Lower Columbia River Channel Improvement: Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands

2005 Project Report

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Introduction

Multiple factors have contributed to the decline of anadromous salmonids throughout the Columbia River basin. The lower Columbia River and estuary are of particular importance because all stocks of anadromous salmonids within the basin use the area to varying extents, especially as rearing habitat for juveniles. Lower Columbia River habitats have been substantially altered by such factors as flow manipulation and reduced connectivity among the river, tidal wetlands, and the floodplain. For instance, the construction of dikes and filling tidal wetlands has resulted in a 65% reduction of tidal marshes and swamps compared to that historically present (Bottom et al. 2005).

Restoring tidally-influenced wetlands to improve conditions for juvenile anadromous salmonids has been included in recovery and management plans and regulatory requirements, such and the Subbasin Plan for the Columbia Mainstem and Estuary (Lower Columbia Fish Recovery Board (LCFRB) 2004) and NOAA Fisheries' FCRPS Biological Opinions (NOAA 2004). Although restoring tidal wetlands and improving fish access to them are major components of recovery strategies for anadromous salmonids, considerable uncertainty exists concerning appropriate restoration actions. Information on specific habitat requirements and restoration needs of juvenile salmonids in these areas is lacking (Bottom et al. 2005). An approach to assist in alleviating uncertainties and evaluating restoration strategies is to conduct before-after-control impact monitoring (BACI; e.g., described in Diefenderfer et al. 2005), which includes comparisons of variables of interest among reference and treatment sites both before and after implementation of restoration actions at treatment sites. In the case of the lower Columbia River the intent of such evaluations is to improve our understanding of the habitat relations of juvenile salmonids and assist in developing and implementing additional restoration actions.

The U.S. Army Corps of Engineers' (USACOE) has proposed a phased restoration project at Tenasillahe Island intended to benefit juvenile salmonids. If hydraulic analyses indicate that integrity of deer habitat will not be negatively affected, activities of the interim phase may include modifications to tidegates and construction of controlled water inlets to improve water movement and juvenile salmonid ingress and egress between the sloughs and river. Activities of the long-term phase may include breaching dikes on the island to restore tidal circulation to natural conditions. Proposed restoration actions are contingent upon delisting of the Columbian white-tailed deer and a finding that the activities are compatible with the purposes and goals of the refuge. This project offers an opportunity to conduct pre- and post-construction monitoring that will assist in evaluating the overall effectiveness of the restoration project and will likely contribute to other potential restoration efforts in the Columbia River estuary. Construction for the interim phase of the project is planned for summer 2006.

The U.S. fish and Wildlife Service, Columbia River Fisheries Program Office (CRFPO) is using a BACI approach to assess the restoration project. The goal of this assessment is to describe fish presence, distribution, habitat use, and accessibility as well as habitat characteristics of two sloughs at Tenasillahe Island and Welch Island. Ultimately, comparisons will be conducted between sloughs on Tenasillahe Island (treatment site) before and after construction associated with the USACOE restoration project, and among sloughs on Welch Island (reference site). Objectives to address this goal are: 1. Assess the periods, frequency, and duration that existing tidegates are likely conducive to passage by juvenile salmonids, 2. Describe the presence, distribution and biological characteristics of salmonids and other fish species inhabiting sloughs on Tenasillahe Island and compare to that observed at reference sloughs on Welch Island, 3. Characterize habitats at the sloughs on Tenasillahe Island and compare to that observed at reference sloughs at Welch Island. We conducted a pilot study in summer 2005 designed to generate preliminary information concerning fish and habitats within sloughs on the two islands. The pilot study sought to assess fish sampling methods amendable to conditions within the sloughs and evaluate logistical constraints (e.g., access to survey sites) in collecting information on fish and habitats. In summer 2005 we focused our efforts on three objectives: 1. Conduct observations of tidegates to assess function, frequency, and duration of operation, 2. Begin to describe presence, species diversity, and relative abundance of fish species in Tenasillahe Island and Welch Island sloughs, 3. Begin to quantify physical habitat and water quality variables in Tenasillahe Island and Welch Island sloughs.

Study Area

Tenasillahe Island

Tenasillahe Island is part of the Julia Butler Hansen National Wildlife Refuge established in 1971, and is managed by the U.S. Fish and Wildlife Service (USFWS). Tenasillahe Island is a 809-hectare island located in the lower Columbia River at river kilometer 56 (Figure 1). Much of the tidal marsh habitat historically occurring at Tensaillahe Island was altered due to the construction of dikes around the island during the course of the last century. Aquatic habitat on the island currently consists primarily of a network of interior sloughs connected to the Columbia River via two tidegates. Habitat on the island is managed primarily for the protection of Columbian white-tailed deer.

Welch Island

Welch Island is part of the Lewis and Clark National Wildlife Refuge (also managed by USFWS), which was established in 1972. Welch Island is a 429-hectare island located in the lower Columbia River at river kilometer 55, adjacent to and just downstream of Tenasillahe Island (Figure 1). The natural tidal marsh habitat on Welch Island is relatively pristine. It appears that Welch Island was never settled by humans. Roads do not currently exist on the island, and there are no dikes or tidegates on the sloughs. Welch Island is currently managed primarily for waterfowl habitat.

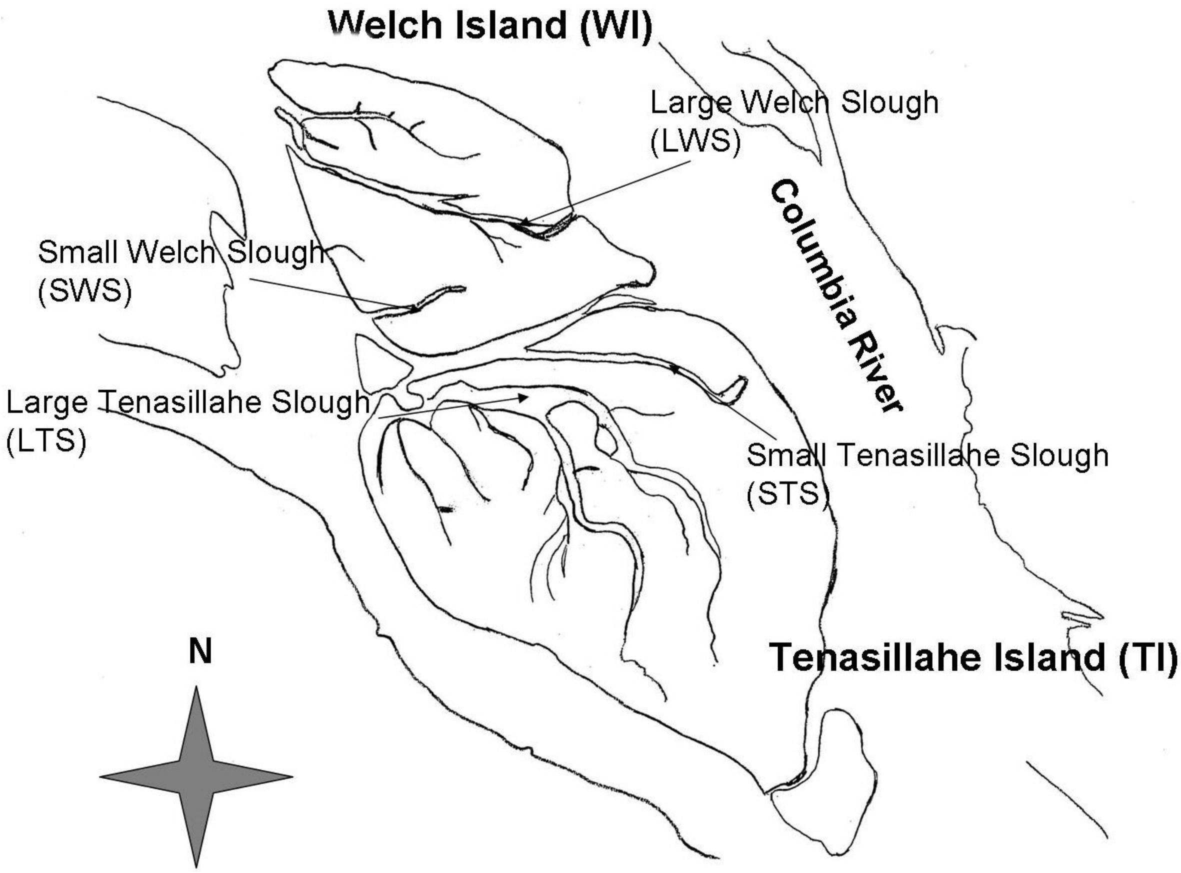

Figure 1. Area map of Tenasillahe Island and Welch Island showing locations of sloughs surveyed in 2005: large Tenasillahe slough (LTS), small Tenasillahe slough (STS), large Welch slough (LWS), small Welch slough (SWS).

