the sampling season. Statistical analysis reveals a strong ($p < 0.001$) influence on water temperature by site (Appendix A, Table 5), strata (Appendix A, Table 6), and season (Appendix A, Tables 5 and 6). Pair-wise comparison of groups for sites and sampling date are shown in Appendix A, Tables 7 and 8, respectively. The seasonal influence is visible in Figures 9 through 15 where temperature generally increases over the season. The site influence is visible in Figure 15 where sites upstream of the floodgate were higher in temperature than sites downstream of the floodgate, and sites within the blind channel lobes were higher in temperature than sites in the channel areas.

Comparison of temperature to temperature thresholds

The daily average surface water temperature recorded by spot measurements taken during fish sampling for the combined sites in Blind Channel 1 and 2 exceeded the 15 °C threshold postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006) from the sampling on June 11 through the end of the fish monitoring on July 24 (Figure 15, panel A). The bottom water temperature in Blind Channel 2 exceeded the 15 °C threshold from May 15 to the end of the season, and at Blind Channels 1 and 3 the bottom water was warmer than 15 °C by the end of the sampling period (Figure 15, panel B). At the main channel sites upstream of the floodgate the temperature threshold was barely exceeded on July 9 with a daily average of 15.05 °C. The average surface water temperature on all other dates and other sites was lower than this threshold level (Figure 15). Based on both the spot measurements and data logger results, water temperature did not exceed the lethal threshold for Chinook salmon (24.8 °C) at any site over the sampling season.

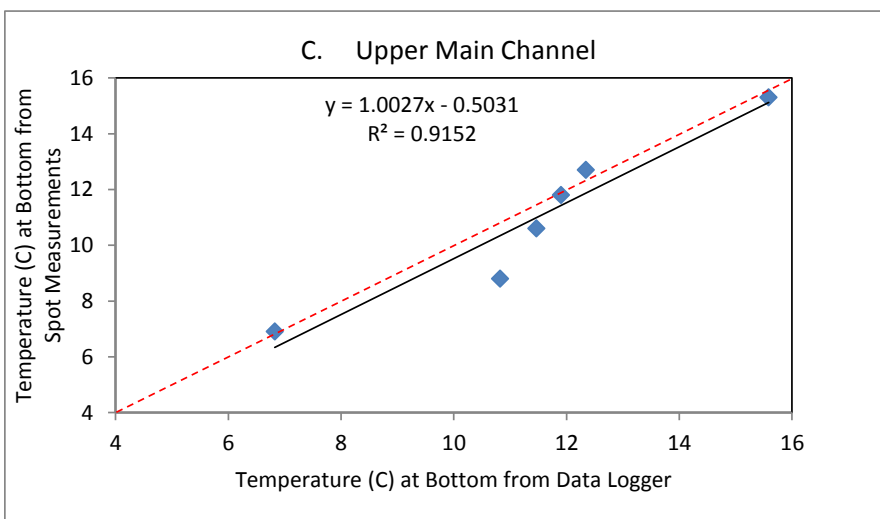
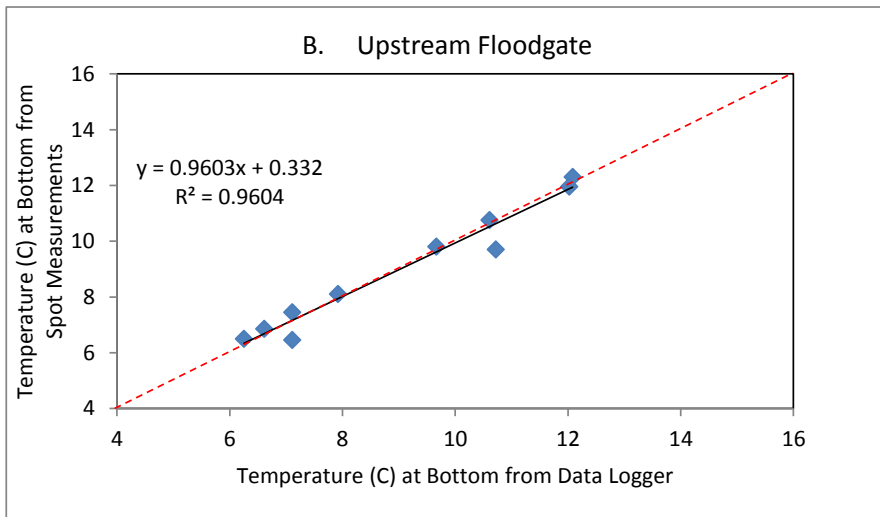
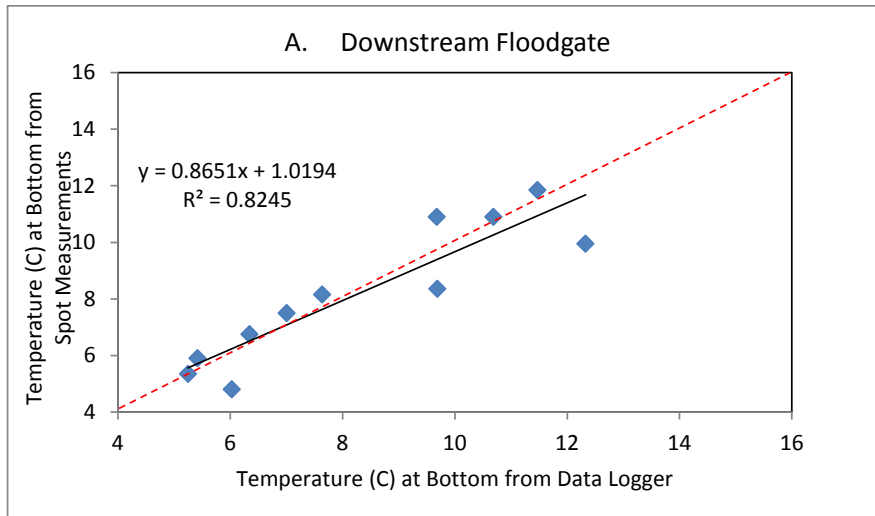


Figure 7. Comparison of water bottom temperatures from continuous-read data loggers (x axis) and spot measurements (y axis) taken during beach seining in the main channel sites at Fisher Slough, 2012. The 1:1 line is shown as a dashed line in each figure.

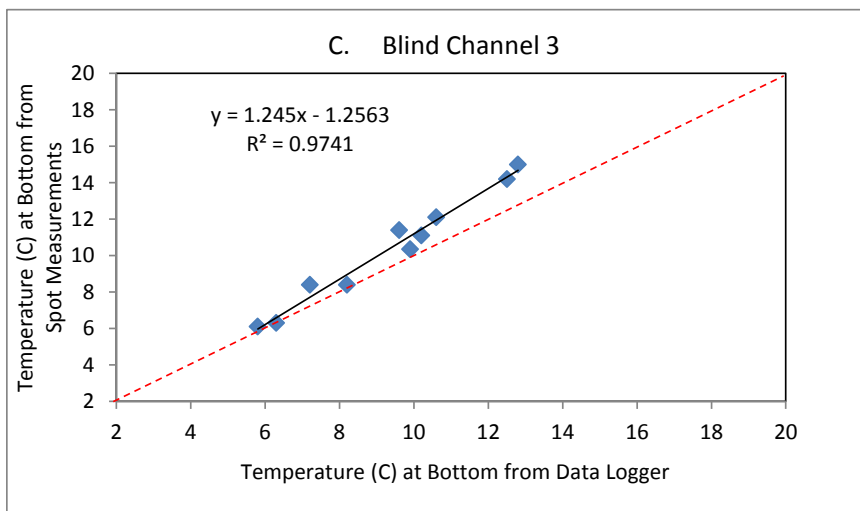
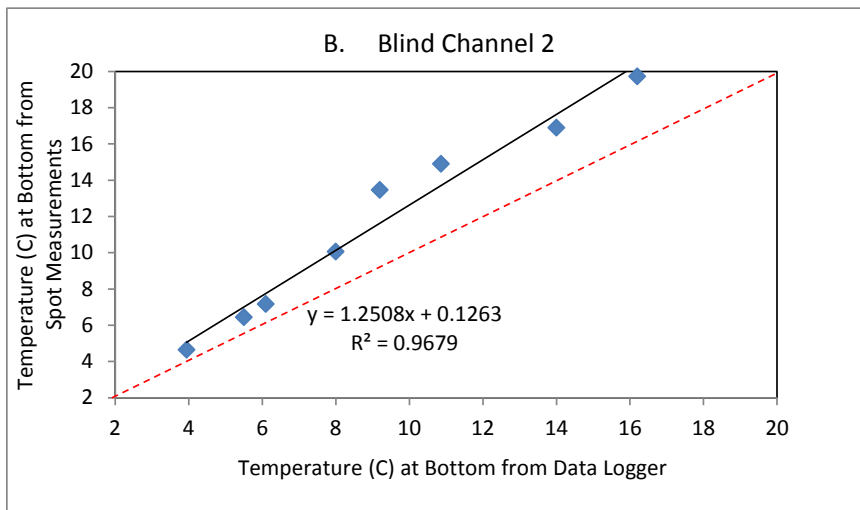
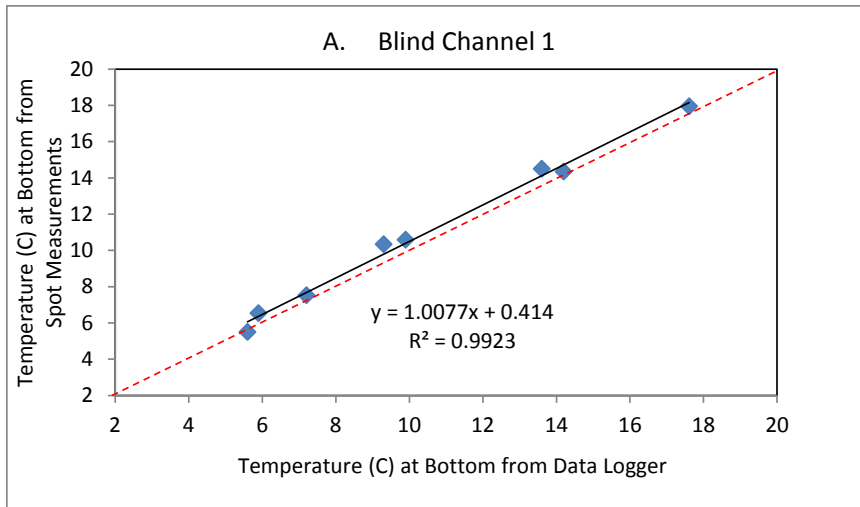


Figure 8. Comparison of water bottom temperatures from the continuous-read data loggers (x axis) and spot measurements (y axis) taken during beach seining in the new blind channel sites at Fisher Slough, 2012. The 1:1 line is shown as a dashed line in each figure.

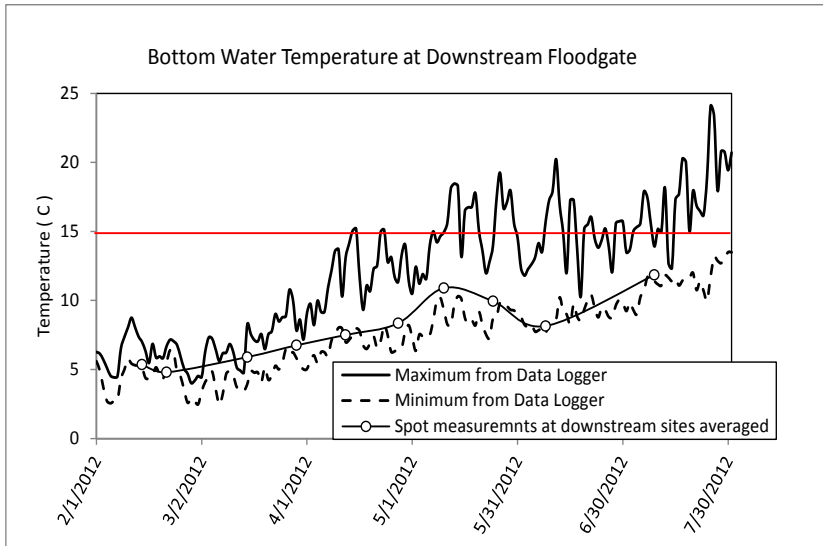


Figure 9. Maximum and minimum of temperature from the data logger at Downstream Floodgate and daily average bottom temperature from spot measurements at sites Fisher Sl Outside Tidegate S and Fisher Sl Blind Ch averaged together during the fish sampling time period in Fisher Slough, 2012. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

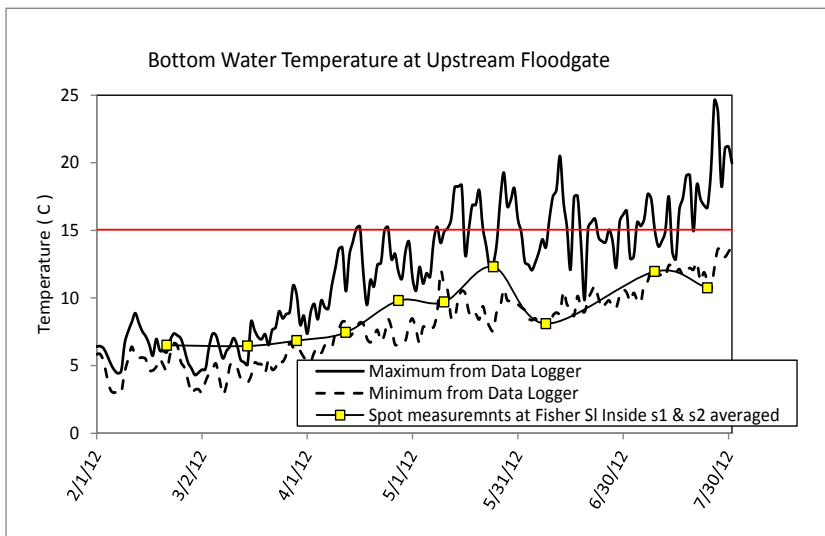


Figure 10. Maximum and minimum of temperature from data logger at Upstream Floodgate and daily average bottom temperature from spot measurements at sites Fisher Sl Inside s1 and s2, averaged together during the fish sampling time period in Fisher Slough, 2012. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

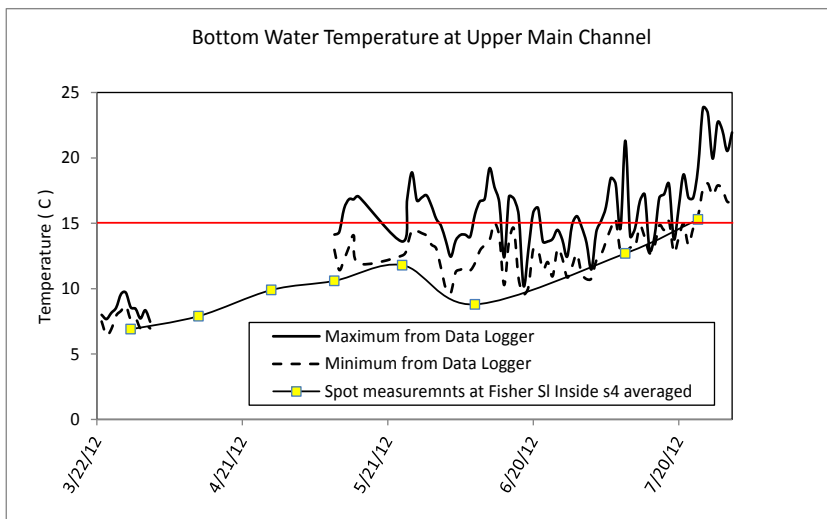


Figure 11. Maximum and minimum of temperature from data logger at Upper Main Channel and daily average bottom temperature from spot measurement at Fisher Sl Inside s4, during the fish sampling time period in Fisher Slough, 2012. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006). Programming problems in the data logger resulted in intermittent data until May 10.

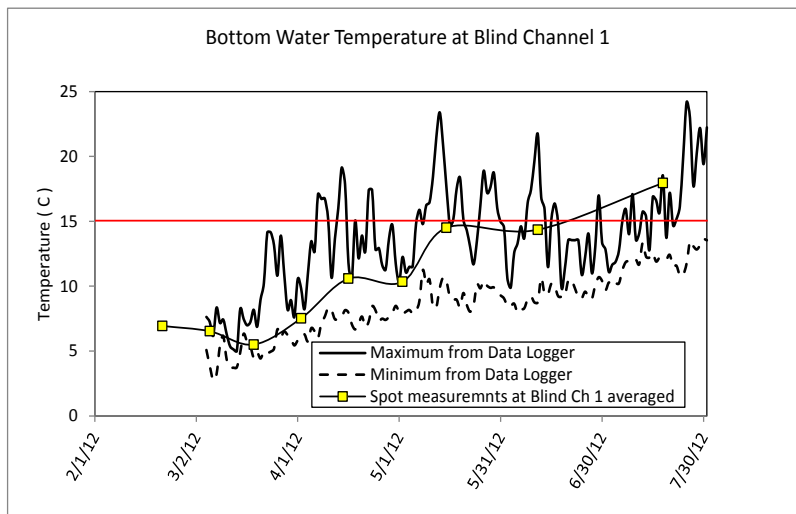


Figure 12. Maximum and minimum of temperature from data logger at Blind Channel 1 site and daily average bottom temperature from spot measurements at the random beach seine sites within Blind Channel 1 during the fish sampling time period in Fisher Slough, 2012. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

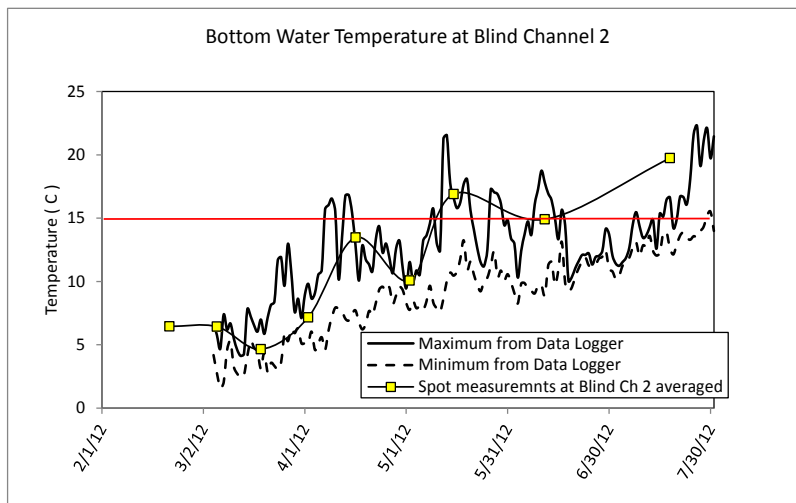


Figure 13. Maximum and minimum of temperature from data logger at Blind Channel 2 site and daily average bottom temperature from spot measurements at the random beach seine sites within Blind Channel lobe 2 during the fish sampling time period in Fisher Slough, 2012. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

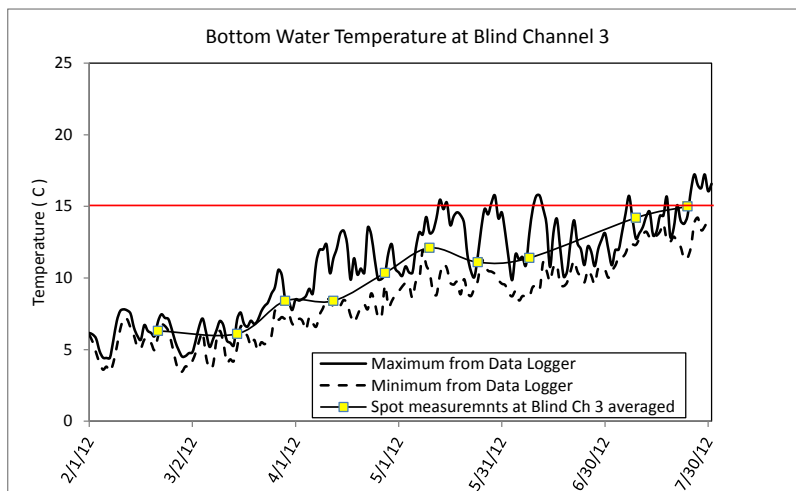


Figure 14. Maximum and minimum of temperature from data logger at Blind Channel 3 site and daily average bottom temperature from spot measurements at Fisher Sl Inside s5 and the random beach seine site within Blind Channel 3 during the fish sampling time period in Fisher Slough, 2012. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

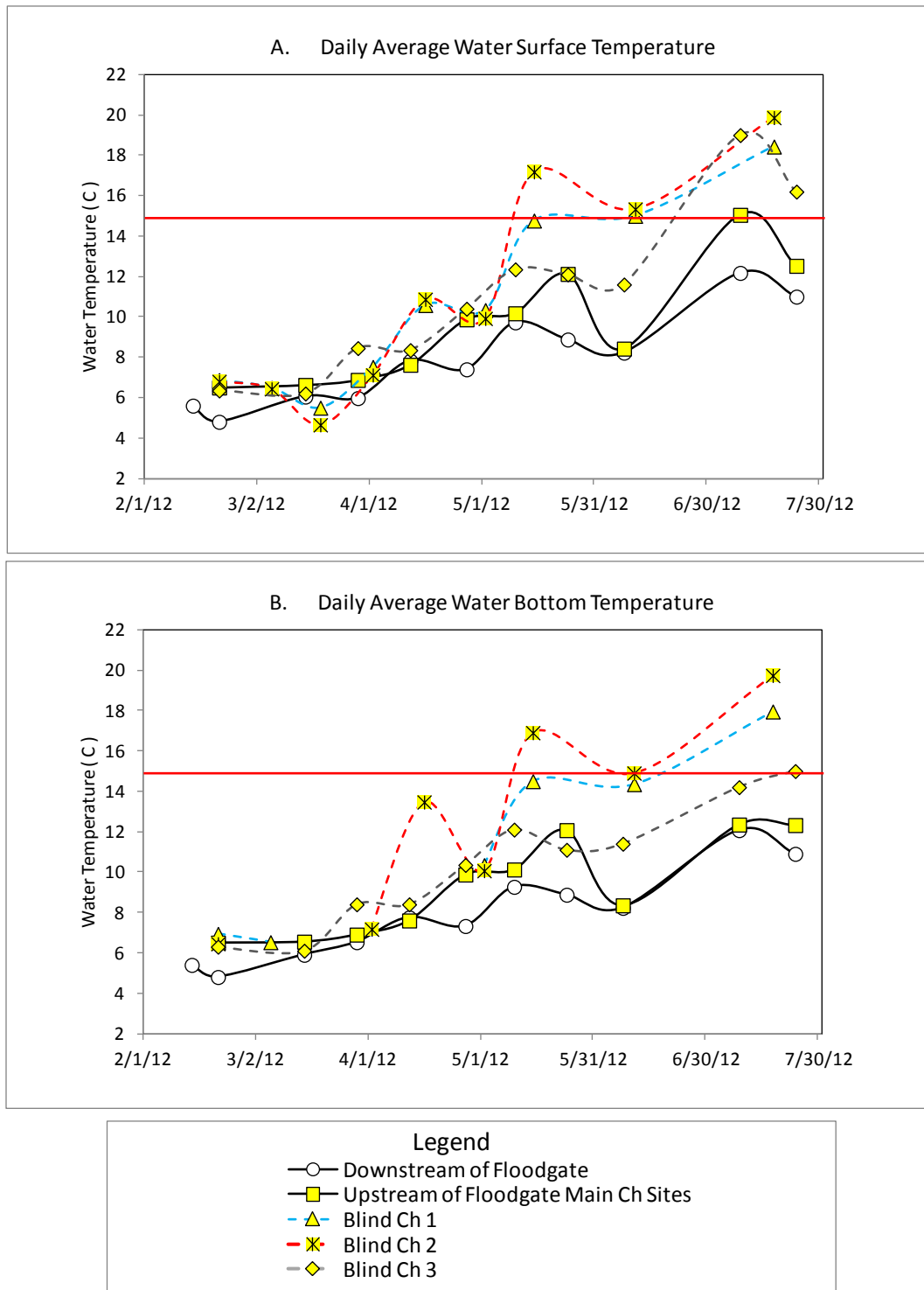


Figure 15. Comparison of daily average water surface (panel A) and water bottom (panel B) temperature in degrees Celsius from spot measurements for combined downstream sites, combined upstream main channel sites and the three blind channel sites by fish sampling day at Fisher Slough in 2012. Horizontal line at 15 °C shows the temperature postulated as stressful to juvenile Chinook salmon in estuaries (Fresh 2006).

