Lower Columbia River Channel Improvement:

Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands

2008 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 its estuary are of particular importance because all stocks of anadromous salmonids within the basin use the area to varying extents, and especially as rearing habitat for juveniles (Bottom et al. 2005). Lower Columbia River habitats have been substantially altered by flow manipulation and reduced connectivity between the main channel, floodplains and tidal wetlands. The construction of flood levees, gated culverts, and the filling of tidal wetlands has resulted in a 65% reduction of estuarine wetland and marsh habitat compared to that historically present (Bottom et al. 2005). Tidal wetlands and floodplains in the Columbia River Estuary were constrained by flood levees during the early part of the 1900's to claim land for agriculture. Culverts through the levees allow rivers to drain into the estuary and tide gates placed at the downstream end of the culverts prevent tidal flows from entering, as the rising tide ensures the gate remains closed. Traditional top-hinged tide gates remain closed by default, except when high pressure upstream flows push them open, posing a barrier to fish. Restoration actions aim to maintain the flow regimes needed to protect agriculture and other infrastructure while also opening under lower pressure and remaining open for longer periods to enhance fish passage (Giannico and Souder 2005).

Restoring tidally-influenced wetlands to improve conditions for juvenile anadromous salmonids has been included in recovery and management plans and regulatory requirements, including the Sub-basin Plan for the Columbia River

Main Stem and Estuary (Lower Columbia Fish Recovery Board (LCFRB) 2004) and NOAA Fisheries' FCRPS Biological Opinion (NOAA 2004). Although restoring tidal wetlands and improving fish access to them are major components of recovery strategies for anadromous salmonids, information regarding habitat requirements is lacking to guide restoration actions (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 BACI evaluations is to improve our understanding of how juvenile salmonids use tidal wetland habitat as well as to assist in developing and implementing additional restoration actions.

Welch and Tenasillahe Islands (Figure 1) are part of the National Wildlife Refuge (NWR) system, managed by the U.S. Fish and Wildlife Service. The islands are located at river kilometer 56 in the lower Columbia River. Welch Island is part of Lewis and Clark NWR (LCNWR). LCNWR was established to preserve wetland habitats of the Columbia River estuary as a wintering area and migration stopover for migratory birds, primarily waterfowl and shorebirds. Tenasillahe Island is part of Julia Butler Hansen National Wildlife Refuge (JBHNWR). JBHNWR is managed primarily for the protection of the endangered Columbian White tailed deer. The tidal marsh habitat historically present on Tenasillahe Island was altered due to the construction of dikes around the perimeter of the island over the course of the last century.

In an attempt to improve conditions for fish, in 2007 the U.S. Army Corps of Engineers (USACOE) replaced the three top-hinge steel tide gates controlling tidal action on the largest Tenasillahe Island slough with side-hinge aluminum gates equipped with a manually controlled fish orifice. This action was to improve aquatic habitat conditions and to improve fish passage for juvenile salmonids while balancing the needs of the endangered white-tailed deer found on the island. It is unclear whether these modifications will result in improved fish passage into and out of the sloughs or in changes to aquatic habitat conditions.

The U. S. Fish and Wildlife Service, Columbia River Fisheries Program Office (CRFPO) is evaluating this project with the goal of assessing the effects of the USACOE restoration actions at Tenasillahe Island. This project will compare slough conditions in Tenasillahe Island sloughs before and after restoration and among treatment and reference sites in Welch Island sloughs. Pre-construction assessment began in 2005. Activities associated with this assessment provided insights into logistical constraints such as access to sample sites and fish sampling methods amenable to conditions within the sloughs. Data collected March through June 2006 and March through May 2007, before gates were replaced, show elevated gated slough water temperatures, more non-native species present in gated sloughs, and limited opportunity for juvenile salmonids to enter gated sloughs. Activities in 2008 focused on collecting post-construction data needed to assess effects of the new tide gates. The following objectives were addressed during 2008 field season: 1. Assess fish passage conditions; 2. Describe fish distribution among treatment and reference sloughs; 3. Characterize aquatic habitats of treatment and reference sloughs; 4. Measure juvenile salmonid growth rate and residence time in treatment and reference sloughs

Methods

Study Area

Tenasillahe Island is an 809-hectare island located in the lower Columbia River at river kilometer 56 (Figure 1). 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 currently consists primarily of two interior sloughs connected to the Columbia River via tide gates. Until summer of 2007, the aquatic habitat on the island consisted primarily of a network of interior sloughs connected to the Columbia River via steel top-hinged tide gates. These gates are designed to close when river water elevation reaches that of slough water elevation. When gates are closed, water flow into sloughs is limited to that which leaks through the gates. Tide gates limit fish passage into or out of the sloughs to times when water is flowing out of the slough. Connection of the smaller of the two sloughs to the Columbia River is controlled by a single top-hinge steel tide gate. Connection of the larger of the sloughs to the Columbia River is now controlled by three side hinge aluminum tide gates equipped with a manually controlled fish orifice. These gates replaced three top-hinge steel tide gates.

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. We have not found any evidence that Welch Island was settled by humans. Sloughs are not diked or controlled by tide gates and have unimpeded connection to surrounding waters and tidal action.

Sample reaches within each slough were randomly selected using a random, spatially-balanced approach to insure that various habitats and conditions were represented (Poirier et.al. 2005). 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 1).

