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

2006 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 of 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.

Both Tenasillahe and Welch islands are part of the National Wildlife Refuge system, which is managed by the U.S. Fish and Wildlife Service. The islands are adjacent to each other and located at about river kilometer 56 in the lower Columbia River. Much of the tidal marsh habitat historically occurring at Tenasillahe Island was altered due to the construction of dikes around the island during the course of the last century. Aquatic habitat on the island now consists primarily of a network of interior sloughs connected to the Columbia River via two tidegates. Tenasillahe Island is currently managed, primarily, to provide habitat for Columbian White-tailed deer. The tidal marsh habitat on Welch Island is relatively pristine. It does not appear that Welch Island was ever settled by humans, roads do not currently exist on the island, and none of the sloughs on the island have been diked. Thus, these two islands provide an opportunity to compare diked sloughs to unimpacted sloughs, under a BACI-type framework.

The U.S. Army Corps of Engineers (USACOE) has proposed a phased restoration project at Tenasillahe Island intended to benefit juvenile salmonids while balancing the needs of white-tailed deer. 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 final phase may include breaching dikes on the island to restore natural tidal circulation. Proposed long-term 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.

The U.S. fish and Wildlife Service, Columbia River Fisheries Program Office (CRFPO) has initiated 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 before and after USACOE restoration actions. 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. Characterize habitats at the sloughs on Tenasillahe Island and compare to that observed at reference sloughs at Welch Island, 3. 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, 4. Describe the movement of juvenile salmon in and out of the sloughs as well as their residence in and use of the sloughs on Tenasillahe Island and compare to that observed at reference sloughs on Welch Island.

USFWS conducted tasks relative to these objectives during the winter and spring of 2006. This work followed summer 2005 reconnaissance when sampling reaches were determined and preliminary information concerning fish and habitats within sloughs was collected. The 2005 reconnaissance 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.

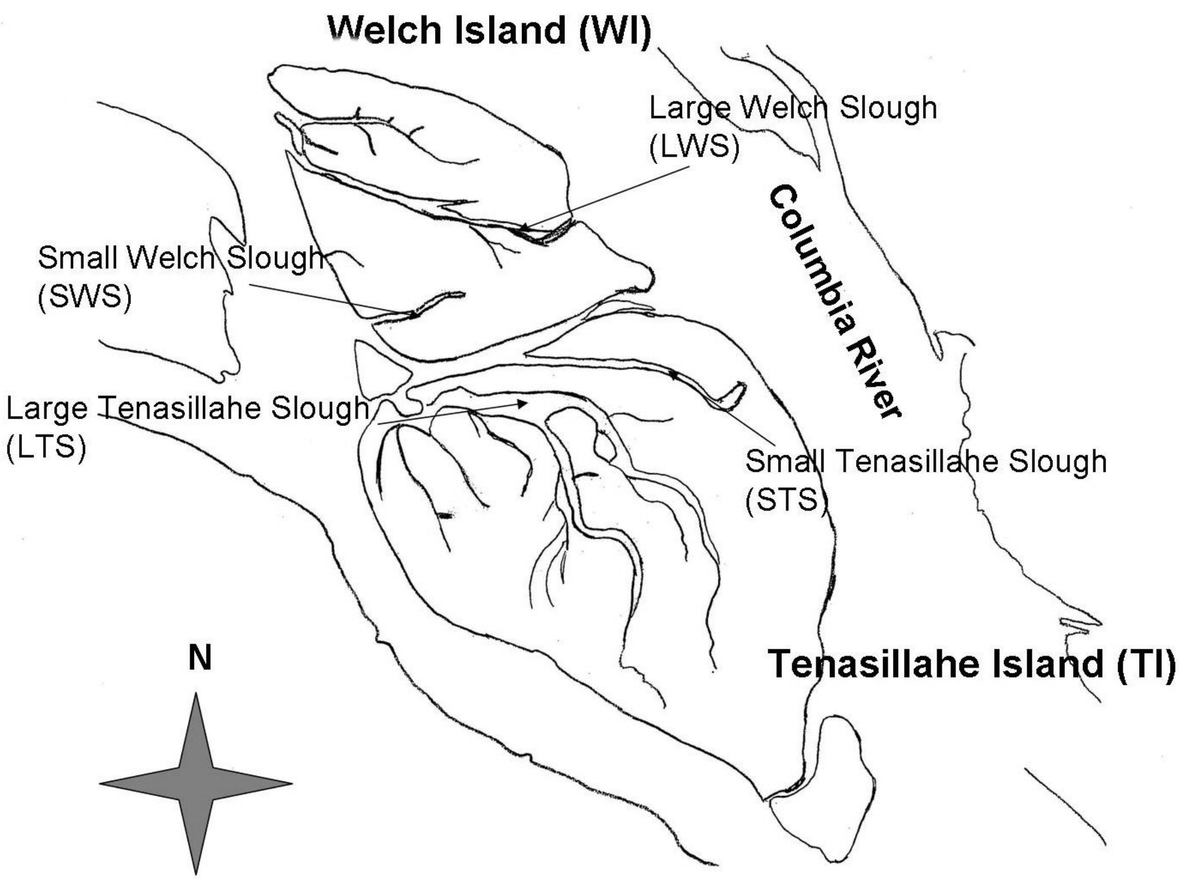

Figure 1. Area map of Tenasillahe Island and Welch Island showing locations of sloughs surveyed in 2006: large Tenasillahe slough (LTS), small Tenasillahe slough (STS), large Welch slough (LWS), small Welch slough (SWS).

Methods

Sample Reaches

Work conducted in 2006 was built off work conducted during June-August 2005. The project focused on two sloughs affected by tidegates on Tenasillahe Island designated as treatment sites, and two natural (unmodified) sloughs on

Welch Island that were used as reference sites (Figure 1). Sampling effort in 2006 focused on the standardized set of sampling reaches selected during the 2005 work. 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. 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 georeferenced so that future sampling efforts could focus on the same set of reaches.