Dissolved oxygen

Water dissolved oxygen values are shown in Appendix A, Tables 9 and 10.

Comparison of collection methods

Dissolved oxygen level results are available from two methodological sources: (1) spot measurements taken at the time of beach seine sampling or fyke trap sampling and (2) continuously-reading data loggers. Spot measurements are limited compared to the data logger results in temporal coverage (one time per site on 19 different sampling days compared to 15-minute readings for five months with the loggers), but stronger than the data loggers in spatial coverage (ten sites compared to four for the loggers).

There was positive correlation in measured DO levels between measurement methods at all of the comparison sites (Figures 16 and 17) but spot measurements were consistently higher than data logger measurements and the relationships are weaker than observed between methods in 2011 (Beamer et al. 2013a). Individual spot-measured and continuous-read data logger-measured DO levels differed by as much as 2.4 mg/L at the Downstream Floodgate site, by 3.6 mg/L at the Upstream Floodgate site, and by 1.7 mg/L at the Upper Main Channel site. Average differences in DO levels between the two methods were less than 2.4 mg/L for the Downstream Floodgate site, 2.2 mg/L for the Upstream Floodgate site, and 0.6 mg/L for the Upper Main Channel site (Figure 16). Comparisons in the blind channel lobes showed that the spot-measured DO data varied by site, higher in Blind Channels 1 and 2 and lower in Blind Channel 3 than those recorded by the continuous-read data loggers (Figure 17). The average difference was 0.31 mg/L.

Statistical comparison of DO level by site and date

Tests were made to see whether our spot measurements of DO collected at the time of fish sampling were influenced by site, strata, or date. Statistical analysis reveals a strong ($p < 0.001$) influence on DO by site (Appendix A, Table 11), strata (Appendix A, Table 12), and season (Appendix A, Tables 11 and 12). Pair-wise comparison of groups for sites and sampling date are shown in Appendix A, Tables 13 and 14, respectively. The main conclusions are:

1. The combined sites located downstream of the floodgate had higher DO values than the combined upstream floodgate sites.
2. The difference in DO between the two groups (up- or downstream) increased as the season progressed.
3. Both groups had a seasonal decrease in DO.

Each of these findings is discussed further in the following sections below.

Temporal variation in DO

Both dissolved oxygen measurement methods show a seasonal decrease in DO levels (Figures 18-23). Daily fluctuations in DO levels existed throughout the monitoring period, but the largest fluctuations occurred in the summer. The fluctuations regularly exceeded 3 mg/L per day at the sites Downstream Floodgate and Upstream Floodgate, and varied by 5 mg/L at the Upper Main Channel site (Figures 18-20). At the blind channel sites DO daily fluctuation was between 3 and 4 mg/L on 36 days and was greater

than 5 mg/L on 20 days of the 109 days it was in use (Figure 21). The maximum daily fluctuation for the Downstream Floodgate site was 5.6 mg/L on May 8; for Upstream Floodgate it was 4.5 mg/L on July 8; for the Upper Main Channel it was 15.9 mg/L on May 17. In the combined blind channel lobes the maximum daily average fluctuation was 10.8 mg/L on May 10.

Comparison of DO level by site

A simple graphical illustration of site influence is visible in Figure 23. Main channel sites upstream of the floodgate were lower in DO levels than sites downstream of the floodgate. The blind channel sites were lower than the sites located in the channels.

Comparison of DO results to Washington State water quality standards

Results from continuous-read data loggers show that the DO levels for the site Downstream Floodgate fell below the 6.5 mg/L threshold level on 136.25 hours (4.9% of the time); at the Upstream Floodgate site the DO was below 6.5 mg/L for 245.0 hours (8.7% of the time); at the Upper Main Channel site it was below 6.5 mg/L for 204.75 hours (7.2% of the time). At the combined Blind Channel lobes it was below 6.5 mg/L for 266.25 hours (14.9% of the time) the loggers were in place and operating correctly (Figures 18 to 24).

Data from the spot measurements during fish sampling show that the DO levels fell below 6.5 mg/L on one of the nine days of sampling (11.1% of the sample days) for surface water and on three of the nine days (33.3% of the sample days) for bottom water for the blind channel sites upstream of the floodgate (Figure 23). Spot-measured DO levels at the sites downstream of the floodgate and the upstream main channel sites never fell below 6.5 mg/L.

Comparison of DO by tidal stage and day/night patterns

Based on DO fluctuation measured in 2011, we expected DO fluctuations based on tidal stage during the time of year when a large daily range in DO exists (Beamer et al. 2013a). Looking at 2012 DO results from loggers during July when daily fluctuation in DO was most extreme, the DO fluctuation was possibly correlated with tidal cycle and day/night cycles (Figure 24).

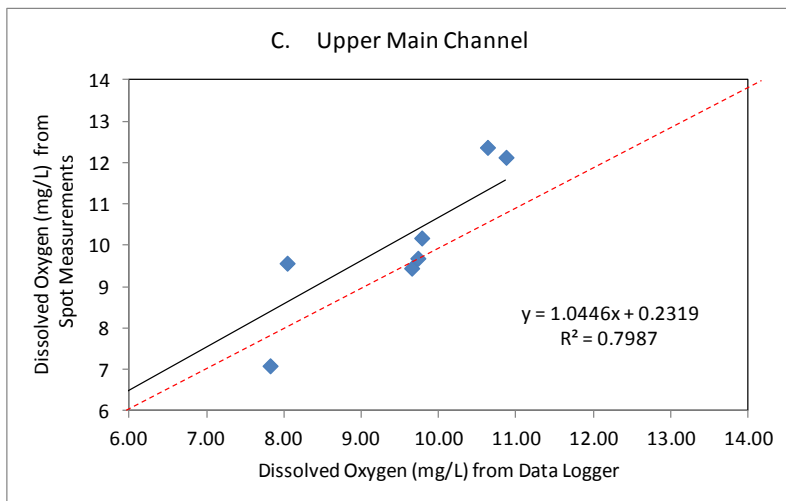
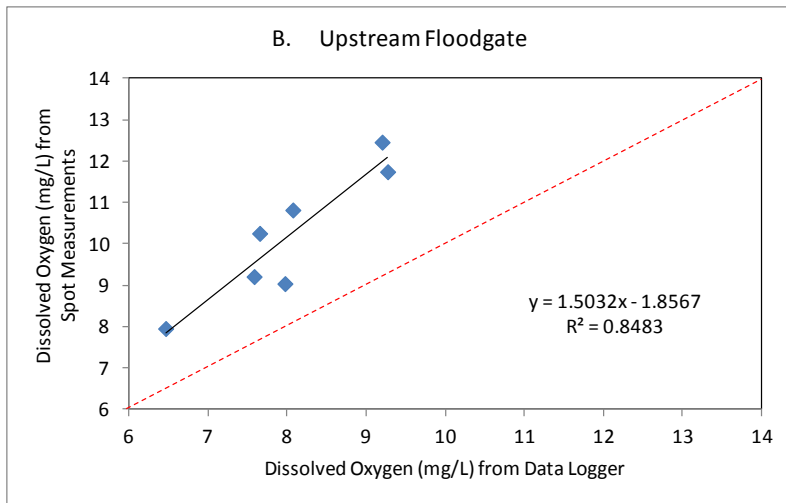
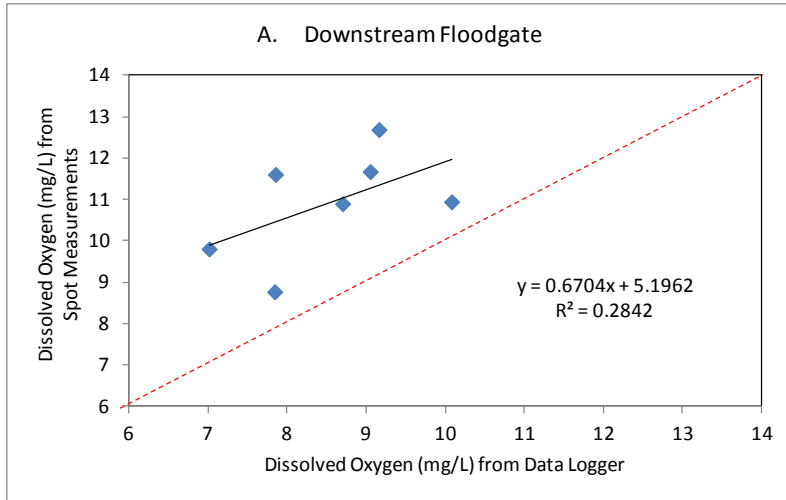


Figure 16. Comparison of water bottom dissolved oxygen levels from continuous-read DO data loggers (x axis) and spot measurements taken during beach seining (y axis) in the main channel sites of Fisher Slough, 2012. The 1:1 line is shown as a dashed line in each figure.

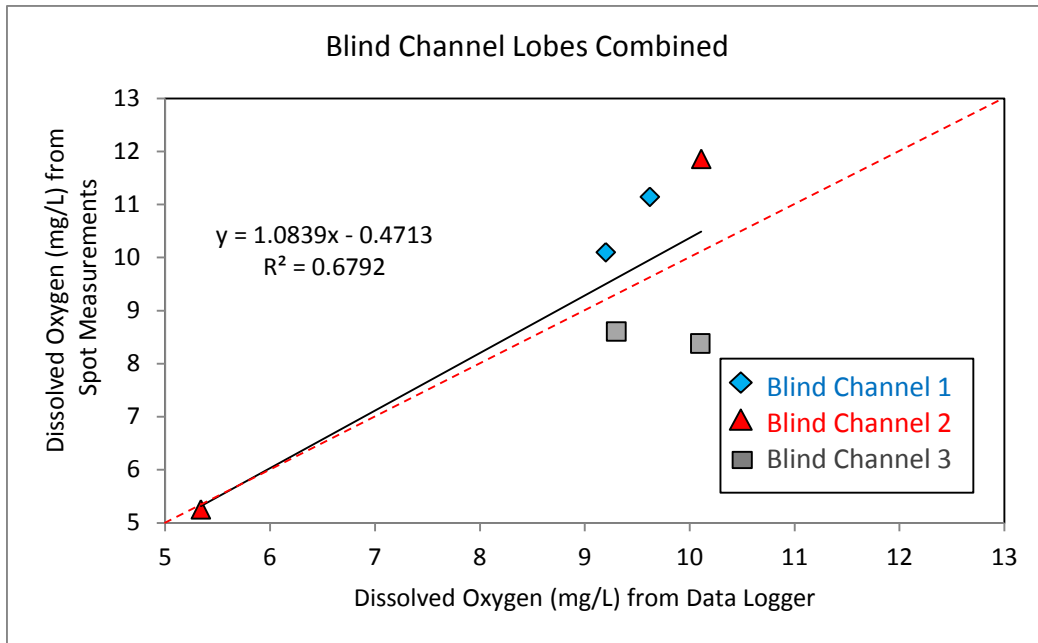


Figure 17. Comparison of water bottom dissolved oxygen levels from the continuous-read DO data logger (x axis) and spot measurements taken during beach seining (y axis) in the blind channel lobes of Fisher Slough, 2012. The 1:1 line is shown as a dashed line.

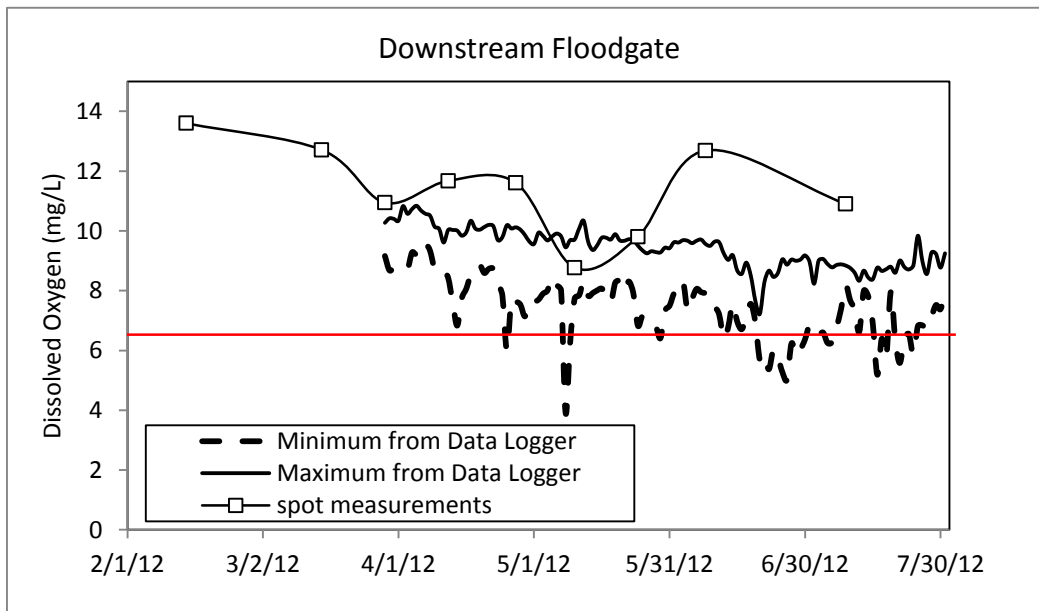


Figure 18. Maximum and minimum of dissolved oxygen from the continuous-read DO data logger at the Downstream Floodgate site and daily average bottom dissolved oxygen from spot measurements at sites Fisher SL Outside Tidegate S and Fisher SI Blind Ch downstream of floodgate during the fish sampling time period in Fisher Slough, 2012. 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.

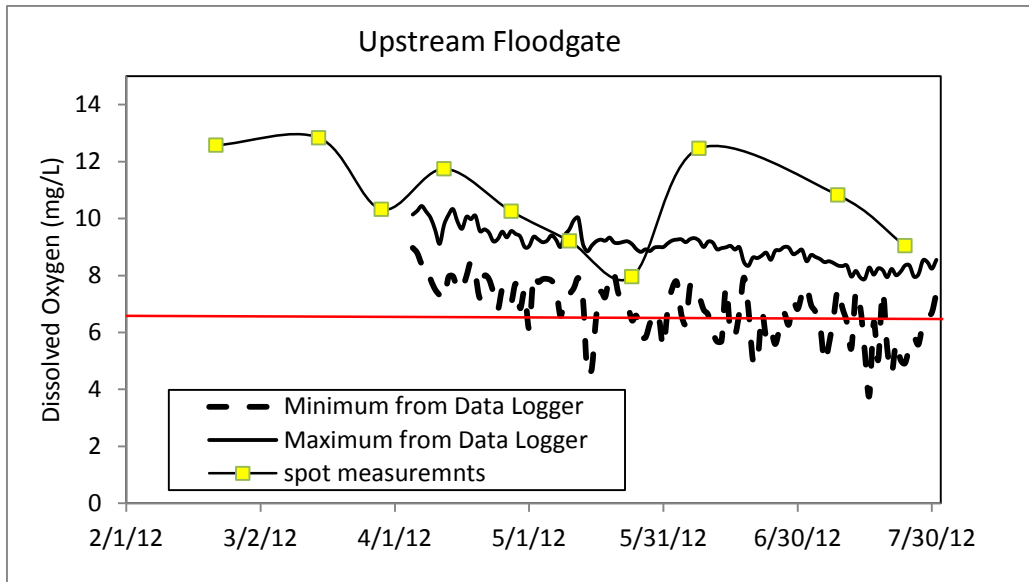


Figure 19. Maximum and minimum of dissolved oxygen from the continuous-read DO data logger at the Upstream Floodgate site and daily average bottom dissolved oxygen at sites Fisher Sl s1 and s2 upstream of floodgate from spot measurements during the fish sampling time period in Fisher Slough, 2012. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migration.

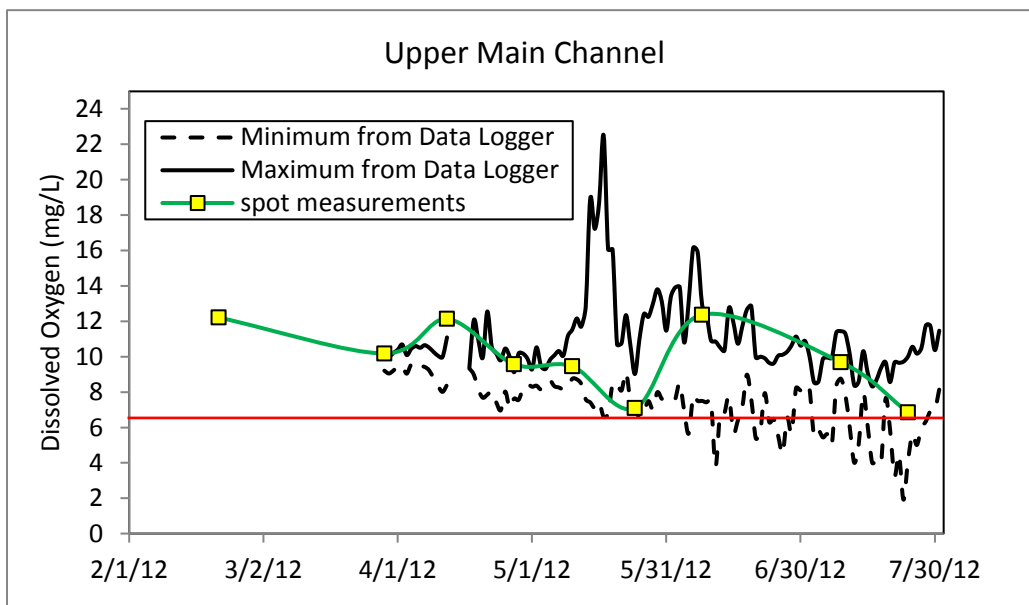


Figure 20. Maximum and minimum of dissolved oxygen from the continuous-read DO logger at the Upper Main Channel site and daily average bottom dissolved oxygen from spot measurements at site Fisher Sl s4 during the fish sampling time period in Fisher Slough, 2012. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migration.

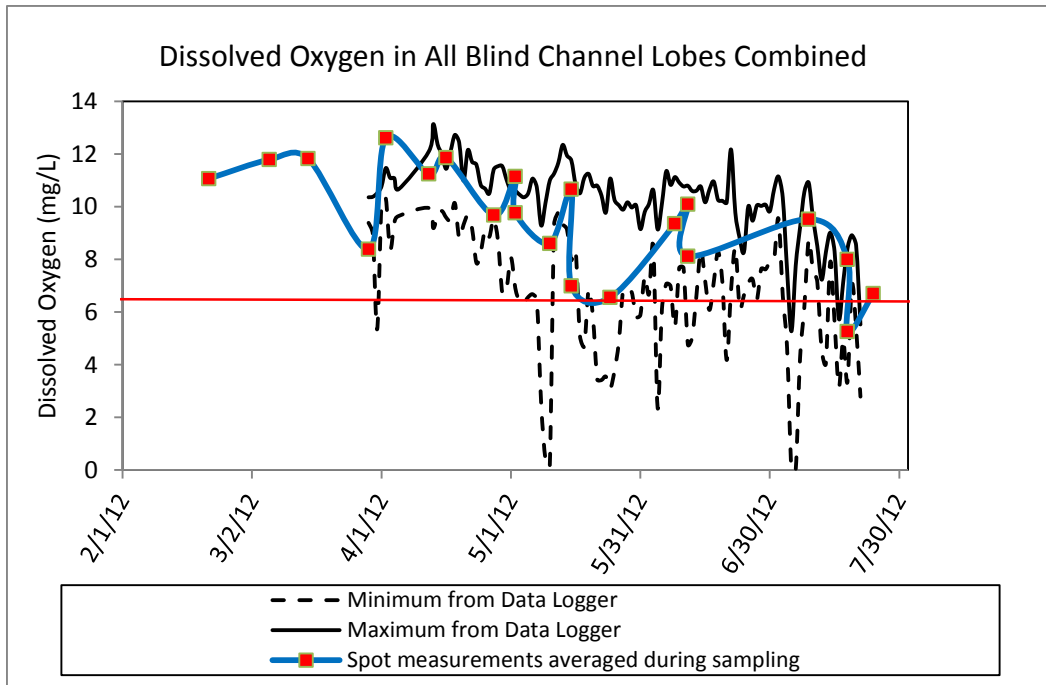


Figure 21. Maximum and minimum of dissolved oxygen from the continuous-read DO data logger rotated through the blind channel lobes and the daily average bottom dissolved oxygen from spot measurements at the random beach seines sites in each blind channel lobe during the fish sampling time period in Fisher Slough, 2012. 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.

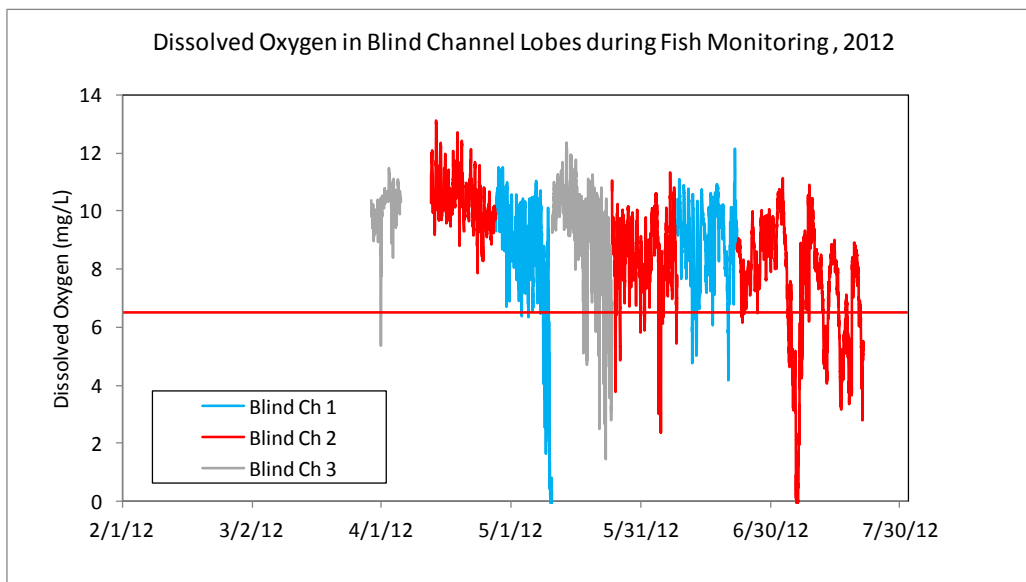


Figure 22. Water bottom dissolved oxygen level in mg/L from the continuous-read DO data logger rotated through the Blind Channel lobes at Fisher Slough in 2012. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migration.