Methods

Identification of Sampling Reaches

Given the uncertainty about the variability in the size and conditions of sloughs on each island, we conducted a reconnaissance trip on 15 February to identify prospective sloughs for the study. Physical characteristics evident on maps, such as total slough length (i.e., large or small) and connectivity with the Columbia River (whether the slough was connected at its downstream and upstream end) were later compared on each island to assist in selecting sloughs. Two sloughs affected by tidegates on Tenasillahe Island were designated as the treatment sites, and two natural (unmodified) sloughs on Welch Island were designated as the reference sites.

Sample reaches within each slough were randomly selected using a spatially-balanced approach to insure that various habitats and conditions were represented. To accomplish this, each slough was divided into three equally sized (within a slough) segments. In each segment, paired reaches were randomly chosen, the first being the desired sample reach and the second being an alternate. A second reconnaissance trip was conducted from 29 June to 1 July in each slough to determine if the desired sampling reaches could be sampled (i.e., allowed for access and contained water). If the desired reach was not one that could be sampled, the alternate reach was then used. The size of each sample reach, and total number of sample reaches, were chosen so that at least 10% of the total slough length was sampled. Eight 50-m sample reaches were established in large Tenasillahe slough (LTS), three 25-m sample reaches were established in small Tenasillahe slough (STS), five 25-m reaches were established in large Welch slough (LWS), and two 25-m sample reaches were established in small Welch slough (SWS) (Figure 2). Once final sample reaches were identified, they were marked with orange survey stakes and their location noted using a Trimble GeoExplorer3 GPS unit so that future sampling efforts could focus on the same set of reaches.

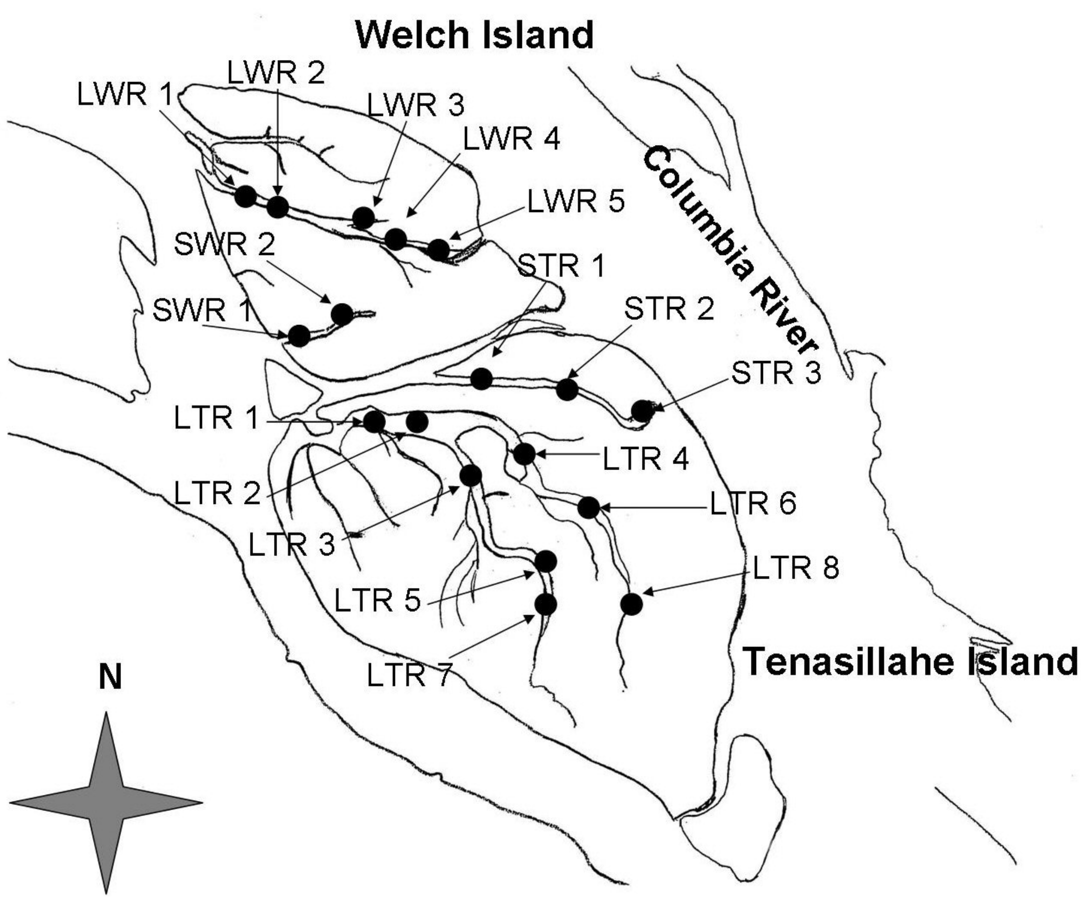

Figure 2. Tenasillahe Island and Welch Island sample reaches, 2005.

Fish Sampling

We conducted preliminary fish sampling during the second reconnaissance trip to examine potential sampling reaches. A total of six baited minnow traps were set overnight in each of eight locations in and around the four sloughs (inside lower LTS, at the south fork road crossing of LTS, inside the LTS tidegate bay, outside the LTS tidegate bay, inside lower STS, outside the STS tidegate, inside the mouth of LWS, and inside the mouth of SWS). All fish captured were identified, enumerated, and released. Because fish sampling in Welch Island and Tenasillahe Island sloughs had not been conducted prior to this pilot study, several methods were used to determine fish species presence and assess sampling methods.

A total of four fish sampling methods were used during the pilot study (21 July to 26 August): minnow traps, crayfish traps, fyke nets, and beach seine. Minnow and crayfish traps were the only fish sampling methods used in each sample reach in all sloughs. Minnow and crayfish traps had 2.5-cm and 5.7-cm openings, respectively. An equal number of crayfish and minnow traps were used within each reach to allow for a relatively large range of fish sizes to be captured. All minnow and crayfish traps were baited with salmon eggs (approximately 113g) and placed on the surface of the substrate with a 3-m rope and attached float. In an attempt to standardize the sampling effort in each reach, a trapping array was developed based on the estimated surface area of the reach (Table 1). Minnow and crayfish traps were set in a reach overnight then removed. All fish captured were identified, enumerated, and released. In an effort to prevent fish captured in minnow and crayfish traps from potentially being exposed to anoxic conditions in LTS, sets of 5 traps were assembled, and floated 60 cm below the surface.

Fyke nets were used for fish sampling in LTS and LWS. In LWS, a rectangular 1.5-m x 1.2-m fyke net with a 15.2-m lead and 4.5-m long wings was used. The fyke net was placed facing downstream in an area that had sufficiently deep water (minimum 60 cm) at low tide to submerge the trap. The fyke net was set overnight and removed. All fish captured were placed in an aerated live well, identified, enumerated and released. In LTS, two 1.2-m circular fyke nets with 15.2-m leads and 4.5-m wings were used. Circular fyke nets were set overnight in reaches that had sufficient water depth to submerge the trap (minimum 60 cm). In sample reaches with an average wetted width greater than 100 m, two fyke nets were set facing different directions (i.e., one facing upstream and one downstream). Fyke nets were not used in STS due to dense aquatic vegetation. Fyke nets were not used in SWS because of insufficient water depth at low tide.

Beach seines were used to sample fish in the channel outside the tidegate at LTS, within LTS off the south point of the island where LTS spits into north and south forks, and in the lower portion of SWS. A 15.2-m long 1.8-m deep seine with 0.6-cm mesh was held at shore and towed by boat making a series of 180 degree sweeps.

Table 1. Trapping array for Tenasillahe Island and Welch Island sloughs, 2005.

Reach Length (m)	Reach Width (m)	Max. Surface Area (km^2)	Number Traps Used	Min. Traps per km^2
50	0-25	1.25	5	4.00
50	26-50	2.50	10	4.00
50	51-75	3.75	15	4.00
50	76-100	5.00	20	4.00
50	101-125	6.25	25	4.00
25	0-25	0.63	3	4.80
25	26-50	1.25	5	4.00
25	51-75	1.88	8	4.27
25	76-100	2.50	10	4.00
25	101-125	3.13	13	4.20

Habitat Characterization

Water quality variables (temperature, dissolved oxygen, conductivity, pH, turbidity, and water transparency) were recorded in each survey reach to describe the physical and chemical conditions in the four sloughs. Water temperature and depth was recorded hourly using temperature/depth loggers during 5 August through 3 October. Each logger was placed along the side of the slough within a perforated PVC pipe installed approximately 15-20 cm above the surface of the substrate. Two temperature/depth loggers were installed in each slough on Welch Island (one in the lower half and one in the upper half of a slough), two loggers were installed in STS (one in the lower half and one in the upper half of the slough), three loggers were installed in LTS (one in the lower half and one at the mid-point of each fork), and one logger was installed inside the tidegate bay of LTS (Figure 3). A single logger recording temperature only was placed along the side of the slough at the mid-point of each of the four sloughs to record hourly water temperature during 5 August through 3 October (Figure 3). In the middle of each sample reach in each slough, dissolved oxygen and conductivity were measured using an YSI meter, pH was measured, turbidity was measured using a LaMotte turbidity water test kit, and water transparency was measured using a Secchi disc and calibrated line marked in 10 cm increments.