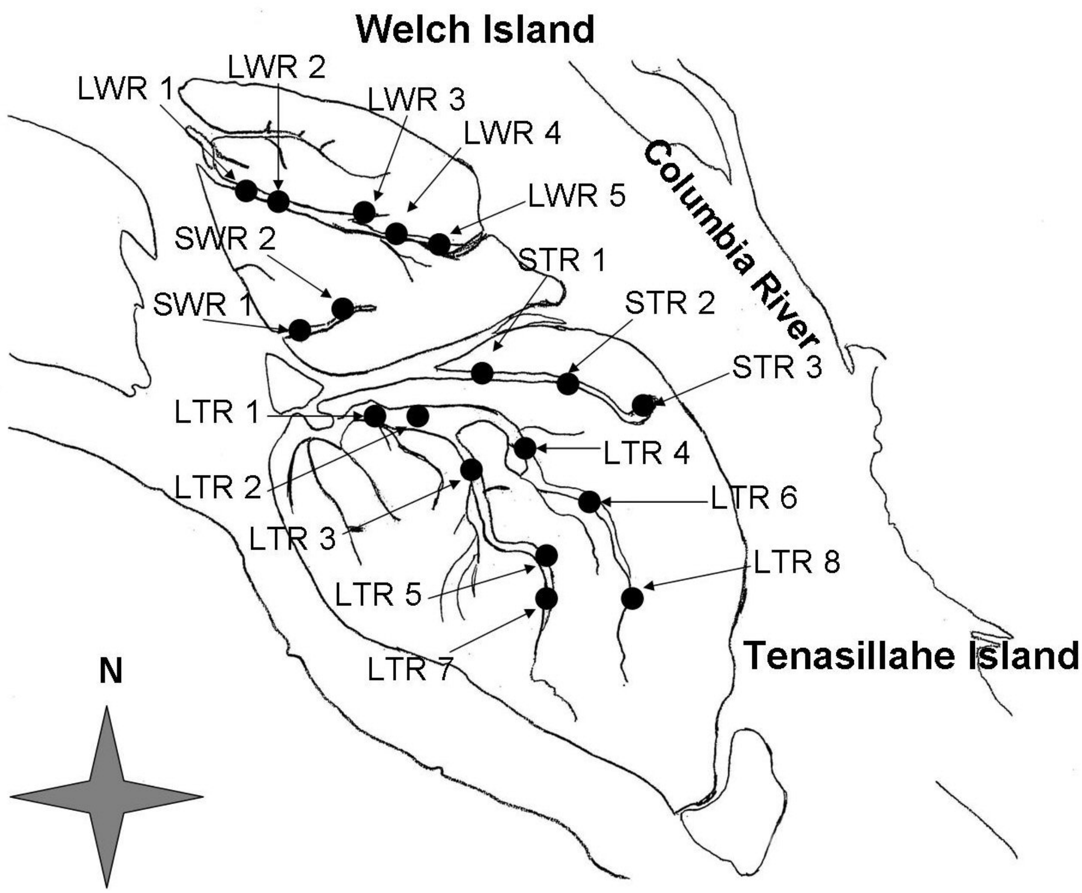

Figure 2. Tenasillahe Island and Welch Island sample reaches, 2006.

<u>Tidegate Function</u>

Measuring rods were installed inside the three large Tenasillahe slough tidegate bays on 27 March to record openings of the three individual gates in the structure. Measuring rods were constructed such that a rubber washer would slide along the rod as the tidegate opened and would remain at the new location on the rod when the tidegate closed. Before a tidal cycle, each rubber washer was seated in the fully closed position. After a tidal cycle, the rods were checked to see if the washers had moved indicating a tidegate opening (Figure 3). Rod measurements were taken on 19 field days following 21 outgoing tides. Measurements made after multiple tidal cycles (i.e., over weekend) were assumed to occur during the lowest tide of the time period.

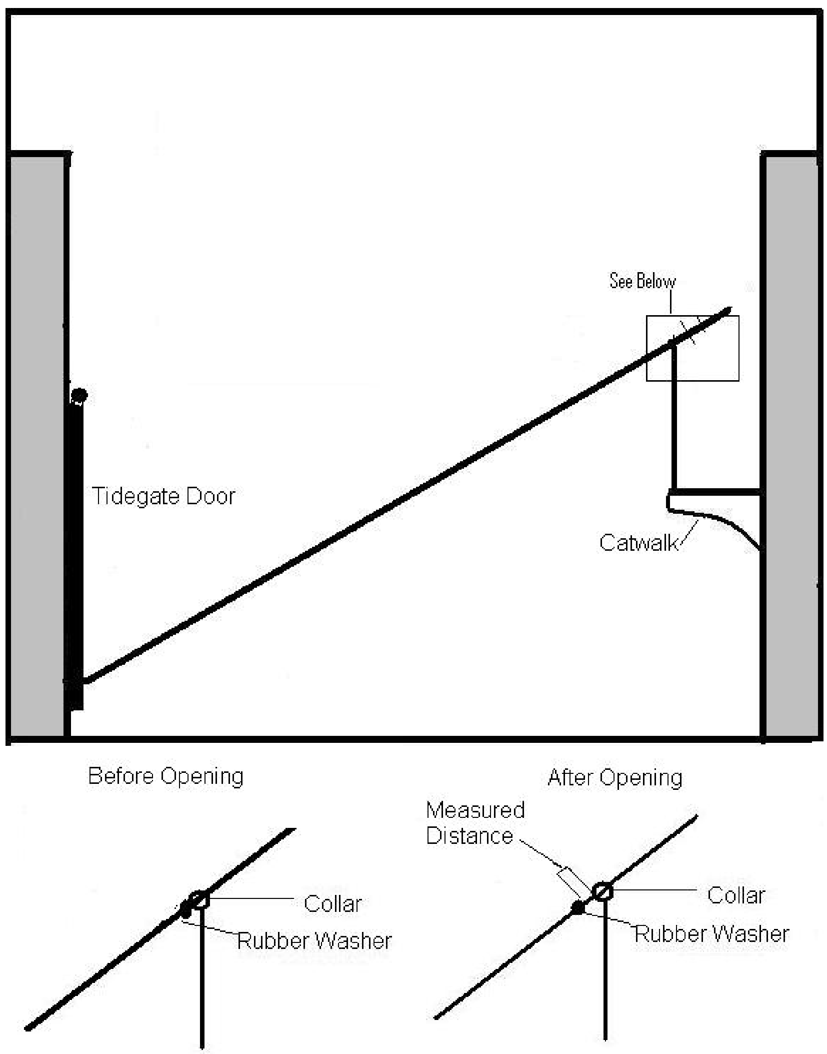

Figure 3. Diagram of tidegate measuring rod located inside each tidegate bay at LTS, 2006.

Data from temperature/depth loggers installed within lower LTS and the tidegate bay of LTS, and recorded tides at Skamokawa, Washington, were used to determine frequency and duration of tidegate opening and the relationship between Columbia River tidal activity and tidegate operation. We compared information on known tidegate openings from measuring rods and emigration detection time of released PIT tagged fish (methods below) to water elevation differential between slough side and river side of tidegates. The difference between slough and Skamokawa water levels when known tidegate openings occurred and PIT tagged fish were able to pass the tidegates was determined to be the water level differential needed to open the gates. This water level differential was then applied through the time period 30 March though 31 July 2006 to estimate total number and duration of tidegate openings.