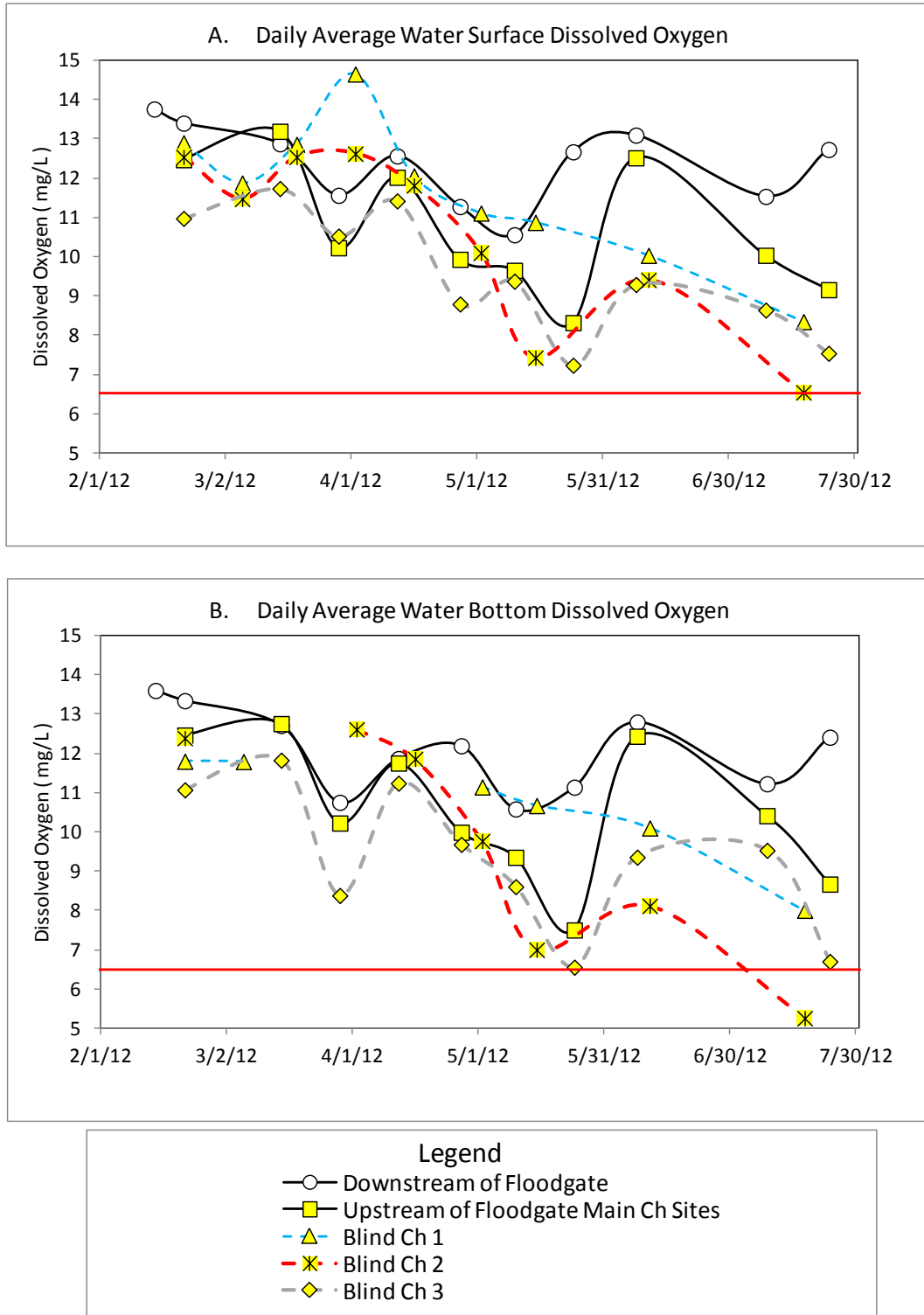


Figure 23. Comparison of daily average dissolved oxygen level in mg/L at the water surface (panel A) and water bottom (panel B) for combined upstream and combined downstream sites by sampling day at Fisher Slough in 2012. Horizontal line at 6.5 mg/L is the water quality standard in Washington State for DO levels in waters with salmonid rearing and migration.

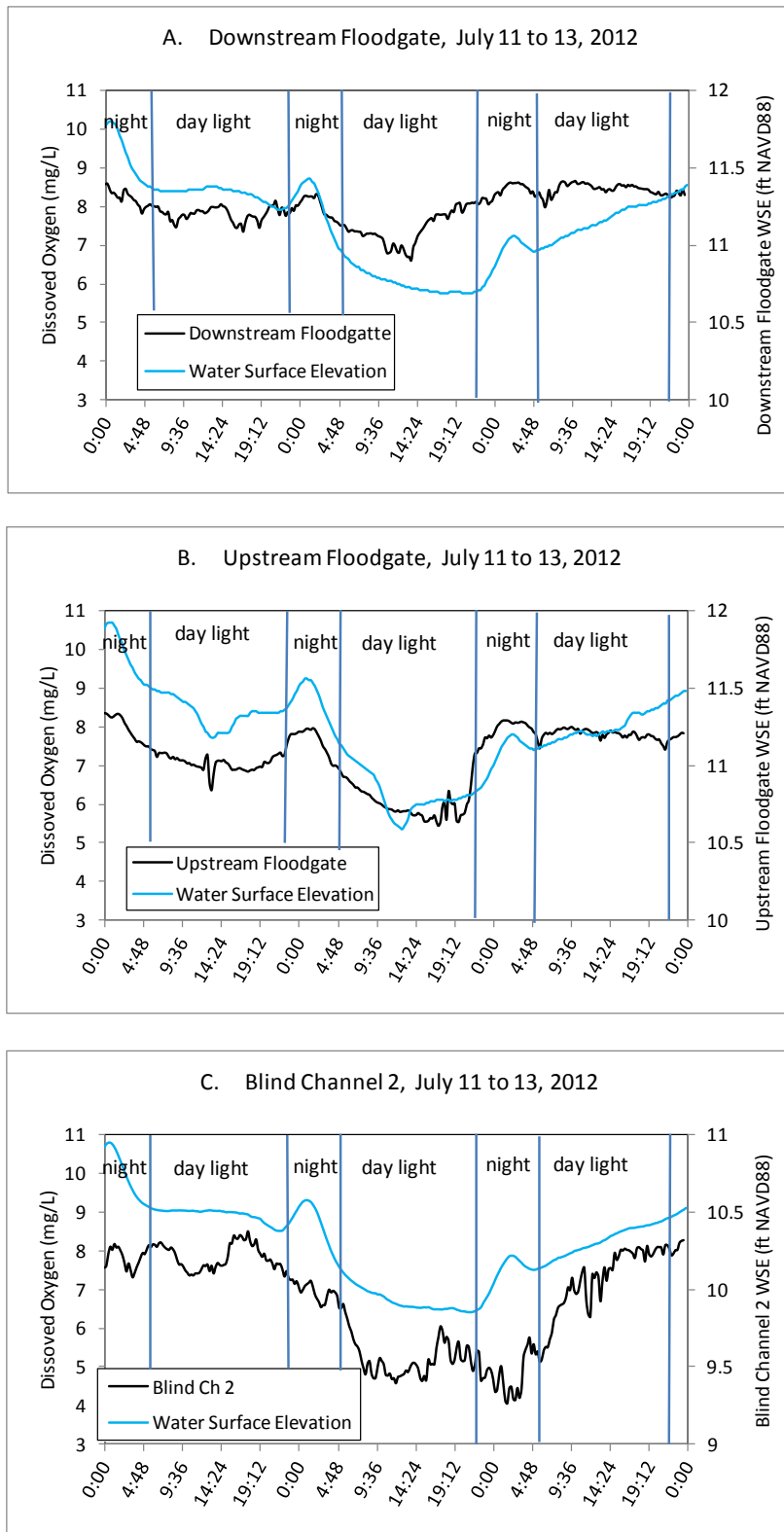


Figure 24. Dissolved oxygen levels from the continuous-read DO data logger and water surface elevation downstream (panel A) and upstream (panel B) of the Fisher Slough floodgate and at Blind Channel 2 (panel C) over a three-day period, July 11-13, 2012. Note different scale on the secondary Y axis in panel C.

Water depth

The water depth at each site varied with tidal conditions and surface water flow. Water depth for sites located upstream of the floodgate also varied with distance from the floodgate, getting gradually shallower further upstream (Table 5). Water depth at each site met our minimum water depth threshold (0.20 meters) for juvenile Chinook salmon rearing on all sample dates.

Table 5. Maximum water depth in meters for sites at Fisher Slough in 2012. The first three columns under 'Upstream of Floodgate' represent combined random sampling sites in each blind channel lobe.

Date	Upstream of Floodgate							Downstream of Floodgate		
	Blind Ch 1	Blind Ch 2	Blind Ch 3	Fisher Sl Inside s1	Fisher Sl Inside s2	Fisher Sl Inside s3	Fisher Sl Inside s4	Fisher Sl Tidegate Outside S	Tom Moore Sl Upper Area	Fisher Sl Blind Ch
14-Feb										1.93
21-Feb	0.55	0.67	1.35	1.90	1.40	1.45	1.30	2.50	1.55	
6-Mar	0.57	0.48								
15-Mar			1.60	2.00	2.50	1.80	1.80	2.00	1.55	1.76
19-Mar	0.37	0.49								
29-Mar			0.95	2.15	2.15	1.50	1.20	3.90	1.00	1.55
2-Apr	0.26	0.55								
12-Apr			1.28	2.00	2.40	1.55	1.25	2.00	1.50	1.37
16-Apr	0.23	0.49								
27-Apr			1.73	2.20	2.60	1.89	1.69	3.00	1.60	1.74
2-May	0.71	0.69								
10-May			1.10	2.25	2.20	1.55	1.35	3.75	1.63	1.44
15-May	0.92	0.81								
24-May			1.75	2.80	2.50	2.00	2.00	3.30	2.05	1.95
8-Jun			1.40	3.30	2.50	1.50	1.50	3.00	1.73	1.49
11-Jun	0.52	0.78								
9-Jul			1.45	3.60	3.20	1.90	1.90	3.70	1.88	2.11
18-Jul	1.13	0.94								
24-Jul			1.20	1.80	1.60	1.30	1.20	2.00	1.50	

Water velocity

Water velocity upstream of the floodgate increased slightly with distance from the floodgate and location within Fisher Slough (Table 6). At Fisher Sl Inside s1, there was measurable velocity on three of the ten sampling days. There was measureable velocity on two of the nine sampling days at Blind Channel 1, while at Blind Channel 2 and 3 there was no measureable velocity on any of the sampling days.

For the main channel sites upstream of the floodgate, the velocity threshold for juvenile Chinook salmon preference (0.20 m/s) and the threshold for presence (0.38 m/s) were exceeded during 10.0% of the sampling occurrences. This occurred all on one day, February 21, when the sampling followed a major rain event that resulted in flows around 0.5 m/s at the four main channel sites. For sites downstream of the floodgate, the velocity threshold for juvenile Chinook salmon presence was exceeded on 9.7% of the sampling occurrences. On 22.5% of the sampling occurrences the velocity threshold for juvenile Chinook salmon preference was exceeded. The majority of the occurrences were at Tom Moore Sl Upper Area.

Table 6. Average water velocity (m/s) at Fisher Slough in 2012. Values that exceed juvenile Chinook salmon preference of 0.20m/s are shown in bold (Beamer et al. 2005). The first three columns under 'Upstream of Floodgate' represent combined random sampling sites in each blind channel lobe.

Date	Upstream of Floodgate							Downstream of Floodgate		
	Blind Ch 1	Blind Ch 2	Blind Ch 3	Fisher Sl Inside s1	Fisher Sl Inside s2	Fisher Sl Inside s3	Fisher Sl Inside s4	Fisher Sl Tidegate Outside S	Tom Moore Sl Upper Area	Fisher Sl Blind Ch
14-Feb										0.00
21-Feb	0.00	0.00	0.00	0.50	0.51	0.51	0.54	0.60	0.00	0.00
6-Mar	0.00	0.00								
15-Mar			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19-Mar	0.00	0.00								
29-Mar			0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00
2-Apr	0.00	0.00								
12-Apr			0.00	0.00	0.00	0.00	0.00	0.20	0.24	0.00
16-Apr	0.06	0.00								
27-Apr			0.00	0.00	0.08	0.00	0.00	0.05	0.24	0.00
2-May	0.02	0.00								
10-May			0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00
15-May	0.00	0.00								
24-May			0.00	0.11	0.00	0.08	0.00	0.26	0.43	0.00
8-Jun			0.00	0.00	0.00	0.00	0.00	0.17	0.19	0.00
11-Jun	0.00	0.00								
9-Jul			0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00
18-Jul	0.00	0.00								
24-Jul			0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00

Substrate and vegetation

The substrate classification found 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 29 the vegetation within the main channel grew so that all sites were classified as fresh water aquatic plants, made up primarily of pondweed. Seventy-nine percent of the sets within Blind Channels 1 and 2 were classified as unvegetated while 75% of the sets made in Blind Channel 3 were covered with pond weed. The pondweed species were not identified.

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 14,832 fish representing 19 fish species found in the sampling at Fisher Slough from February 14 to July 24, 2012. 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 7.

Table 7. Total catch by species at Fisher Slough sites February 14 through July 24, 2012. Mean catch per unit effort (beach seine set or per fyke trap daily catch) is in parentheses.

Gear:	beach seine					fyke trap
Strata:	Upstream of floodgate				Downstream of floodgate	
Strata2:	Blind Ch 1 sites	Blind Ch 2 sites	Blind Ch 3 sites	Main channel sites	Main channel sites	Fisher Sl Blind Ch
Salmonid species:						
Chinook salmon, unmarked subyearling <i>Oncorhynchus tshawytscha</i>	266 (4.93)	873 (16.17)	250 (12.50)	112 (5.77)	102 (3.40)	59 (6.56)
Chinook salmon, hatchery origin, all marks and ages combined <i>Oncorhynchus tshawytscha</i>	1 (0.02)	2 (0.04)	0 (0.12)	5 (0.48)	0 (0.00)	0 (0.00)
Coho salmon, unmarked subyearling <i>Oncorhynchus kisutch</i>	21 (0.39)	3522 (65.22)	107 (0.54)	22 (1.40)	5 (0.17)	1 (0.11)
Coho salmon, unmarked yearling <i>Oncorhynchus kisutch</i>	15 (0.28)	144 (2.67)	18 (0.51)	21 (2.21)	9 (0.30)	0 (0.00)
Chum salmon subyearling <i>Oncorhynchus keta</i>	3 (0.06)	12 (0.22)	2 (0.05)	2 (0.22)	4 (0.13)	2 (0.22)
Pink salmon subyearling <i>Oncorhynchus gorbuscha</i>	0 (0.00)	2 (0.04)	0 (0.00)	0 (0.00)	23 (0.77)	3 (0.33)
Cutthroat trout, all ages <i>Oncorhynchus clarki</i>	11(0.20)	5 (0.09)	24 (0.15)	6 (0.65)	1 (0.03)	3 (1.00)
Steelhead salmon subyearling <i>Oncorhynchus mykiss</i>	0 (0.00)	0 (0.00)	3 (0.02)	0 (0.00)	0 (0.00)	0 (0.00)
Steelhead salmon, unmarked yearling <i>Oncorhynchus mykiss</i>	0 (0.00)	0 (0.00)	1 (0.02)	1 (0.16)	0 (0.00)	0 (0.00)
Unidentified trout, subyearling <i>Oncorhynchus mykiss or clarki</i>	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.16)	1 (0.03)	0 (0.00)
Whitefish, all ages <i>Prosopium williamsi</i>	24 (0.44)	9 (0.17)	2 (0.10)	3 (0.47)	3 (0.1)	0 (0.00)
Total salmonids:	341	4566	407	173	147	68
Other fish species:						
Three-spine stickleback <i>Gasterosteus aculeatus</i>	905 (16.76)	1997 (36.98)	1925 (96.25)	3037 (74.07)	546 (18.20)	37 (4.11)
Peamouth chub <i>Mylocheilus caurinus</i>	60 (1.11)	169 (3.13)	73 (3.65)	5 (0.12)	2 (0.07)	180 (20.00)
Large scale sucker <i>Catostomus macrocheilus</i>	0 (0.00)	0 (0.00)	75 (16.30)	2 (0.31)	0 (0)	1 (0.11)
Prickly sculpin <i>Cottus asper</i>	5 (0.29)	3 (0.30)	5 (0.44)	7 (0.50)	10 (0.33)	28 (4.54)
Pacific staghorn sculpin <i>Leptocottus armatus</i>	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0)	1 (0.11)
Starry flounder <i>Platichthys stellatus</i>	2 (0.04)	6 (0.11)	0 (0.00)	6 (0.15)	6 (0.20)	1 (0.11)
Redside shiner <i>Richardsonius balteatus</i>	0 (0.00)	5 (0.09)	0 (0.00)	0 (0.00)	0 (0)	0 (0.00)
Unidentified Bass <i>Micropterus spp</i>	0 (0.00)	0 (0.00)	1 (0.05)	0 (0.00)	0 (0)	0 (0.00)
Bluegill <i>Lepomis macrochirus</i>	1 (0.02)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0)	0 (0.00)
Pumpkinseed <i>Lepomis gibbosus</i>	1 (0.02)	5 (0.09)	0 (0.00)	0 (0.00)	0 (0)	1 (0.11)
Unidentified juvenile sunfish	0 (0.00)	0 (0.00)	1 (0.05)	0 (0.00)	0 (0)	0 (0.00)
Unidentified Chub	0 (0.00)	17 (0.31)	0 (0.00)	0 (0.00)	0 (0)	0 (0.00)
Lamprey	0 (0.00)	1 (0.02)	0 (0.00)	0 (0.00)	0 (0)	0 (0.00)
Total other fish species:	974	2203	2080	3057	564	249
Total fish catch:	1315	6769	2487	3230	711	317
Other non-fish species:						
Roughskin newt <i>Taricha granulosa</i>	0 (0.00)	0 (0.00)	2 (0.10)	2 (0.05)	0 (0)	0 (0.00)
Freshwater mussel <i>Anodonta spp.</i>	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.31)	0 (0)	0 (0.00)
Total non- fish species:	0	0	2	4	0	0
Total Catch:	1315	6769	2489	3234	711	307

Upstream of the floodgate

The sampling effort at the sites upstream of the floodgate caught 13,802 fish of 19 different species (Table 5). All juvenile salmon species combined represented 39.8% of the total fish catch above the floodgate. Wild sub-yearling (young of the year) Chinook salmon comprised 27.4% of the juvenile salmon catch in 2012. The wild sub-yearling coho salmon comprised 66.9% of the juvenile salmon group. Cutthroat trout accounted for 0.8% of the juvenile salmon catch. Chum salmon fry, pink salmon fry, hatchery Chinook salmon, steelhead salmon and Mountain whitefish were a minor part of the juvenile salmon catch upstream of the floodgate. There was one trout fry that was too small to be identified to species.

Three-spined stickleback was the predominant species caught, accounting for 57.0% 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 (2.2%), prickly sculpin (0.1%), pumpkinseed sunfish (0.04%), starry flounder (0.10%), large scale sucker (0.56%) and red-sided shiner (0.04%).

Downstream of the floodgate

The sampling effort at the sites downstream of the floodgate caught 1,028 fish of 14 different species (Table 5). All juvenile salmon species combined represented 20.9% of the total fish catch below the floodgate. Wild sub-yearling Chinook salmon comprised 74.9% of the combined salmon group catch in 2012. Wild sub-yearling coho salmon comprised 2.8% of the salmon caught. Pink salmon fry accounted for 12.1% of the juvenile salmon catch. The remainder of the salmonid catch was minor in their percentages and 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 56.7% of the fish caught below the floodgate. Peamouth chub accounted for 17.7% and prickly sculpin 3.7% of the fish catch below the floodgate. The remainder of the catch included starry flounder (0.68%), large scale sucker (0.10%), pumpkinseed sunfish (0.10%) and Pacific staghorn sculpin (0.10%). Pumpkinseed sunfish and Pacific staghorn sculpin were not caught in 2011 (Table 5).

The fish assemblage is shown in Figures 25 and 26 as the monthly average density of fish per hectare for the various sampling locations at Fisher Slough.

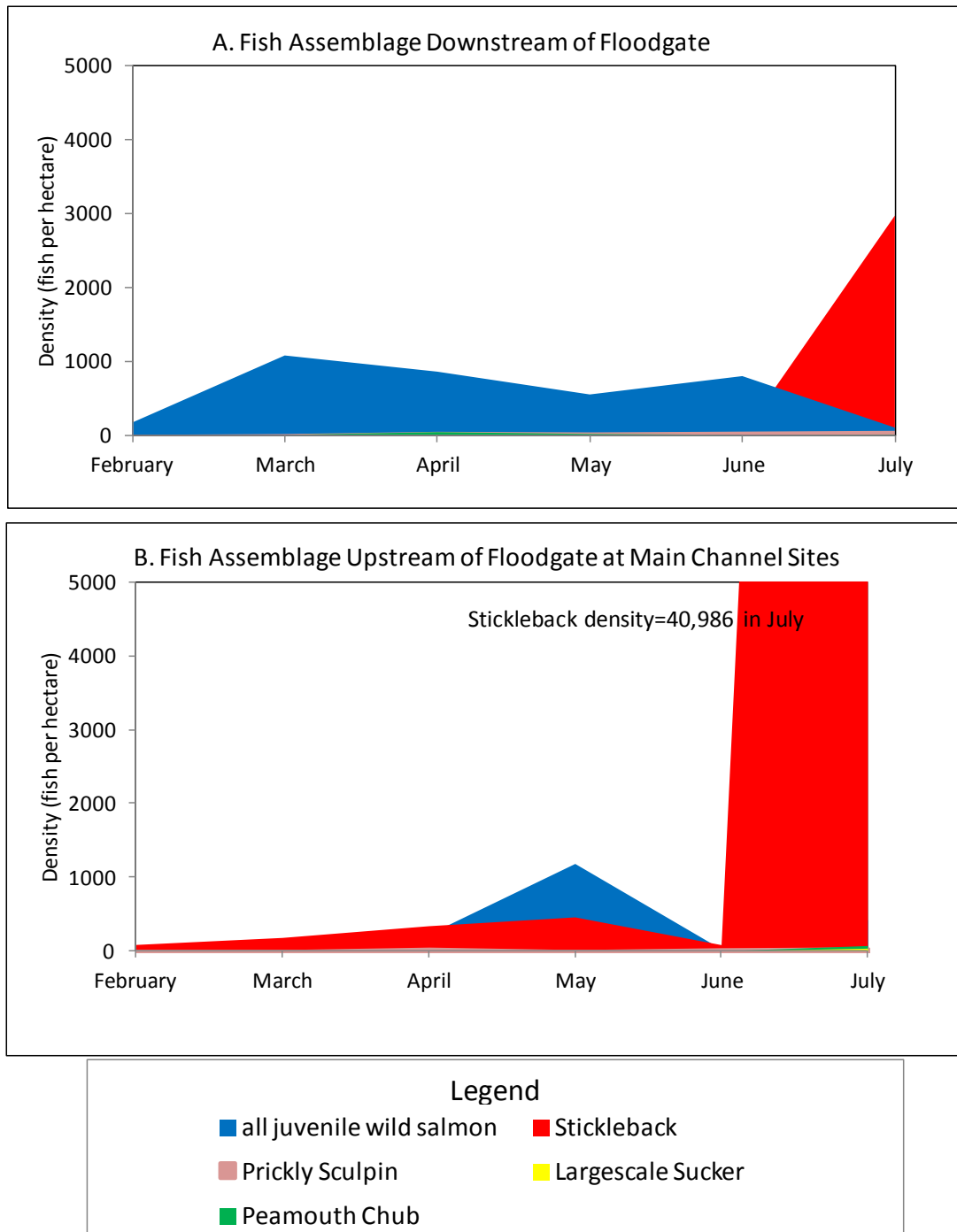


Figure 25. Fish assemblage at Fisher Slough in 2012 at the combined downstream sites and the combined main channel sites upstream of the floodgate.