Physical habitat characteristics (mean wetted width, mean depth, substrate, riparian vegetation, percent shade, and physical channel cover) were recorded at the mid-point of each sample reach to describe overall aquatic habitats in the four sloughs. Wetted width was measured to the nearest meter using a laser rangefinder. To calculate mean channel depth, measurements were taken at a minimum of 20 equidistant points across a transect (perpendicular the main channel). Dominant and sub-dominant surface substrate composition was estimated for each sample reach using a visual inspection of the surface of the substrate, or by testing the bottom with a wading rod, a minimum of 20 times, across the survey transect. Substrate type was recorded using six categories of substrate size: silt/clay/organic material (<0.059 mm), sand (0.06-1 mm), gravel (2-15 mm), pebble (16-63 mm), cobble (64-255 mm), and boulder (>256 mm). Dominant and sub-dominant riparian vegetation was estimated using a visual inspection of a 10-m band of land adjacent to each bank along the total length of the sample reach. Riparian vegetation was recorded using five classes of vegetation type: no vegetation (bare soil), rock/gravel, grasses/forbs, shrubs, and trees. Percent shade was a visual estimation of the amount of cover provided by the overstory or other riparian vegetation above the wetted channel along the total length of the sample reach. Physical channel cover was an estimation of the percentage of physical cover within the wetted channel provided by instream structures such as aquatic vegetation, boulders, or woody debris, and riparian features such as overhanging trees/shrubs. A digital photograph was taken at each sample reach to document current physical habitat conditions within the four sloughs.

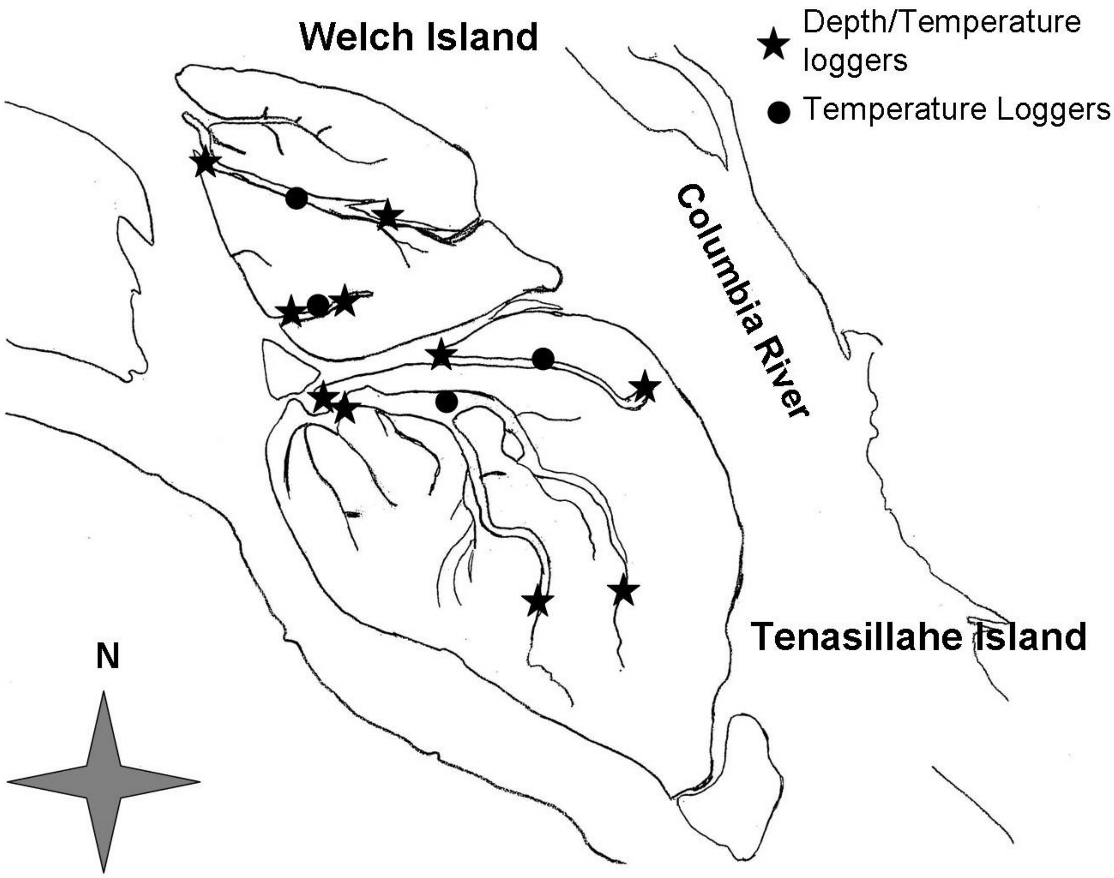

Figure 3. Location of depth/temperature loggers and temperature loggers on Tenasillahe Island and Welch Island, 2005.

Tidegate Function

Because it was unclear whether the tidegates on Tenasillahe Island were functioning properly, we contacted refuge personnel, the Clatsop County Diking District, and co-op farmers that work on Tenasillahe Island for information regarding the function and maintenance of the two tidegates. National Wildlife Refuge files were searched to find records on operation and function of the tidegates. A visual inspection of each tidegate was conducted at low tide to determine whether they opened.

Measuring rods were installed inside the three large Tenasillahe slough tidegate bays on 20 July to determine if the gates opened, and potential opening distance of each of the three individual gates in the structure. Measuring rods were constructed to span the distance between the concrete gate caisson and the catwalk. Each rod, constructed of conduit, was placed on the lower most horizontal strengthening splines of the tidegate and rested on top of boards fixed to the hand rail of the caisson catwalk. Rubber gasket material was placed over the measuring rods so that they moved freely but would not slide unless pressure was applied. A conduit collar was then placed on the rods above the rubber washer and secured to the board. When the gate opened, the forward movement of the rod pushed the rubber washer against the collar and down the rod. An initial measurement was taken from the end of the rod to the rubber washer when the gates were fully closed to establish reference points. After a tidal cycle, the rods were measured again from the ends to the rubber washers. The difference between the initial and final measurements would indicate how far the gates potentially opened (Appendix 1). Rod measurements were conducted on 14 field days, after the lowest low tide when possible.

Data from temperature/depth loggers installed inside lower LTS and the tidegate bay of LTS, and recorded tides at Skamokawa, Washington, were compared to investigate the relationship between Columbia River tidal activity and the frequency and duration of tidegate operation.

Results

Fish Sampling

Reconnaissance trip

A total of 1,774 fish representing six taxa were collected at nine locations in and around the four island sloughs. Threespine stickleback (*Gasterosteus aculeatus*) was the most abundant fish collected in the minnow traps representing over 99% of the total catch (Table 2). A single juvenile chinook salmon (*Oncorhynchus tshawytscha*) was collected inside LWS on 1 July.

Table 2. Total fish captured by species during June-July reconnaissance trip, 2005.

Scientific Name	Common Name	Total Captured	Percent of Total
Centrarchidae *Lepomis gibbosus*[1]	Pumpkinseed	1	0.06%
Centrarchidae spp.[1]	Unidentified sunfish	3	0.17%
Cottidae spp.	Sculpin	6	0.34%
Fundulidae *Fundulus diaphanus*[1]	Banded killifish	1	0.06%
Gasterosteidae *Gasterosteus aculeatus*	Threespine stickleback	1,762	99.32%
Salmonidae *Oncorhynchus tshawytscha*	Chinook salmon	1	0.06%

[1]Non native species

LTS

A total of 420 fish representing 12 taxa were collected in LTS (Appendix 2). Of the total, 94.1% of the fish captured were non-native species, and 5.9% were native (Table 3). The majority of fish in LTS (78.6%) were captured using circular fyke nets. Seining, minnow traps, and crayfish traps made up 11.6%, 7.6%, and 2.1% of the catch, respectively (Table 4). The most abundant fish species captured in LTS was white crappie (*Pomoxis annularis*), which made up 60.0% of the total catch. Carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*) were the next most abundant species, making up 8.6% and 8.1% of the total catch, respectively. We performed two beach seine hauls outside of the tidegate on LTS. A total of 159 fish representing two taxa were captured. Threespine stickleback and largemouth bass made up 93.7% and 6.3% of the total catch, respectively (Appendix 2).

Table 3. Percentage of total fish by native and non-native taxa that were captured in Tenasillahe Island and Welch Island sloughs, 2005.