Habitat Characterization

Water quality variables (temperature, dissolved oxygen, conductivity, pH, turbidity, and water transparency) were recorded during each survey in each reach to describe the physical and chemical conditions in the four sloughs during the two sampling trials. Water temperature and depth was recorded hourly using temperature/depth loggers during March 29 through August 6. Each logger was placed along the perimeter 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 4). To record ambient atmospheric pressure in the study area, an additional depth logger was installed on the dike adjacent to the LTS caisson. A single logger recording temperature only was placed along the margin of each slough at the longitudinal mid-point to record hourly water temperature during March 29 through August 6 (Figure 4). Seven-day average daily maximum (7-DADM) were calculated from the temperature logger data. Seven-DADM levels were compared to threshold criteria above which juvenile salmonids exhibit sub-lethal effects (Richter and Kolmes 2005, EPA 2003). In the middle of each sample reach in each slough, dissolved oxygen and conductivity were measured using a 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.

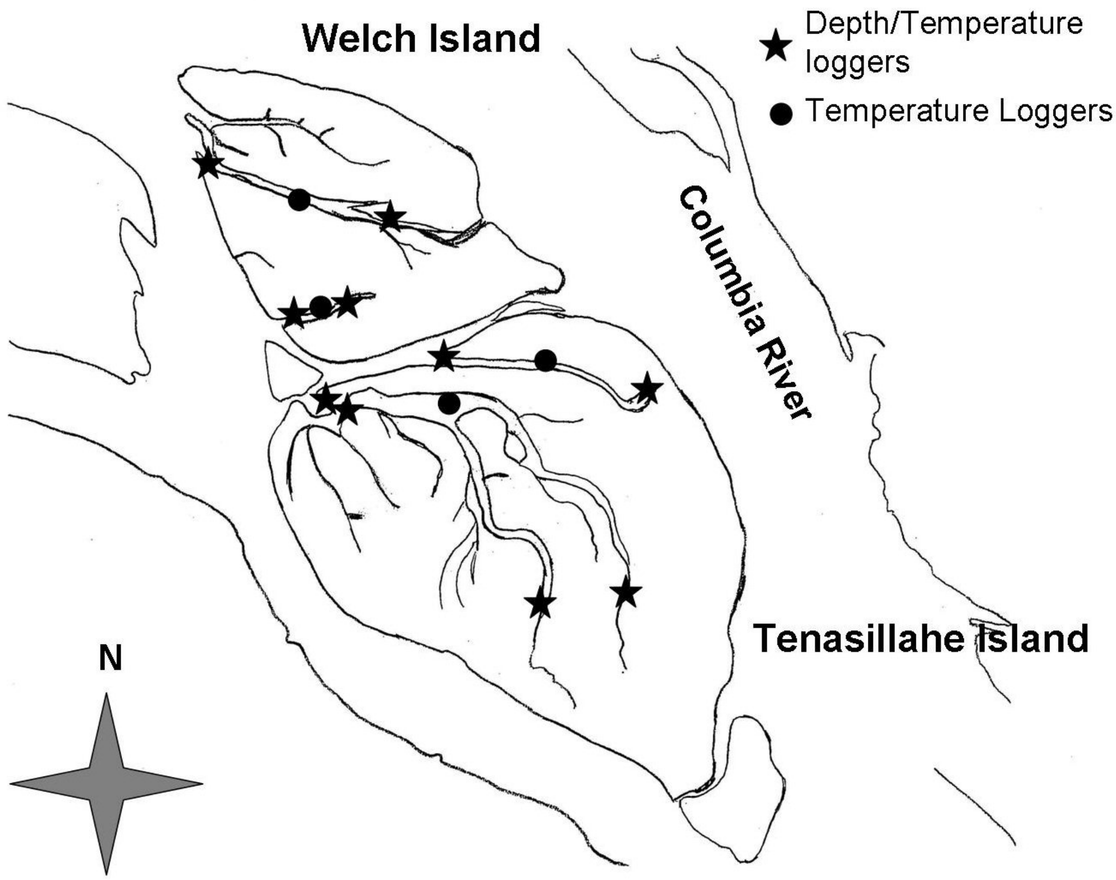

Figure 4. Location of depth/temperature loggers and temperature loggers on Tenasillahe Island and Welch Island, 2006

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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 during the first sampling trial 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 over story 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.

Community Structure

Four fish sampling methods were used during the two sampling trials in 2006 (March 27 to April 14 and May 8 to May 26): minnow traps, crayfish traps, fyke nets (rectangular and hoop), and beach seines. All captured fish were placed in an aerated live well, identified, enumerated and released. In addition, fork length and weight of salmonids were recorded. Individual fish were anaesthetized in a 0.3 g/l solution of MS-222, measured, weighed, and examined for external marks. Juvenile salmon greater than 60 mm in length were also scanned for a PIT tag. Prior to release, fish were allowed to recover in an aerated live well for 15-30 minutes.

Minnow and crayfish traps were the only fish sampling methods used in each sample reach in all sloughs (both trials). 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 large range of fish sizes to be captured. All minnow and crayfish traps were baited with salmon eggs (approximately 113 g) 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. Minnow and crayfish traps set in both Welch Island sloughs were attached to a 25 m weighted trap line to keep traps stationary during tidal fluctuation.

Table 1. Trapping array for Tenasillahe Island and Welch Island sloughs, 2006.

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

Fyke nets were used for fish sampling in the lower reaches of all four sloughs. Due to water depth limitations, fyke nets were not used in upper reaches. Three different sizes of fyke nets were employed during the two sampling trials: a 1.2 m circular fyke, a 0.9 m circular fyke, and a 1.5 m x 1.2 m rectangular fyke. Fyke nets were set overnight in reaches with sufficient water depth to submerge the trap (minimum 60 cm). In LTS, a single 1.2 m circular fyke net with two 4.5 m wings and a 15.2 m lead was set a minimum of one time during the two sampling trials in sample reaches 1-4, reach 6, directly inside the tidegate (south of culvert), and at four other experimental locations in the lower portion of the slough. In LTS reach five, average water depth was insufficient to submerge a 1.2 m fyke net, so a 0.9 m circular fyke net with 9 m wings was used in its place. Circular fyke nets were normally set perpendicular to the channel with the cod end against the bank. In STS, the use of fyke nets was limited primarily by the small size of the boat. A single circular hoop net (same dimensions as above) was set one time in reach 1 during the first sampling trial. In addition, a 0.9 m circular fyke net with 9 m wings was set immediately inside the STS tidegate (north of culvert grating) one time during each sampling trial. In SWS, a single 1.2 m circular fyke net with 4.5 m wings was set a minimum of one time during the two sampling trials in reaches 1 and 2. The circular fyke nets were set 5-10 m out from either shore fishing the incoming and/or outgoing tide. In LWS, a rectangular 1.5 m x 1.2 m fyke net (15.2 m lead, 15.2 m and 4.5 m wing) was used to sample fish in reach 1 and 3. The rectangular fyke net was typically set for 2-3 consecutive days, 10-25 m out from either shore, fishing the incoming and/or outgoing tides. May 23-25, a rectangular fyke (no lead and two 15.2 m wings) was set with one wing on the south bank of LTS reach 1 fishing the outgoing tide. A 1.2 m circular fyke net (15.2 m lead, 4.5 m wings) was set a minimum of one time during each sampling trial in LWS reach 2, 4, and 5. The hoop nets were set 5-10 m out from either shore, fishing the incoming and/or outgoing tide.

