Assessment of Fishes, Habitats, and Fish Passage at Tide gates on Deer Island Slough and lower Tide Creek

2009 Project Report

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Introduction

Multiple factors have contributed to the decline of anadromous salmonids throughout the Columbia River basin. Currently, there are 13 evolutionary significant units of salmonids listed under the Endangered Species Act (ESA) that migrate through the Columbia River. 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 and foraging 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 dikes, tide-gated culverts, and the 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 or improving the connectivity between tidally-influenced side channel habitats and 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 Mainstem and Estuary (Lower Columbia Fish Recovery Board (LCFRB) 2004) and NOAA Fisheries' FCRPS Biological Opinion (National Marine Fisheries Service (NMFS) 2004). Tidal wetland restoration is also consistent with the Northwest Power and Conservation Council's biological objectives outlined in the 2000 *Columbia Basin Fish and Wildlife Program.*

Several entities are working together to develop appropriate habitat restoration strategies for the Deer Island area. Deer Island is located at river kilometer 125-130 along the south shore of the lower Columbia River near the town of St. Helens in Columbia County, Oregon. The area encompasses over 1,821 hectares within the Columbia River floodplain, which historically consisted of tidally influenced backwater and slough habitats (i.e., Deer Island Slough), as well as stream habitats in relatively small tributaries adjacent to the area (e.g., Tide and Merrill creeks). Presently, the value of these habitats for anadromous salmonids has been reduced by such activities as dike construction, tide gate installation, and stream channelization, resulting in restricted access by fish and degraded habitat conditions. However, anadromous fish continue to use the area.

The Oregon Department of Fish and Wildlife (ODFW) has documented the presence of four species of anadromous fish within the area, coho salmon (*Oncorhynchus kisutch*), steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and Pacific lamprey (*Lampetra tridentate*). Coho salmon in the area are listed as threatened species under the ESA, and coastal cutthroat trout and Pacific lamprey are considered species of concern.

The Columbia Soil and Water Conservation District (Columbia SWCD) and Lower Columbia River Watershed Council (LCRWC) are leading efforts to engage natural resource agencies, private landowners, and others to develop habitat restoration strategies that are compatible with private land uses and provide benefits to anadromous fish and other species. In spring 2009, the U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office (CRFPO), contributed to these efforts by monitoring biological and physical attributes of Deer Island Slough and lower Tide Creek for the preparation of this biological assessment. The ultimate goal of this assessment was to provide information concerning fish presence, aquatic habitat conditions, and fish access to habitats that would assist with the identification and prioritization of future restoration actions intended to improve juvenile salmonid habitats and access to habitats, as well as providing information useful for describing baseline conditions prior to implementing restoration actions. Our monitoring efforts occurred during the time when juvenile salmonids were likely to be in the area, March-June.

We addressed three primary objectives during the field season: 1. Determine whether juvenile salmonids are able to pass from the Columbia River into the slough through the existing tide gates, specifically during March-June when juvenile salmon are likely in the area; 2. Describe the fish community inhabiting Deer Island Slough and lower Tide Creek; and 3. Characterize aquatic habitats in Deer Island Slough and lower Tide Creek.

Methods

Study Area

Deer Island Slough.—Deer Island Slough is a 9.7-km backwater channel of the Columbia River that separates the western side of Deer Island from the adjacent floodplain. Most of Deer Island and adjacent lands are enclosed within levees. Water levels within Deer Island Slough are regulated by two series of tide gates located on the northern- and southern-most ends of the slough (Figure 1). An earthen berm was constructed at about the midpoint of Deer Island Slough (4.3 km from the northern confluence) that completely separates the slough into northern and southern portions, which we refer to as North Deer Island Slough and South Deer Island Slough and treated as separate areas for establishing sample sites. Currently, there is no direct water connection between North Deer Island Slough and South Deer Island Slough. Because tide gates at North Deer Island Slough were submerged, we focused our activities on the series of tide gates at South Deer Island Slough. The tide gate structure consists of four 1.8-m diameter cast iron gates with hinges at the top (Figure 2). The gates are designed to open when the water elevation inside the slough is greater than the water elevation on the downstream (Columbia River) side of the tide gates. On the downstream side of the tide gates, the bottom of the lowest-most culvert is set at an elevation of 2.41 m, which conveys water onto a concrete pad whose lowest elevation is 1.85 m (data from Statewide Land Surveying, Inc., fall 2008). Water flow into the slough from the Columbia River is primarily limited to that which is able to leak past debris or other obstructions preventing the tide gates from completely closing.