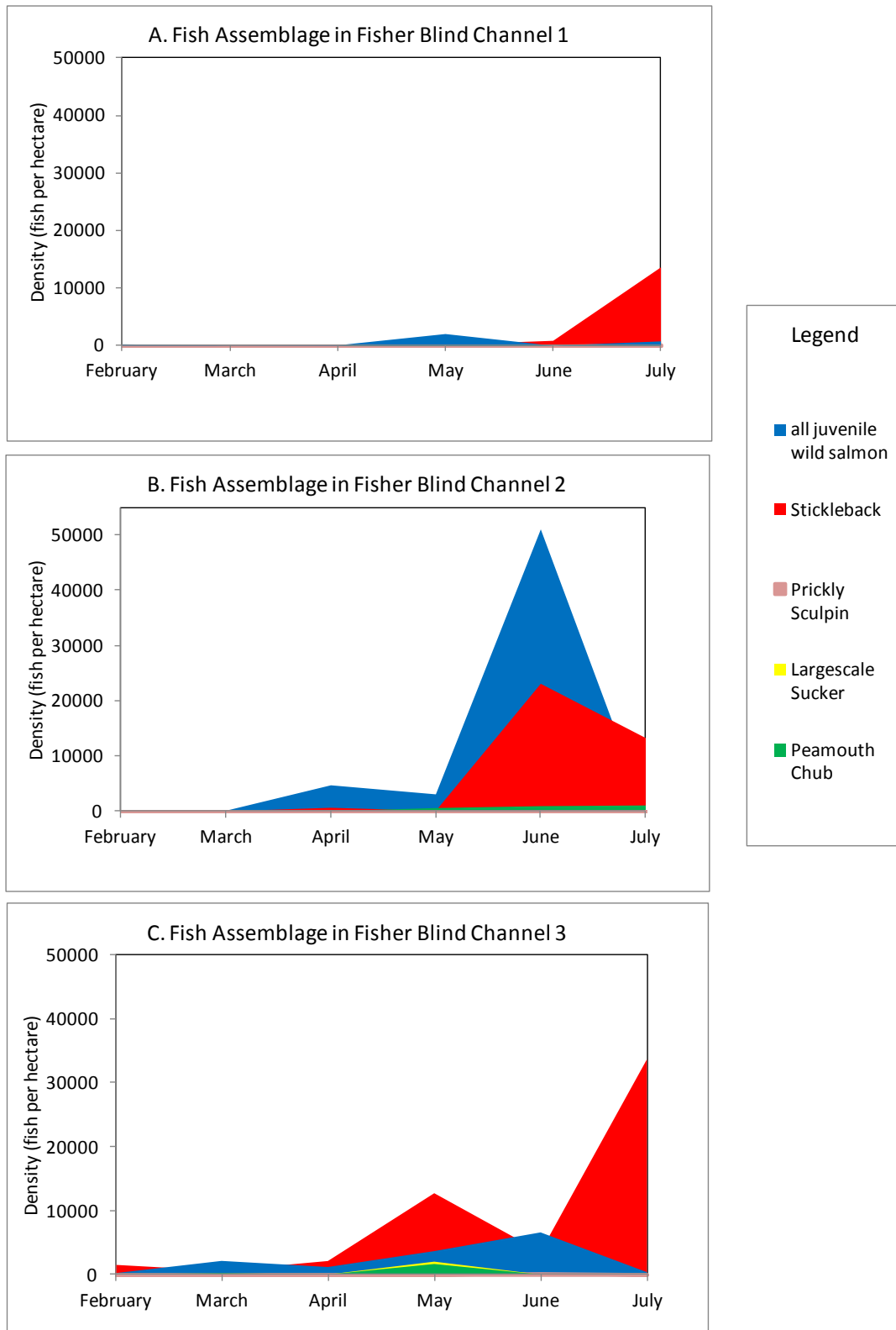


Figure 26. Fish assemblage at Fisher Slough in 2012 at the blind channel sites. Note the difference in Y axis scale between Figure 25 and 26.

Juvenile Chinook salmon density

Comparison of juvenile Chinook salmon density by site and date

Upstream of the floodgate

Juvenile wild Chinook salmon were found upstream of the floodgate in Fisher Slough in February 2012. Peak density of juvenile wild Chinook salmon caught in the main channel sites was during May when the monthly average density was 911 fish per hectare. In the blind channel lobes the peak density varied by lobe. In Blind Channel 1 the peak was during May with a monthly average of 1,836 fish per hectare, in Blind Channel 2 it was in April with a monthly average of 3,753 fish per hectare, and in Blind Channel 3 the peak was in May with a monthly average of 2,188 fish per hectare (Figure 27). These results demonstrate use by juvenile Chinook salmon of the restored area in the first year after completion, as Blind Channels 1 and 2 were farmed fields in 2009 through 2011. There was still juvenile sub-yearling Chinook salmon present in every section of the upstream area when sampling ended on July 24.

Downstream of the floodgate

Juvenile wild Chinook salmon were present downstream of the floodgate in the main channel sites at Fisher Slough in February and in the reference blind channel site in March 2012. Peak density of juvenile wild Chinook salmon for the main channel sites was in March with 1,117 fish per hectare. Peak density in the reference blind channel fyke trap site was in April with 2,116 fish per hectare. The density of Chinook salmon declined in May and increased slightly in June. Juvenile Chinook salmon were still present downstream of the floodgate in the main channel sites when sampling was finished July 24 (Figure 27).

Statistical analysis

Statistical analysis revealed juvenile wild Chinook salmon density was influenced by sampling date and strata2 within Fisher Slough, both up- and downstream of the floodgate (Table 8). Group comparisons shows that three of the four blind channel strata2 had higher Chinook salmon density than all other strata2 (Table 9).

Table 8. Two-Way Analysis of Variance results for log transformed wild juvenile Chinook salmon density at Fisher Slough, 2012. Factor A is a surrogate for sampling date (Month.Event). The category Month.Event was developed because it took two weeks to sample all sites. Most months had two sample events. Factor B is Strata2 (sub-groups of sites within areas upstream and downstream of the floodgate, see Table 2 for list of sites).

Source	Sum of Squares	Degrees of freedom	Mean Squares	F	p
Factor A: Month.Event (sampling date)	66.661	7	9.523	6.242	0.000
Factor B: Strata2 (sites within areas upstream and downstream of the floodgate)	62.077	5	12.415	8.138	0.000
Interaction between Factors A&B	132.786	35	3.794	2.487	0.000
Error	598.009	392	1.526		

Table 9. Group comparisons of strata2 using Scheffé Test for sites within areas upstream and downstream of the floodgate (see Table 2 for list of sites).

Groups	Difference	p
DS FG Main Channel v DS FG Ref Blind	-0.930	0.020
DS FG Main Channel v US FG Blind 1	0.533	0.306
DS FG Main Channel v US FG Blind 2	-0.088	0.999
DS FG Main Channel v US FG Blind 3	-1.057	0.077
DS FG Main Channel v US FG Main Channel	0.107	0.993
DS FG Ref Blind v US FG Blind 1	1.463	0.000
DS FG Ref Blind v US FG Blind 2	0.842	0.118
DS FG Ref Blind v US FG Blind 3	-0.126	1.000
DS FG Ref Blind v US FG Main Channel	1.037	0.002
US FG Blind 1 v US FG Blind 2	-0.621	0.304
US FG Blind 1 v US FG Blind 3	-1.590	0.002
US FG Blind 1 v US FG Main Channel	-0.426	0.458
US FG Blind 2 v US FG Blind 3	-0.969	0.200
US FG Blind 2 v US FG Main Channel	0.195	0.967
US FG Blind 3 v US FG Main Channel	1.164	0.024

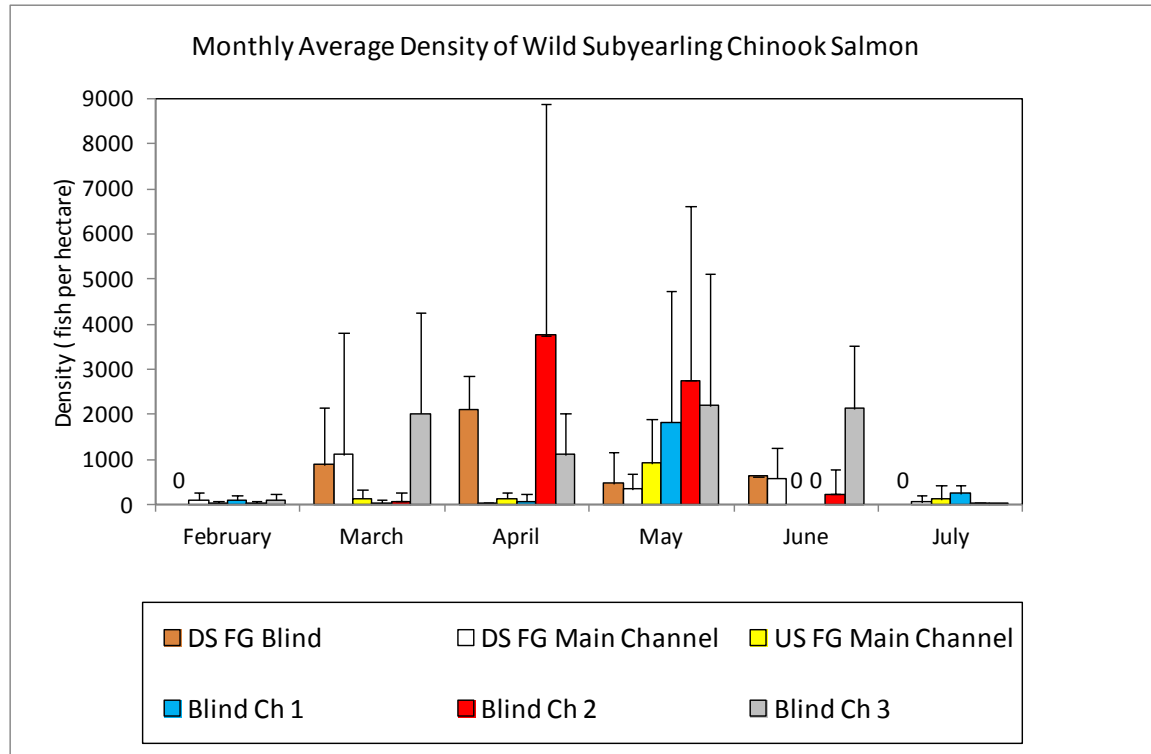


Figure 27. Comparison of the monthly average density of wild subyearling Chinook salmon for combined upstream and combined downstream main channel sites, the downstream reference blind channel site, and the three blind channel sites by sampling day at Fisher Slough, 2012. Error bars are one standard 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 9). Comparison of the strata groups for each year reveals whether differences between groups in wild Chinook salmon density are significant (Table 10).

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 28), but it is not significant at the 0.05 level (Table 11). In 2012 (year 3 after floodgate replacement and the first year with new habitat available for fish via the dike setback) had a combined average juvenile wild Chinook salmon density slightly greater upstream of floodgate than downstream of floodgate, though the difference is not statistically significant (Table 11). Graphical results illustrate how differences in wild Chinook salmon density are organized by sites (Figure 29) and season (Figure 30) for the different treatment years and strata. All strata/treatment comparisons are found in Appendix E, Table 1.

Table 10. Two-Way Analysis of Variance results for log transformed wild juvenile Chinook salmon density at Fisher Slough, 2009 through 2012. Treatment influences are: Before (before floodgate replacement and dike setback), After Year 1 and 2 (after floodgate replacement but before dike setback), and After Year 3 (after floodgate replacement and dike setback). Strata influences are sites upstream of the floodgate and sites downstream of the floodgate.

Source	Sum of Squares	Degrees of freedom	Mean Squares	F	p
Factor A: Treatment	26.561	3	8.854	4.755	0.003
Factor B: Strata	20.503	1	20.503	11.012	0.001
Interaction between Factors A&B	25.435	3	8.478	4.554	0.004
Error	1,025.925	551	1.862		

Table 11. Selected group comparisons using Scheffé Test for treatment and strata. Treatments are “before” or “after” floodgate replacement. Treatment influences are: Before (before floodgate replacement and dike setback), After Year 1 and 2 (after floodgate replacement but before dike setback), and After Year 3 (after floodgate replacement and dike setback). Strata influences are sites upstream of the floodgate (US FG) and sites downstream of the floodgate (DS FG).

Groups	Difference	p
2009: Before*DS FG v Before*US FG	0.236	0.996
2010: AfterYr1*DS FG v AfterYr1*US FG	0.989	0.042
2011: AfterYr2*DS FG v AfterYr2*US FG	0.721	0.495
2012: AfterYr3*DS FG v AfterYr3*US FG	-0.230	0.996

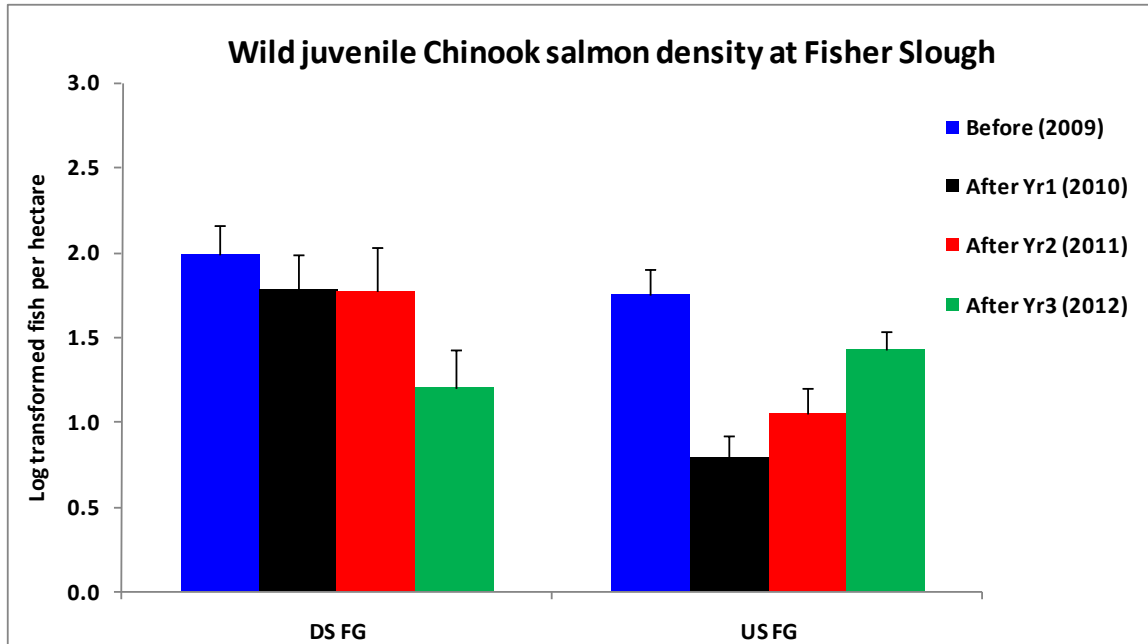


Figure 28. Comparison of mean log transformed wild juvenile Chinook salmon density by treatment and strata. Treatments are “before” or “after” floodgate replacement. Year 3 after floodgate replacement includes dike setback. Strata are “DS FG” (downstream of floodgate) and “US FG” (upstream of floodgate). The sites in each strata are given in Table 2.

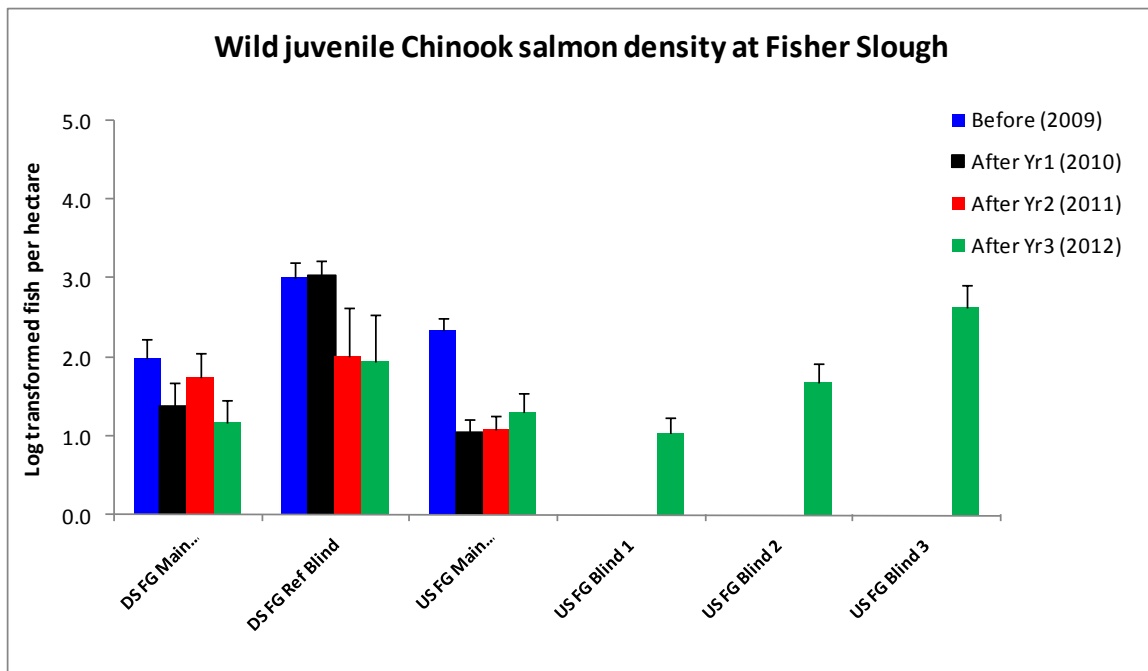


Figure 29. Comparison of mean log transformed wild juvenile Chinook salmon density by treatment and strata2. Treatments are “before” or “after” floodgate replacement. Strata2 are sub-groups of sites up- or downstream of the floodgate. “DS FG” refers to downstream of floodgate. “US FG” refers to upstream of floodgate. Year 3 after floodgate replacement was 2012 and includes habitat restored due to dike setback forming strata2 sites in US FG Blinds 1-3 which were farmed fields in 2009 - 2011.

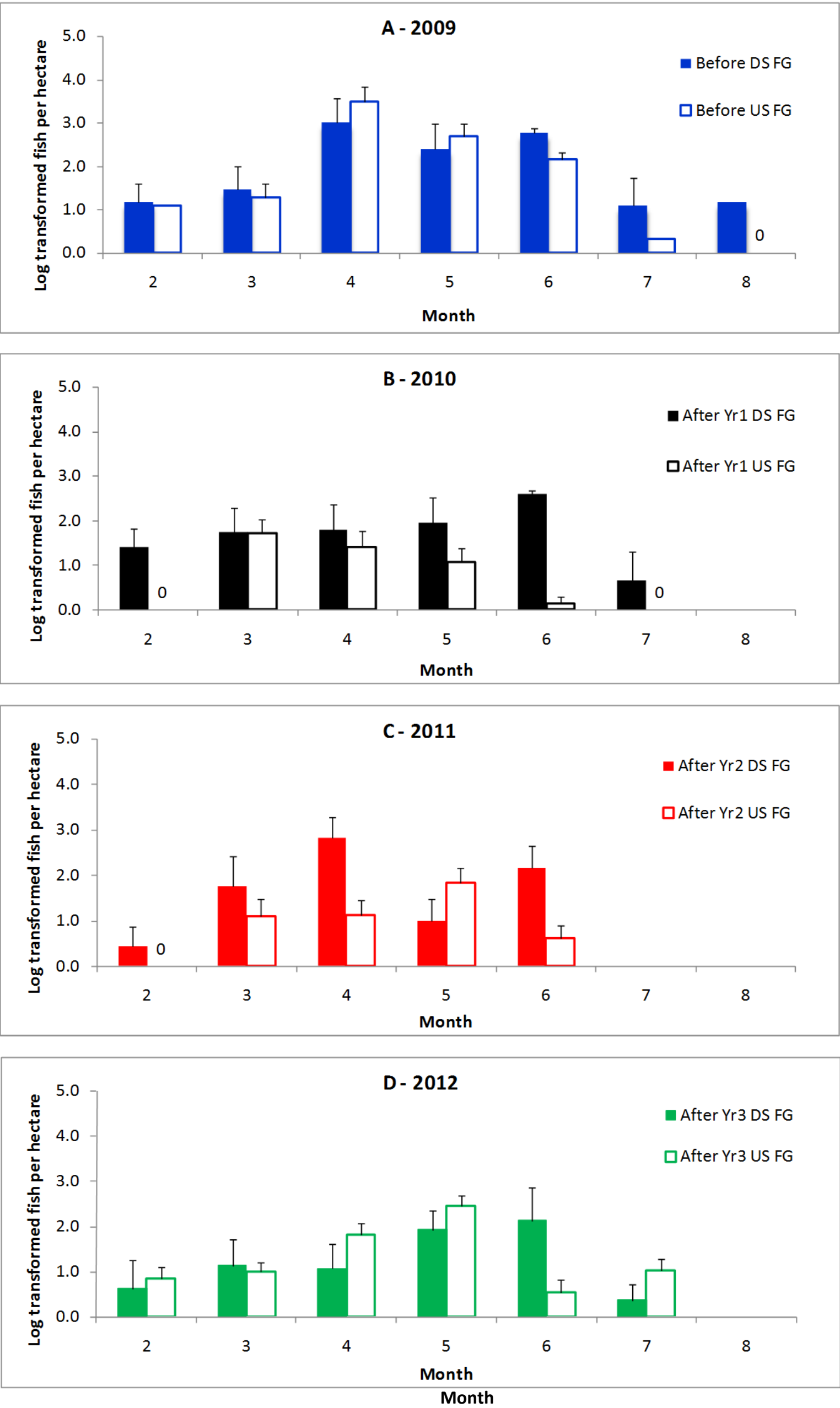


Figure 30. Comparison of mean log transformed wild juvenile Chinook salmon density by treatment and strata combined, and by month. Treatments are “before” or “after” floodgate replacement. Year 3 after floodgate replacement includes dike setback. Strata are “US FG” (upstream of floodgate) or “DS FG”(downstream of the floodgate). Error bars are one standard error. Sample period vary by year; see Table 1 for periods.

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

This section reports 1) the comparison of Fisher Slough monitoring sites for juvenile Chinook salmon density to the long term Skagit River delta monitoring sites and 2) differences in wild Chinook salmon outmigration population estimates for the four years of Fisher Slough monitoring to date: 2009 through 2012.

Landscape connectivity and Chinook salmon seasonal density:

There is a 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 four years when Fisher Slough monitoring has occurred (Figure 31). Depending on the year, landscape connectivity explains 38% 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 cluster within the scatter of the Skagit River long term monitoring sites (Figure 31, panel A). The first two years after floodgate replacement (2010 and 2011), most Fisher Slough sites located upstream of the floodgate plot outside (i.e., lower) of the scatter of the Skagit River long term monitoring sites (Figure 31, panels B and C). In contrast, the Fisher Slough sites located downstream of the floodgate plot within of the scatter of the Skagit River long term monitoring sites during these same years (2010 and 2011). In 2012 (after floodgate replacement and dike setback restoration) all Fisher Slough monitoring sites plot within the scatter of the Skagit River long term monitoring sites (Figure 31, panel D).

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 estimates for the wild juvenile Chinook salmon outmigration are 2.8, 1.6, 3.7 and 4.5 million fish for years 2009, 2010, 2011, and 2012, respectively. All estimates of juvenile Chinook salmon outmigration are from C. Kinsel (WDFW, personal communication).