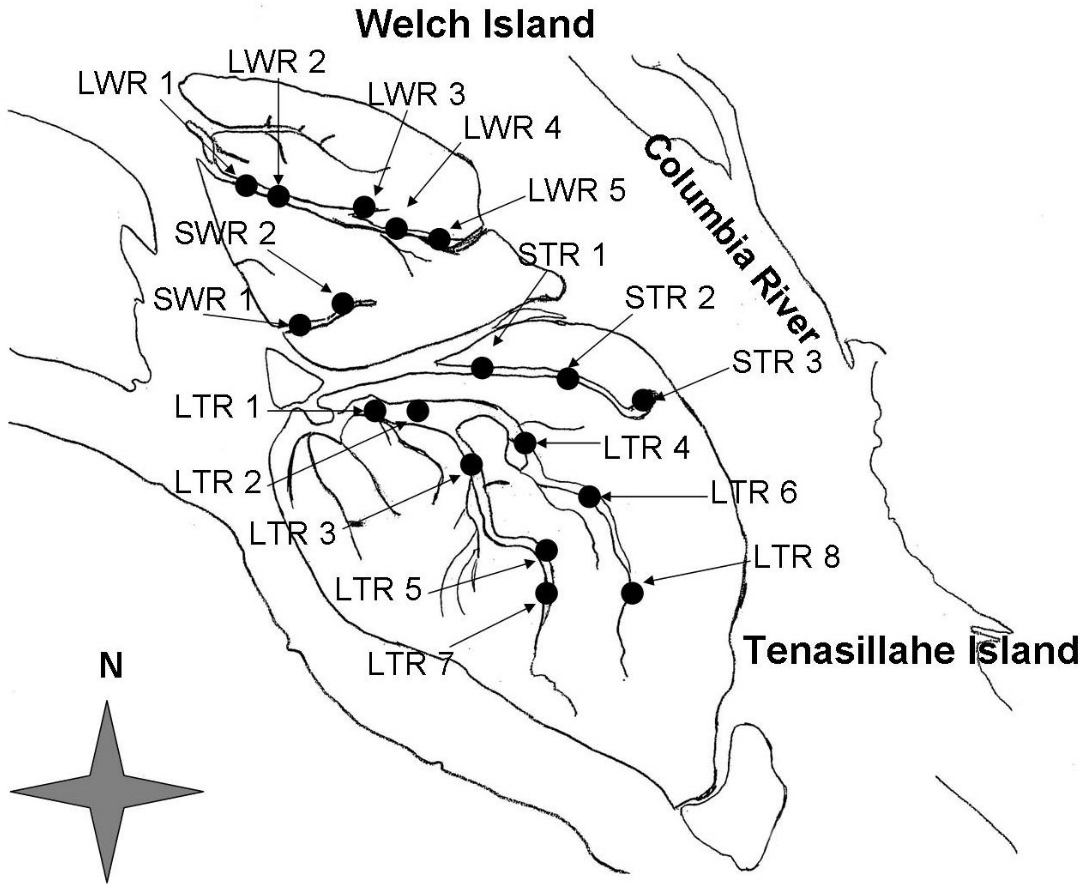


Figure 1. Area map of Tenasillahe Island and Welch Island showing locations of reference sloughs (LWS, SWS), treatment sloughs (LTS, STS) and sample reaches within sloughs.

Fish passage

Tide gate function

Data from temperature/depth loggers installed within lower LTS and the tide gate bay of LTS, as well as recorded tides at Skamokawa, Washington, were used to determine frequency and duration of tide gate opening and the relationship between Columbia River tidal activity and tide gate operation. Depth loggers operated from March 20 through July 10. We compared information on known tide gate openings from measuring rods and detection time of emigrating PIT-tagged fish (see residence time methods below) to water elevation differential between slough side and river side of tide gates. The difference between slough and Skamokawa water levels when known tide gate openings occurred and PIT tagged fish were able to pass the tide gates was determined to be the water level differential needed to open the gates. This water level differential was then extrapolated March 20 through July 10 estimate total number and duration of tide gate openings.

Measuring rods were installed inside the three large Tenasillahe slough tide gate bays on May 19 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 tide gate opened and would remain at the new location on the rod when the tide gate 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 tide gate opening (Figure 2). Rod measurements were taken on 19 days concurrently with scheduled field trips. In addition, date and time of tide gate openings and closings were documented periodically when researchers were present.

LTS tide gate passage

A primary goal of this study is to learn whether juvenile salmonids enter and use large Tenasillahe Slough (LTS). The design of the LTS tide gates and culverts allow capture of fish entering or leaving LTS. Three 2.1 m diameter culverts pass water from LTS toward three separate tide gates. Water flowing by each tide gate enters a separate caisson that in turn drains toward the Columbia River through one of three culverts. To capture fish entering the slough through the tide gates, fish traps were installed on the slough side of two culverts. To capture fish exiting the slough, another fish trap was installed on the river side of the third culvert. These traps were operated 22 days between April 29 and June 10 during scheduled field trips. When not operated, trap fykes were disconnected from the live box leaving the conical mesh attached to the culvert. All three traps were checked daily for fish. All captured fish were identified, enumerated, checked for marks (adipose fin clip) and length was documented for all captured salmonids.

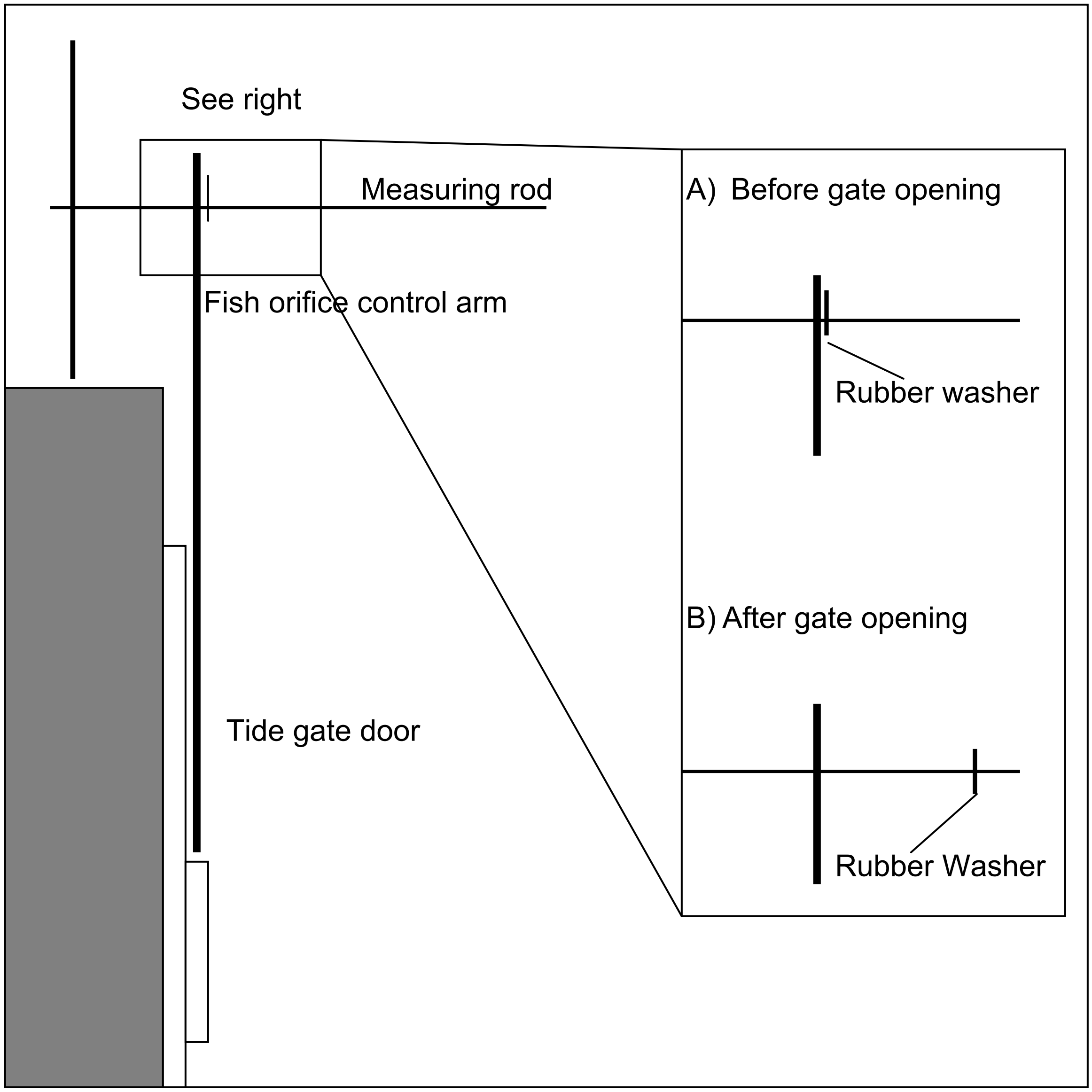


Figure 2. Diagram of tide gate measuring rod located inside each tide gate bay at LTS, 2008. The fish orifice control arm is attached to the tide gate door and moves during gate openings. The control arm moves the rubber washer from position A. to position B. when the gate opens. The washer remains in position B after gate closes, signifying a gate opening.