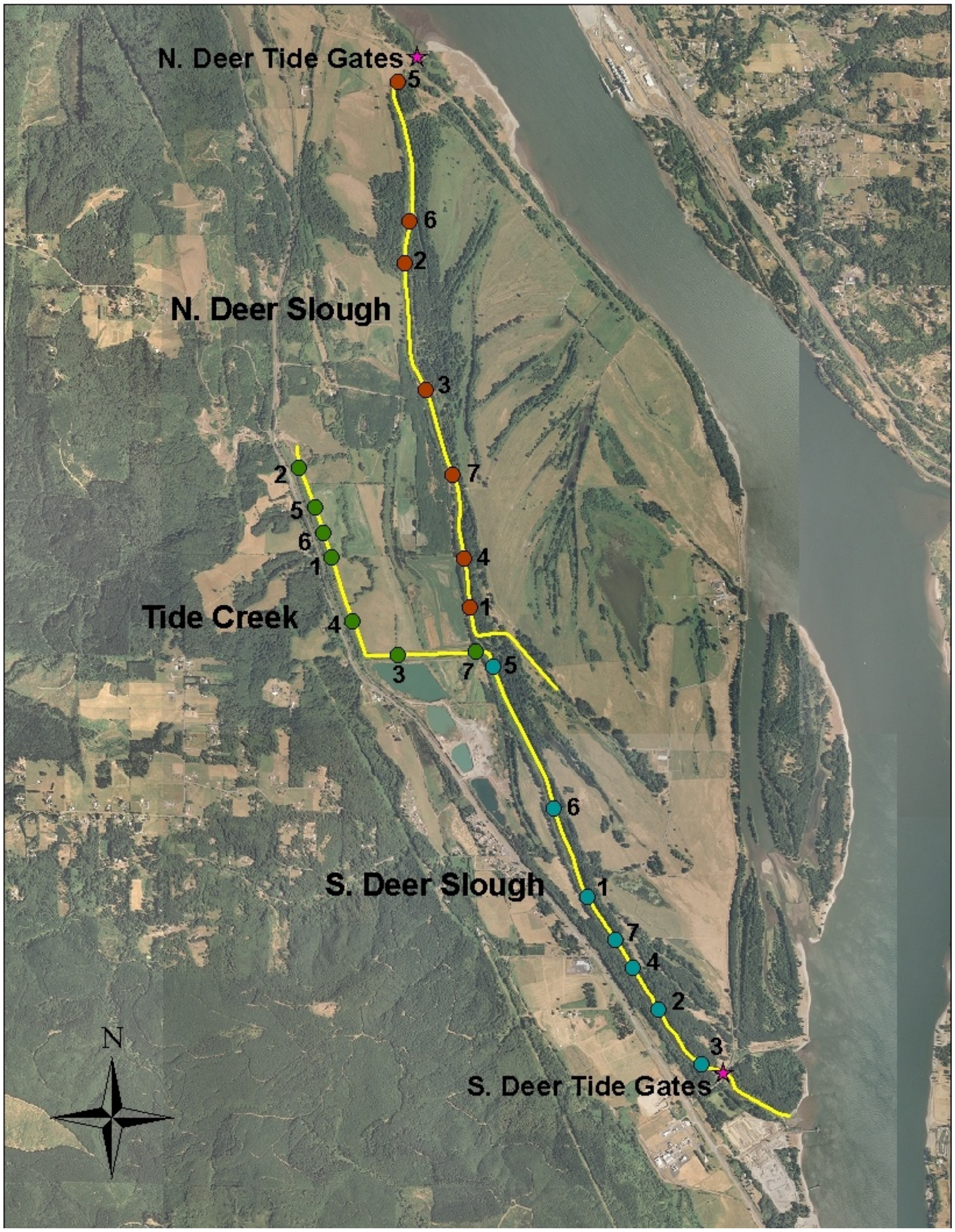

Figure 1. Area map of Deer Island showing survey locations and reaches sampled in South Deer Island Slough, North Deer Island Slough, and lower Tide Creek, 2009.