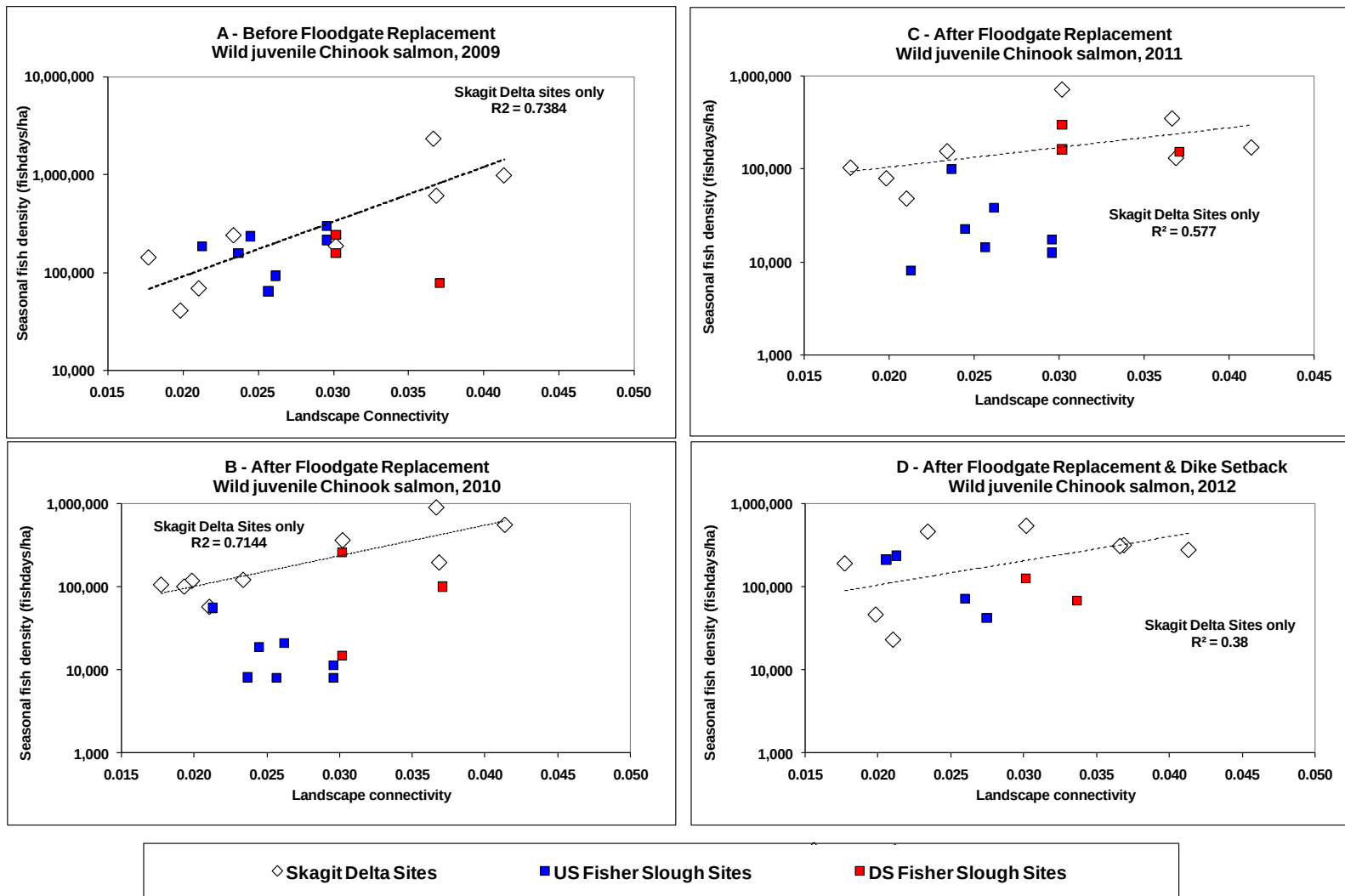


Figure 31. Relationship between landscape connectivity and seasonal Chinook salmon density for Skagit River delta long-term monitoring sites and Fisher Slough monitoring sites, 2009 through 2012. All panels show connectivity calculated to Fisher Slough sites based on fish migration pathways using the downstream end of Tom Moore Slough (avoiding the current log jam at the north end of Tom Moore). Note the different scale on the y-axis in panel A.

Juvenile Chinook salmon size

The fork length was measured on a subsample of all wild subyearling Chinook salmon caught upstream and downstream of the floodgate in 2012 (Figure 32). Chinook salmon lengths up- and downstream of the floodgate from February through April were small and showed no strong increasing or decreasing trend for this period (Figure 32). During this early period, the average juvenile Chinook salmon fork length ranged from 39 to 45 mm, similar to lengths observed in 2009-11. Increased growth started in May and continued until the end of sampling in July.

Fish found downstream of the floodgate increased on average 6.4 and 4.7 mm in length per month during May and June respectively. During July there was a decrease in size but there was only one Chinook salmon measured that month downstream of the floodgate. The average Chinook salmon length was 59.6 mm at the end of June.

Upstream of the floodgate, the size increased on average 12.8, 16.3 and 17.2 mm per month during May through July, respectively, for all sites combined. The average size at the end of sampling in July was 95.5 mm in the main channel sites combined, and 93.3, 114.0, and 76.0 mm in Blind Channels 1, 2 and 3, respectively (Figure 32).

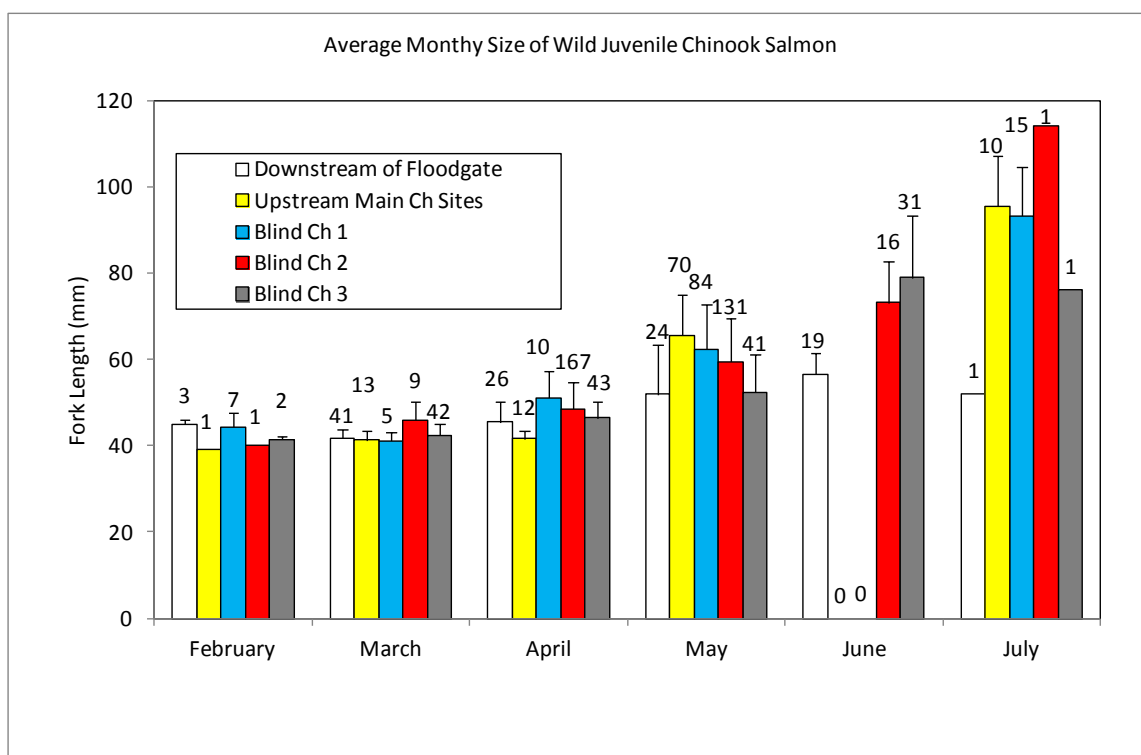


Figure 32 Comparison of the monthly average size of wild subyearling Chinook salmon for combined upstream and combined downstream sites by sampling day at Fisher Slough, 2012. Error bars are one standard deviation. The sample size of fish measured in each month is shown above the bar for each group (upstream and downstream of floodgate). There was only one sampling event in June. During July the main channel sites were sampled twice and the blind channel sites were sampled once.

Other salmon

Yearling coho salmon

Upstream of the floodgate

Yearling coho salmon were present in Fisher Slough upstream of the floodgate when sampling started in February and were found sporadically only in the blind channel lobes. Coho salmon were present in all months in Blind Channel 2 from February through June. The peak density for the upstream floodgate area occurred in this blind channel lobe and was in April, with a monthly average density of 854 fish per hectare of area seined (Figure 33, panel A). In May coho salmon were found in all areas upstream of the floodgate. When fish sampling ended in July, yearling coho salmon were still present in the upstream main channel sites and in Blind Channel 1.

Downstream of the floodgate

Yearling coho salmon were only found in May at sites downstream of the floodgate. The average (and peak) abundance was 117 fish per hectare (Figure 33, panel A).

Sub-yearling coho salmon

Upstream of the floodgate

Coho salmon fry were found in our upstream beach seine catches starting in April (Figure 33, panel B). The density steadily increased, peaking in June and occurred in Blind Channel 2 with 50,593 fish per hectare of area seined. This value was driven by a catch of 3,496 fish in one set made on June 11. Rain during the previous week resulted in a freshet that likely moved fish from the watershed upstream of the project area (Carpenter Creek, Fisher Creek and Hill Ditch areas), relocating them to the refugia within the blind channel lobe. River discharge at the USGS gage at Nookachamps Creek near Clear Lake reached 26.58 ft NAVD88 on June 3, 2012 and then receded to 20.38 feet NAVD88 on June 10, the day prior to this catch (Appendix C, Figure 1).

Downstream of the floodgate

Subyearling coho salmon were found starting in April at sites downstream of the floodgate (Figure 33, panel B). The peak density was in June with an average of 52 fish per hectare of area seined. Coho salmon fry were still present when the sampling stopped in July and the monthly average density was 50 fish per hectare at that time.

Chum salmon

Chum salmon were observed at Fisher Slough in 2012 both up- and downstream of the floodgate. The peak density at sites downstream of the floodgate was in April with a monthly average of 30 fish per hectare of area seined. Upstream of the floodgate, chum salmon were caught every month from February through June, with a peak density of 53 fish per hectare in Blind Channel 3 in June (Figure 33, panel C).

Pink salmon

Pink salmon were caught primarily downstream of the floodgate and had a peak monthly average density of 200 fish per hectare of area seined in April. Upstream of the floodgate,

they were found only in Blind Channel 2, with an average monthly density of 15 fish per hectare, also occurring in April.

Cutthroat trout

Cutthroat trout were present in the catch upstream of the floodgate every month during sampling except for March. The peak catch was in June, with a monthly average density of 938 fish per hectare of area seined. The peak catch occurred in Blind Channel 3. Cutthroat trout were found downstream of the floodgate in the months of March and June. The density of cutthroat trout was always higher at sites upstream of the floodgate than at downstream sites (Figure 33, panel D).

Hatchery-origin salmon

There were eight hatchery-origin Chinook salmon caught at Fisher Slough in 2012, all upstream of the floodgate. Six were sacrificed in order to read the Coded Wire Tag (CWT) located in their snout. Two of the fish were marked only with an adipose fin clip and did not have a CWT in their snout and therefore were released unharmed. All of the tags came from the WDFW hatchery at Marblemount on the Skagit River. Three of the hatchery Chinook salmon were caught in the blind channel sites on July 18 and five were caught in the main channel sites on July 24.

Steelhead

Two juvenile yearling steelhead salmon were found during sampling in 2012. They were captured upstream of the floodgate in the main channel sites and in Blind Channel 3. One sub-yearling was found in the upstream main channel sites as well.

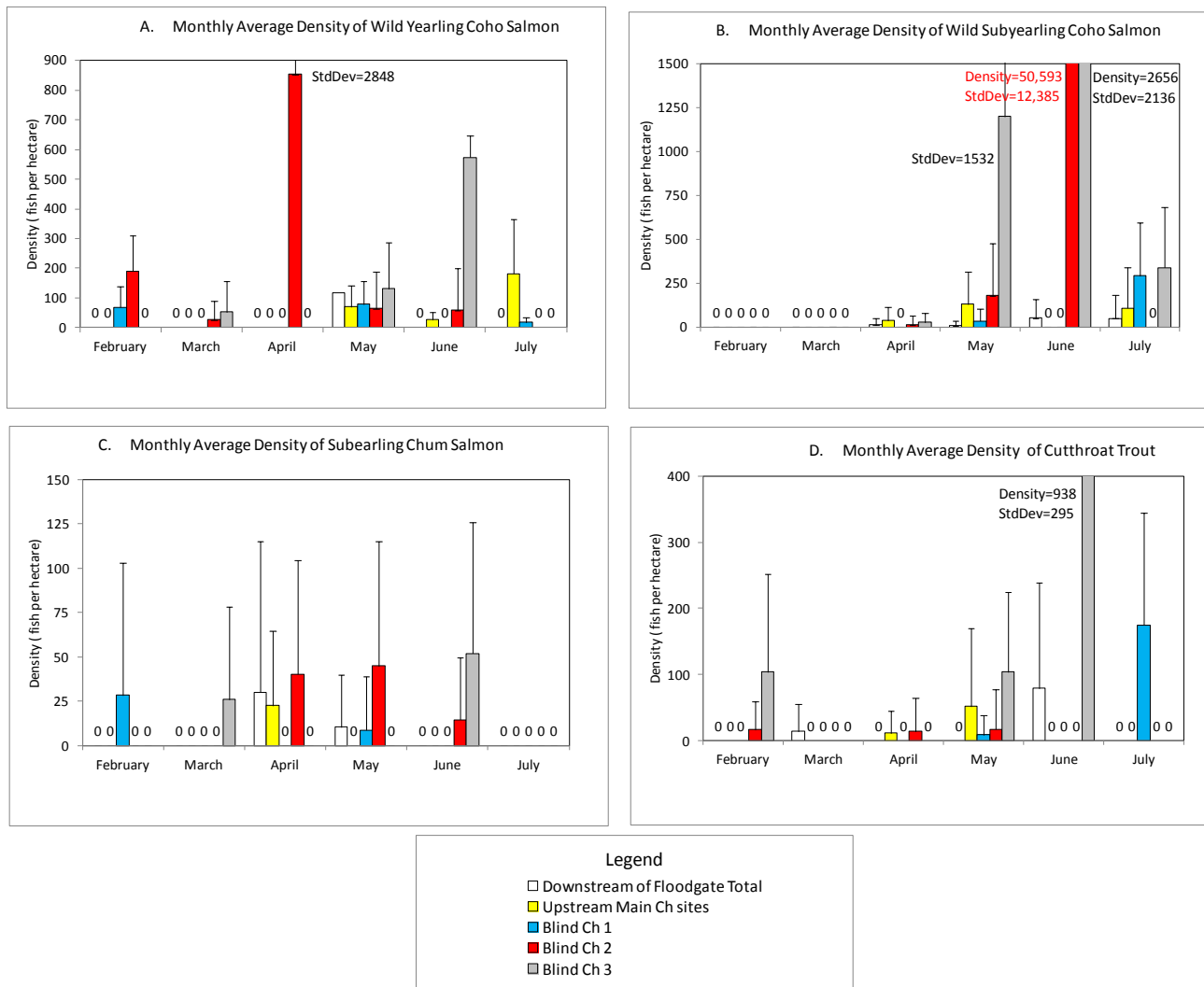


Figure 33. Comparison of the monthly average density of coho salmon, chum salmon and cutthroat trout for combined upstream and combined downstream sites by sampling day at Fisher Slough in 2012. Error bars are one standard deviation. Note the different scales on the y axes.

Non-fish biota

Rough-skinned newts

There were four rough-skinned newts caught in the sampling at Fisher Slough, all upstream of the floodgate. Two of the newts were found in the main channel sites and two were caught in Blind Channel 3. In 2011 there were 37 newts captured, 35 at the old sampling sites Fisher Sl Inside s6 and s7. These two sites are not sampled in the strategy established for fish monitoring in 2012.



Rough-skinned newt.

Freshwater mussels

There were two freshwater mussels counted in the 2012 beach seine samples, both upstream of the floodgate. As with the newts described above, during 2009 through 2011 the mussels were caught in the old side channel sites at Fisher Sl Inside s6 and Fisher Sl Inside s7, which are not currently sampled.

Discussion

Upstream juvenile salmon fish passage opportunity at the floodgate

Fisher Slough floodgate monitoring results for Water Year 2012 (WY2012), which encompasses October 1, 2011 through September 30, 2012, are presented in Beamer and Henderson (2013). Floodgate door opening characteristics thought to equate to juvenile salmon upstream passage opportunity are discussed in Beamer and Henderson (2012). This section reiterates these characteristics and presents results for each of the four 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 14.5% of the time in 2012 (Table 12). 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 is 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 occurred from 38% to 47% of the time over the four years of monitoring at Fisher Slough (Table 12). 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. It is recommended this statistic be calculated as part of future floodgate monitoring at Fisher Slough.

Table 12. Summary of floodgate door results for each year of Fisher Slough fish monitoring.

Year	% of time doors closed	% of time doors open	% of time upstream migration possible
2009 ^A	28.3	71.7	45.5
2010 ^B	10.0	90.0	45.0
2011 ^C	7.0	93.0	46.8
2012 ^C	14.5	85.5	37.6

^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 The methods used in 2009 were repeated 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

Fisher Slough is 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 because estimated values are well below the > 4.5 ppt threshold value hypothesized to be stressful for juvenile Chinook salmon.

A caveat to the 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. This test was not conducted 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 –The conclusion is that data logger results help our understanding of temporal variation in water temperature (e.g., complete seasonal and daily fluctuations) for the sites within Fisher Slough, whereas our spot measurements of water temperature conducted during beach seining help our understanding of spatial variation in water temperature within Fisher Slough. It is recommended these data continue to be collected.

Fluctuations in water temperature – Both temperature measurement methods (spot and data 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. It is important to understand how much the water temperature fluctuates daily to determine whether there exists a temperature refuge for juvenile Chinook when the average water temperature is above the 15°C threshold of being stressful.

Comparison to temperature thresholds - Two water temperature threshold values were adopted: 1) $> 15^{\circ}\text{C}$ (stressful to salmon in estuarine habitat) and 2) $> 24.8^{\circ}\text{C}$ (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 period. The upstream sites were warmer than downstream sites and may be driven by Blind Channels 1 and 2 which were generally warmer than all other sites. The overall temperature range in Fisher Slough for sites up- and downstream of the floodgate during fish sampling (through July 24) included water lower in temperature than the 15°C that is postulated as stressful to juvenile Chinook salmon in estuaries. The daily maximum temperature exceeded 15°C at all logger sites but on each day where the threshold was exceeded, the daily minimum temperature was lower than the threshold level. Therefore, fish were not subjected to continual high temperature conditions (Figures 9-14). Maximum water temperature did not exceed the reported lethal temperature for juvenile Chinook salmon (24.8°C) at any site during the 2012 fish monitoring period. We conclude that site differences in water temperature are likely not influencing juvenile Chinook monitoring results between strata in 2012.

Dissolved oxygen

Comparison of collection methods - It is concluded that data logger results help our understanding of temporal variation in DO levels (e.g., complete seasonal and daily fluctuations). We have concerns as to the accuracy of some continual DO measurements in 2012. It is possible that continual DO measurement results in 2012 are lower than the true value because some spot measurements of DO were higher than DO measured by loggers (Figures 16, 18 and 19). The instrument used for spot measurements was calibrated daily.

Spot measurements of DO levels conducted during beach seining helps our understanding of spatial variation in DO levels within Fisher Slough. If measuring accurately, data logger DO results help our understanding of temporal variation in DO levels (e.g., complete seasonal or daily fluctuations).

Comparison to dissolved oxygen thresholds - In 2012 spot measurements of DO were consistently above our minimum threshold of 6.5 mg/L throughout the monitoring period at all sites (Figures 18 through 23). In spite of the concern over data logger accuracy, i.e., measuring DO lower than what it really is, results from loggers show that DO higher than the minimum threshold of 6.5 mg/L was available during each day for most sites upstream of the floodgate and all sites downstream of the floodgate through our last sampling date. The exceptions were in blind channel lobes in July when few Chinook salmon were caught at any Fisher Slough monitoring site (Figure 27). We conclude that low DO did not likely influence juvenile Chinook salmon monitoring results between strata in 2012.

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 2012 this condition may have occurred in July. 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. Low DO should be more of a problem for juvenile coho salmon or cutthroat trout, which can rear in Fisher Slough year-round. However, the results in 2012 do not support this theory as coho salmon fry and cutthroat trout catches were higher in the blind channel sites upstream of the floodgate compared to the catch at all other sites during July when DO was lowest (Figure 33, 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 all four years of monitoring, 2009 through 2012 (Beamer et al. 2010, 2011, 2013a, and this report). Prior to 2012, the Fisher Slough monitoring sites were exclusively in existing narrowly confined channel area, so factors influencing DO likely were primarily from exterior sources (areas up- or downstream of the restoration project area). In fact, in 2011 and years prior, very low DO from upstream in Carpenter Creek/Hill Ditch (Skagit County Public Works 2012) appears to have contributed to low DO in Fisher Slough (Beamer et al. 2013a). Low DO probably occurred in Hill Ditch in the summer months of 2012, although Skagit County water quality data were not available at the time this report was written. Starting with the 2012 fish monitoring period much more habitat area was available to fish within Fisher Slough because of completion of the dike setback restoration. Therefore, factors influencing habitat conditions had more potential to originate from within the restoration project area as well as from exterior sources. Dissolved oxygen results in 2012 seemed to support the idea of a more complex pattern, influenced by tidal stage as well as by the day/night cycle (Figure 24).

Regardless of the cause of low DO, tidal dilution is an immediate remedy, which can be influenced by floodgate operations such as holding the gate open (the normal operational plan for the floodgate's Summer Irrigation management period). For the four years of fish monitoring at Fisher Slough (2009-2012), the floodgates were held open for the full irrigation period only in 2009. Due to restoration and/or railroad bridge construction in all other years, floodgates were not held open for the full irrigation period. Longer-term remedies for low DO might include restoration of riparian or nutrient-input areas located upstream.

Water depth

Water depth in 2012 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 site and dates sampled. Site differences in water depth are likely not influencing juvenile Chinook salmon monitoring results between sites up- and downstream of the 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 (m/s) and essentially none were captured in velocities greater than 0.38 m/s 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. This suggests the threshold relationship changes over the season, likely related to an increased swimming ability of progressively larger juvenile Chinook salmon.

Water velocity at the Fisher Slough sites during fish sampling in 2012 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. Many of the incidents of preference threshold exceedance occurred February 21, coinciding with a freshet period for tributary inflow and the Skagit River (Beamer and Henderson 2013, Appendices 2 and 3). Juvenile Chinook salmon catches were uniformly low at all sites that day (Figure 27). Because water velocity results compared to the threshold for juvenile Chinook salmon presence were low and similar between strata (10.0% upstream of floodgate, 9.7% downstream of floodgate), we conclude that site differences in water velocity are likely not influencing juvenile Chinook salmon monitoring results between strata.

Substrate and vegetation

The site differences in substrate are likely not influencing juvenile Chinook salmon monitoring results between strata. While substrates are different between the two areas, both are fine-grained material that is known to be used by juvenile salmon and should have equal gear efficiency issues.