Beach seines were used to sample fish in the lower reaches of LWS (100-200 m below reach 3, reach 3, between reach 3 & 1, reach 1), SWS (reach 1), and

LTS (reach 1, reach 2, and the large back channel south of the tidegates). Three different sizes of seines were utilized depending on water depth and prevailing tide: 30 m x 1.8 m, 30 m x 3.7 m, and 22.9 m x 4.9 m (all with 0.6 cm mesh). The seine was held at shore and towed into the channel by boat making a 180 degree sweep (boat to beach), or towed across the channel and allowed to drift with the tide while making a 180 degree sweep (boat to boat).

Capture Efficiency

Tenasillahe Island sloughs

In an attempt to determine trapping efficiency of juvenile salmonids, a known number of marked fish were released in LTS and were available for recapture during May trapping efforts. On May 8, 922 PIT tagged Tule Fall Chinook were transported from Little White Salmon National Fish Hatchery to Cathlamet, Washington where they were transferred to aerated 165 liter coolers, and transported by boat to Tenasillahe Island. Water temperature and dissolved oxygen (DO) levels were monitored every 5 minutes during transport using a YSI meter. Every 30 minutes, crews drained 40 liters of water from coolers and replaced with 40 liters Columbia River water to maintain DO levels and acclimate fish to Columbia River water temperatures. On Tenasillahe Island, groups of fish (240-380) were individually scanned with a handheld PIT tag reader to obtain PIT tag codes, and transferred to an aerated 95 liter staging tote containing approximately 80% Columbia River water, and 20% LTS water (average temp 13.4°C). To acclimate fish to Tenasillahe Island water temperatures, crews drained 40 liters water from staging tote and replaced with 40 liters LTS water (average temperature 16.0°C) every 30 minutes for 1 hour. Fish were transferred from the staging tote to an aerated 130 liter live well (average temperature 15.0°C) and held for 30 minutes before release into LTS. Groups of PIT tagged fall chinook (238-380) were released into reach 1, 2 and 4 (Figure 2). Following their release, fish were allowed to disperse for approximately fifteen hours before setting traps. A single 1.2 m circular fyke net was set in reaches 1-4, and four cray/minnow trapping arrays (80 traps total) were set 50 m downstream of each fyke net. All traps were checked after 24 and 48 hours. All captured fish were identified, enumerated, and released. After 48 hours, the four circular fyke nets were re-set in experimental locations throughout the lower slough. To test delayed mortality, ten PIT tagged fish were held inside a pair of holding traps (five fish per trap) at each release location for the duration of the study. Holding traps consisted of a pair of minnow traps with the opening pinched closed. Each set of holding traps was suspended approximately 0.5 meter below the surface of the water. Holding traps were checked every 24 hours for 96 hours. Prior to release, delayed mortality fish were anesthetized in a 0.3 g/l solution of MS-222, measured, weighed, and scanned for a PIT tag code. All delayed mortality fish (30 total) survived and were subsequently released into reach 8 (Figure 2).

Welch Island Sloughs

There is a great deal of uncertainty about how to capture fish efficiently in sloughs for quantitative assessment (Bottom et.al, 2005). To evaluate our capture efficiency, we released marked juvenile fall chinook in LWS and subjected them to recapture through trapping efforts. We tested trapping efficiency using mark recapture, to detect presence and abundance of juvenile salmon residing in sloughs. On May 16, 1400 right ventral (RV) clipped Tule Fall Chinook were transported from Little White Salmon National Fish Hatchery to Cathlamet, Washington where they were transported by boat to LWS. Fish were acclimated to Columbia River temperatures over 2.5 hours by draining water from coolers and replacing with Columbia River water every 30 minutes as described above.

Fish were released into a side channel within reach 2 that was blocked from the main slough with a 30 m x 3.7 m seine at the mouth. Immediately after release, one 1.2 m circular fyke net and two five-trap weighted trap lines were placed within the blocked area. An additional 20 fish held inside four holding traps (pinched minnow traps, 5 fish per trap) to test delayed mortality. These were placed in the upper and lower portion of reach 2 approximately 0.5 m below the waters surface. All traps were checked after the next low tide approximately six hours after trap deployment and after the following low tide which occurred after an additional 11 hours. All fish captured were identified, enumerated, and released. In addition, fork length and weight of juvenile salmon were recorded.

Slough Use

Field crews installed PIT antennas inside each tide gate bay on March 22, to monitor habitat use, residence timing, and movement of fish out of LTS.

Results

Tide gate function

The tidegate at STS was found to be blocked closed by debris March 27, the onset of trial one. Refuge personnel manually blocked the tide gate open and removed this blockage on 5 April. The tidegate remained in the blocked open position until 10 April when it was allowed to operate with tidal fluctuation. This tidegate was again blocked closed at the onset of trial two (8 May) due to a debris jam.

A 0.4-meter differential between slough water elevation and river water elevation was required to open LTS tidegates. Applying this criterion to depth logger data colleted within the slough and verified water level data from Skamakawa, we estimate that 140 tide gate openings occurred between 30 March and 31 July 2006. Opening duration averaged 3.4 hours. This equates to an average of 1.1 openings per day and 3.8 open hours per day (15.8% of a day). Openings always occurred during low tide. During the study, 100 low tides failed to open the gates (42% of low tides).

Habitat Characterization

Large Tenasillahe and small Tenasillahe sloughs followed different temperature patterns from large and small Welch Island sloughs. Large and small Tenasillahe Island sloughs exhibited a narrower range of daily temperature than large and small Welch Island sloughs (Average and SE daily temperature range in ºC 1.4±0.06, 2.1±0.09, 3.2±0.16, 3.3±0.14 respectively; Figure 5 and 6). However, LTS and STS showed broader day-to-day variation than the two Welch sloughs (Average SE of weekly average temperature in ºC, 0.34, 0.32, 0.19 and 0.19 respectively). The 16ºC 7-DADM threshold was reached and remained above first by LTS (28 April) followed by STS (13 May), SWS (3 June) and LWS (3 June, Figure 7).