Figure 2. Top hinge cast iron tide gates on South Deer Island Slough, 2009.

Tide Creek.—Tide Creek is a 26-km long tributary draining slopes on the western side of the Columbia River floodplain adjacent to Deer Island. Upstream of the Highway 30 bridge, Tide Creek has a drainage area of 52.3 km^2 (20.2 $mile^2$) and a 2-year peak flow of 19.1 m^3/s (673 cfs; data available from http://streamstats.usgs.gov). The lower three kilometers of Tide Creek historically flowed north parallel to Deer Island Slough before entering the Columbia River west of the north confluence of Deer Island Slough. Presently, lower Tide Creek has been diverted from its historical floodplain into a constructed channel flowing south and then east before entering South Deer Island Slough at a point about four kilometers upstream from the south Deer Island Slough confluence (Figure 1). We refer to the constructed channel as lower Tide Creek, and focused our sampling efforts to the reach between South Deer Island Slough and the Highway 30 bridge. Anadromous fish distribution (i.e., coho salmon), extends approximately 22.5 km upstream from the mouth of Tide Creek (Faucera personal comm.). However, a waterfall approximately 1.2 km upstream from the Highway 30 bridge may restrict anadromous fish use to the lower 4.8 km of tide Creek (PSU 2001). Merrill Creek is a tributary of lower Tide Creek that also includes anadromous fish habitat. Upstream of the Highway 30 bridge, Merrill Creek has a drainage area of 20.5 km^2 (7.9 $mile^2$) and a 2-year peak flow of 8.4 m^3/s (295 cfs; data available from http://streamstats.usgs.gov). Our sampling effort focused on lower Tide Creek.

Juvenile Salmon Passage at South Deer Island Slough Tide Gates

To determine whether juvenile salmonids are able to pass from the Columbia River into South Deer Island Slough through the existing tide gates, fish passage trials were performed early (22 April) and late (1 June) during the field season. During each trial, five seine hauls were performed immediately inside and outside the tide gates to determine the presence of juvenile salmonids, and a net was attached directly to a tidegate culvert to capture fish attempting to enter the slough through the tide gate during a 24-hour period. During the early trial, a 0.9-m circular hoop net was attached to on a tide gate culvert, and a 1.8-m circular net (“sock”) with live box was attached to a tide gate culvert during the later trial. The sock net was set on 14 additional 24-hour periods (18 May-18 June) to capture fish attempting to enter the slough. The sock net was set at the beginning of a survey week and allowed to fish continuously for up to 96 hours. The live box was checked and all contents removed every 24 hours.

To estimate the frequency and duration of likely tide gate openings, water depth was continuously recorded (30-minute intervals) using temperature-depth loggers (In-Situ, Inc.) placed immediately inside and outside of the tide gates at South Deer Island Slough (Figure 3). Each logger was placed within a perforated PVC pipe installed at a known elevation to allow the estimation of water surface elevations relative to mean sea level (msl). We compared water surface elevation outside the tide gates to that inside the slough to determine when tide gates were assumed to be open (i.e., water surface elevations higher inside the slough than outside) and also to the elevation of the lowest culvert (2.41 m) to determine when the culverts may be inaccessible to fish (i.e., water surface elevation outside the tide gate is less than that of the culverts, which are about 0.61 m higher than the concrete pad outside of the tide gates). Tide gate openings and incidences of "perched culverts" were estimated relative to periods primarily affecting adult salmonids (i.e., 1 October-31 January) and juveniles (1 March-15 June), and specifically during fish passage trials and when the sock net was set.