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, there is no way to determine whether vegetation significantly influences juvenile Chinook salmon monitoring results. However, future monitoring could investigate whether vegetation characteristics influence juvenile Chinook salmon abundance and sampling gear efficiency.

Salmonids other than Chinook upstream and downstream of the floodgate

It is not surprising to find other species of salmonids in abundance upstream of the floodgate because there are known natal populations of coho salmon and cutthroat trout in the watersheds upstream of Fisher Slough. Adult salmonids returning to these watersheds, due to their larger size, more easily pass through floodgate sites 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 densities of salmon other than Chinook. 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

Comparison of fish density up- and downstream of floodgate

Wild juvenile Chinook salmon density was higher downstream of the floodgate than upstream of the floodgate in 2010, one year after floodgate replacement (Table 11; Figure 30). The results from 2010 were in contrast to results from 2009, before floodgate replacement, where there was no statistical difference in Chinook salmon density upstream versus downstream of the floodgate. The 2010 results were a surprise because the assumption was that the new floodgate would work better for upstream juvenile salmon passage. Year 2 after floodgate replacement (2011) yielded graphical results showing Chinook salmon density to be higher downstream of the floodgate than upstream of the floodgate, but it is not significant at the 0.05 level. Year 3 after floodgate replacement (2012) is the first year with new habitat available for fish via dike setback restoration. Results from 2012 had a combined average juvenile wild Chinook salmon density slightly greater upstream of the floodgate than downstream of the floodgate, though the difference is not statistically significant. Blind channel sites within the dike setback area typically had high juvenile Chinook salmon densities compared to other sites, including the main channel sites downstream of the floodgate. Comparative juvenile Chinook salmon density results from all years suggest there was a positive response of juvenile Chinook salmon to dike setback. Many species of fish were documented as present, if not abundant, in the newly restored habitat as well.

Comparison to Skagit River tidal delta long term monitoring sites

The graphical analysis of juvenile Chinook salmon density and landscape connectivity shows a disruption in the trend with all Skagit River 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 River delta sites after the floodgate was replaced (2010 and 2011). In contrast, scatter plot results from 2012 (Figure 31, panel D) show that Fisher Slough sites (both up- and downstream of the floodgate) are within the normal pattern observed at all other Skagit sites, suggesting there was no disruption at the site of the floodgate in 2012 after completion of dike setback restoration.

New habitat available for juvenile Chinook salmon rearing

While juvenile wild Chinook salmon densities are similar between strata in 2012, the fact that there was so much more habitat available in 2012 suggests overall juvenile wild Chinook salmon abundance was higher in 2012 than in the previous three years. We updated juvenile Chinook salmon carrying capacity for Fisher Slough as all three

restoration elements have been completed, then compared the carrying capacity estimates to juvenile Chinook salmon abundance estimates from our 2012 monitoring results.

Juvenile Chinook salmon carrying capacity is based on two variables: 1) tidal channel area available to fish and 2) landscape connectivity. The methods are described in Beamer et al. (2005) (page 89). Fisher Slough has 4.8 acres (1.943 hectares) of tidal channel upstream of the floodgate now that all three restoration elements have been completed (Beamer et al. 2013b, Hypothesis 7). This amount of tidal channel has the capacity to support 38,773 or 23,935 tidal delta-rearing Chinook salmon smolts annually, depending on which landscape connectivity values are used (Table 13).

The updated carrying capacity and observed fish population estimates for juvenile Chinook salmon at Fisher Slough must be considered in the context of landscape connectivity and outmigrating smolt population size:

- 1) Landscape connectivity – We demonstrated that landscape connectivity to Fisher Slough may have changed from what was reported in the Skagit Chinook Recovery Plan (Beamer et al. 2010); therefore we estimated juvenile Chinook carrying capacity using two different landscape connectivity values. Our analysis of juvenile Chinook density and landscape connectivity (e.g., Figure 31) supports the idea that fish are taking the longer pathway, which predicts the smaller of the two carrying capacity estimates found in Table 13. The smaller carrying capacity estimate (23,953 fish) is lower than the point estimate (37,999 fish) for the number of juvenile wild Chinook salmon that used habitat upstream of the floodgate in 2012, but is within the 95% confidence intervals of the point estimate (Table 14).
- 2) Skagit River Chinook salmon smolt outmigration – The point estimate for wild juvenile Chinook salmon outmigration size in 2012 is 4.5 million fish (3.6-5.6 million 95% CI), which is 88% of the juvenile Chinook population size (5.1 million) determined by stock production analysis to fully seed the Skagit River tidal delta with juvenile Chinook salmon (Beamer et al. 2005). Because Skagit River tidal delta habitat should mostly be filled by juvenile Chinook salmon in 2012 during the estuary rearing period, the expectation was that Fisher Slough habitat would be used at or near carrying capacity by juvenile Chinook salmon in 2012 if habitat conditions were suitable and fish passage opportunity was adequate through the floodgate. The point estimate for juvenile wild Chinook salmon population size in tidal habitat of Fisher Slough upstream of the floodgate in 2012 was 37,999 (Table 14) and is essentially equivalent (i.e., 98%) to the higher carrying capacity estimate found in Table 13. Both carrying capacity estimates are within the 95% confidence intervals of juvenile Chinook salmon population size estimated for 2012.

Table 13. Juvenile wild Chinook salmon carrying capacity model results for tidal habitat upstream of Fisher Slough floodgate after completion of all three restorations elements. Channel area from Beamer et al. (2013b).

Connectivity comment	Landscape connectivity	Channel (ha)	Smolts annually
Fish migration pathway via upper end of Tom Moore Slough	0.0416	1.943	38,773
Assume logjam denies access via upper end of Tom Moore; dominant fish migration pathway is via lower end of Tom Moore Slough	0.0258	1.943	23,935

Table 14. Population estimate of individual juvenile wild Chinook salmon that used habitat upstream of the Fisher Slough floodgate during the 2012 monitoring period (Feb 21-July 24, 154 days) based on expansion of juvenile wild Chinook density result from sites upstream of the floodgate (US FG) in 2012.

	Seasonal Chinook abundance in fishdays	Average Chinook delta residence period (days)	Juvenile Chinook population
Strata2	Point estimate (upper & lower 95% CI)		Point estimate (upper & lower 95% CI)
US FG Blind 1	358,389 (43,158-673,620)	35 ^a	10,240 (1,233-19,246)
US FG Blind 2	894,678 (345,460-1,443,896)		25,562 (9,870-41,254)
US FG Blind 3	20,638 (7,232-34,045)		590 (207-973)
US FG Main Channel	56,273 (18,929-93,617)		1,608 (541-2,675)
Total			37,999 (11,851-64,148)

a – based on juvenile Skagit Chinook salmon otolith results reported in Beamer et al. (2000).

Change in juvenile Chinook salmon carrying capacity after restoration

Dike setback increased tidal habitat area upstream of the floodgate in Fisher Slough. The first year when juvenile salmon and other fish could occupy this new tidal habitat was 2012. Wild juvenile Chinook salmon abundance and carrying capacity results for before (pre-2010) and after restoration (2012) are summarized in Table 15. In summary, the additional juvenile Chinook smolt carrying capacity that is a result of the Fisher Slough restoration project is 21,823 as of 2012. However this estimate only takes into consideration one year of post-restoration results and is subject to change as more information becomes available from future years of fish monitoring. The results could change based on: 1) how fish find the area each year (i.e., fluctuations in habitat connectivity) and 2) how channel/impounded areas change over time within the restoration project area.

Table 15. Summary of Fisher Slough juvenile Chinook salmon abundance and carrying capacity estimates. 'US of FG' is Upstream of floodgate.

Monitoring Year or Source of estimate	Juvenile Chinook monitoring results			Juvenile Chinook salmon Carrying Capacity and production estimates			Juvenile Chinook salmon Carrying Capacity model inputs			
	Skagit River juvenile Chinook outmigration Level (% of carrying capacity of Skagit estuary)	Wild juvenile Chinook population size US of FG		Wild juvenile Chinook carrying capacity US of FG		Estimate of new smolt production due to restoration (smolts annually)	Landscape Connectivity		Tidal Channel area US of FG	
		Point Estimate (smolts annually)	% of best carrying capacity estimate	High Estimate (smolts annually)	Low Estimate (smolts annually)		High	Low	Total Tidal Channel Habitat (ha)	New Tidal Channel Habitat
Skagit Chinook Recovery Plan						16,431	0.423		2.186	0.81 hectares estimated to be restored
2009 ¹	54%	8,236	48%	27,459	16,950	No new fish	0.0416	0.0258	1.376	No new habitat
2012	88%	37,999	98%	38,773	23,935	21,823 ²	0.0416	0.0258	1.943	0.567 hectares actually restored

¹The carrying capacity estimates for 2009 were re-calculated from what was reported in the 2009 fish report (Beamer et al. 2010) based on updated estimates of tidal channel area upstream of the floodgate.

²The additional smolt production is the result of subtracting the low carrying capacity estimate in 2009 from the high carrying capacity estimate in 2012 which most closely matches the observed fish monitoring results in both years.

Our model for estimating carrying capacity for juvenile Chinook salmon is based on landscape connectivity and tidal channel area. The Skagit Chinook Recovery Plan estimate of juvenile Chinook carrying capacity for the conceptual Fisher Slough Restoration project used a different estimate for landscape connectivity (0.0423) than actual (either 0.0416 or 0.0258, depending on pathway). Also, the Recovery Plan assumed 0.81 hectares of new tidal channel habitat would be created at Fisher Slough whereas the actual amount of habitat is less (0.567 hectares of new tidal channel).

These two higher-than-actual values resulted in the 16,431-fish estimate found in the Chinook Recovery Plan of new juvenile Chinook to be produced by the Fisher Slough restoration project. This fish estimate is higher than the value that is now predicted by subtracting the before/after restoration estimates for carrying capacity. Estimates of increased juvenile Chinook salmon carrying capacity between 2009 and 2012 (before and after restoration) are 6,445 fish (38,773 minus 32,328 for the estimates based on high landscape connectivity) or 3,979 fish (23,935 minus 19,956 for the estimates based on low landscape connectivity). Both estimates are much lower than the original estimate of 16,431 fish. Based on 2012 monitoring results, the best estimate of increased carrying capacity as a result of Fisher Slough restoration is 21,823 juvenile Chinook salmon

annually, which is derived from the high carrying capacity estimate post-restoration (38,773 fish) minus the low carrying capacity estimate before restoration (16,950 fish).

The best estimate of changed carrying capacity is based on fish monitoring data and looking for consistency in the percentage of carrying capacity between the Skagit estuary and Fisher Slough for a given year. The percentage of carrying capacity is monitored fish population size divided by carrying capacity estimate. We believe this is a good approach because it considers how fish actually use the site in a given year.

Other Potential influences on juvenile Chinook salmon

Floodgate operation

Differences in fish density are expected from a migrating species such as Chinook salmon when monitoring the entire period of juvenile tidal delta residence. Differences in fish density (beyond natural variation) is not expected at such a small spatial scale 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 of the ability of fish to colonize habitat. Earlier in the discussion section of this report, the conclusion was stated that environmental variation in salinity, temperature, DO, depth, velocity, substrate, and vegetation were not likely influencing juvenile Chinook salmon monitoring results between sites up- and downstream of the floodgate in 2012. Thus, the environmental reasons for varying Chinook salmon density by site within Fisher Slough monitoring have been ruled out.

Differences in wild juvenile Chinook salmon density exist and may be related to differences in floodgate operation over the season, or to varying abilities of different-sized fish over the season (smaller fish early; larger fish later) to pass through the floodgate. Statistical analysis revealed treatment and strata do influence juvenile wild Chinook salmon density, suggesting the floodgate, or its operation, may be responsible for the lower juvenile Chinook salmon densities observed at sites upstream of the floodgate in 2010 and 2011. Operation of the floodgate in 2010 and 2011 produced similar results for upstream passage opportunity of juvenile salmon; 2012 showed poorer results (Table 10). Floodgate operation in 2010 through 2012 was different than floodgate operation in 2009, before replacement, where the gates were manually held open for the entire summer irrigation period. Floodgate operation during the summer irrigation period in 2010 through 2012 accommodated habitat restoration and construction occurring upstream of the floodgate site or at the railroad bridge adjacent to the floodgate. The differences in operation between pre- and post-floodgate replacement may explain much of the difference in Chinook salmon density results across years. This hypothesis cannot be tested as an isolated factor because a new treatment to the dike setback was completed before the 2012 fish monitoring season. It is possible that fish could respond to the dike setback independent of the floodgate replacement. Juvenile Chinook salmon density results both up- and downstream of the floodgate are graphically more favorable in 2012 than in 2010 and 2011, even with lower upstream fish passage opportunity (Figure 34). The favorable response may be due to completion of the dike setback restoration, which gave fish more habitat for rearing.

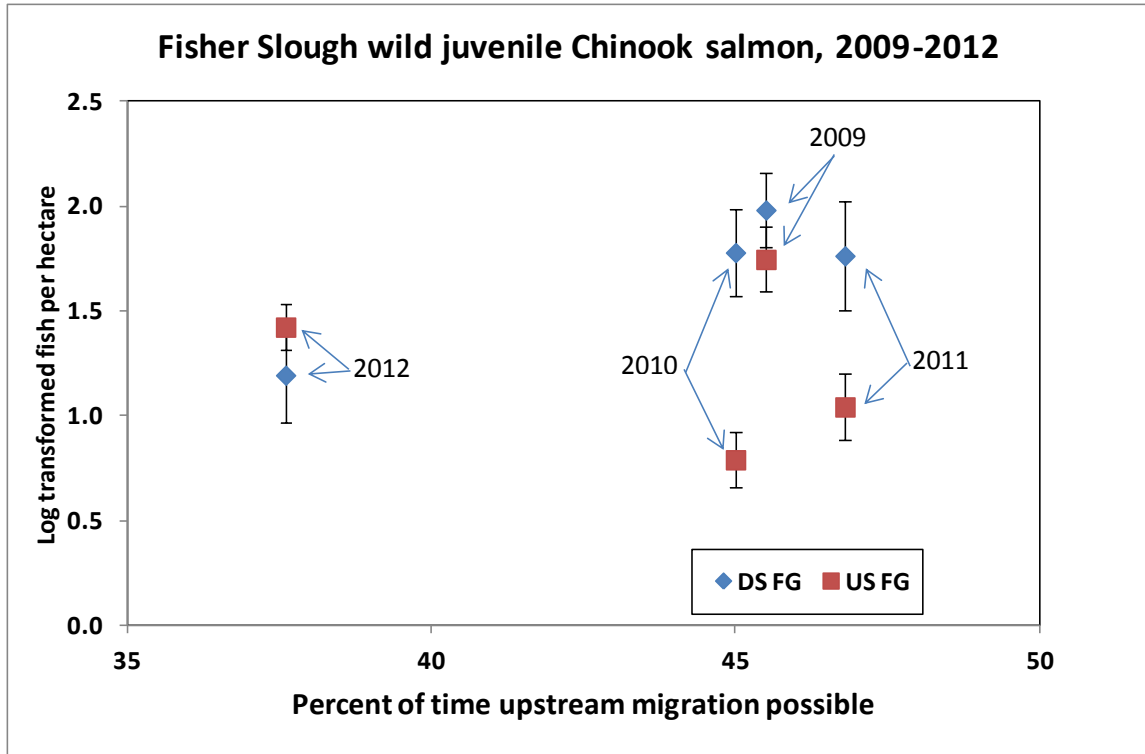


Figure 34. Relationship of a single indicator of floodgate operation and average wild juvenile Chinook salmon density for combined sites upstream of the floodgate (US FG) and downstream of the floodgate (DS FG). Error bars are standard error. Floodgate operation is percent time upstream migration is possible (from Table 10).

Juvenile Chinook salmon outmigration 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 a lack of positive results at Fisher Slough for the two years following floodgate replacement and without dike setback. 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 Slough results, then more fish would be expected upstream of the floodgate in 2011 than in 2009 or 2010, which was not observed (Figure 35). The pattern is reversed after dike setback in 2012.

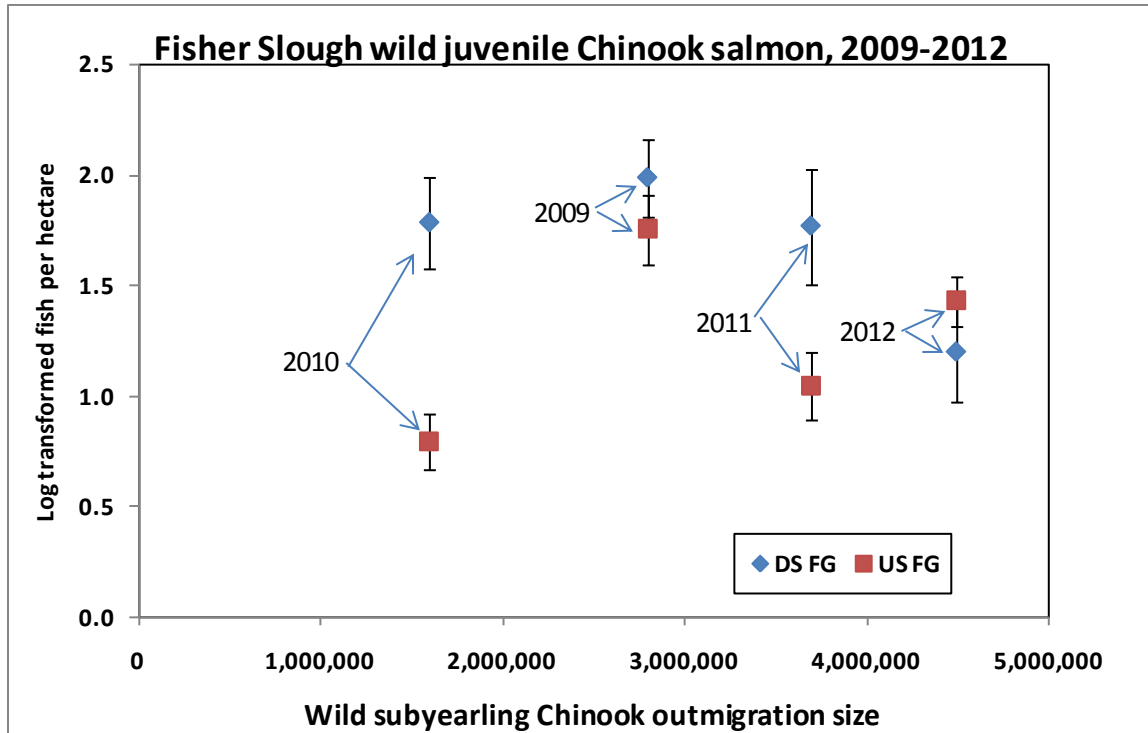


Figure 35. Relationship of wild juvenile Chinook salmon outmigration population size and average wild juvenile Chinook salmon density for combined sites upstream of the floodgate (US FG) and downstream of the floodgate (DS FG). Error bars are standard error.

Conclusions

Our limited statistical tests and graphical trends over four years of monitoring support two tentative conclusions:

1. The new floodgate alone did not influence juvenile wild Chinook salmon as hypothesized (i.e., juvenile wild Chinook salmon abundance would increase upstream of the floodgate after its replacement) in 2010 and 2011.
2. Juvenile Chinook salmon responded as hypothesized to dike setback restoration (along with the new floodgate) in 2012. Dike setback restoration was hypothesized to increase fish abundance and carrying capacity through increasing available habitat.

A summary of the lines of evidence supporting these conclusions over four years of monitoring are found in Table 16. The lines of evidence are derived from juvenile wild Chinook salmon data and are as follows:

- a) Comparison of fish density results by strata (up- and downstream of the floodgate).
- b) Comparison of cumulative fish density results by Fisher Slough strata to Skagit River tidal delta long-term monitoring sites.
- c) Fish abundance upstream of the floodgate: (a) before any restoration and (b) after all three restoration elements were completed at Fisher Slough.

Table 16. Summary of key juvenile wild Chinook salmon results by restoration treatment and monitoring year at the Fisher Slough Restoration Project. Strata within Fisher Slough are “DS FG” (downstream of floodgate) and “US FG” (upstream of floodgate).

Monitoring Year	Restoration Treatment	Juvenile wild Chinook salmon result				
		Comparison of strata within Fisher Slough		Fisher Slough compared to Skagit River tidal delta long-term monitoring sites		Fish population estimate US FG
		Metric: Fish density		Metric: Cumulative density		Metric: abundance
		Statistical	Visual	DS FG sites	US FG sites	
2009	Before floodgate replacement	No difference US FG v. DS FG	No difference US FG v. DS FG	2 of 3 sites consistent	All sites consistent	8,236 (95% CI = 4,769 to 11,703)
2010	After floodgate replacement	DS FG > US FG (p<0.05)	DS FG > US FG	2 of 3 sites consistent	1 of 7 sites consistent	na
2011	After floodgate replacement	No difference US FG v. DS FG	DS FG > US FG	All sites consistent	1 of 7 sites consistent	na
2012	After floodgate replacement & dike setback	No difference US FG v. DS FG	US FG > DS FG	All sites consistent	All sites consistent	37,999 (95% CI = 11,851 to 64,148)

We describe these conclusions as tentative because there is still uncertainty in them due to the short length of the monitoring record and because factors potentially exist that may change the conclusion as more results become available. Two main factors are described below in the Recommendations section under “Continue annual monitoring.”

Recommendations

We repeat below some of the same recommendations described in Beamer et al. (2013a) because there has not been an opportunity to implement them due to the timing of completing reports from fish data collected from Fisher Slough in 2011 and 2012.

Data collection

Make sure continuously-measuring DO data loggers work properly and are consistent with the instruments used for spot measurements, which are calibrated daily. Add additional protective cages around the DO logger standpipes at Upper Main Channel and in the three blind channel lobes to help prevent the standpipes from being encased in pondweed or floating green algae.

Continue annual monitoring

Continue fish monitoring along with floodgate operation monitoring for several years **without** any additional restoration treatments in order to determine whether patterns observed in 2012 are consistent or spurious. The consistency between modeled juvenile Chinook salmon carrying capacity for post restoration habitat at Fisher Slough (Tables 13 and 15) and observed juvenile Chinook salmon abundance in 2012 (Table 14) suggests the Fisher Slough Restoration Project did provide benefits to juvenile Chinook salmon in 2012 consistent with or better than predicted by the Chinook Recovery Plan (SRSC and WDFW 2005) and updated in the 2009 fish report (Beamer et al. 2010). While results in 2012 are encouraging, more than one year of monitoring is necessary to determine whether the 2012 results are representative for juvenile Chinook salmon response to dike setback and floodgate operation. Two important factors may have influenced results in 2012 and may or may not be sustainable over time:

1. Floodgate operation – The 2012 juvenile Chinook salmon abundance result is in spite of a lower result for “upstream fish passage opportunity” at the floodgate in 2012 than in 2010 and 2011. Improvement in floodgate operation may increase juvenile Chinook salmon abundance. Future floodgate operation should improve, benefitting upstream juvenile salmon passage, because restoration construction and the BNSF railroad bridge replacement have been completed. Completion of these construction and maintenance efforts will allow the floodgates to be held open during the full irrigation management periods (June through September each year). In most years, juvenile Chinook salmon are still in the estuary habitat through mid-August. Also, adaptive management learning of which floodgate operations provide upstream fish passage opportunity may improve fish passage opportunity for future years.
2. Initial response – Initial response by fish to newly available habitat may be different than later response. In the case of Fisher Slough, habitat quality may increase or decrease for fish as natural vegetation, sediment accretion, and channel formation within the dike setback area matures. For example, wetted area at low tide was greater than bankfull channel area in 2012. This was because blind channel lobes 1 and 2 had large impounded areas at low tide during 2012 fish sampling. These inflated the actual wetted area available for fish over the full tidal cycle to be much larger than the channel area used in the carrying capacity model

prediction. Average wetted area for blind channel lobes 1 and 2 over the 2012 season during the time of fish sampling was 4.819 and 4.059 hectares, respectively. Average wetted area of all tidal habitat upstream of the floodgate over the 2012 season during the time of fish sampling was 10.341 hectares and is five times larger than the 1.943 hectares of tidal channel used to model juvenile Chinook salmon carrying capacity. It is uncertain how sustainable the impounded area will be over time (Beamer et al. 2013b, Hypothesis 7).