Island Slough	Native	Non-Native	**Excluding stickleback**	
			Native	Non-Native
Large Tenasillahe	5.9%	94.1%	N/A	N/A
Small Tenasillahe	0.0%	100.0%	N/A	N/A
Large Welch	99.8%	0.2%	76.3%	23.7%
Small Welch	99.6%	0.4%	50.0%	50.0%

Table 4. Percentage of total fish that were captured by gear type in Tenasillahe Island and Welch Island sloughs, 2005.

Island slough	Minnow	Cray	Fyke	Seine
Large Tenasillahe	7.6%	2.1%	78.6%	11.6%
Small Tenasillahe	85.7%	14.3%	N/A	N/A
Large Welch	20.8%	0.7%	78.5%	N/A
Small Welch	95.4%	1.3%	N/A	3.3%

*Note: Not all gear types were used in each area.

STS

A total of 14 fish representing two taxa were collected in STS (Appendix 2). Of the total, 100% of the fish captured were non-native species (Table 3). The only fish sampling method used in STS was minnow and crayfish traps, which made up 85.7% and 14.2% of the total catch, respectively (Table 4). The two species captured in STS were largemouth bass, representing 85.7% of the total catch, and banded killifish (*Fundulus diaphanous*), representing 14.3% of the total catch (Appendix 2).

LWS

A total of 6,667 fish representing six taxa were collected in LWS (Appendix 2). Of the total, 99.8% of the fish species captured were native and 0.2% were non-native (Table 3). The most abundant species captured in LWS was threespine stickleback, which represented 99.1% of the total catch. Excluding threespine stickleback, 76.3% of the species captured in LWS were native, 23.7% were non-native (Table 3), and the most abundant fish species was peamouth (*Myolcheilus caurinus*), which made up 61.0% of the total catch (Appendix 2). Fyke nets, minnow traps, and crayfish traps made up 78.5%, 20.8%, and 0.7% of the total catch, respectively (Table 4).

SWS

A total of 540 fish representing three taxa were collected in SWS (Appendix 2). Of the total, 99.6% of the fish species captured were native and 0.4% were non-native (Table 3). Threespine stickleback was the most abundant species making up 99.3% of the total catch (Appendix 2). Excluding threespine stickleback, 50.0% of the fish species captured in SWS were native, with the two most abundant fish species being banded killifish and sculpin (*Cottidae spp*.). Of the three fish sampling methods used in SWS, minnow traps were the most successful method for capturing fish making up 95.4% of the total catch. Beach seines and crayfish traps made up 3.3% and 1.3% of the total catch, respectively (Table 4).

Habitat Characterization

LTS

Range in water depth recorded by three depth/temperature loggers was 0.2-0.9 m. Range in water temperature was 12.5-25.1 °C with a mean of 18.9 °C (SD=1.9) throughout LTS (Figure 4). Mean dissolved oxygen was 4.3 mg/l (SD=2.7), mean specific conductivity was 1940.6 µS (SD=755.6), mean pH was 7.1 (SD=0.8), mean turbidity was 38.1 JTUs (SD=50.3), and mean water transparency was 39 cm (SD=11.8) in the eight survey reaches (Table 5). Wetted width was 24-121 m, and cross-sectional depth was 10-210 cm, with a mean of 80 cm (SD=37.3). Dominant and sub-dominant substrate was silt (100% of sample reaches) and sand (100% of sample reaches), respectively. Riparian vegetation in LTS was primarily grass/forb (dominant in 75% of sample reaches) and woody shrubs (dominant in 25% and sub-dominant in 50% of sample reaches). Percent shade was low (0-5% of the total reach area), and physical channel cover was provided by aquatic vegetation (5-100% of total reach area) and a few overhanging trees (5-10% of total reach area) (Table 6).

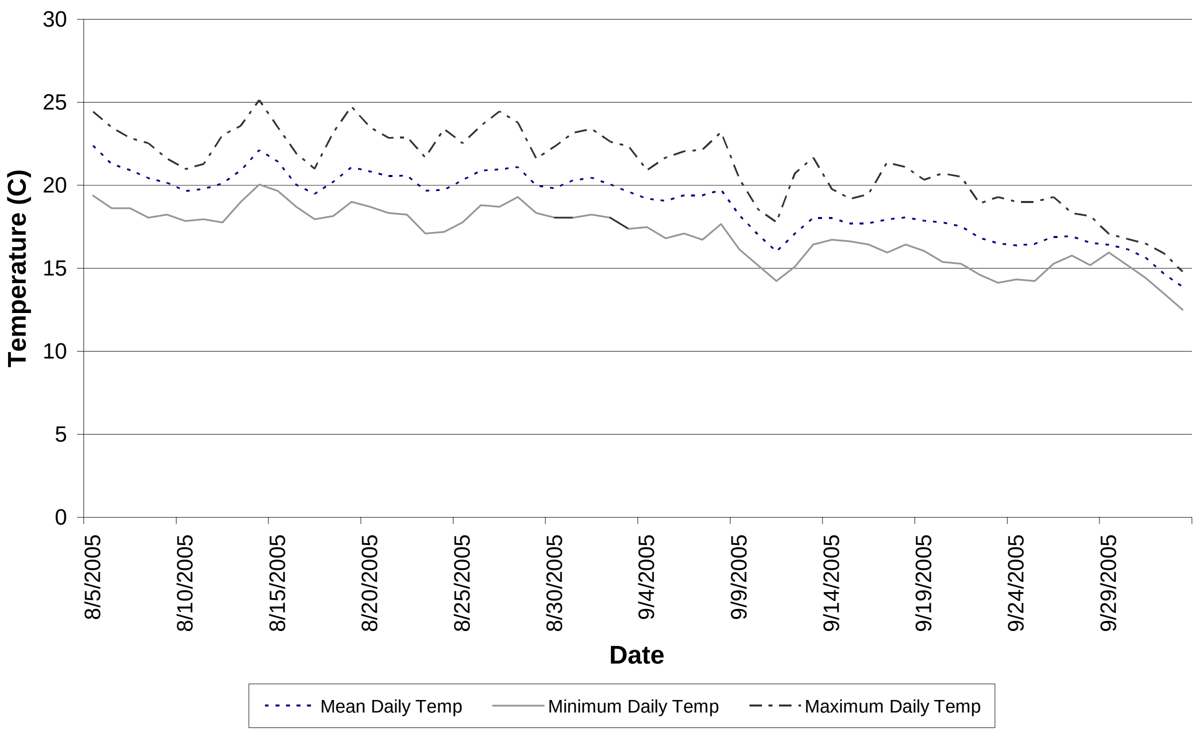

Figure 4. Daily minimum, daily maximum, and mean daily temperature in large Tenasillahe slough, 2005.

Table 5. Mean (standard deviation, range) of water quality variables within large Tenasillahe slough (LTS), small Tenasillahe slough (STS), large Welch slough (LWS), and small Welch slough (SWS), 2005.

Variables	LTS	STS	LWS	SWS
DO (%)	44.8 (33.4, 4.2-80.3)	31.1 (4.4, 27.5-36)	92.4 (24.8, 56.1-117.2)	68.6 (10.8, 60.9-76.2)
DO (mg/l)	4.3 (2.7, 0.6-7.5)	2.6 (0.5, 2.4-3.2)	8.1 (2.1, 5.1-10.3)	6.1 (0.8, 5.5-6.6)
Specific Conductivity (µS)	1940.6 (755.6, 268.5-2489)	136.3 (10.3, 124.8-144.7)	127.6 (32.8, 69.5-147.2)	162.3 (19.0, 148.9-175.7)
Relative Conductivity (µS)	2140.7 (859.0, 234.5-2841)	119.4 (9.7, 108.9-128)	153.2 (3.6, 149.3-158.2)	150.5 (12.6, 141.6-159.4)
pH	7.1 (0.8, 6.4-8.6)	8.9 (1.4, 7.3-10.4)	8.0 (0.5, 7.4-8.7)	7.9 (1.0, 7.2-8.6)
Turbidity (JTU)	38.1 (50.3, 5-150)	13.3 (7.6, 5-20)	24 (6.5, 20-35	10 (0.0, 10-10)
Transparency (cm)	39 (11.8, 30-55)	30 (0.0, 30-30)	92 (45.1, 45-160)	98 (10.6, 90-105)

Table 6. Physical habitat variables within large Tenasillahe slough (LTS, n=8 sites), small Tenasillahe slough (STS, n=3), large Welch slough (LWS, n=5), and small Welch slough (SWS, n=2), 2005.