Fish Community

To describe the fish community inhabiting Deer Island Slough and lower Tide Creek, sample reaches were selected using a Generalized Random Tessellation Stratified (GRTS) approach (Stevens and Olsen 2004). This sampling design was used to generate a random, spatially-balanced selection of sample reaches that would include the range of habitats and conditions present within North Deer Island Slough, South Deer Island Slough, and lower Tide Creek. Each of the three areas was georeferenced on a 100K stream layer in ArcMap. Potential sample reaches in each of the three areas were drawn at a density of one reach per every 150 m of stream length. A final spatially-balanced, randomly ordered output table of all reaches was used to select the desired number sample reaches in each area. Sampling effort progressed in the order reaches were assigned in the output table. Any sample reach that fell outside of Deer Island Slough (i.e., outside of the tide gates), were inaccessible by boat, or were in close proximity to another reach (within 200 m), were eliminated from the survey. A total of seven 100-m reaches were sampled in North Deer Island Slough, South Deer Island Slough, and lower Tide Creek (Figure 1).

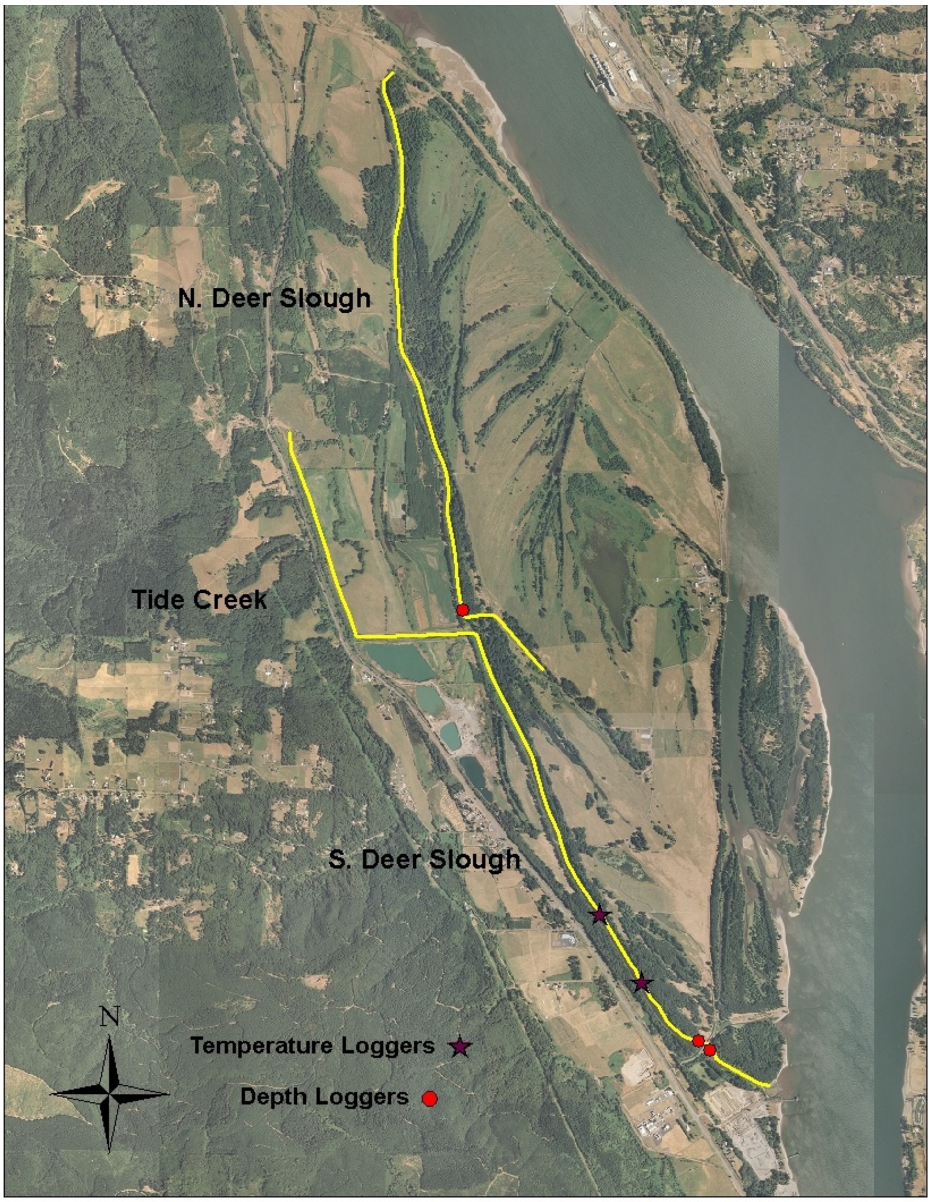

Figure 3. Location of temperature-depth loggers and temperature loggers in South Deer Island Slough and North Deer Island Slough, 2009.

When possible, sampling effort was distributed evenly among the three areas (two or three reaches surveyed per week in each of the areas). This sampling regime was used to ensure the various habitats and conditions present within each area were represented, as well as to capture the seasonal variation and changes in fish distribution and community composition. All sample reaches were surveyed early in the season (March-April), and late in the season (May-June).