Adaptive management

Dissolved oxygen

Tidal dilution is an immediate remedy to improve DO in Fisher Slough, which can be influenced by floodgate operations 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.

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 densities upstream and downstream of the floodgate. We used the environmental data compared to known standards for juvenile Chinook salmon 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 in 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.

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Appendix A. Water quality data analysis and field collection summary in 2012.

Appendix A Table 1. Daily average water surface salinity in parts per thousand on sampling days at Fisher Slough in 2012.

Date	Down- stream of floodgate avg	Down- stream of floodgate min	Down- stream of floodgate max	Upstream of floodgate main ch sites avg	Upstream of floodgate main ch sites min	Upstream of floodgate main ch sites max	Blind Ch 1 avg	Blind Ch 1 min	Blind Ch 1 max	Blind Ch 2 avg	Blind Ch 2 min	Blind Ch 2 max	Blind Ch 3 avg	Blind Ch 3 min	Blind Ch 3 max
2/14	0.03	0.03	0.03												
2/21	0.03	0.03	0.03	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.02	0.04	0.06	0.06	0.06
3/6							0.05	0.05	0.05	0.12	0.04	0.50			
3/15	0.05	0.05	0.05	0.04	0.04	0.05							0.05	0.05	0.05
3/19							0.05	0.04	0.05	0.04	0.04	0.05			
3/29	0.03	0.03	0.03	0.04	0.03	0.05							0.07	0.06	0.08
4/2							0.05	0.05	0.05	0.05	0.05	0.05			
4/12	0.03	0.03	0.03	0.03	0.03	0.03							0.04	0.04	0.04
4/16							0.04	0.04	0.04	0.04	0.04	0.04			
4/27	0.03	0.02	0.05	0.06	0.05	0.06							0.06	0.06	0.06
5/2							0.04	0.04	0.04	0.04	0.04	0.04			
5/10	0.04	0.02	0.06	0.06	0.06	0.07							0.06	0.06	0.06
5/15							0.04	0.03	0.04	0.06	0.06	0.06			
5/24	0.03	0.02	0.06	0.06	0.06	0.06							0.06	0.06	0.06
6/8	0.07	0.02	0.20	0.02	0.02	0.02							0.06	0.05	0.06
6/11							0.04	0.03	0.05	0.04	0.03	0.05			
7/9	0.02	0.02	0.02	0.03	0.02	0.05							0.05	0.05	0.05
7/18							0.05	0.05	0.05	0.07	0.07	0.07			
7/24	0.02	0.02	0.02	0.04	0.02	0.06							0.07	0.06	0.07

Appendix A Table 2. Daily average water bottom salinity in parts per thousand on sampling days at Fisher Slough in 2012.

Date	Down- stream of floodgate avg	Down- stream of floodgate min	Down- stream of floodgate max	Upstream of floodgate main ch sites avg	Upstream of floodgate main ch sites min	Upstream of floodgate main ch sites max	Blind Ch 1 avg	Blind Ch 1 min	Blind Ch 1 max	Blind Ch 2 avg	Blind Ch 2 min	Blind Ch 2 max	Blind Ch 3 avg	Blind Ch 3 min	Blind Ch 3 max
2/14	0.03	0.03	0.03												
2/21	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.06
3/6				0.05				0.05	0.05						
3/15	0.05	0.05	0.05		0.04	0.04	0.05						0.05	0.05	0.05
3/19															
3/29	0.04	0.03	0.04		0.04	0.04	0.04						0.06	0.06	0.06
4/2										0.05	0.05	0.05			
4/12	0.03	0.03	0.03		0.03	0.03	0.03						0.04	0.04	0.04
4/16										0.04	0.04	0.04			
4/27	0.03	0.02	0.05		0.06	0.05	0.06						0.06	0.06	0.06
5/2				0.04				0.04	0.04	0.05	0.04	0.06			
5/10	0.03	0.02	0.06		0.06	0.06	0.06						0.06	0.06	0.06
5/15				0.04				0.03	0.04	0.06	0.06	0.06			
5/24	0.03	0.02	0.06		0.06	0.06	0.06						0.05	0.04	0.06
6/8	0.07	0.02	0.20		0.02	0.02	0.02						0.05	0.05	0.05
6/11				0.04				0.03	0.04	0.04	0.04	0.05			
7/9	0.02	0.01	0.02		0.02	0.02	0.02						0.03	0.02	0.03
7/18				0.05				0.03	0.05	0.07	0.07	0.07			
7/24	0.02	0.02	0.02		0.03	0.02	0.06						0.06	0.05	0.06

Appendix A Table 3. Daily average water surface temperature in degrees Celsius on sampling days at Fisher Slough in 2012. Numbers in bold are postulated as stressful to juvenile Chinook salmon in estuaries (>15°C).

Date	Down- stream of floodgate avg	Down- stream of floodgate min	Down- stream of floodgate max	Upstream of floodgate main ch sites avg	Upstream of floodgate main ch sites min	Upstream of floodgate main ch sites max	Blind Ch 1 avg	Blind Ch 1 min	Blind Ch 1 max	Blind Ch 2 avg	Blind Ch 2 min	Blind Ch 2 max	Blind Ch 3 avg	Blind Ch 3 min	Blind Ch 3 max
2/14	5.6	5.6	5.6												
2/21	4.8	4.8	4.8	6.5	6.5	6.5	6.9	6.8	6.9	6.8	6.8	6.8	6.4	6.3	6.4
3/6							6.5	6.4	6.6	6.4	6.4	6.5			
3/15	6.1	6	6.1	6.6	6.4	7							6.2	6.1	6.3
3/19							5.5	5.3	5.7	4.7	4.4	4.9			
3/29	6.0	5.2	6.9	6.9	6.7	7							8.5	8.3	8.6
4/2							7.5	7.3	8	7.1	6.6	7.6			
4/12	7.8	7.6	8	7.6	7.4	8							8.4	7.1	9.6
4/16							10.6	10.4	10.9	10.9	10.6	11.2			
4/27	7.4	6.3	10.1	9.9	9.5	10.1							10.4	10.4	10.4
5/2							10.3	10	10.7	9.9	9.5	10.3			
5/10	9.7	8.4	11.1	10.2	8.8	10.7							12.4	11.8	12.9
5/15							14.8	13.7	15.5	17.2	16.7	17.6			
5/24	8.9	7.7	12.2	12.1	11.9	12.3							12.1	12	12.2
6/8	8.2	8.1	8.3	8.4	8.1	8.9							11.6	11.5	11.7
6/11							15.0	13.5	15.8	15.3	14.9	16.2			
7/9	12.2	11.9	12.4	15.1	12	18.2							19.0	18.8	19.2
7/18							18.4	17.7	18.7	19.9	19.7	19.9			
7/24	11.0	11	11	12.5	10.7	15.3							16.2	16.1	16.3

Appendix A Table 4. Daily average water bottom temperature in degrees Celsius on sampling days at Fisher Slough in 2012 Numbers in bold are postulated as stressful to juvenile Chinook salmon in estuaries (>15°C).

Date	Down- stream of floodgate avg	Down- stream of floodgate min	Down- stream of floodgate max	Upstream of floodgate main ch sites avg	Upstream of floodgate main ch sites min	Upstream of floodgate main ch sites max	Blind Ch 1 avg	Blind Ch 1 min	Blind Ch 1 max	Blind Ch 2 avg	Blind Ch 2 min	Blind Ch 2 max	Blind Ch 3 avg	Blind Ch 3 min	Blind Ch 3 max
2/14	5.4	5.4	5.4												
2/21	4.8	4.8	4.8	6.5	6.5	6.5	6.9	6.8	7.0	6.5	6.1	6.8	6.3	6.3	6.3
3/6							6.5	6.4	6.6						
3/15	5.9	5.9	5.9	6.6	6.4	6.9							6.1	6.1	6.1
3/19															
3/29	6.5	6.3	6.8	6.9	6.8	7.0							8.4	8.2	8.6
4/2										7.2	6.7	7.5			
4/12	7.8	7.5	8.0	7.6	7.4	7.9							8.4	8.4	8.4
4/16										13.5	10.4	18.8			
4/27	7.3	6.3	10.0	9.9	9.5	10.1							10.4	10.3	10.4
5/2							10.3	10.0	10.7	10.1	9.6	10.3			
5/10	9.3	8.4	11.0	10.1	8.7	10.7							12.1	11.6	12.6
5/15							14.5	12.8	15.0	16.9	16.6	17.3			
5/24	8.9	7.7	12.2	12.1	11.8	12.3							11.1	10.5	11.7
6/8	8.2	8.0	8.3	8.4	8.1	8.8							11.4	11.4	11.4
6/11							14.4	14.1	14.6	14.9	14.7	15.3			
7/9	12.1	11.8	12.3	12.4	11.9	12.8							14.2	13.1	15.3
7/18							18.0	16.2	18.7	19.7	19.3	19.9			
7/24	10.9	10.9	10.9	12.3	10.6	15.3							15.0	14.8	15.2

Appendix A Table 5. Two factor ANOVA results for surface temperature in 2012. Factor A is simplified site name. Simplified site names were developed because of the randomly selected sites used in blind channel lobes (B1, B2, and B3). Factor B is Month.Event was developed because it took two weeks to sample all sites. Most months had two sample events.

Source	Type III sum of squares	Degrees of freedom	Mean squares	F-ratio	p-value
Factor A: Simplified Site Name	115.656	9	12.851	86.879	0.000
Factor B: Month.Event	695.037	8	86.880	587.365	0.000
Interaction between factors	462.739	69	6.706	45.339	0.000
Error	15.531	105	0.148		

Appendix A Table 6. Two factor ANOVA results for surface temperature in 2012. Factor A is Month.Event. This was developed because it took two weeks to sample all sites. Most months had two sample events. Factor B is Strata (upstream or downstream of floodgate).

Source	Type III sum of squares	Degrees of freedom	Mean squares	F-ratio	p-value
Factor A: Month.Event	937.358	8	117.170	51.768	0.000
Factor B: Strata	158.579	1	158.579	70.063	0.000
Interaction between factors	164.869	8	20.609	9.105	0.000
Error	393.828	174	2.263		

Appendix A Table 7. Scheffé Test for surface temperature by Simplified site name in 2012. Simplified site names was developed because of the randomly selected sites used in blind channel lobes (B1, B2 and B3).

Simplified site name (i)	Simplified site name (j)	Difference	p-Value
Fisher SI Blind Ch	Fisher SI Inside s1	-0.933	0.003
Fisher SI Blind Ch	Fisher SI Inside s2	-0.833	0.019
Fisher SI Blind Ch	Fisher SI Inside s3	-1.556	0.000
Fisher SI Blind Ch	Fisher SI Inside s4	-1.825	0.033
Fisher SI Blind Ch	Fisher SI Tidegate Outside	-1.488	1.000
Fisher SI Blind Ch	Tom Moore SI Upper Area	-0.372	1.000
Fisher SI Blind Ch	US FG B1	-2.609	0.000
Fisher SI Blind Ch	US FG B2	-2.907	0.000
Fisher SI Blind Ch	US FG B3	-2.533	0.000
Fisher SI Inside s1	Fisher SI Inside s2	0.100	1.000
Fisher SI Inside s1	Fisher SI Inside s3	-0.622	0.222
Fisher SI Inside s1	Fisher SI Inside s4	-0.892	0.863
Fisher SI Inside s1	Fisher SI Tidegate Outside	-0.555	1.000
Fisher SI Inside s1	Tom Moore SI Upper Area	0.562	1.000
Fisher SI Inside s1	US FG B1	-1.676	0.000
Fisher SI Inside s1	US FG B2	-1.974	0.000
Fisher SI Inside s1	US FG B3	-1.600	0.000
Fisher SI Inside s2	Fisher SI Inside s3	-0.722	0.084
Fisher SI Inside s2	Fisher SI Inside s4	-0.992	0.769
Fisher SI Inside s2	Fisher SI Tidegate Outside	-0.655	1.000
Fisher SI Inside s2	Tom Moore SI Upper Area	0.462	1.000
Fisher SI Inside s2	US FG B1	-1.776	0.000
Fisher SI Inside s2	US FG B2	-2.074	0.000
Fisher SI Inside s2	US FG B3	-1.700	0.000
Fisher SI Inside s3	Fisher SI Inside s4	-0.270	1.000
Fisher SI Inside s3	Fisher SI Tidegate Outside	0.067	1.000
Fisher SI Inside s3	Tom Moore SI Upper Area	1.184	1.000
Fisher SI Inside s3	US FG B1	-1.054	0.000
Fisher SI Inside s3	US FG B2	-1.352	0.000
Fisher SI Inside s3	US FG B3	-0.978	0.000
Fisher SI Inside s4	Fisher SI Tidegate Outside	0.337	1.000
Fisher SI Inside s4	Tom Moore SI Upper Area	1.454	1.000
Fisher SI Inside s4	US FG B1	-0.784	0.918
Fisher SI Inside s4	US FG B2	-1.082	0.604
Fisher SI Inside s4	US FG B3	-0.708	0.961
Fisher SI Tidegate Outside	Tom Moore SI Upper Area	1.117	1.000
Fisher SI Tidegate Outside	US FG B1	-1.121	1.000
Fisher SI Tidegate Outside	US FG B2	-1.419	1.000
Fisher SI Tidegate Outside	US FG B3	-1.045	1.000
Tom Moore SI Upper Area	US FG B1	-2.238	1.000
Tom Moore SI Upper Area	US FG B2	-2.536	1.000
Tom Moore SI Upper Area	US FG B3	-2.162	1.000

Simplified site name (i)	Simplified site name (j)	Difference	p-Value
US FG B1	US FG B2	-0.298	0.088
US FG B1	US FG B3	0.076	1.000
US FG B2	US FG B3	0.374	0.199

Appendix A Table 8. Scheffé Test for surface temperature by Month.Event in 2012. Month.Event was developed because it took two weeks to sample all sites. Most months had two sample events.

Month.Event(i)	Month.Event(j)	Difference	p-Value
2.2	3.1	-0.498	1.000
2.2	3.2	0.331	1.000
2.2	4.1	-0.867	1.000
2.2	4.2	-2.654	0.998
2.2	5.1	-3.569	0.987
2.2	5.2	-5.214	0.876
2.2	6.1	-3.212	0.993
2.2	7.1	-8.569	0.270
3.1	3.2	0.829	1.000
3.1	4.1	-0.369	1.000
3.1	4.2	-2.156	1.000
3.1	5.1	-3.071	0.998
3.1	5.2	-4.716	0.966
3.1	6.1	-2.714	0.999
3.1	7.1	-8.071	0.544
3.2	4.1	-1.198	0.000
3.2	4.2	-2.985	0.000
3.2	5.1	-3.900	0.000
3.2	5.2	-5.545	0.000
3.2	6.1	-3.543	0.000
3.2	7.1	-8.900	0.000
4.1	4.2	-1.787	0.000
4.1	5.1	-2.702	0.000
4.1	5.2	-4.346	0.000
4.1	6.1	-2.345	0.000
4.1	7.1	-7.702	0.000
4.2	5.1	-0.915	0.000
4.2	5.2	-2.560	0.000
4.2	6.1	-0.558	0.086
4.2	7.1	-5.915	0.000
5.1	5.2	-1.644	0.000
5.1	6.1	0.357	0.662
5.1	7.1	-5.000	0.000
5.2	6.1	2.001	0.000
5.2	7.1	-3.355	0.000
6.1	7.1	-5.357	0.000

Appendix A Table 9. Daily average water surface dissolved oxygen in mg/L on sampling days at Fisher Slough in 2012. Bold values are less than Washington State's standard for DO in freshwater bodies with salmonid rearing and migration.

Date	Down-stream of floodgate avg	Down-stream of floodgate min	Down-stream of floodgate max	Upstream of floodgate main ch sites avg	Upstream of floodgate main ch sites min	Upstream of floodgate main ch sites max	Blind Ch 1 avg	Blind Ch 1 min	Blind Ch 1 max	Blind Ch 2 avg	Blind Ch 2 min	Blind Ch 2 max	Blind Ch 3 avg	Blind Ch 3 min	Blind Ch 3 max
2/14	13.8	13.8	13.8												
2/21	13.4	13.4	13.4	12.5	12.3	12.6	12.9	12.3	13.3	12.5	12.0	13.2	11.0	10.3	11.6
3/6							11.9	10.8	13.2	11.5	11.0	12.7			
3/15	12.9	12.8	13.0	13.2	13.0	13.5							11.7	11.5	11.9
3/19							12.9	12.2	15.1	12.5	11.7	13.8			
3/29	11.6	10.4	12.0	10.2	9.9	10.5							10.5	8.4	12.7
4/2							14.7	13.2	15.7	12.6	11.1	13.5			
4/12	12.6	11.9	13.0	12.0	11.6	12.7							11.4	10.4	12.4
4/16							12.1	11.3	12.9	11.8	11.5	12.1			
4/27	11.3	8.1	12.8	9.9	9.4	10.4							8.8	8.5	9.1
5/2							11.1	10.5	12.1	10.1	9.4	11.4			
5/10	10.6	9.0	12.0	9.7	9.4	9.9							9.4	9.0	9.8
5/15							10.9	10.5	11.4	7.4	6.8	8.0			
5/24	12.7	8.3	15.2	8.3	7.3	9.0							7.2	6.9	7.5
6/8	13.1	12.7	13.3	12.5	12.5	12.6							9.3	9.0	9.5
6/11							10.0	9.1	11.3	9.4	6.4	11.8			
7/9	11.5	11.0	11.9	10.0	8.6	10.9							8.6	8.4	8.9
7/18							8.3	8.2	8.7	6.5	4.4	7.1			
7/24	12.7	12.7	12.7	9.2	7.0	12.5							7.5	6.2	8.9

Appendix A Table 10. Daily average water bottom dissolved oxygen in mg/L on sampling days at Fisher Slough in 2012. Bold values are less than Washington State's standard for DO in freshwater bodies with salmonid rearing and migration.

Date	Down-stream of floodgate avg	Down-stream of floodgate min	Down-stream of floodgate max	Upstream of floodgate main ch sites avg	Upstream of floodgate main ch sites min	Upstream of floodgate main ch sites max	Blind Ch 1 avg	Blind Ch 1 min	Blind Ch 1 max	Blind Ch 2 avg	Blind Ch 2 min	Blind Ch 2 max	Blind Ch 3 avg	Blind Ch 3 min	Blind Ch 3 max
2/14	13.6	13.6	13.6												
2/21	13.3	13.3	13.3	12.5	12.2	12.6	11.8	11.5	12.6	12.4	12.0	12.7	11.1	10.6	11.5
3/6							11.8	10.6	12.5						
3/15	12.7	12.7	12.8	12.8	12.6	13.1							11.8	11.8	11.9
3/19															
3/29	10.8	10.0	11.9	10.2	10.1	10.4							8.4	8.3	8.5
4/2										12.6	12.0	13.0			
4/12	11.9	11.7	12.1	11.8	11.4	12.1							11.2	11.2	11.2
4/16										11.9	11.3	12.6			
4/27	12.2	10.0	13.2	10.0	9.6	10.3							9.7	8.7	10.7
5/2							11.1	10.5	11.7	9.8	9.6	10.1			
5/10	10.6	8.8	11.5	9.4	9.1	9.5							8.6	8.0	9.2
5/15							10.7	10.1	11.2	7.0	6.4	8.0			
5/24	11.1	7.9	12.5	7.5	7.0	8.1							6.6	6.4	6.7
6/8	12.8	12.6	12.9	12.4	12.4	12.5							9.4	9.3	9.4
6/11							10.1	9.6	10.6	8.1	6.2	10.0			
7/9	11.2	10.9	11.6	10.4	9.7	10.9							9.5	8.7	10.3
7/18							8.0	7.8	8.2	5.3	3.1	6.0			
7/24	12.4	12.4	12.4	8.7	6.9	10.9							6.7	6.5	6.9

Appendix A Table 11. Two factor ANOVA results for surface DO in 2012. Factor A is simplified site name. This was developed simplified site names because of the randomly selected sites used in blind channel lobes (B1, B2, and B3). Factor B is Month.Event. Month.Event was developed because it took two weeks to sample all sites. Most months had two sample events.

Source	Type III sum of squares	Degrees of freedom	Mean squares	F-ratio	p-value
Factor A: Simplified Site Name	134.775	9	14.975	18.347	0.000
Factor B: Month.Event	110.779	8	13.847	16.965	0.000
Interaction between factors	241.177	69	3.495	4.282	0.000
Error	84.070	103	0.816		

Appendix A Table 12. Two factor ANOVA results for surface DO in 2012. Factor A is Month.Event. Month.Event was developed because it took two weeks to sample all sites. Most months had two sample events. Factor B is Strata (upstream or downstream of floodgate).

Source	Type III sum of squares	Degrees of freedom	Mean squares	F-ratio	p-value
Factor A: Month.Event	112.303	8	14.038	7.084	0.000
Factor B: Strata	42.494	1	42.494	21.444	0.000
Interaction between factors	69.859	8	8.732	4.407	0.000
Error	340.840	172	1.982		

Appendix A Table 13. Scheffé Test for surface DO by Simplified site name in 2012. Simplified site names was developed because of the randomly selected sites used in blind channel lobes (B1, B2, and B3).