Community Structure

Fyke nets and beach seines were the two fish sampling methods used to qualitatively assess the presence and distribution of fish in the reaches of Welch and Tenasillahe sloughs during 2008. Fyke nets were used for fish sampling in all the reaches of all four sloughs. Fyke nets were set overnight, parallel to shore in water with sufficient depth to submerge the trap's fyke (minimum 60 cm). Two sets were conducted at each sample reach in all sloughs. Seines were also used to sample fish in all reaches of all sloughs. Two different lengths of seines were utilized: 15 m x 1.8 m and 30 m x 1.8 m (both with 0.6 cm mesh). The larger seine was used where sufficient fishing area without wood or other debris could accommodate its length. The smaller seine was used where fishable area would not accommodate the large seine. The method of seine deployment was such that, one end of the seine was held on shore and the other end either walked by foot or towed into the channel by boat and pulled parallel to shore. Once deployed, the seine was pulled toward shore. The size of the seined area was estimated and documented (effort). In reaches where near-shore conditions would not allow effective seine use (i.e. cut bank, large woody debris), a boat-to-boat seine method was used. Here, as the seine was fed into the slough from the boat, the boat was maneuvered to allow the seine to enclose an area of water. Then the seine was pulled into the boat. The size of the seined area was estimated and documented (effort).

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.

Habitat Characterization

Habitat data were conducted in all sample reaches reach once between March to April and once May to June. Data were recorded in each sample reach to describe overall aquatic habitats in the four sloughs. Data on the following water quality attributes were collected: water temperature and atmospheric pressure; dissolved oxygen, specific and relative conductivity, pH, turbidity; water transparency. The following physical parameters were also included: wetted width, mean depth, substrate, riparian vegetation, percent shade, and physical channel cover.

In reference and gated sloughs, water temperature and depth was recorded hourly in the lowest reach and highest reach of sloughs using Onset HOBO water level loggers during March 20 through July 10. Each logger was placed along the side of the slough within a perforated PVC pipe installed 15-20 cm above the surface of the substrate. A single logger (Onset StowAway Tidbit), recording temperature only was placed at mid-point of each slough to record hourly water temperature during March 20 through July 10 (Figure 3). Seven-day average daily maximums (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). Daily temperature range (maximum – minimum daily temperature) was calculated for each slough. Median daily temperature range was compared between sloughs using Kruskal-Wallis ANOVA on ranks followed by Dunn's multiple comparison procedure.

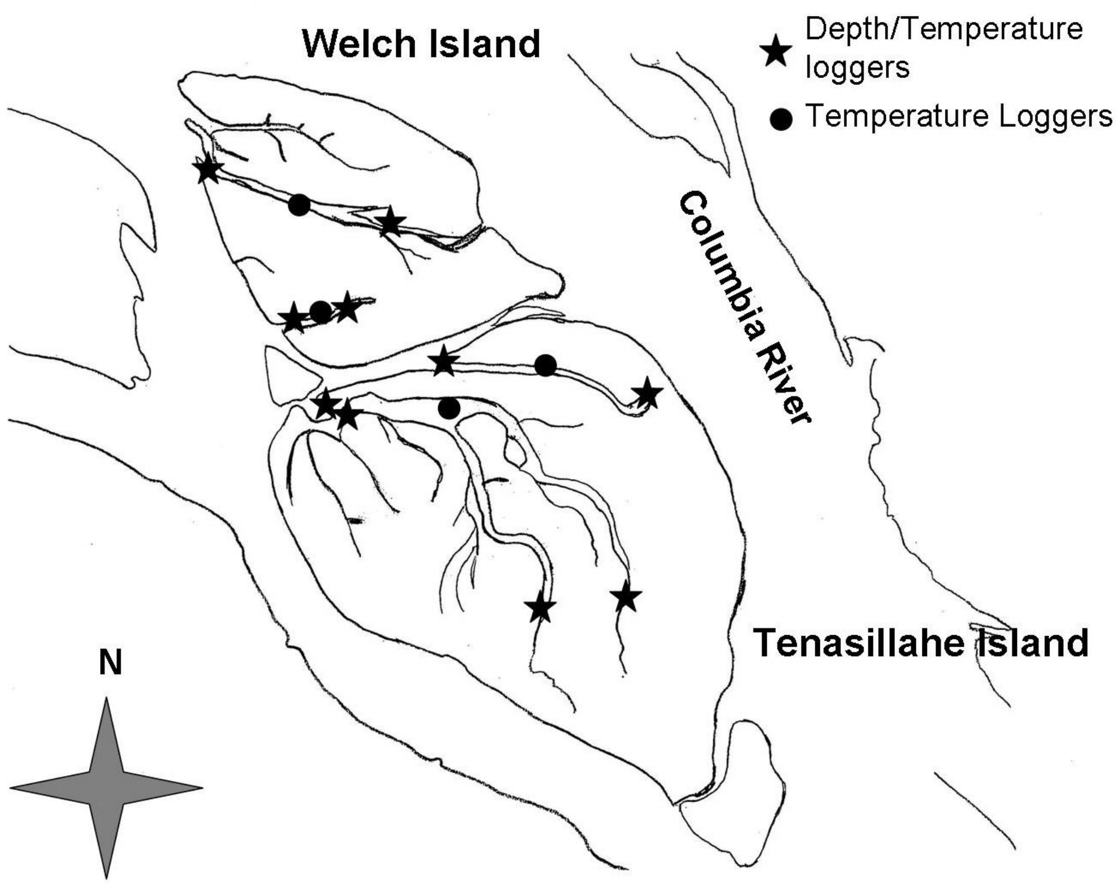


Figure 3. Location of depth/temperature loggers and temperature loggers on Tenasillahe Island and Welch Island, 2008

Dissolved oxygen, temperature and conductivity were measured in each sample reach using an YSI meter. Mean DO% among sloughs was tested for significance using ANOVA followed by Bonferroni multiple comparisons. Habitat characteristics (pH, turbidity, water transparency, mean wetted width, mean depth, substrate, riparian vegetation, percent shade, and physical channel cover) were recorded at the linear mid-point of each sample reach to describe overall aquatic habitats in treatment and reference sloughs. An Oakton data meter was used to measure pH and turbidity was measured using a LaMotte turbidity water test kit. Water transparency was measured using a Secchi disc and calibrated depth staff marked in 10 cm increments. Wetted width was measured to the nearest meter using a laser rangefinder. Water depth was measured at twenty equidistant points along a transect (perpendicular to the main channel) to derive mean channel depth. Dominant (highest percentage) and sub-dominant (second highest percentage) surface substrate composition was determined for each sample reach using a visual inspection of the surface of the substrate, or by scraping the substrate with a wading rod, at a minimum of 20 locations, across the survey transect. Substrate type was recorded using six categories of substrate size: silt/clay/organic material, sand, gravel, pebble, cobble, and boulder. Dominant and sub-dominant riparian vegetation was determined 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 in-stream structures such as aquatic vegetation, boulders, or woody debris, and riparian features such as overhanging trees/shrubs. A digital photograph was taken at sample reaches to document current physical habitat conditions within the sloughs.