Seines, circular hoop nets, minnow traps, and crayfish traps were used to sample fish. Seines (15 m x 1.8 m and 4.6 m x 1.2 m, both with 0.6-cm mesh) were used to sample fish in South Deer Island Slough and lower Tide Creek. The smaller stick seine was used exclusively in lower Tide Creek where stream width and velocity would not accommodate the larger seine. Each seine was held on or along the shore and either hauled by foot or towed into the channel by boat making a sweep along the shore. The size of the encircled area was estimated and recorded to document sampling effort. In South Deer Island Slough where near-shore woody debris would not allow effective seine use, the seine was fed into the slough from the boat in a circular sweep and pulled back into the boat. A minimum of five seine hauls were performed in each sample reach during early and late sampling dates. Seines were not used in North Deer Island Slough due to dense near-shore aquatic vegetation and soft substrates.

Circular hoop nets (1.2-m hoops with 4.5-m wings and 0.9-m hoops with 4.5-m wings, both with 0.6-cm mesh) were used to sample fish in North Deer Island Slough, South Deer Island Slough, and lower Tide Creek. Hoop nets were set overnight, oriented to capture fish moving upstream or downstream, in areas with sufficient water depth to submerge the trap (minimum 60 cm). A single hoop net was set in each sample reach during both early and late sampling dates.

Minnow traps and crayfish traps (2.5-cm and 5.7-cm openings, respectively) were used to sample fish in North Deer Island Slough and South Deer Island Slough. All traps were baited with salmon eggs (approximately 113 g) and placed on the surface of the substrate with a 3-m rope attached to a float. An array of five traps, consisting of both types of traps so that a larger size range of fish may be captured than using a single type of trap, was typically set perpendicular to shore. Minnow traps and crayfish traps were set overnight in a reach and then removed the next day during both early and late sampling dates.

All fish captured were placed in an aerated bucket of water, identified, enumerated, and released. For salmonids, fish were anaesthetized in a 0.3 g/l solution of MS-222, measured (fork length), weighed, and examined for external marks. Adipose-fin clipped Chinook salmon greater than 60-mm fork length were also scanned for a passive integrated transponder (PIT) tag. Prior to release, fish were allowed to recover in an aerated bucket for 10-15 minutes.