Simplified site name (i)	Simplified site name (j)	Difference	p-Value
Fisher SI Blind Ch	Fisher SI Inside s1	0.951	0.819
Fisher SI Blind Ch	Fisher SI Inside s2	0.983	0.801
Fisher SI Blind Ch	Fisher SI Inside s3	1.228	0.508
Fisher SI Blind Ch	Fisher SI Inside s4	1.495	1.000
Fisher SI Blind Ch	Fisher SI Tidegate Outside	1.397	0.995
Fisher SI Blind Ch	Tom Moore SI Upper Area	-1.003	0.996
Fisher SI Blind Ch	US FG B1	0.400	0.997
Fisher SI Blind Ch	US FG B2	1.539	0.015
Fisher SI Blind Ch	US FG B3	2.258	0.000
Fisher SI Inside s1	Fisher SI Inside s2	0.032	1.000
Fisher SI Inside s1	Fisher SI Inside s3	0.277	1.000
Fisher SI Inside s1	Fisher SI Inside s4	0.544	1.000
Fisher SI Inside s1	Fisher SI Tidegate Outside	0.446	1.000
Fisher SI Inside s1	Tom Moore SI Upper Area	-1.954	0.728
Fisher SI Inside s1	US FG B1	-0.551	0.962
Fisher SI Inside s1	US FG B2	0.588	0.945
Fisher SI Inside s1	US FG B3	1.307	0.178
Fisher SI Inside s2	Fisher SI Inside s3	0.244	1.000
Fisher SI Inside s2	Fisher SI Inside s4	0.512	1.000
Fisher SI Inside s2	Fisher SI Tidegate Outside	0.414	1.000
Fisher SI Inside s2	Tom Moore SI Upper Area	-1.986	0.713
Fisher SI Inside s2	US FG B1	-0.583	0.953
Fisher SI Inside s2	US FG B2	0.555	0.967
Fisher SI Inside s2	US FG B3	1.274	0.232
Fisher SI Inside s3	Fisher SI Inside s4	0.267	1.000
Fisher SI Inside s3	Fisher SI Tidegate Outside	0.169	1.000
Fisher SI Inside s3	Tom Moore SI Upper Area	-2.231	0.549
Fisher SI Inside s3	US FG B1	-0.827	0.691
Fisher SI Inside s3	US FG B2	0.311	1.000
Fisher SI Inside s3	US FG B3	1.030	0.558
Fisher SI Inside s4	Fisher SI Tidegate Outside	-0.098	1.000
Fisher SI Inside s4	Tom Moore SI Upper Area	-2.498	1.000
Fisher SI Inside s4	US FG B1	-1.095	1.000
Fisher SI Inside s4	US FG B2	0.044	1.000
Fisher SI Inside s4	US FG B3	0.763	1.000
Fisher SI Tidegate Outside	Tom Moore SI Upper Area	-2.400	0.129
Fisher SI Tidegate Outside	US FG B1	-0.997	1.000
Fisher SI Tidegate Outside	US FG B2	0.142	1.000
Fisher SI Tidegate Outside	US FG B3	0.861	1.000
Tom Moore SI Upper Area	US FG B1	1.403	0.936
Tom Moore SI Upper Area	US FG B2	2.542	0.253
Tom Moore SI Upper Area	US FG B3	3.261	0.045

Simplified site name (i)	Simplified site name (j)	Difference	p-Value
US FG B1	US FG B2	1.138	0.000
US FG B1	US FG B3	1.857	0.000
US FG B2	US FG B3	0.719	0.510

Appendix A Table 14. Scheffé Test for surface DO by Month.Event in 2012. Month.Event was developed because it took two weeks to sample all sites. Most months had two sample events.

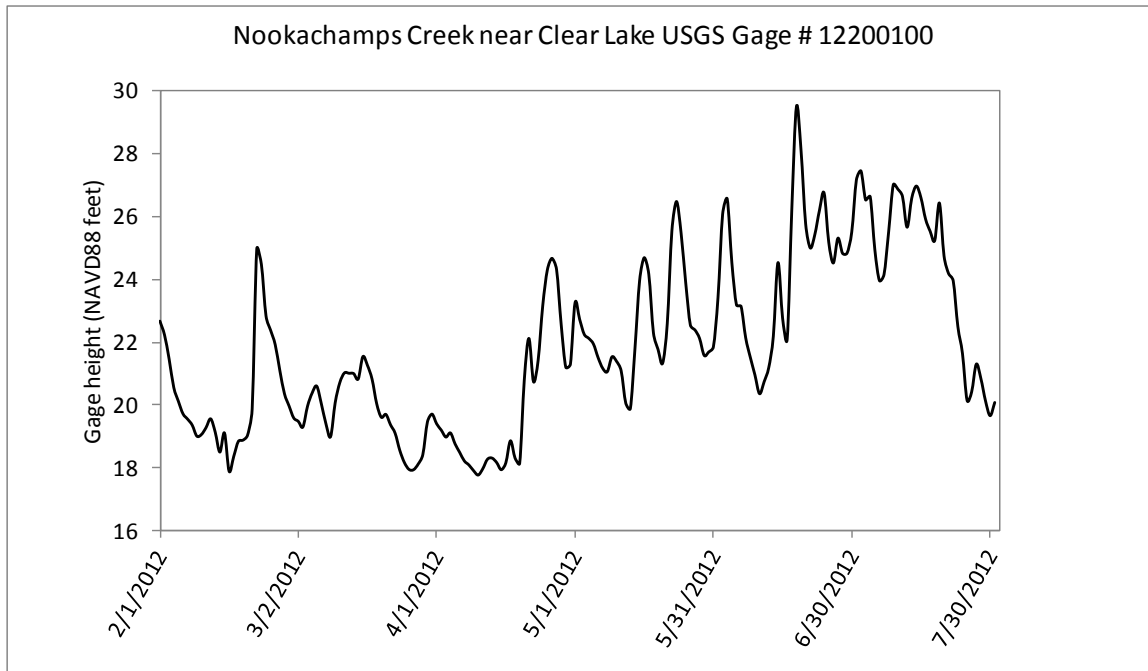
Month.Event(i)	Month.Event(j)	Difference	p-Value
2.2	3.1	-0.220	1.000
2.2	3.2	1.262	0.983
2.2	4.1	-0.030	1.000
2.2	4.2	1.838	0.835
2.2	5.1	2.430	0.504
2.2	5.2	2.951	0.225
2.2	6.1	0.590	1.000
2.2	7.1	2.588	0.409
3.1	3.2	1.482	1.000
3.1	4.1	0.190	1.000
3.1	4.2	2.057	1.000
3.1	5.1	2.650	1.000
3.1	5.2	3.171	1.000
3.1	6.1	0.810	1.000
3.1	7.1	2.808	1.000
3.2	4.1	-1.292	0.097
3.2	4.2	0.576	0.946
3.2	5.1	1.168	0.197
3.2	5.2	1.689	0.005
3.2	6.1	-0.672	0.874
3.2	7.1	1.326	0.079
4.1	4.2	1.868	0.001
4.1	5.1	2.460	0.000
4.1	5.2	2.981	0.000
4.1	6.1	0.620	0.917
4.1	7.1	2.618	0.000
4.2	5.1	0.592	0.936
4.2	5.2	1.113	0.256
4.2	6.1	-1.248	0.127
4.2	7.1	0.751	0.786
5.1	5.2	0.521	0.971
5.1	6.1	-1.840	0.001
5.1	7.1	0.158	1.000
5.2	6.1	-2.361	0.000
5.2	7.1	-0.363	0.997
6.1	7.1	1.998	0.000

Appendix B. Fisher Slough floodgate operation log.

Appendix B Table 1. Operations and maintenance log for Fisher Slough floodgates in WY 2012 (October 1, 2011 through September 30, 2012).

Date	Time	Name of person completing work	Change to float setting	Per- iod
10/1/2011			Floodgates still disengaged for restoration construction	Fall/Winter Flood Control
10/31/2011	16:00	Dave Olson and Kris Knight	Re-engaged float/floodgates for first time after 2011 summer and fall construction. Kept gates disengaged until this date due to construction and also to let marsh seed germinate.	
11/3/2011	16:15	Dave Olson and Kris Knight	Raised FG setting since gates closing at ~7 ft rather than target of 7.5 ft	
11/4/2011	11:35	Kris Knight	Lowered FG setting since gates still open at 8.0 ft at downstream gage	
11/6/2011	8:20	Kris Knight	Raised FG setting since gates closing < 7.5 ft upstream of gates	
11/12/2011	12:10	Kris Knight	Raised FG setting because gates closing < 7.5 ft	
2/29/2012	14:00	Dave Olson and Kris Knight	Raised FG setting for start of spring operating period - so gates will close when water surface elevation reaches ~9.5 ft NAVD88	Spring Juvenile Chinook Salmon Migration
3/28/2012	11:15	Kris Knight and Dave Olson	Raised FG setting since it appeared gates were closing at a water elevation that was too low (~8.5 ft), though gates had been observed closing at higher water levels but that may have had more to do with water levels upstream due to tributary flows	
4/5/2012	8:30	Kris Knight	Raised setting 1.5 feet after watching gates slam shut when water elevation was ~8.0 feet upstream of gates	
4/5/2012	16:15	Kris Knight and Dave Olson	Raised floodgate setting additional 0.5 feet	
4/7/2012	9:00	Kris Knight	Raised floodgate setting additional 0.7 feet	
4/11/2012	9:45	Kris Knight	Added 5 sandbags to float (~200 - 250 lbs) as counter weight to prevent float from lifting up and doors slamming shut too early	
4/11/2012	9:50	Kris Knight	Lowered gate frame setting to 15.5 to prevent the float from touching concrete bridge in a couple locations	
4/26/2012	13:30	Dave Olson and Kris Knight	Lower gate frame setting to 14.0 - river rose up and water level upstream and downstream of gates was 10.1 and gates were ~60 degrees open. Ideally they would be closed in that situation. We are still testing gate elevation settings now that new weight has been added to float	
5/8/2012	~18:00	Leo Kuntz, Dave Olson	Leo was installing hydraulic cylinder as upgrade to floodgates and shaft broke, leaving the gates in a disengaged (free-swinging) situation until a fix was completed	
5/11/2012	~17:00	Nehalem Marine staff (Henry)	Henry completed repair of floodgate shaft and re-engaged to spring operations	
5/31/2012	~16:00	Dave Olson, Darrin Morrison	Floodgate setting changed to summer operations setting per O&M plan, including underwater flapgate being opened	Summer Irrigation
8/3/2012	10:30	Dave Olson and Brad Smith	Float disengaged (hoisted up) and small flapgate closed by DD3 because of work to take place by DD3 upstream on Hill Ditch. It was determined with WDFW and TNC and SRSC that this could be allowed because of the work already happening with the railroad. In future years, DD3 has been asked to hold off on work until after Aug. 15th if it will impact fish monitoring activities.	
8/20/2012	10:00	Dave Olson	Float re-engaged back to summer setting by DD3 as Hill Ditch project is complete	

Appendix C. Nookachamps Creek streamflow gage data.



Appendix C. Figure 1. Mean daily gage height (ft) of Nookachamps Creek near Clear Lake, WA during the fish monitoring period in 2012 (from USGS gage # 12200100).

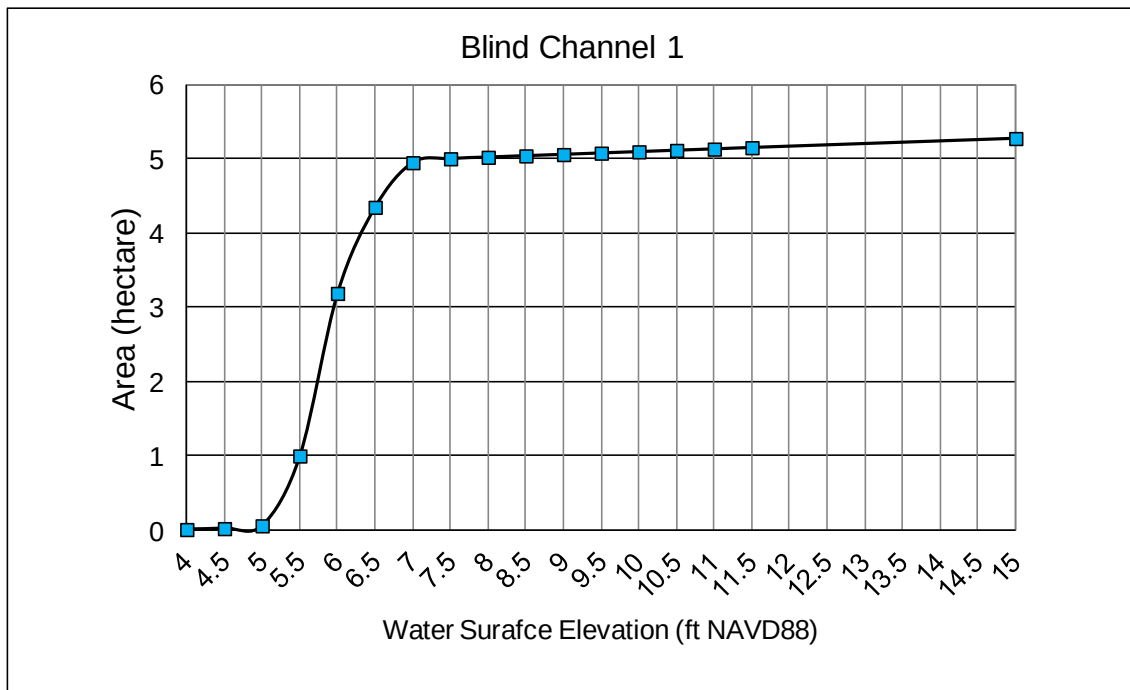
Appendix D. Fisher Slough blind channel area data.

The wetted area within blind channel lobes 1 and 2 varied each day of fish sampling because water surface elevation (WSE) varied by tides and river/creek flow.

A WSE-to-wetted area relationship was developed for both blind channel lobes. The wetted area of each lobe was determined by digitizing elevation polygons from a high-resolution As-Built surface TIN created by Shannon & Wilson Inc in February 2012, and supplied to SRSC by The Nature Conservancy. The TIN was classified to display half-foot elevation increments, over which polygons were digitized on a Wacom DTU-2231 Interactive Pen Display tablet at a scale generally between 1:100 and 1:200. Polygons represent half-foot elevation increases between 4 and 12 feet NAVD88; because of the steep slopes of the dikes, one polygon was created to represent the elevation increase between 12 and 15 feet NAVD88. Polygon areas are interpolated for each tenth of a foot (the resolution at which WSE measurements are made in the field during sampling) in Tables 1 & 2 in this appendix; the areas are graphed by individual polygons in Figures 1 & 2 below.

Appendix D Table 1. Fisher Slough Blind Channel 1 wetted area of habitat (hectares) at each tenth-foot water surface elevation from 4.0 to 15.0 feet NAVD88.

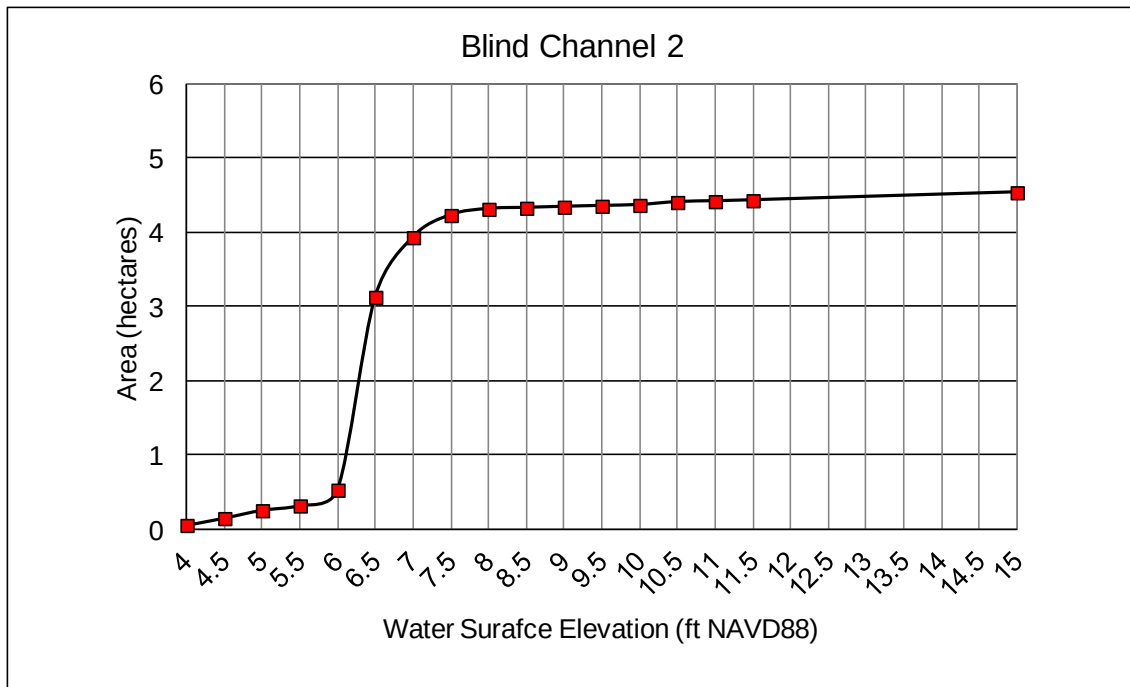
WSE	Hectare		WSE	Hectare		WSE	Hectare		WSE	Hectare
4.0	0.0085		7.0	4.9780		10.0	5.0930		13.0	5.2079
4.1	0.0110		7.1	4.9818		10.1	5.0968		13.1	5.2118
4.2	0.0135		7.2	4.9857		10.2	5.1006		13.2	5.2156
4.3	0.0160		7.3	4.9895		10.3	5.1045		13.3	5.2194
4.4	0.0185		7.4	4.9933		10.4	5.1083		13.4	5.2233
4.5	0.0209		7.5	4.9972		10.5	5.1121		13.5	5.2271
4.6	0.0284		7.6	5.0010		10.6	5.1160		13.6	5.2309
4.7	0.0359		7.7	5.0048		10.7	5.1198		13.7	5.2348
4.8	0.0434		7.8	5.0086		10.8	5.1236		13.8	5.2386
4.9	0.0509		7.9	5.0125		10.9	5.1275		13.9	5.2424
5.0	0.0585		8.0	5.0163		11.0	5.1313		14.0	5.2463
5.1	0.2466		8.1	5.0201		11.1	5.1351		14.1	5.2501
5.2	0.4348		8.2	5.0240		11.2	5.1389		14.2	5.2539
5.3	0.6229		8.3	5.0278		11.3	5.1428		14.3	5.2578
5.4	0.8110		8.4	5.0316		11.4	5.1466		14.4	5.2616
5.5	0.9992		8.5	5.0355		11.5	5.1504		14.5	5.2654
5.6	1.4361		8.6	5.0393		11.6	5.1543		14.6	5.2692
5.7	1.8741		8.7	5.0431		11.7	5.1581		14.7	5.2731
5.8	2.3121		8.8	5.0470		11.8	5.1619		14.8	5.2769
5.9	2.7501		8.9	5.0508		11.9	5.1658		14.9	5.2807
6.0	3.1881		9.0	5.0546		12.0	5.1696		15.0	5.2846
6.1	3.4210		9.1	5.0585		12.1	5.1734			
6.2	3.6530		9.2	5.0623		12.2	5.1773			
6.3	3.8850		9.3	5.0661		12.3	5.1811			
6.4	4.1169		9.4	5.0700		12.4	5.1849			
6.5	4.3489		9.5	5.0738		12.5	5.1888			
6.6	4.9076		9.6	5.0776		12.6	5.1926			
6.7	4.9182		9.7	5.0815		12.7	5.1964			
6.8	4.9287		9.8	5.0853		12.8	5.2003			
6.9	4.9393		9.9	5.0891		12.9	5.2041			



Appendix D Figure 1. Fisher Slough Blind Channel 1 wetted area of habitat (hectares) at mapped water surface elevations from 4.0 to 15.0 ft NAVD88.

Appendix D Table 2. Fisher Slough Blind Channel 2 wetted area of habitat (hectares) at each tenth-foot water surface elevation from 4.0 to 15.0 feet NAVD88.

WSE	Hectare		WSE	Hectare		WSE	Hectare		WSE	Hectare
4.0	0.0568		7.0	3.9309		10.0	4.3763		13.0	4.4745
4.1	0.0747		7.1	3.9905		10.1	4.3795		13.1	4.4778
4.2	0.0926		7.2	4.0502		10.2	4.3828		13.2	4.4810
4.3	0.1105		7.3	4.1098		10.3	4.3861		13.3	4.4843
4.4	0.1284		7.4	4.1695		10.4	4.3894		13.4	4.4876
4.5	0.1463		7.5	4.2291		10.5	4.3926		13.5	4.4909
4.6	0.1642		7.6	4.2459		10.6	4.3959		13.6	4.4941
4.7	0.1821		7.7	4.2626		10.7	4.3992		13.7	4.4974
4.8	0.2000		7.8	4.2793		10.8	4.4025		13.8	4.5007
4.9	0.2179		7.9	4.2960		10.9	4.4057		13.9	4.5039
5.0	0.2358		8.0	4.3127		11.0	4.4090		14.0	4.5072
5.1	0.2537		8.1	4.3141		11.1	4.4123		14.1	4.5105
5.2	0.2716		8.2	4.3173		11.2	4.4156		14.2	4.5138
5.3	0.2895		8.3	4.3206		11.3	4.4188		14.3	4.5170
5.4	0.3074		8.4	4.3239		11.4	4.4221		14.4	4.5203
5.5	0.3155		8.5	4.3272		11.5	4.4254		14.5	4.5236
5.6	0.3579		8.6	4.3304		11.6	4.4286		14.6	4.5269
5.7	0.4004		8.7	4.3337		11.7	4.4319		14.7	4.5301
5.8	0.4428		8.8	4.3370		11.8	4.4352		14.8	4.5334
5.9	0.4853		8.9	4.3403		11.9	4.4385		14.9	4.5367
6.0	0.5281		9.0	4.3435		12.0	4.4417		15.0	4.5400
6.1	1.0478		9.1	4.3468		12.1	4.4450			
6.2	1.5675		9.2	4.3501		12.2	4.4483			
6.3	2.0872		9.3	4.3533		12.3	4.4516			
6.4	2.6069		9.4	4.3566		12.4	4.4548			
6.5	3.1266		9.5	4.3599		12.5	4.4581			
6.6	3.2871		9.6	4.3632		12.6	4.4614			
6.7	3.4480		9.7	4.3664		12.7	4.4647			
6.8	3.6090		9.8	4.3697		12.8	4.4679			
6.9	3.7699		9.9	4.3730		12.9	4.4712			



Appendix D Figure 2. Fisher Slough Blind Channel 2 wetted area of habitat (hectares) at mapped water surface elevations from 4.0 to 15.0 feet NAVD88.

Appendix E. Juvenile Chinook salmon density.

Appendix E Table 1. All group comparisons using Scheffé Test. Treatments are “before” or “after” floodgate replacement. Treatment influences are: Before (before floodgate replacement and dike setback), After Year 1 and 2 (after floodgate replacement but before dike setback, and After Year 3 (after floodgate replacement and dike setback). Strata influences are sites upstream of the floodgate (US FG) and sites downstream of the floodgate (DS FG).

Groups	Difference	p
AfterYr1*DS FG v AfterYr1*US FG	0.989	0.042
AfterYr1*DS FG v AfterYr2*DS FG	0.015	1.000
AfterYr1*DS FG v AfterYr2*US FG	0.737	0.375
AfterYr1*DS FG v AfterYr3*DS FG	0.585	0.802
AfterYr1*DS FG v AfterYr3*US FG	0.356	0.936
AfterYr1*DS FG v Before*DS FG	-0.203	0.999
AfterYr1*DS FG v Before*US FG	0.033	1.000
AfterYr1*US FG v AfterYr2*DS FG	-0.974	0.088
AfterYr1*US FG v AfterYr2*US FG	-0.252	0.991
AfterYr1*US FG v AfterYr3*DS FG	-0.404	0.943
AfterYr1*US FG v AfterYr3*US FG	-0.633	0.126
AfterYr1*US FG v Before*DS FG	-1.192	0.002
AfterYr1*US FG v Before*US FG	-0.956	0.007
AfterYr2*DS FG v AfterYr2*US FG	0.721	0.495
AfterYr2*DS FG v AfterYr3*DS FG	0.570	0.859
AfterYr2*DS FG v AfterYr3*US FG	0.340	0.968
AfterYr2*DS FG v Before*DS FG	-0.219	0.999
AfterYr2*DS FG v Before*US FG	0.017	1.000
AfterYr2*US FG v AfterYr3*DS FG	-0.151	1.000
AfterYr2*US FG v AfterYr3*US FG	-0.381	0.827
AfterYr2*US FG v Before*DS FG	-0.940	0.076
AfterYr2*US FG v Before*US FG	-0.704	0.216
AfterYr3*DS FG v AfterYr3*US FG	-0.230	0.996
AfterYr3*DS FG v Before*DS FG	-0.788	0.412
AfterYr3*DS FG v Before*US FG	-0.553	0.736
AfterYr3*US FG v Before*DS FG	-0.559	0.510
AfterYr3*US FG v Before*US FG	-0.323	0.871
Before*DS FG v Before*US FG	0.236	0.996