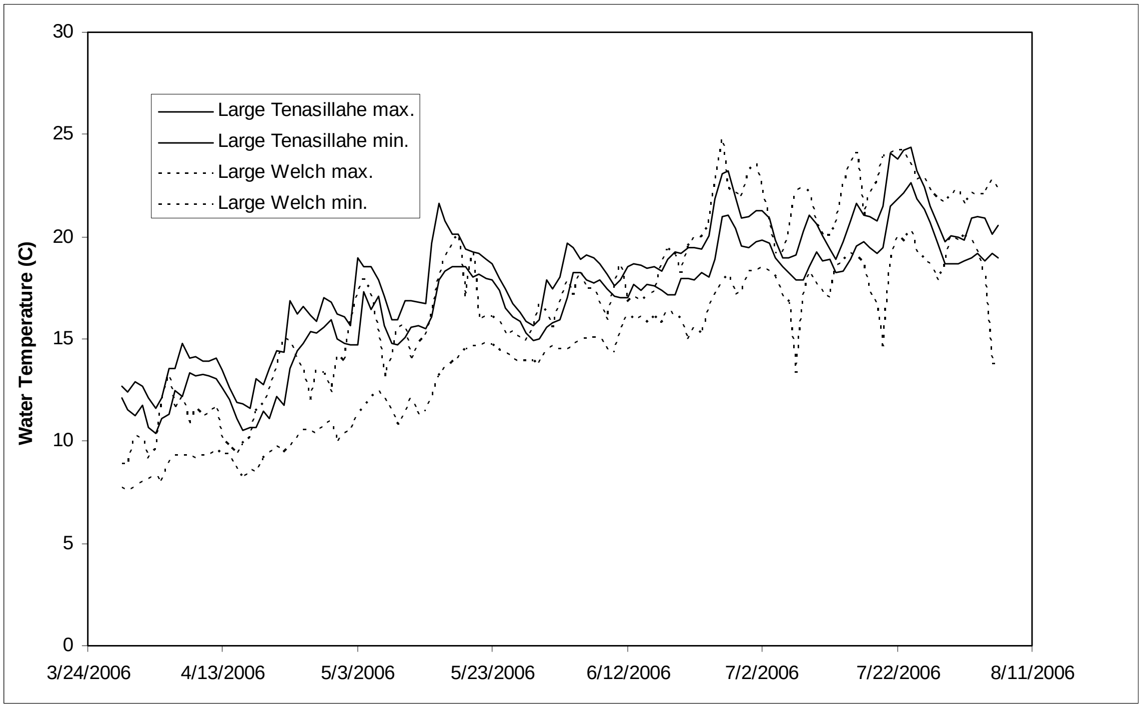

Figure 5. Daily maximum and minimum water temperature for the lowermost sampling reaches within large Tenasillahe slough and large Welch slough, 29 March through 6 August 2006.

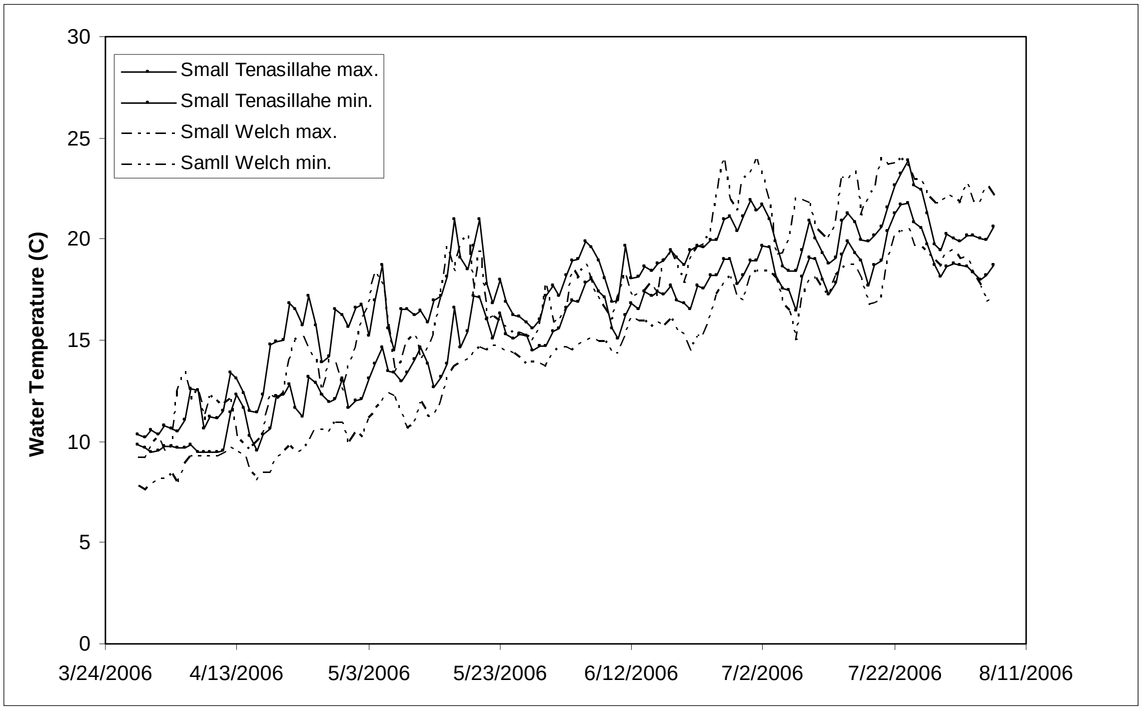

Figure 6. Daily maximum and minimum water temperature for the lowermost sampling reaches within small Tenasillahe slough and small Welch slough, 29 March through 6 August 2006.