Habitat Characterization

To characterize aquatic habitats in Deer Island Slough, water temperature and depth was continuously recorded (30-minute intervals) in North Deer Island Slough (March-June 2009) and South Deer Island Slough (September 2008-June 2009) using temperature-depth loggers (In-Situ, Inc.). The logger in North Deer Island Slough was installed similarly to those in South Deer Island Slough described above (see Juvenile Salmon Passage at South Deer Island Slough Tide Gate). Two additional temperature loggers (Onset Computer Corporation, 30-minute intervals) were placed in two reaches upstream of the tide gates in South Deer Island Slough during 13 March-15 June (Figure 3). Daily temperature range (maximum minus minimum temperature) was calculated for North Deer Island Slough and South Deer Island Slough. Daily temperature range was compared between sloughs using the Kruskal-Wallis ANOVA on ranks and Dunn's multiple comparison procedure (SigmaSTAT 3.0). Seven-day average daily maxima (7-DADM) were calculated from the temperature data. These values were compared to threshold criteria (16.8°C) above which juvenile salmonids exhibit sub-lethal effects (EPA 2003; Richter and Kolmes 2005). Because no temperature loggers were installed in lower Tide Creek, instantaneous temperature measurements collected at fish sample reaches were analyzed to describe habitat conditions. Mean daily temperature was compared among North Deer Island Slough, South Deer Island Slough, and lower Tide Creek using the Kruskal-Wallis ANOVA followed by the Holm-Sidak multiple comparison procedure. Our use of statistical tests for water temperature, as well as other habitat variables, was to identify relative extreme values among sites and areas.

During fish surveys, dissolved oxygen (DO, percent saturation and concentration (mg/l)) and conductivity (μS) were measured at each sample reach using a YSI meter. Dissolved oxygen was compared among the three sampling areas using ANOVA and the Holm-Sidak comparison procedure; and specific conductivity was compared between the three areas using ANOVA on ranks and the Dunn's multiple comparison procedure. Habitat attributes (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 North Deer Island Slough, South Deer Island Slough, and lower Tide Creek. Turbidity was measured using a LaMotte turbidity water test kit; and pH was measured using an Oakton data meter. 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 visual inspection or by probing the substrate at a minimum of 20 points across a transect. Substrate type was recorded using six categories of substrate size: silt/clay/organic material (<0.059 mm diameter), 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 determined using visual inspection of a 10-m band of the riparian area 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, and woody debris, and riparian features such as overhanging trees/shrubs. A digital photograph was taken at most sample reaches to document current physical habitat conditions within the sloughs. Habitat surveys were conducted twice, corresponding to fish sampling in each sample reach.

Results

Juvenile Salmon Passage

A total of 73 juvenile salmon (Chinook salmon and coho salmon) were captured during early and late fish passage trials on 22 April and 1 June (Table 1). Juvenile salmon were captured during both fish passage trials, with the majority of fish being captured during the 22 April trial (83.6%). Chinook salmon were the most abundant species captured during both trials, making up 98.6% of the total salmon catch (Table 1). A total of 20 seine hauls were performed directly inside and outside of the South Deer Island Slough tide gates during trials, and juvenile salmonids were collected within 50 m of the tide gates during both trials. During the 22 April trial, a total of 51 chinook salmon (83.6% of total) were captured by seining (Table 1). Of these, 29.4% were captured inside the tide gates and 70.6% were captured outside the tide gates. The majority of juvenile Chinook salmon (94.1%) captured during the 22 April trial had an adipose-fin clip, indicating they were from a hatchery. Eleven Chinook salmon and one coho salmon (16.4% of total) were captured by seining during the 1 June fish passage trial (Table 1). Of these, 41.7% of fish were captured on the inside of the tide gates and 58.3% were captured on the outside of the tide gates, and one juvenile Chinook salmon had an adipose-fin clip. The single juvenile coho salmon, which was captured inside the tide gates, did not have an adipose-fin clip. A total of 10 juvenile Chinook salmon (16.4% of total) were captured entering the slough in a hoop net during the 22 April trial (Table 1). Of these, nine had an adipose-fin clip. There were no juvenile salmonids captured in the sock net during the 1 June fish passage trial or during the additional sets of the sock net (Appendix A).

Table 1. Number per square meter (count) of salmonids captured in seines inside and outside of tide gates and number per hour (count) of salmonids captured in hoop and sock k nets during the 22 April and 1 June fish passage trials in South Deer Island Slough, 2009.