Variables	LTS	STS	LWS	SWS
Dominant Substrate [a]	Silt (100%)	Silt (100%)	Silt (100%)	Silt (100%)
Sub-Dominant Substrate [a]	Sand (100%)	Silt (66.6%), Sand (33.3%)	Sand (100%)	Sand (50%), Cobble (50%)
Dominant Riparian Veg. [b]	Grass Forb (75%), Shrubs (25%)	Shrubs (66.6%), Grass Forb (33.3%)	Grass Forb (60.0%), Shrubs (40.0%)	Grass Forb (50.0%) Shrubs (50.0%)
Sub-Dominant Riparian Veg. [b]	Shrubs (50%), Grass Forb (25%), Trees (12.5%), No Vegetation (12.5%)	Trees (66.6%), Shrubs (33.3%)	Shrubs (60.0%), Trees (40.0%)	Grass Forb (50.0%) Shrubs (50.0%)
Mean Percent Shade (SD, range)	2.3% (2.3, 0-5%)	23.3% (15.3, 10-40%)	1.8% (1.8, 1-5%)	5.5% (6.36, 1-10%)
Percent Physical Cover[c]	Aquatic Vegetation (50.6%) Overhanging Trees/Shrubs (1.88%)	Aquatic Vegetation (76.6%) Woody Debris (23.3%)	Aquatic Vegetation (24.0%)	Aquatic Vegetation (20.0%) Woody Debris (5.0%)

Note [a] substrate categories: silt, sand, gravel, pebble, cobble, boulder. [b] riparian vegetation categories: no vegetation, rock/gravel, grassland forb, shrubs, trees. [C] physical cover categories: overhanging tree/shrub, aquatic vegetation, woody debris.

STS

Range in water depth recorded by depth/temperature loggers was 0.4-0.7 m. Range in water temperature was 12.9-21.8 °C, with a mean of 17.7 °C (SD=1.8) throughout STS (Figure 5). Mean dissolved oxygen was 2.6 mg/l (SD=0.5), mean specific conductivity was 136.3μS (SD=10.3), mean pH was 8.9 (SD=1.4), mean turbidity was 13.3 JTUs (SD=7.6), and water transparency was 30 cm (SD=0.0) in the three survey reaches (Table 5). Wetted width was 33-53 m, and cross-sectional depth was 10-100 cm, with a mean of 60 cm (SD=11.2). Dominant substrate type was silt in 100% of sample reaches and sub-dominant in 67% of sample reaches. Riparian vegetation in STS was primarily woody shrubs (dominant in 67% of sample reaches) and deciduous trees (sub-dominant in 67% of sample reaches). Percent shade was moderate (10-40% of the total reach area), and physical channel cover was provided by aquatic vegetation (60-90% of total reach area) and some submerged large woody debris (10-40% of total reach area) (Table 6).

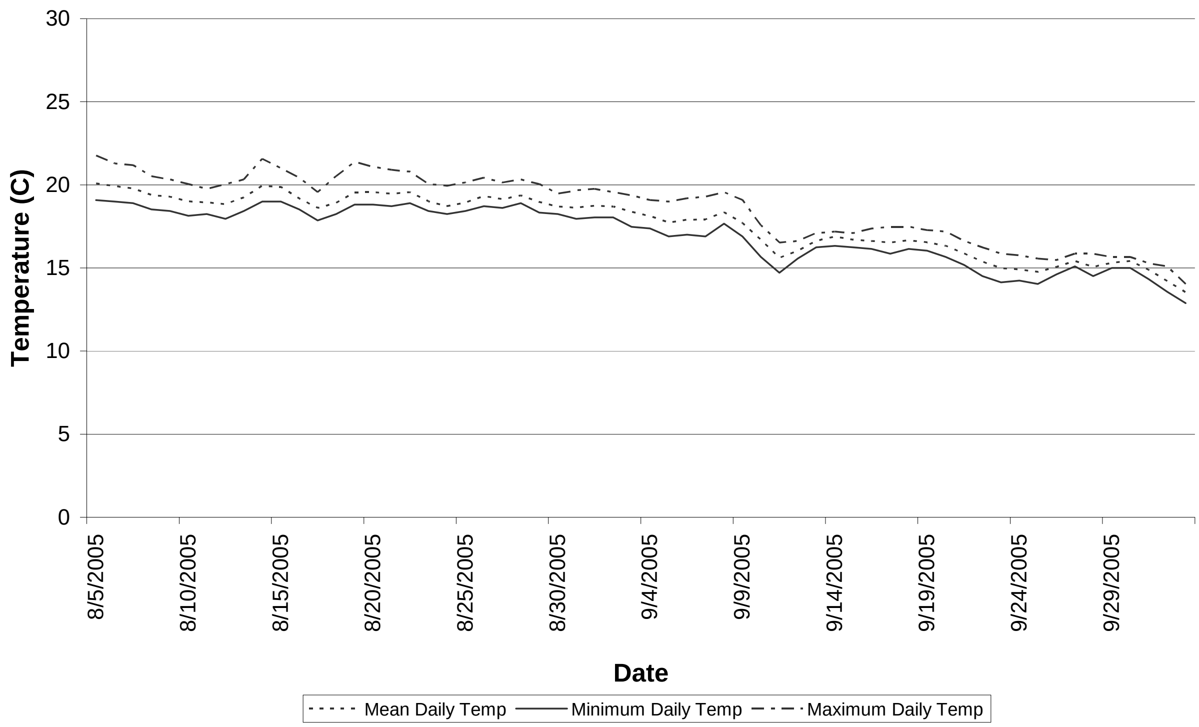

Figure 5. Daily minimum, daily maximum, mean daily temperature in small Tenasillahe slough, 2005.

LWS

Range in water depth recorded by depth/temperature loggers was 0.0-3.3 m. Range in water temperature was 7.5-28.8 °C, with a mean of 19.2 °C (SD=1.9) throughout LWS (Figure 6). Mean dissolved oxygen was 8.1 mg/l (SD=2.1), mean specific conductivity was 127.6μS (SD=32.8), mean pH was 8.0 (SD=0.5), mean turbidity was 24 JTUs (SD=6.5), and mean water transparency was 92 cm (SD=45.1) in the five survey reaches (Table 5). Wetted width was 20.5-52.5 m, and cross-sectional depth was 10-160 cm, with a mean of 80 cm (SD=24.4). Dominant substrate was silt in 100% of sample reaches and sub-dominant substrate was sand in 100% of sample reaches. Riparian vegetation in LWS was primarily grass/forb (dominant in 60% of sample reaches) and woody shrubs (dominant in 40% and sub-dominant in 60% of sample reaches). Percent shade was minimal (1-5% of the total reach area), and physical channel cover was provided by aquatic vegetation (10-35% of total reach area) (Table 6).

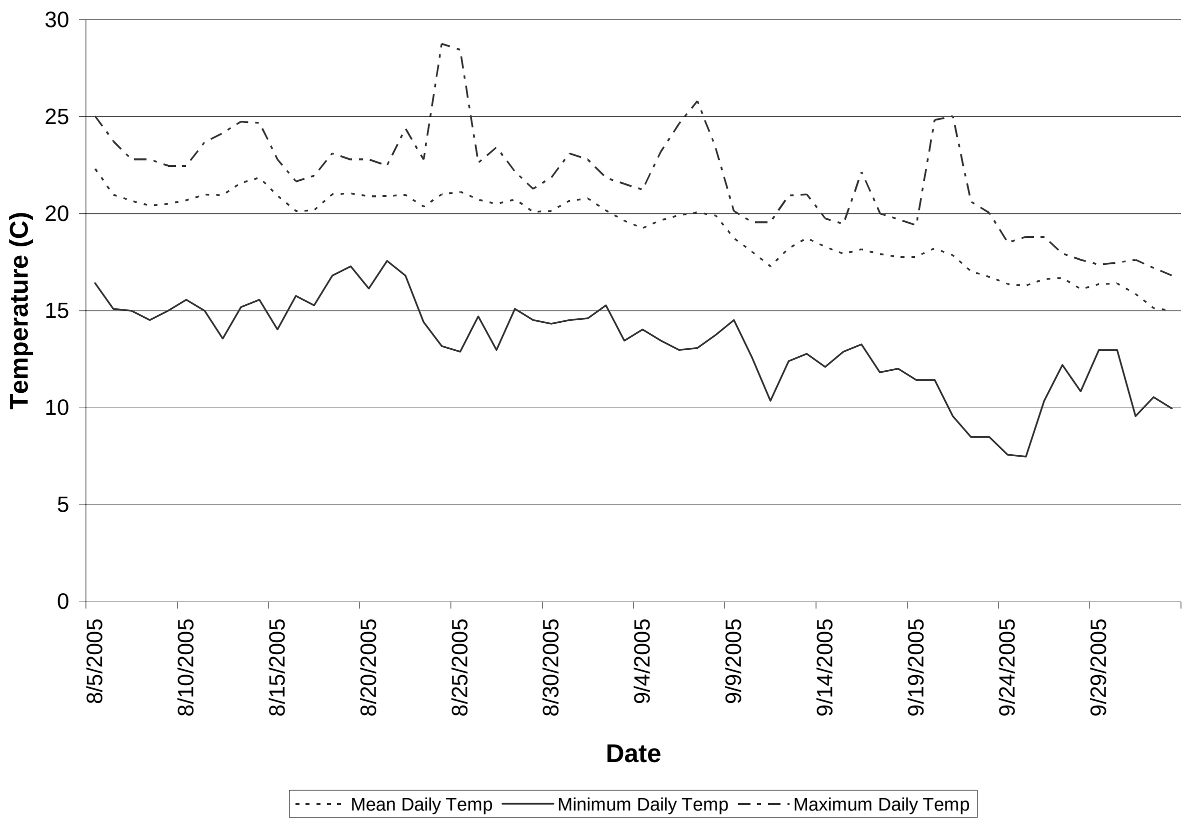

Figure 6. Daily minimum, daily maximum, and mean daily temperature in large Welch slough, 2005.