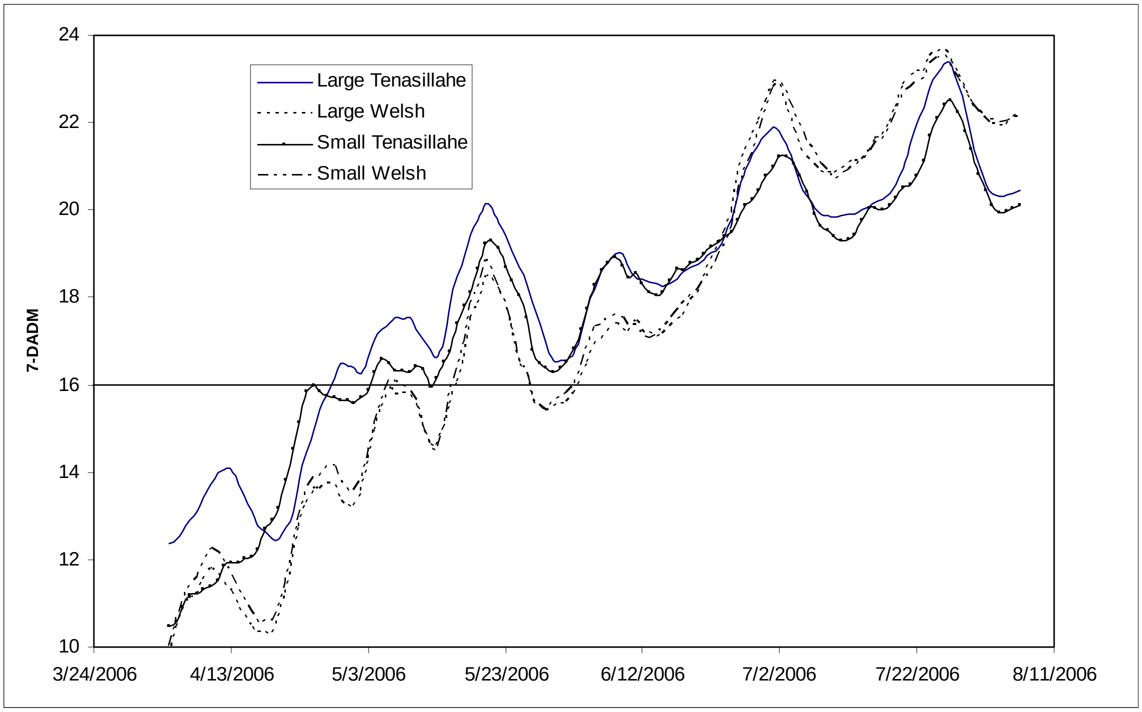

Figure 7. Seven-day average daily maximum water temperature (7-DADM) for lowermost sampling reach within large Tenasillahe slough, small Tenasillahe slough, large Welch slough, and small Welch slough, 4 April through 6 August 2006. Horizontal line represents 16 ºC.

Dissolved oxygen was consistently higher in Welch Island sloughs than in Tenasillahe Island sloughs between March 27 and April 14. Mean DO (mg/l) was 10.92 and 12.12 for large and small Welch respectively, 6.08, and 8.09 for large and small Tenasillahe respectively (Table 2). Small Welch slough exhibited the greatest decrease between the first and second trials in dissolved oxygen though it consistently remained above 6 mg/l (Table 3). Large Tenasillahe slough dissolved oxygen never dropped below 3.09mg/l whereas small Tenasillahe slough dropped to 0.33 mg/l between May 8 and May 26. Large Welch slough remained consistently above 6.9mg/l.

Small Tenasillahe, small Welch and large Welch sloughs exhibited conductivities in the range of 132 to 186 µs between 27 March and 26 May. Large Tenasillahe slough exhibited the highest conductivities where values up to 2251 µs were measured between May 8 and May 26. Average pH measurements ranged between 6.3 and 8.7 among all sloughs and sampling dates.

Table 2. Mean (95% CI, range) of water quality variables within large Tenasillahe slough (LTS), small Tenasillahe slough (STS), large Welch slough (LWS), and small Welch slough (SWS), 27 March through 14 April 2006.

Variables	LTS	STS	LWS	SWS
DO (mg/l)	6.08 (1.95, 3.17-10.06)	8.09 (1.17, 7.13-8.4)	10.92 (0.68, 10.28-11.98)	12.12 (0.39, 11.98-12.26)
Relative Conductivity (µs)	981.5 (281, 327.2-1574.0)	133.1 (2.1, 132.2-134.9)	179.5 (3.9, 177.4-186.5)	177.2 (0.42, 177.0-177.3)
pH	6.7 (0.25, 6.3-7.2)	6.9 (0.17, 6.7-7.0)	7.0 (0.17, 6.9-7.3)	7.4 (0.03, 7.4-7.4)
Turbidity (JTU)	33.1 (6.8, 15.0-45.0)	13.3 (4.0, 10.0-15.0)	11.0 (4.1, 5.0-15.0)	5.0 (0.0, 5.0-5.0)
Transparency (cm)	41.9 (11.2, 24.0-63.0)	60.0 (24, 40.0-70.0)	73.2 (7.1, 62.0-80.0)	107.5 (20.8, 100.0-115.0)

Table 3. Mean (95% CI, range) of water quality variables within large Tenasillahe slough (LTS), small Tenasillahe slough (STS), large Welch slough (LWS), and small Welch slough (SWS), 8 May though 26 May 2006.

Variables	LTS	STS	LWS	SWS
DO (mg/l)	5.9 (1.6, 3.09-8.3)	6.96 (8.0, 0.33-10.28)	9.08 (1.3, 6.91-9.9)	7.0 (1.8 6.36-7.64)
Relative Conductivity (µs)	1496.0 (427.5, 265.0-2251)	156.3 (31.1, 143.4-182.2)	142.0 (1.0, 141.2-143.7)	143.4 (3.6, 142.1-144.7)
pH	7.2 (0.3, 6.4-7.5)	8.1 (1.3, 7.0-8.7)	7.4 (0.3, 6.9-7.7)	6.8 (0.2, 6.7-6.9)
Turbidity (JTU)	13.1 (5.6, 5.0-25.0)	5.0 (0.0, 5.0-5.0)	4.0 (2.2, 0.0-5.0)	0.0 (0.0, 0.0-0.0)
Transparency (cm)	52.3 (15.6, 25.0-91.0)	81.0 (43.2, 45.0-100.0)	109.6 (15.9, 90.0-135.0)	128.5 (23.6, 120.0-137.0)

Riparian vegetation around both Small and Large Welch Island sloughs was dominated by shrubs, trees and grasses (Table 4). All sloughs included grasses as dominant (LTS) or sub-dominant (STS, LWS, and STS) vegetation. Trees were dominant in the riparian area of Small Tenasillahe Slough whereas trees were subdominant in the riparian area of Large Tenasillahe Slough. Small Tenasillahe Slough had a higher level of shade cover (5-25% across all reaches) when compared to large Tenasillahe slough (0-10%) and large and small Welch sloughs (0-25% and 0-10% respectively). Physical cover within Tenasillahe

Island sloughs changed from woody debris and tree dominance during March 27 through April 14 to aquatic vegetation dominant during May 8 to May 26. Welch Island sloughs remained dominated by woody debris throughout the study. Dominant and sub-dominant substrate remained silt and sand respectively for all sloughs throughout sampling.

Table 4. 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), 27 March though 26 May 2006.

Variables	LTS	STS	LWS	SWS
Dominant Riparian Veg. [a]	Grass Forb Shrubs	Shrubs Trees	Shrubs	Shrubs
Sub-Dominant Riparian Veg. [a]	Trees	Trees Grass Forb	Trees Grass Forb	Trees Grass Forb
Percent Shade (range)	0-10%	5-25%	0-25%	0-10%
Physical Cover [b] **Trial #1**	Aquatic Vegetation Woody Debris	Overhanging tree/shrub Woody Debris	Woody Debris Overhanging Tree/Shrub	Woody Debris Overhanging Tree/Shrub
Physical Cover [b] **Trial #2**	Aquatic Vegetation (10-40%)	Aquatic Vegetation (50-100%)	No Change	No Change
Dominant Substrate [c]	Silt	Silt	Silt	Silt
Sub-Dominant Substrate [c]	Sand	Sand	Sand	Sand

Note [A] riparian vegetation categories: no vegetation, rock/gravel, grassland forb, shrubs, and trees.

[B] physical cover categories: overhanging tree/shrub, aquatic vegetation, and woody debris.