Residence time and Growth Rate

Residence time

To determine residence in LWS and LTS, a known number of marked fish were released and were available for recapture during April and May sampling efforts. In LWS, 1500 adipose and left ventral fin-clipped sub-yearling fall Chinook from Little White Salmon National Fish Hatchery were released in reach 3 (Figure 3) on April 15th. One thousand PIT-tagged sub-yearling fall Chinook from the same hatchery were released in LTS. Prior to release on April 28th and 29th, each fish was anesthetized in MS as described above and scanned for PIT tag identification numbers, weighed and fork length measured. Groups of 225 PIT-tagged fall Chinook were released into reaches 1, 2, 4 and 7 (Figure 4), respectively. Fish were acclimated to LTS water following methods used during 2006 (Johnson *et. al*. 2007).

Three methods were used to recapture and track the released fish: seining, culvert traps and PIT tag antennas. After fish release in LTS and LWS, seining was conducted to improve the chance of recapture and assess seining efficiency. The culvert traps were operated as described previously, also in LTS.

Field crews activated PIT tag antenna arrays inside each tide gate bay on April 28, to detect movement of PIT-tagged fish exiting LTS.

To determine the effects of handling, transportation and habitat on fish, ten PIT-tagged fish were held inside a pair of holding traps (five fish per trap) at each release location. Holding traps consisted of a pair of minnow traps with the openings pinched closed. Suspended approximately 0.5 meter below the surface of the water, each trap was checked 48, 72 and 96 hours after suspension. After 96 hours fish were released into the respective reach.

Growth Rate Comparison

To compare survival and growth rates of juvenile salmonids in LTS to LWS, 50 PIT-tagged hatchery fall Chinook juveniles were placed in enclosures located in reaches 1,3 and 4 in LWS and reaches 1, 2, and 6 in LTS on April 29th for a total of 6 enclosures and 300 fish. The enclosures consisted of a 1.2 x 1.2 meter cubic net structure with 0.6 cm mesh. Fish were weighed, measured and mortalities enumerated on June 11th and June 12th for LTS and LWS, respectively.

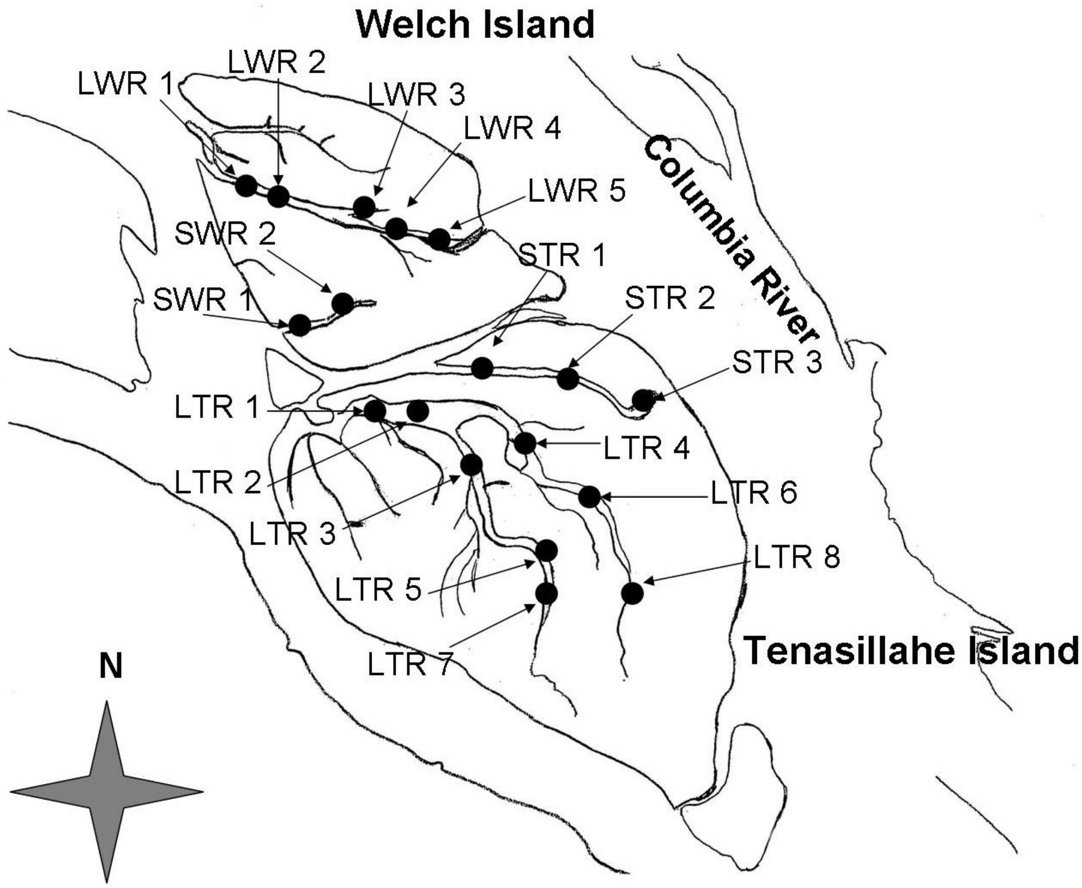


Figure 4. Tenasillahe Island and Welch Island sample reaches, 2008.

Results

Fish passage

Tide gate function

Two hundred and twenty-three low tides occurred between March 20 and July 10, 2008. We estimate that the LTS replacement tide gates opened during 143 of these low tides (64%). Tide gates failed to open during 80 low tides (36%). Tide gates remain open an average 3.4 hours per opening. This equates to 1.3 openings per day and 4.4 open hours per day.