SWS

Range in water depth recorded by depth/temperature loggers was 0.0-2.5 m. Range in water temperature was 8.5-24.4 °C, with a mean of 19.1 °C (SD=1.9) throughout SWS (Figure 7). Mean dissolved oxygen was 6.1 mg/l (SD=0.8), mean specific conductivity was 162.3 µS (SD=19.0), mean pH was 7.9 (SD=1.0), mean turbidity was 10 JTUs (SD=0.0), and mean water transparency was 98 cm (SD=10.6) in the two survey reaches (Table 5). Wetted width was 13.0-34.5 m, and cross-sectional depth was 10-110 cm, with a mean of 70 cm (SD=20.5). Dominant substrate was silt in 100% of sample reaches, and sub-dominant substrate was sand and cobble in 50% of sample reaches. Riparian vegetation in SWS was primarily grass/forb (dominant and sub-dominant in 50% of sample reaches) and woody shrubs (dominant and sub-dominant in 50% of sample reaches). Percent shade was low (1-10% of the total reach area), and physical channel cover was provided by aquatic vegetation (15-25% of total reach area) and submerged woody debris (10% of total reach area) (Table 6).

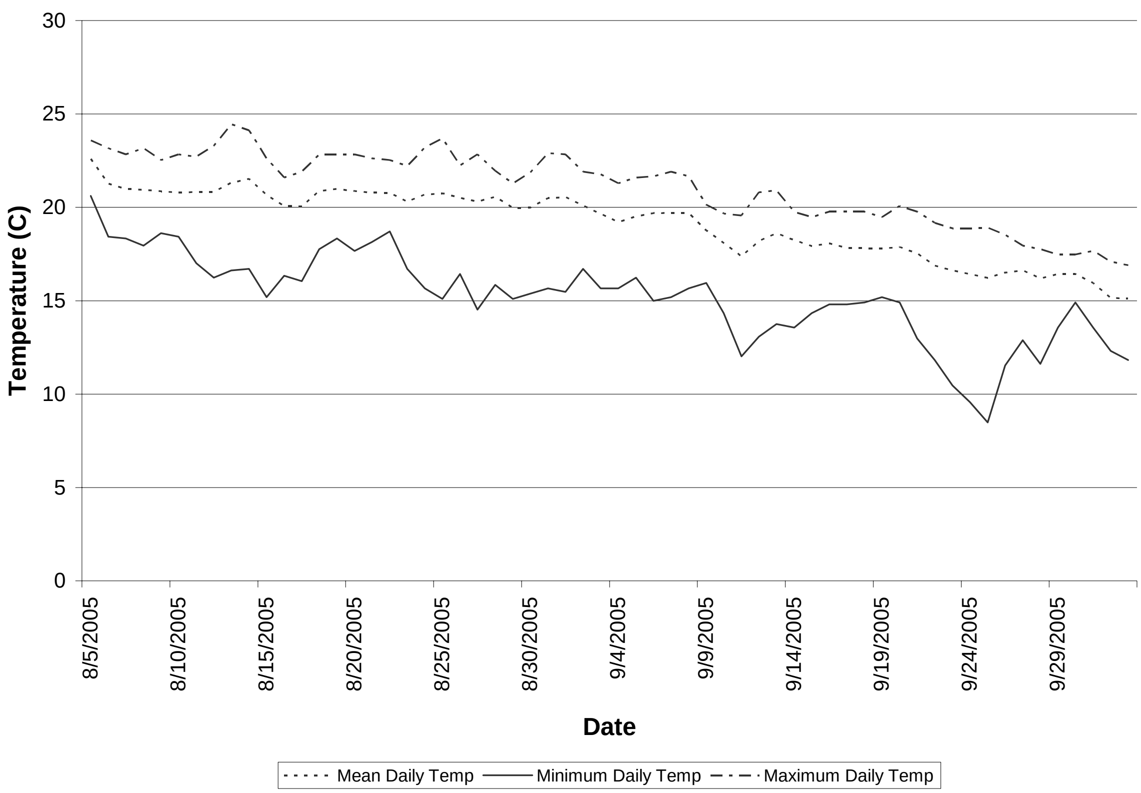

Figure 7. Daily minimum, daily maximum, and mean daily temperature in small Welch slough, 2005.

Tidegate Function

Limited information was produced by our research and inquiries regarding tidegate function and maintenance. Multiple visual observations of the large and small tidegate structures on Tenasillahe Island revealed that the large tidegate appeared to be functioning properly (i.e., opened in response to tidal fluctuation in the Columbia River), but the small tidegate did not. Inspection of rod-measurement data revealed that all three tidegate doors opened to varying degrees (Table 7), but that the middle tidegate had the most consistent motion throughout the pilot study (i.e., was not fouled by logs or debris). Bay 1 opened 93% of days measured, bay 2 opened 100% of days measured, and bay 3 opened 43% of days measured. Data from the middle tidegate (bay 2) was thus considered as the most reliable to evaluate potential tidegate opening distance. The greatest range of motion for the middle tidegate was recorded on 3 August at 6.35 cm. The least amount of movement recorded on 8 August was 1.60 cm (Table 7).

Table 7. Maximum range of motion of each tidegate on large Tenasillahe slough, 2005.

Date	Bay 1 (cm)	Bay 2 (cm)	Bay 3 (cm)	Min. H_2o level (cm), Bay 2
7/21/2005	4.78	4.78	2.87	N/A
8/3/2005	4.78	6.35	3.18	N/A
8/4/2005	3.18	3.81	2.54	N/A
8/8/2005	1.60	1.60	N/O	28.35
8/8/2005	4.32	4.57	1.45	30.48
8/9/2005	3.18	2.87	N/O	29.87
8/16/2005	1.60	3.18	N/O	28.65
8/17/2005	1.42	3.18	N/O	24.38
8/18/2005	1.60	3.18	N/O	25.60
8/23/2005	2.87	4.45	2.87	29.87
8/24/2005	2.24	5.41	N/O	28.35
8/24/2005	N/O	5.08	N/O	28.96
8/25/2005	1.27	4.78	N/O	23.77
8/26/2005	1.60	2.87	4.78	26.82

N/O = not open

Water level and tidegate function were compared using the recorded tides at Skamokawa, Washington, and recorded water depth from the depth/temperature logger located inside the tidegate bay. Preliminary data indicates the gates open in response to a water level below 30 cm inside the tidegate bay. During 19 August through 26 August, the low tide at Skamakawa was below 30 cm on twelve occasions (Figure 8). During this same time period, water level inside the middle tidegate bay fell below 30 cm seven times (58% of days Skamokawa was below 30 cm), and tidegate movement was recorded on five of the seven occasions (100% of days measured). Of the eleven days tidegate movement was measured using the rod system (first three days depth loggers not installed), movement occurred when water level inside the tidegate bay was less than 30 cm on 100% of the days (Table 7). The depth logger inside the tidegate indicates water level decreases until it reaches a relatively constant minimum water level (below 30 cm). We believe this minimum level is maintained by water flowing out of the slough through the open tidegate. When the water level falls below 30 cm in the tidegate bay, there is a flat segment at the perigee of the curve on the graph (Figure 8). The flattened graph segments are believed to represent the duration of time that the gate is open. On 8 August we recorded a known gate closure at 10:26AM (water level 32.4 cm). The next known point of closure occurred on 8 August at 3:55PM (water level 186.1 cm). Between the two known closures, the measuring rod in bay two recorded tidegate movement of 4.57 cm. Assuming the tidegate opened when the water level inside the bay was below 30 cm, we theorize the gate was open from 11:00AM (28.4 cm) to 12:30PM (30.4 cm) (Figure 9). The length of the flattened graph segments (duration of opening) appears to be associated with the length and range of the tide. The lower the water level falls below 30cm in the Columbia River, the longer the tidegate remains open.