[C] substrate categories: silt, sand, gravel, pebble, cobble, boulder.

Community Structure

A total of 25,596 fish representing 16 taxa were collected from 18 sample reaches between 27 March and 26 May 2006 (Appendix 1). Threespine stickleback (*Gasterosteus aculeatus*) was the most abundant fish collected, representing over 97% of the total catch. Two hundred seventy-nine salmonids representing three species were collected. Chinook salmon, *Oncorhynchus tshawytscha* dominated salmonid collections followed by chum salmon, *Oncorhynchus keta* and coho salmon, *Oncorhynchus kisutch* (table 5). Fishing effort for each sampling technique used is shown in appendices 1 through 5.

Table 5: Species, number and size range of salmonids that were captured in Tenasillahe Island and Welch Island sloughs, 2006.

Island	Species	Total	Size Range (mm)
Tenasillahe	Chinook	1*	46
	Chum	1*	46
Welch	Chinook	270	36-195
	Chum	6	44-50
	Coho	1	47

* Caught in STS during non-scheduled sampling when tide gate was blocked open.

Large Tenasillahe Slough

A total of 700 fish representing 10 taxa were collected in LTS (Appendix 1). Native species represented 83.4% of the total individuals captured (Table 6). Threespine Stickleback was the most abundant specie accounting for 79.6% of captured individuals. Non-native fish account for 81.1% of the remaining catch. Banded Killifish (*Fundulus diaphanous*) was the second most abundant species (8.7%) followed by sculpin (*Cottus sp*.). No salmonids were captured in LTS.

Small Tenasillahe Slough

A total of 10 fish representing three taxa were collected in STS (Appendix 1). Of the total, 20% of the fish captured were non-native species (Table 6). Eight Sculpin, one Banded Killifish and one Pumpkinseed (*Lepomis gibbosus*) were collected (Appendix 1). No salmonids were caught within designated sample reaches during scheduled trapping. One chinook salmon and one chum salmon were captured during an unscheduled trapping event (Table 5). This event occurred while Refuge personnel blocked the slough tidegate open to conduct maintenance.

Table 6. Percentage of total fish by native and non-native taxa that were captured in Tenasillahe Island and Welch Island sloughs, 2006

			Excluding Stickleback	
Island Slough	**Native**	**Non-Native**	**Native**	**Non-Native**
Large Tenasillahe	83.4%	16.6%	18.9%	81.1%
Small Tenasillahe	80.0%	20.0%	80.0%	20.0%
Large Welch	99.9%	0.1%	95.3%	4.7%
Small Welch	99.7%	0.3%	83.0%	17.0%

Table 7. Salmonid catch per unit effort (number per hour) of hoop and fyke traps in Tenasillahe and Welch Islands sloughs, 2006.

		Chinook	*Coho*	*Chum*
March 27 – April 14	Large Tenasillahe	0	0	0
	Small Tenasillahe	0.05*	0	0.05*
	Large Welch	0.11	0	0
	Small Welch	0.04	0.01	0.02
May 8 – May 26	Large Tenasillahe	0	0	0
	Small Tenasillahe	0	0	0
	Large Welch	0.51	0	0
	Small Welch	0.30	0	0

* Caught in STS during non-scheduled sampling when tide gate was blocked open.

Table 8. Salmonid capture per seine pull in Tenasillahe and Welch Island sloughs, 2006. Small Tenasillahe island slough was not sampled with seines.

		Chinook	*Coho*	*Chum*
March 27 – April 14	Large Tenasillahe	0	0	0
	Large Welch	14.3	0	0.5
	Small Welch	12.5	0	1
May 8 – May 26	Large Tenasillahe	0	0	0
	Large Welch	55.0	0	0
	Small Welch	9.5	0	0

Large Welch Slough

A total of 19,433 fish representing twelve taxa were collected in LWS (Appendix 1) sample reaches. Of the total, 99.9% of the fish captured were native (Table 6). The most abundant species captured in LWS was threespine stickleback, which represented 97.9% of the total catch. Excluding threespine stickleback, 95.3% of captured fish were native, 4.7% were non-native (Table 6). The second most abundant fish captured was chinook salmon, which made up 1.1% of the total catch (Appendix 1). Juvenile salmonids were collected from all sample reaches within Large Welch Slough. Chinook salmon capture increased from 70 in the early trial to 134 in the late trial. Chinook CPUE increased from 0.11/hour during the early trial trapping to 0.51/hour during the late trial (Table 7). Chinook seine captures were 14.3/seine pull during trial one and 55.0/seine pull during trial 2 (Table 8). Chinook were found in all sample reaches during the early trial and in all but reach four during the late trial (Table 9). Two chum salmon were collected in reach 1 during the early trial but none were encountered during the late trial. Chum seine captures were 0.5/seine pull.

Table 9. Number of Chinook salmon collected from Large Welch Slough sample reaches from 27 March though 14 April 2006 and from 8 May though 26 May 2006.

	Sample reach number					
Date	**1**	**2**	**3**	**4**	**5**	**Total**
3/27 – 4/14	20	1	33	13	3	70
5-5 – 5-26	70	7	53	0	4	134

Small Welch Slough

A total of 5,453 fish representing nine taxa were collected in SWS (Appendix 1). Of the total, 99.7% of the fish captured were native (Table 6). The most abundant species captured in SWS was threespine stickleback, which represented 97.9% of the total catch. Excluding threespine stickleback, 83.0% of captured fish were native, 17% were non-native (Table 6). The second most abundant fish captured was Chinook salmon, which made up 1.1% of the total catch (Appendix 1). Juvenile salmonids were collected from both sample reaches within Small Welch Slough. Twenty-nine Chinook salmon were found in reach one and none were captured in reach two during the early trial. Twenty-two Chinook salmon were captured in reach one and ten in reach two during the late trial (Table 10). Chinook CPUE increased from 0.04/hour in the early trial to 0.30/hour in the late trial (Table 7). Chinook seine captures were 12.5/seine pull during the early trial and 9.5/seine pull during the late trial (Table 8). Three chum salmon were collected in reach 1 and one was captured in reach 2 during the early trial. Chum seine captures were 0.1/seine pull. One coho salmon was collected in reach 2 during the early trial.

Table 10. Number of Chinook salmon collected from Small Welch Slough sample reaches from 27 March though 14 April 2006 and from 8 May though 26 May 2006.

	Sample reach number		
Date	**1**	**2**	**Total**
3/27 – 4/14	29	0	29
5/5 – 5/26	22	10	32

Capture efficiency

Tenasillahe Island sloughs

A total of 844.78 hours of trapping time occurred after release of PIT tagged hatchery Chinook salmon within LTS. Zero tagged fish were recaptured.

Welch Island sloughs

A total of 464.63 hours of trapping time and twelve seine hauls occurred after release of marked hatchery Chinook salmon within LWS. All trapping occurred in designated sample reaches and all twelve seine hauls occurred in experimental locations separate from sample reaches. One marked fish was recaptured during a seine haul in experimental reach 3B.