LTS tide gate passage

Culvert traps installed at the mouth of LTS captured fish both entering and exiting the slough. Twelve fish species were captured entering the slough through the tide gates (Table 1). Three-spine stickleback was the predominant specie contributing 78.6% and 89% of total captures in the two immigration traps. No salmon were captured entering LTS through the tide gates in 2008. Thirteen fish species were captured exiting LTS through the tide gates. Three-spine stickleback made up 92% of all individual fish captured. Twenty-seven Chinook salmon (marked and unmarked) and one coho salmon (unmarked, 189 mm FL) were captured exiting LTS (Table 2). Of the Chinook salmon captured, 12 were PIT tagged (123 – 141 mm FL) and had been released into LTS April 28th or 29th, 11 were adipose fin clipped but not PIT tagged (129 – 150 mm FL) and 4 were unmarked (56 – 127 mm FL). There was no significant difference in fork length or weight of the differently marked groups.

Table 1: Total fish captured and percentage of total trap catch in Large Tenasillahe Island slough tide gate traps, 2008.

Fish Species	# of individuals	% of Total
	Immigration trap #1	
3-spine stickleback	1518	89.40%
Peamouth	129	7.60%
Common Carp	11	0.65%
Largescale Sucker	11	0.65%
Northern Pikeminnow	10	0.59%
Sculpin	7	0.41%
Eastern Banded Killifish	6	0.35%
Sunfish	3	0.18%
Pumpkinseed	2	0.12%
Yellow Perch	1	0.06%
Total	**1698**	
	Immigration trap #2	
3-spine Stickleback	977	80.21%
Peamouth	213	17.49%
Eastern Banded Killifish	9	0.74%
Sculpin	8	0.66%
Common Carp	4	0.33%
Largescale Sucker	4	0.33%
Unknown Sunfish	2	0.16%
Northern Pikeminnow	1	0.08%
Total	**1218**	
	Emigration trap	
3-spine Stickleback	5466	93.64%
Peamouth	188	3.22%
Sculpin	68	1.16%
Unknown Sunfish	44	0.75%
Chinook Salmon	27	0.46%
Eastern Banded Killifish	23	0.39%
Pumpkinseed	7	0.12%
Bluegill	5	0.08%
Brown Bullhead	3	0.05%
Northern Pikeminnow	2	0.03%
Coho Salmon	1	0.02%
Largescale Sucker	1	0.02%
Smallmouth Bass	1	0.02%
Yellow Bullhead	1	0.02%
Total	**5837**	

Table 2: Number, median fork length and median weight of Chinook salmon captured exiting Large Tenasillahe Island Slough.

	number	Median Fork length(mm)	Median weight
PIT tagged	12	136.5	30.9
Ad marked	10	135.0	29.3
Unmarked	4	127.0	26.5

Community Structure

A total of 40 hoop nets were set and 180 seine hauls were performed in 18 sample reaches in 2008. A total of 48,879 fish representing 20 species were collected in two reference sloughs and two gated sloughs (Table 3). In reference sloughs, 8 of 10 species (LWS) and 8 of 9 species (SWS) were native. In treatment sloughs, 5 of 12 species (LTS) and 3 of 8 species (STS) were native. Of the total, 99.4% of fish captured were native species. Three-spine stickleback was the most abundant species in all sloughs, making up 98% of the total catch. A total of 255 salmonids representing 3 taxa were captured. Chinook salmon were the most abundant salmon species making up 90.6% of the total salmon catch. Both adipose fin-clipped and unmarked Chinook salmon were captured. Adipose fin clipped Chinook salmon composed 35 of the 231 (15%) Chinook salmon captured. Two Chinook salmon were captured in LTS. Both were adipose fin clipped. Twenty-eight of 175 (16%) Chinook salmon captured in LWS were adipose fin-clipped. Two of 54 (4%) Chinook salmon in SWS were adipose fin-clipped. Twenty-three chum salmon were captured in LWS. No other chum salmon were captured. One steelhead trout (adipose fin clipped, FL = 223 mm) was captured in SWS.

Table 3: Species type and percentage (number) of total fish captured (all sampling methods combined) in large Tenasillahe (LTS), large Welch (LWS), small Tenasillahe (STS) and small Welch (SWS) sloughs, 2008.

Fish Species	# of individuals	% of Total
	LTS	
3-spine Stickleback	185	38.95%
Sculpin	91	19.16%
Eastern Banded Killifish	61	12.84%
Largescale Sucker	53	11.16%
Peamouth	25	5.26%
Bluegill	22	4.63%
Unknown Sunfish	13	2.74%
Yellow Bullhead	8	1.68%
Common Carp	6	1.26%
Pumpkinseed	6	1.26%
Largemouth Bass	3	0.63%
Chinook Salmon	2	0.42%
Total	475	
	STS	
3-spine Stickleback	296	66.22%
Shiner	45	10.07%
Unknown Sunfish	44	9.84%
Bluegill	22	4.92%
Pumpkinseed	22	4.92%
Sculpin	12	2.68%
Eastern Banded Killifish	4	0.89%
Smallmouth Bass	2	0.45%
Total	447	
	LWS	
3-spine Stickleback	35002	98.80%
Chinook Salmon	175	0.49%
Peamouth	126	0.36%
Eastern Banded Killifish	53	0.15%
Sculpin	31	0.09%
Chum Salmon	23	0.06%
Starry Flounder	10	0.03%
Largescale Sucker	3	0.01%
Northern Pikeminnow	3	0.01%
Unknown Sunfish	2	0.01%
Total	35428	

Table 3: continued

	SWS	66.22%
3-spine Stickleback	12375	98.77%
Peamouth	63	0.50%
Chinook Salmon	54	0.43%
Sculpin	26	0.21%
Eastern Banded Killifish	4	0.03%
Largescale Sucker	4	0.03%
Pacific Lamprey	1	0.01%
Steelhead Trout	1	0.01%
Western Brook Lamprey	1	0.01%
Total	12529	

Habitat Characterization

Water quality

All sloughs reached a 7-DADM of 16ºC two times between March 20 and July 10. The duration to which they remained above this threshold varied among sloughs. During the 113 days of temperature data collection, LTS and STS water temperature remained above 7-DADM 16ºC for 47 days. LWS and SWS water temperature remained above 7-DADM 16ºC for 26 and 24 days, respectively. The 7-DADM reached 16ºC on May 15 in LTS, and May 18 in STS, LWS and SWS (Figure 5). LWS and SWS remained above 16ºC four days whereas LTS and STS remained for 23 and 19 days, respectively. STS, LTS, LWS and SWS again reached 16ºC on June 13, 17, 18 and 20, respectively and remained above until loggers were removed on July 9 (LWS and SWS) and July 10 (LTS and STS).