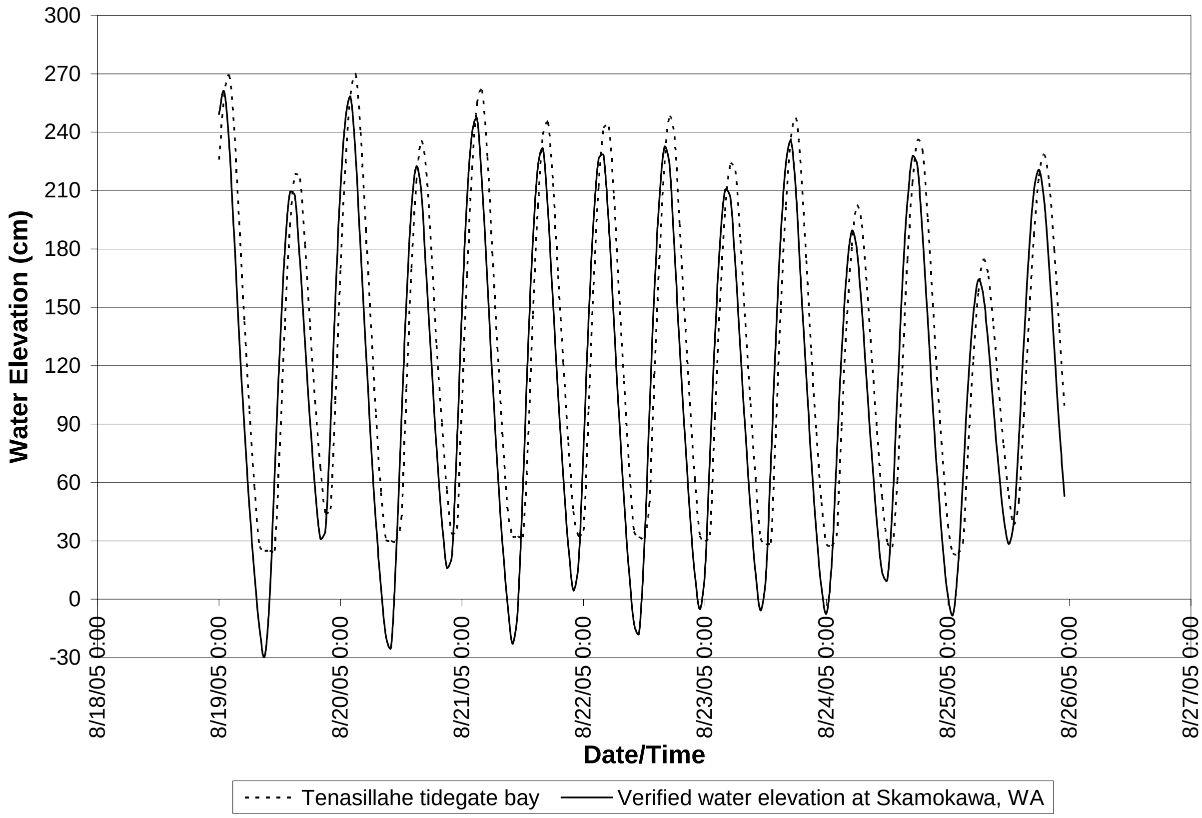

Figure 8. Comparison of verified water elevation and water depth recorded by the depth/temperature logger located inside LTS tidegate bay from 19 August through 26 August, 2005.

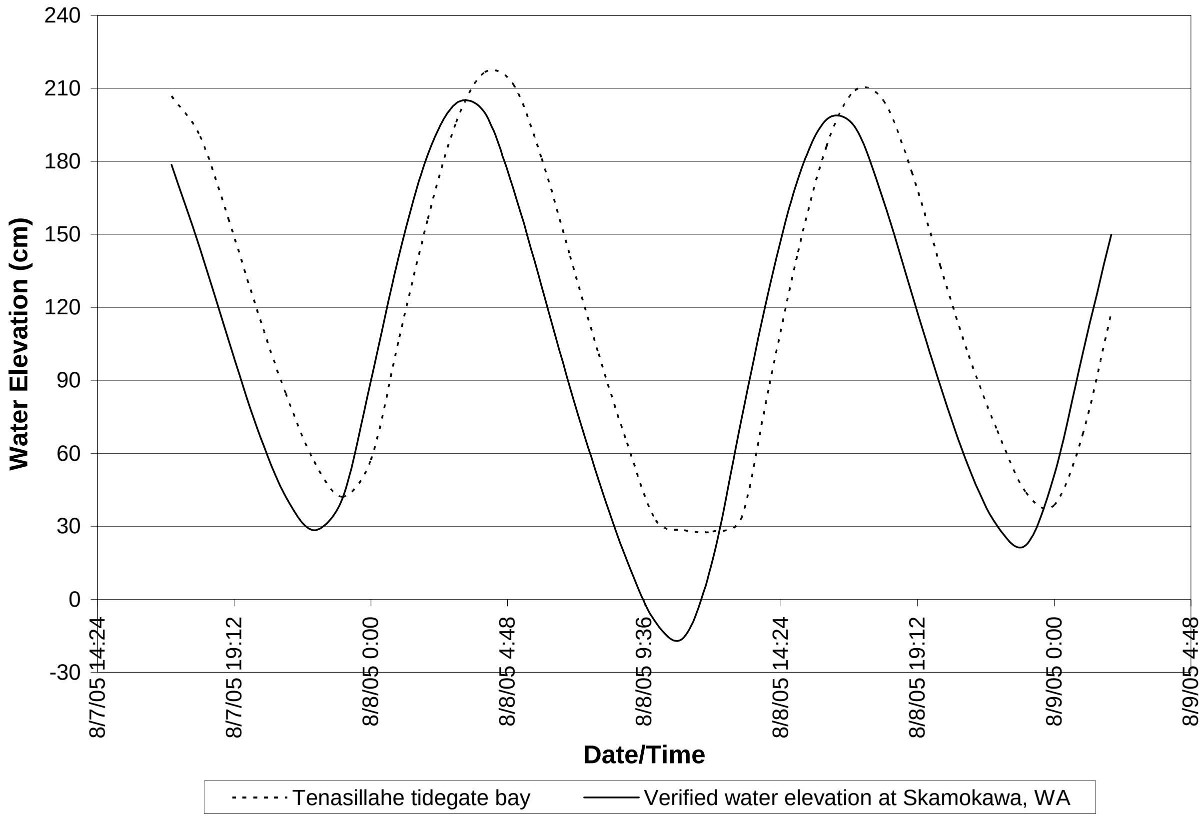

Figure 9. Comparison of verified water elevation and water depth recorded by the depth/temperature logger located inside LTS tidegate bay during a 48 hour period, 2005.

Discussion

Fish Sampling

We observed fundamental differences in species composition and relative abundance between Tenasillahe Island and Welch Island sloughs. Although few taxa occurred in the small sloughs on both islands (two and three in STS and SWS, respectively), greatest overall diversity of species occurred in LTS (12 taxa) and LWS (6 taxa) (Appendix 2). A higher percentage of non-native species were captured in both Tenasillahe Island sloughs (>94.1%) compared to both Welch Island sloughs (<1%). Relative abundance of individuals was higher in Welch Island sloughs than Tenasillahe Island sloughs.

Fyke nets were the most effective gear for capturing fish in the sloughs. In areas where multiple fish sampling methods were used, fyke nets captured the largest number of individuals and greatest diversity of species. In both LTS and LWS, about, 79% of all fish were captured in fyke nets. Minnow and Crayfish traps were used in all sample reaches with varying results. Comparing total fish captured using the two methods, minnow traps had better success in all Island sloughs. This may be due to the different species that are in the sampling reach, or the size selectivity of minnow and crayfish traps. The 2.5-cm opening of minnow traps may exclude larger species (e.g., crappie, carp, and largemouth bass), while the 5.7-cm opening of crayfish traps may allow smaller species such as threespine stickleback to escape. Beach seines proved to be a moderately effective sampling tool for determining fish species presence in an area at a specific time. Seining was limited to LTS and SWS because they were the only areas with sufficient open water (i.e., minimal debris) and enough shoreline to effectively sweep the entire seine.

Columbia River salmon generally smolt and emigrate past these islands in the spring, between the months of February and June. It is likely that this pilot study was conducted too late for salmon to be present in substantial abundance. Sampling in spring 2006 is planned during the February – June period when juvenile salmonids are likely in the area. Although it is unclear which sampling method will work best for capturing salmon in the island sloughs, the pilot study conducted in summer 2005 has enabled us to assess sampling methods appropriate to conditions within the island sloughs. It is likely, however, that environmental conditions in spring 2006 will be vastly different than those experienced in summer 2005. Sampling methods may need to be modified for different sampling conditions (i.e., greater water depth, less aquatic vegetation), and the potential for capturing ESA listed species (setting traps for a tidal cycle rather than overnight).