Slough Use

Tenasillahe Island sloughs

PIT tagged hatchery Chinook salmon that exited LTS took from one to 68 days to travel from release site and exit the tidegate (Table 11). The median number of days to exit was 26 - 27 for groups. Distance between release sites to the tidegate antenna array was between 330 and 2800 meters. Percent of fish detected leaving the slough ranged from 60 to 77 percent for different release groups. No PIT tagged fish other than study fish were detected at the array.

Welch Island sloughs

One marked fish was recaptured 36 hours after release in LWS.

Table 11. Percent and number of PIT tagged and released hatchery chinook salmon detected at tidegate antenna array and the median days and range of time between release and detection.

	Reach 1	Reach 2	Reach 4	Reach 8
Distance to TG (m)	330	595	1500	2800
% detected (n)	72 (281)	77 (195)	75 (187)	60 (18)
Days to detection median (range)	26 (1 – 67)	26 (1 – 68)	26 (1 – 67)	27 (13 – 40)

Discussion

Juvenile salmonid access to Tenasillahe Island sloughs is limited. Current tide gates do not allow salmonids to have regular access to the island sloughs and may not allow them to have any access. One Chum and one Chinook salmon juvenile were captured in STS during a time when the tide gate was blocked open for maintenance. These were the only salmonids captured to date within either Small or Large Tenasillahe sloughs. This contrasts with both Large and Small Welch Island sloughs where juvenile salmonids were captured at all sampling locations.

All three tide gate doors on LTS opened in response to tidal fluctuation. Measurements of tide gate openings and evidence of PIT tagged fish exiting LTS during this study show that the gape is sufficient to allow juveniles to pass at certain times. What is unclear is whether juvenile salmonid behavior is such that individuals will swim against the outflow to enter the slough. Haskell *et.al* (2004) found that juvenile Chinook salmon would swim against the prevailing tide to enter freshwater sloughs not controlled by tide gates. However, little evidence exists suggesting juvenile salmonids will access traditional tide gate controlled sloughs.

Our inability to recapture PIT tagged fish released into LTS shows that our capture efficiency was too low to determine conclusively that salmonids were unable to enter the slough. However, data collected does suggest marked differences in salmonid relative abundance between reference and treatment sloughs. Fish have free access into Welch Island sloughs throughout the tidal cycle though they likely make gross movements with the prevailing water flow and may forage with or against the flow (Miller and Sadro, 2003). Their access into Tenasillahe Island sloughs is dependent upon tide gate opening. This limits their opportunity to less than four hours per day on average giving a narrow window for access when compared to access into un-gated sloughs.

Juvenile salmonids can inhabit and persist in and exit Large Tenasillahe Island slough. Depending on release location, 60-77% of Pit tagged hatchery chinook survived and exited LTS. Some exited up to 60 days after release, giving evidence that juvenile salmonids can survive Tenasillahe Island sloughs if given access.

Tide gated sloughs don not provide optimal habitat for salmonids. Water quality in Tenasillahe Island sloughs during the spring is below optimal for juvenile salmon and some areas reach lethal levels. Current spring water temperature in Tenasillahe Island sloughs may be detrimental to juvenile salmonids. Temperatures reach sub-lethal threshold levels earlier in May in Tenasillahe island sloughs than was found in Welch island sloughs. This was most pronounced in large Tenasillahe slough where 7-DADM reached the threshold criteria of 16 ºC eighteen days earlier than large Welch slough. Juvenile Pacific salmon species prefer temperatures between 12-14°C, but will tolerate temperatures of 15-20°C for brief periods (Brett 1952). A 7-DADM of 16 ºC is the threshold above which coho and chinook juveniles begin to exhibit sub-lethal effects such as delayed smoltification (Richter and Kolmes 2005, EPA 2003). 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 concentrations remained above optimum levels in 100% of Welch Island sample reaches. Oxygen levels were at or below optimal levels in 50% of LTS sample reaches. Lethal levels were recorded in small Tenasillahe slough (0.33 mg/l). Because measurements were made at one time and during the day when dissolved oxygen would be highest (Bamforth 1962) diurnal range differences among sloughs is unknown and are likely important. These differences in temperature and dissolved oxygen regimes between Tenasillahe and Welch island sloughs is likely due to differences in tidal influence and resulting water exchange. This reduced tidal influence in Tenasillahe island sloughs may compound the effect of high temperatures and low dissolved oxygen by reducing passive movement of juveniles to river water.

Tide gates had a significant influence on fish community structure. There are fundamental differences in species composition and relative abundance between Tenasillahe Island and Welch Island sloughs. The greatest overall species richness occurred in un-gated large Welch slough (12 species) followed by large Tenasillahe slough (10 species). Small Welch contained three times the number of species that were found in small Tenasillahe slough. A higher percentage of non-native species were captured in both Tenasillahe Island sloughs compared to both Welch Island sloughs. Relative abundance of individuals was higher in Welch Island sloughs than Tenasillahe Island sloughs. These differences are likely related to Tenasillahe Island sloughs lack of tidal influence and the water quality parameter values resulting from limited water exchange in addition to access issues caused by tidegate operation.

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Appendix 1. Total fish captured and percentage of total catch (all sampling methods combined) in Tenasillahe Island and Welch Island sloughs, 2006.

Species	**# individuals Captured**	**% of Total**
Large Tenasillahe (LTS)		
Threespine Stickleback	557	79.6
Banded Killifish	61	8.7
Sculpin	26	3.7
Bluegill	19	2.7
Unknown Sunfish	10	1.4
Pumpkinseed	14	2
Yellow Bullhead	6	0.9
White Crappie	5	0.7
Largescale Sucker	1	0.1
Yellow Perch	1	0.1
Total	700	
Small Tenasillahe (STS)		
Sculpin	8	80.0
Banded Killifish	1	10.0
Pumpkinseed	1	10.0
Total	10	
Large Welch (LWS)		
Threespine Stickleback	19,029	97.9
Chinook Salmon	204	1.1
Peamouth	68	0.3
Largescale Sucker	54	0.3
Sculpin	34	0.2
Banded Killifish	15	0.1
Starry Flounder	9	0.0
Northern Pike Minnow	6	0.0
Western Brook Lamprey	3	0.0
Chum Salmon	2	0.0
Pumpkinseed	2	0.0
Unknown Sunfish	2	0.0
Total	19,433	
Small Welch (SWS)		
Threespine Stickleback	5341	97.9
Chinook Salmon	61	1.1
Banded Killifish	19	0.3
Sculpin	14	0.3
Starry Flounder	7	0.1
Peamouth	5	0.1
Chum Salmon	4	0.1
Coho Salmon	1	0.0
Western Brook Lamprey	1	0.0
Total	5453	