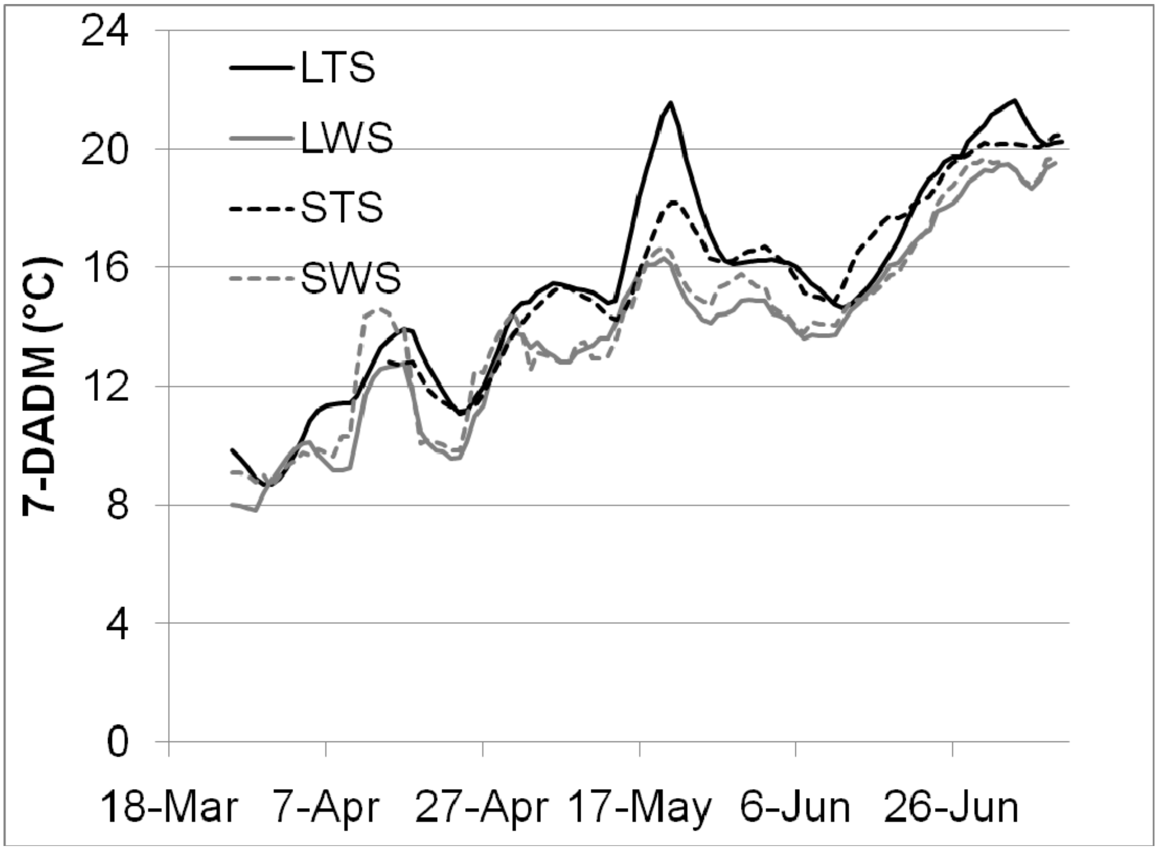


Figure 5: Seven day daily average maximum (7-DADM) water temperature of large Tenasillahe (LTS), large Welch (LWS), small Tenasillahe (STS) and small Welch (SWS) sloughs, 2008.

Daily temperature range varied among sloughs. Median daily temperature range varied from 1.2ºC and 3.1ºC (Table 4). LTS showed the lowest daily temperature range (1.2ºC) and SWS had the highest (3.1ºC). Significant differences were found among sloughs in 5 of 6 pair wise comparisons. LTS and STS (gated sloughs) had significantly lower daily temperature range than either LWS or SWS (reference sloughs). LTS had significantly lower daily temperature range than STS). Significant difference was not found between LWS and SWS.

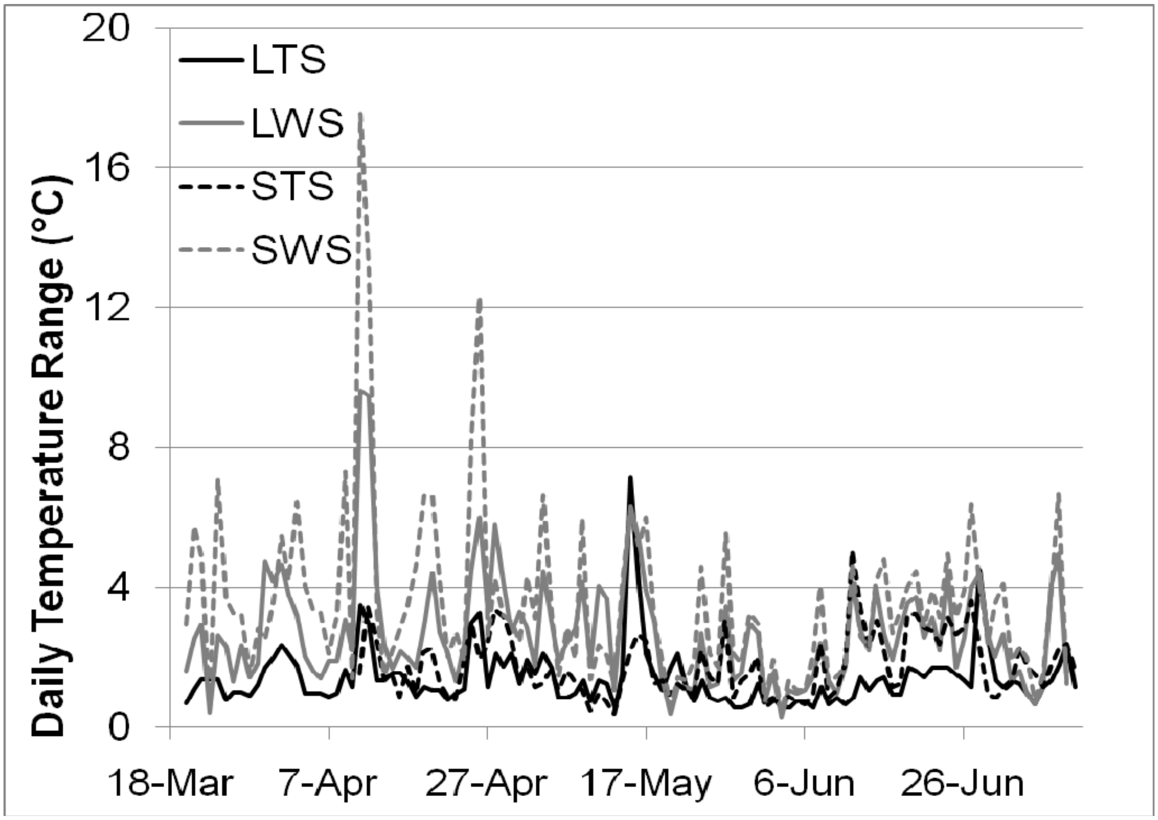


Figure 6: Daily water temperature range of large Tenasillahe (LTS), large Welch (LWS), small Tenasillahe (STS) and small Welch (SWS) sloughs, 2008.

Table 4. Median daily temperature range (ºC) of large Tenasillahe (LTS), large Welch (LWS), small Tenasillahe (STS) and small Welch (SWS) sloughs, 2008. "X" signifies significant differences among sloughs as determined using Kruskal-Wallis ANOVA on Ranks followed by Dunn's multiple comparison procedure.