Habitat Characterization

Current summer water temperature in Tenasillahe Island sloughs may not be able to support salmonids. Juvenile Pacific salmon species prefer temperatures between 12-14°C, but will tolerate temperatures of 15-20°C for brief periods (Brett 1952). Water temperatures in all island sloughs approached upper tolerable levels on almost a daily basis, ranging from 15.5-25.1°C in LTS, 12.9-21.8°C in STS, 7.5-28.8°C in LWS, and 8.5-24.4°C in SWS. Overall, water temperature was an average of 0.85°C higher in Welch Island sloughs than in Tenasillahe Island sloughs. This apparent difference in temperature seems counter-intuitive given that Tenasillahe Island sloughs are essentially closed systems. The difference in temperature between the two islands may be attributable to the depth/temperature loggers going dry in Welch more frequently than recorded depth measurements indicate.

Other water quality parameters in Tenasillahe Island sloughs may also make it difficult for salmonids to exist. Dissolved oxygen concentrations above 5 mg/l are optimal for most fish species, while concentrations below 2.5 mg/l (depending on species and water temperature) may be lethal (Hicks 2000). Dissolved oxygen levels were 0.6-7.5 mg/l in LTS, 2.4-3.2 mg/l in STS, 5.1-10.3 mg/l in LWS, and 5.5-6.6 mg/l in SWS. Dissolved oxygen concentrations remained above optimum levels in 100% of Welch Island sample reaches. Oxygen levels were at or below lethal levels in 50% of LTS sample reaches and 67% of STS sample reaches. We observed distinct diurnal variations in dissolved oxygen levels within both Tenasillahe Island sloughs. The tolerable range range of pH for fish depends on factors such as water temperature, dissolved oxygen, water chemistry and prior acclimatization. A pH range of 6.7-8.3 is optimal for most fish species (Bell 1986). Average pH levels in all island sloughs remained within this range throughout the study. Turbidity levels in Tenasillahe Island sloughs were moderately high as compared to Welch Island sloughs. Current suspended sediment levels are not likely a concern to fish species in the sloughs.

Tidegate Function

Current tidegates may not allow for salmonids to have regular access to the island sloughs. The small tidegate on STS remained inoperable throughout the study. This was likely due to the large quantity of woody debris and sediment blocking the slough culvert from the inside that prevented water from flowing out of the slough. Although all three tidegate doors on LTS opened in response to tidal fluctuation to varying degrees (1.3-6.4 cm), visual observation revealed that logs and debris fouled two of the three gates (and measuring rods) on eight occasions during the study.

It remains unclear whether the gate system opens progressively, or opens a maximum distance once a threshold pressure head is met. Acquisition of a complete set of data regarding the range of gate opening and rate of flow at different points in the tidal cycle will be important in determining the window of opportunity for juvenile salmonid ingress in Tenasillahe Island sloughs. Even though a tidegate may be open, it remains unclear whether juvenile salmon can actually swim through the opening.

Whether tidegates would open could be predicted by water elevations associated with the tides. During average summer water levels, the frequency and duration of tidegates being open was associated with water levels below 30 cm inside the tidegate bay. Tide predictions for Harrington Point, Washington (Skamokawa tide elevations unavailable) suggest that, between 1 March – 31 March 2006, 36 tides will result in water levels in the tidegate bay less than 30 cm. Based on our model, 100% of tides below mean sea level (eight), and 58% of the remaining 28 tides will result in a water level below 30 cm inside the tidegate bay. Thus, we estimate the tidegate will open 24 times during the month of March 2006. Given typical tidal cycles and the estimated period when water levels will remain below 30 cm, we also estimate that the tidegates will be open for a total of 40 hours during March 2006. Since the water level in the Columbia River and LTS will be much higher in spring 2006 than it was in the summer of 2005, it will be necessary to validate the modeling we are using to predict the frequency and duration of tidegate openings.

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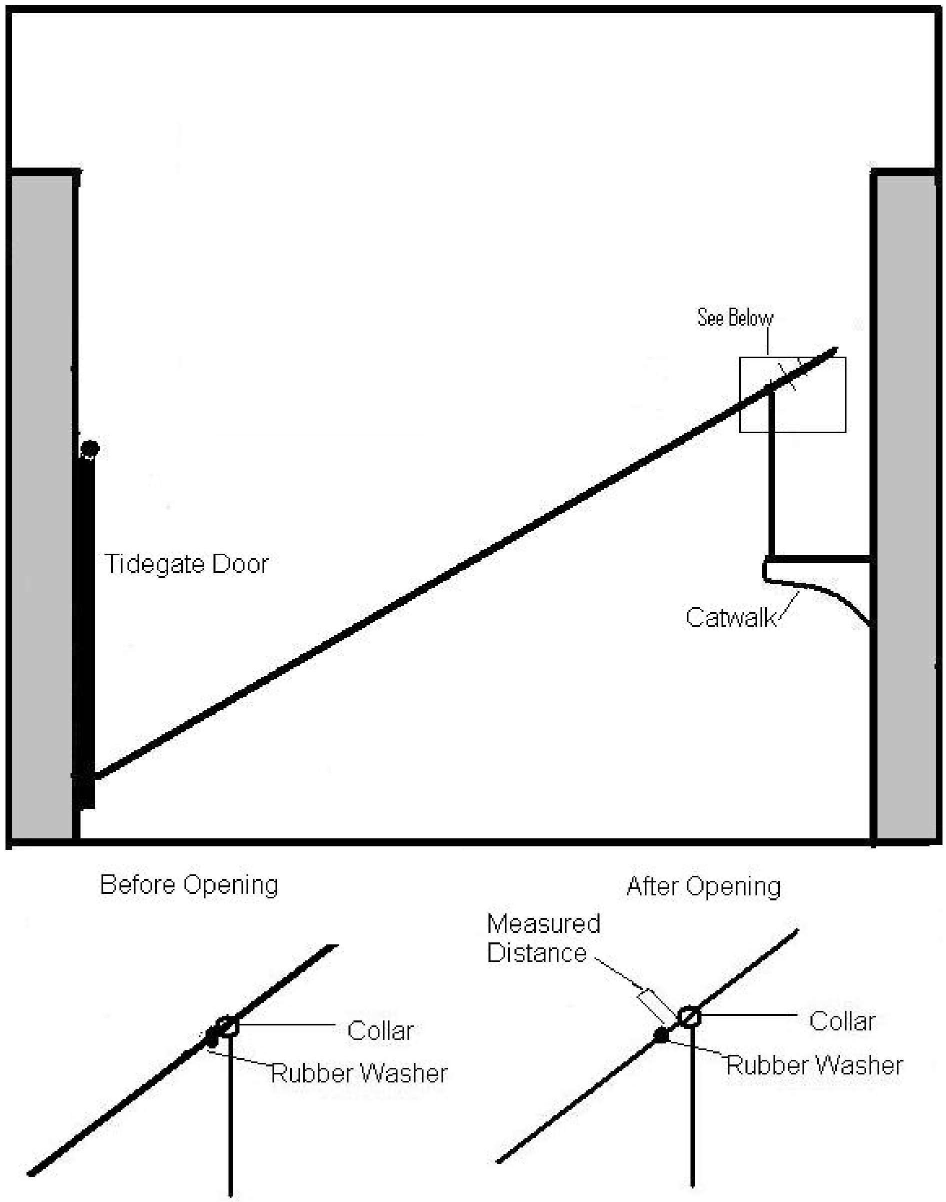
Appendices



Appendix 1. Diagram of tidegate measuring rod located inside each tidegate bay at LTS, 2005.

Appendix 2. Total fish captured and percentage of total catch (all sampling methods combined) in Tenasillahe Island and Welch Island sloughs, 2005.

Species	# Individuals Captured	% of Total
Large Tenasillahe (LTS)		
White Crappie	252	60.0
Common Carp	36	8.6
Largemouth Bass	34	8.1
Sculpin	18	4.3
Pumpkinseed	17	4.0
Bluegill	16	3.8
Unknown Sunfish	15	3.6
Yellow Bullhead	12	2.8
Banded Killifish	11	2.6
Peamouth	6	1.4
Brown Bullhead	2	0.5
Threespine Stickleback	1	0.2
Total	420	
Outside Large Tenasillahe Tidegate		
Threespine Stickleback	149	93.7
Largemouth Bass	10	6.3
Total	159	
Small Tenasillahe (STS)		
Largemouth Bass	12	85.71
Banded Killifish	2	14.28
Total	14	
Large Welch (LWS)		
Threespine Stickleback	6608	99.1
Peamouth	36	0.5
Banded Killifish	14	0.2
Sculpin	4	0.1
Sucker	4	0.1
Northern Pikeminnow	1	0.0
Total	6667	
Large Welch (LWS) excluding threespine stickleback		
Peamouth	36	61.0
Banded Killifish	14	23.7
Sculpin	4	6.8
Sucker	4	6.8
Northern Pikeminnow	1	1.7
Total	59	
Small Welch (SWS)		
Threespine Stickleback	536	99.3
Banded Killifish	2	0.4
Sculpin	2	0.4
Total	540	