	SWS	LWS	STS	LTS	ºC
LTS	X	X	X		**1.237**
STS	X	X			**1.527**
LWS					**2.428**
SWS					**3.145**

Dissolved oxygen levels ranged from 32.8% to 95.8% in gated sloughs with median levels of 75% and 85.9% in LTS and STS, respectively (Table 5). Dissolved oxygen levels ranged from 69.2% to 108.1% in reference sloughs with median levels of 94.2% and 83.3% in LWS and SWS, respectively. Conductivity was significantly higher in LTS than the other three sloughs. Conductivity ranged from 128.9µS to 167.2µS in reference sloughs. STS conductivity ranged from 131.1µS to 158.2µS. The highest conductivity level was measured in LTS (2700µS). Among sloughs, pH ranged from 6.19 to 8.04. In gated sloughs, turbidity ranged from 10 to 40 JTU in LTS and 5 to 10 JTU in SWS. In reference sloughs, turbidity ranged from 5 to 10 JTU in both LWS and SWS. Water transparency ranged from 0.13 to 0.85-m in LTS and 0.44 to 0.80-m in STS. In reference sloughs, transparency ranged from 0.57 to 1.03-m in LWS and 0.42 to 1.22-m in SWS.

Table 5: Median (min-max) levels of water quality variables within large Tenasillahe (LTS), large Welch (LWS), small Tenasillahe (STS) and small Welch (SWS) sloughs, 2008.

Slough	% Dissolved Oxygen	Conductivity (µS)	pH	Turbidity (JTU)	Transparency (m)
LTS	**75** (32.8-95.8)	**903.5** (174.5-2700)	**6.69** (6.19-7.67)	**15** (10-40)	**0.47** (0.13-0.85)
STS	**85.9** (70.2-94.2)	**147.75** (131.1-158.2)	**7.21** (6.47-7.87)	**10** (5-10)	**0.67** (0.44-0.80)
LWS	**94.15** (82.7-108.1)	**148.7** (128.9-161.1)	**7.02** (6.17-8.04)	**10** (5-10)	**0.7** 0.57-1.03)
SWS	**83.3** (69.2-90.4)	**153.6** (138.6-167.2)	**6.75** (6.27-6.81)	**7.5** (5-10)	**1.07** (0.42-1.22)

Physical Habitat

A total of 18 reaches were sampled to document physical habitat in 2008 (table 6). A total of 7 reaches were sampled in reference sloughs (LWS = 5, SWS = 2). A total of 11 reaches were sampled in gated sloughs (LWS = 8, SWS = 3). Silt was the dominant substrate in all reaches. Riparian vegetation was predominantly shrub and forb-grassland in the reference sloughs. Shrubs and trees dominated STS riparian areas. Grassland-forb and shrub dominated in LTS. Physical cover was dominated by aquatic vegetation in both gated sloughs whereas overhanging trees/shrubs and woody debris provided cover in LWS and SWS.

Table 6: Summary of physical habitat features (percentage of reaches with physical habitat feature) within large Tenasillahe (LTS), large Welch (LWS), small Tenasillahe (STS) and small Welch (SWS) sloughs, 2008 (all reaches combined).

Slough	Dominant Substrate [a]	Sub-Dominant Substrate [a]	Dominant Riparian Veg.	Sub-Dominant Riparian Veg. [b]	Percent Shade (Range)	Percent Physical Cover [c]
LTS	Silt	Silt	Grassland Forb	Shrub	0-5%	40% Aquatic Vegetation
STS	Silt	Silt	Shrub	Trees	15-40%	75% Aquatic Vegetation 30% Overhanging Tree/Shrub
LWS	Silt	Silt	Shrub	Grassland Forb	1-10%	5% Overhanging Tree/Shrub 5% Woody Debris*
SWS	Silt	Sand	Shrub	Grassland Forb	3-10%	15% Woody Debris 10% Overhanging Tree/Shrub

Note [a] substrate categories: silt, sand, gravel, pebble, cobble, and boulder. [B] riparian vegetation categories: no vegetation, rock/gravel, grassland forb, shrubs, trees.

Residence Time and Growth Rate

In LWS, one of the 1500 left ventral fin-clipped Chinook fry released was recaptured. Recapture occurred April 16th in a hoop net placed in reach 2. Recapture effort was reduced to the two days immediately following fish release due to technical difficulties with the boat motor.

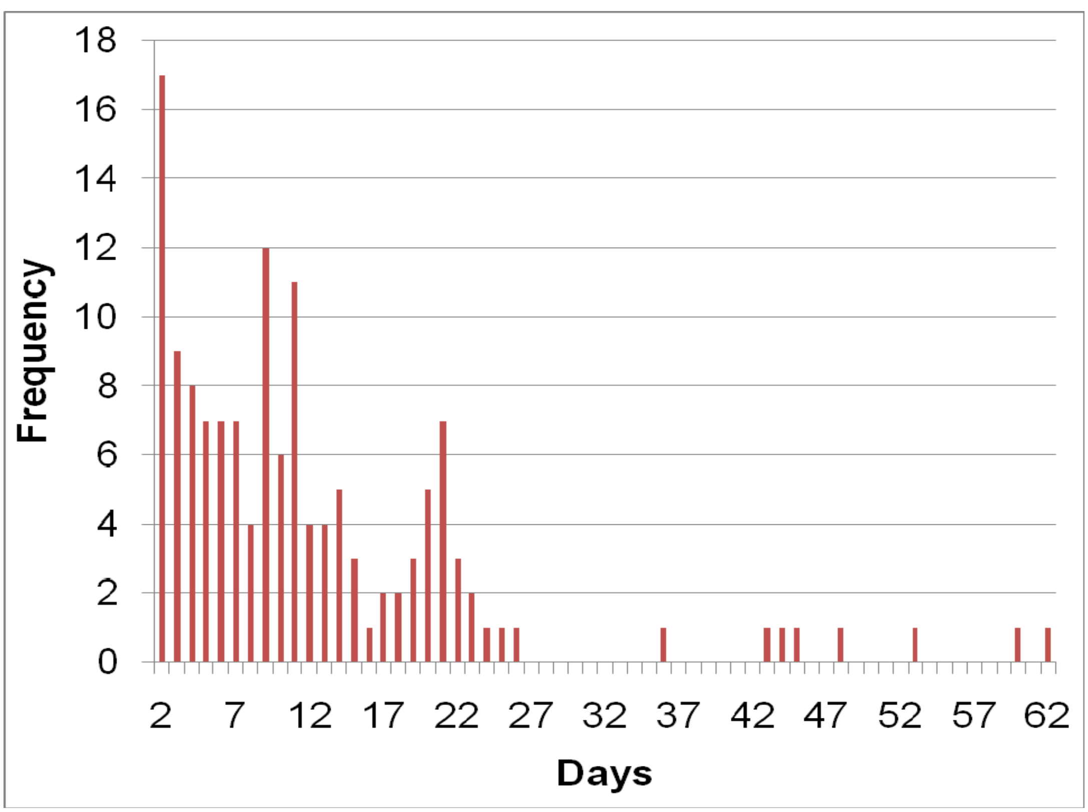
Eight hundred ninety-eight PIT tagged hatchery Chinook salmon were released in LTS April 28 and 29. Of these, 589 were detected at the PIT antenna array between April 29 and September 15. PIT tagged hatchery Chinook salmon released in LTS that exited LTS took from one to 119 days to travel from release site and exit the tide gate (Table 7). The median number of days to exit was 41 to 45 for groups. Distance between release sites to the tide gate antenna array was between 330 and 2800 meters. Percent of fish detected leaving the slough ranged from 64 to 67% percent for different release groups.

Table 7: Percent and number of PIT tagged and released hatchery Chinook salmon detected at tide gate antenna array and the median days and range of time between release and detection.

	Reach 1	Reach 2	Reach 4	Reach 7
Distance to TG (m)	330	595	1500	2800
% detected (n)	64 (225)	65 (226)	67 (222)	66 (225)
Median days to detection	42	42	43	45
(range)	(20 – 119)	(2 – 97)	(1 – 61)	(21 – 101)

Of the 589 PIT tagged Chinook salmon detected leaving LTS through the tide gates, 255 (43%) were detected one time. The remainder (334) had detection histories of two or multiple detection times. The time between the first and last detection for an individual fish ranged from less than one day to 61.5 days. One hundred fifty fish had first and last detections occurring greater than 24 hours apart (Figure 6). The greatest time between the first and last detection was 61.5 days. This fish was first detected May 27 and the last detected on July 28.

Figure 7: Number of individual fish and number of days between first and last PIT detection of tagged Chinook salmon released in large Tenasillahe slough, 2008.



Ten PIT-tagged and released fish were recaptured in the culvert traps. Growth rate was calculated for these individuals (Table 8). Growth rate ranged from 1.29 to 1.62 mm per day and 0.51 to 0.79 g per day.

Table 8: Growth rate of PIT tagged and released hatchery Chinook salmon in Large Tenasillahe Slough (LTS), 2008.

Release			Recapture			Growth	
date	FL (mm)	Weight (g)	date	FL (mm)	Weight(g)	mm/day	g/day
4/29	80	4.9	5/27	123	22.5	1.54	0.63
4/29	85	6.5	5/27	130	28.5	1.61	0.79
4/28	93	8.2	5/27	134	29.6	1.41	0.74
4/29	84	5.7	5/31	130	25.7	1.44	0.63
4/29	78	4.3	6/2	132	26.1	1.59	0.64
4/28	72	3.6	6/2	123	21.5	1.46	0.51
4/29	97	8.5	6/2	141	33.3	1.29	0.73
4/29	80	5.4	6/2	135	31.7	1.62	0.77
4/29	84	6.4	6/2	135	28.5	1.50	0.65
4/29	81	5.7	6/10	143	32.5	1.48	0.64

Mortalities occurred in each net pen (Table 9). Growth was slow when compared to recaptured PIT-tagged fish that had been released into the slough. One hundred thirty of the 150 (87%) net penned fish in LWS survived. Of these, 42 (32%) exhibited negative growth rate (mm/day). Growth rate ranged from -0.07 to 0.12 mm per day. A disproportionately high number of fish perished (100%) in one of the LTS net pens and are not included in survival comparisons between sloughs. Of the other two net pens, 96 of the 100 (96%) net-penned fish in LTS survived. Of these, no fish (0%) exhibited negative growth. Growth rate ranged from 0.02 to 0.26 mm per day. Growth rate (mm/day) for surviving fish was significantly higher in LTS than LWS ($p<0.001$, Mann-Whitney Rank Sum Test)

Table 9: Growth rate range and survival of hatchery Chinook salmon enclosed in net pens in large Welsh slough (LWS) and large Tenasillahe slough (LTS), 2008.

	LWS Reach			LTS Reach		
	1	3	4	1	2	6
n	50	50	50	50	50	50
# survived	37	45	48	47	49	0
Growth rate						
(mm/day)	-0.07-0.12	-0.07-0.07	-0.07-0.07	0.02-0.26	0.02-0.24	na
(g/day)	-0.04-0.02	-0.05-0.0	-0.03-0.01	-0.02-0.05	-0.02-0.05	na

Summary

Fish passage

Fish, including Chinook salmon, do enter and exit LTS through tide gates. However, juvenile salmonid access to Tenasillahe Island sloughs appears to be limited. Their access into Tenasillahe Island sloughs is dependent upon tide gate opening. Though all three tide gates on LTS open in response to tidal fluctuation, the duration of opening is limited to times when slough water elevation is above that of river water elevation. As such, fish have access to LTS on average less than 20% of any given day. In addition, fish must swim against the water flow to enter the slough through the gates.

Community Structure

More salmon species were captured in reference sloughs than in gated sloughs. Three species of salmonid (Chinook, chum salmon and steelhead trout) were captured in reference sloughs whereas only Chinook salmon were captured in LTS. Both hatchery origin (adipose fin clipped) and unmarked Chinook salmon were captured in gated and reference sloughs. More non-natives species were captured in gated sloughs than reference sloughs. Non-native species captured include those known to prey on juvenile salmonids (e.g. Smallmouth Bass).

Habitat Characterization

Gated slough aquatic habitat resembles that of lentic habitats. Reference sloughs are subjected to full tidal cycles and changes in river flow whereas gated sloughs exhibit low water flow and exchange with the river main stem. The result is elevated water temperature, reduced dissolved oxygen, and increased extent of emergent vegetation in gated sloughs. Water temperatures in gated sloughs may be more limiting to juvenile salmon than temperatures in reference sloughs. Gated sloughs had higher daily maximum temperatures and lower daily temperature ranges than did reference sloughs. Between March 20 and July 10 (113 days), LTS and STS exceeded 7-DADM upper threshold level of 16C° for 47 days. LWS and SWS exceeded threshold levels for 26 and 24 days, respectively. The lowest dissolved oxygen levels were recorded in LTS. Low dissolved oxygen levels or high temperatures likely played a role in the death of all Chinook salmon in one of the LTS net pens.

Residence Time and Growth Rate

Released hatchery Chinook salmon remained in and near LTS throughout the summer. Median days to exit of release groups ranged from 42 to 45 days (June 9-12). The last PIT tag detection of an emigrating fish occurred August 26th. PIT tagged Chinook salmon that exited LTS through the tide gates, were detected by the PIT antennas up to 61 days after the first detection. The last detection occurred September 15, 2008.

Hatchery Chinook salmon grew well in LTS. Pit-tagged hatchery Chinook salmon released in LTS grew faster than net penned fish from either LTS or LWS. Growth of released Chinook salmon ranged from 1.29 to 1.62 mm per day compared to 0.02 to 0.26mm per day for LTS net-penned Chinook salmon. Growth of net-penned Chinook salmon was slower in LWS than LTS.

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