Species	Trap type	22 April passage trial	1 June passage trial
Chinook salmon	Inside seining	0.049 (15)	0.009 (4)
	Outside seining	0.087 (36)	0.021 (7)
	Hoop net	0.50 (10)	n/a
	Sock net	n/a	0.000 (0)
Coho salmon	Inside seining	0.000 (0)	0.002 (1)
	Outside seining	0.000 (0)	0.000 (0)
	Hoop net	0.000 (0)	n/a
	Sock net	n/a	0.000 (0)

Range in fork length (FL) of juvenile Chinook salmon was 62–141 mm for the 22 April fish passage trial and 51–104 mm for the 1 June trial (Figure 4). Fork length of the single coho salmon captured during the 1 June trial was 111 mm. The length frequency distribution of Chinook salmon suggests two age classes of fish, sub-yearlings (age 0) and yearlings (age 1). The majority of fish captured during fish passage trials were sub-yearling Chinook salmon (90.3%).

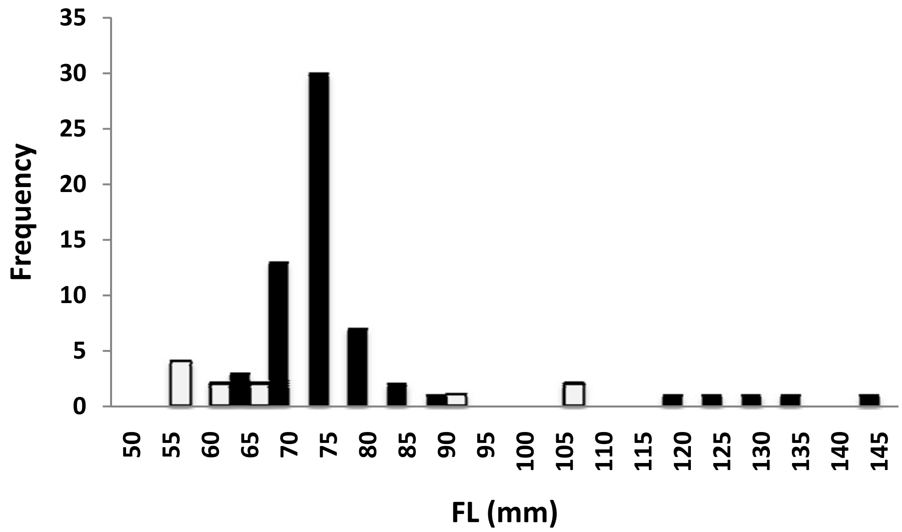

Figure 4. Length frequency of juvenile Chinook salmon captured during the 22 April (solid bars) fish passage trial and 1 June (open bars) trials (sampling methods combined) in South Deer Island Slough, 2009.

Water surface elevations were typically higher inside the tide gates than outside (Figure 5). For the period that adult salmon would likely be entering the slough (1 October-31 January), water surface elevation was higher inside the tide gates than outside during a portion of all days. Tide gates were assumed to be open for a total of 2,805 hours during the entire 123-day period (i.e., 2,952 hours). Water surface elevation outside the tide gates was lower than the elevation of the lowest culvert for 1,347.5 hours so that culverts were "perched" 46% of the time during this period. For the period that juvenile salmonids would likely be entering the slough (1 March-15 June), water surface elevation was higher inside the tide gates than outside during a portion of all days with the exception of one (9 June; see Appendix B). Tide gates were assumed to be open for a total of 1,806 hours during the entire 107-day period (i.e., 2,568 hours). Water surface elevation outside the tide gates was lower than the elevation of the lowest culvert for 131.5 hours so that culverts were "perched" 5% of the time during this period.

During the 22 April fish passage trial, water surface elevation was higher inside the tide gates than outside for 11 hours, indicating that the gates were assumed open half of the 22-hour period that a hoop net was set (Appendix B). During the 1 June fish passage trial, water surface elevation was higher inside the tide gates than outside for 5 hours, indicating that the gates were assumed open for a fifth of the 25-hour period that a sock net was set. For the 14 additional sock-net sets, the net was fished during 18-22 May, 2-5 June, and 15-19 June for a total of 286.5 hours. Because the temperature-depth loggers were removed for retrieving data on 16 June, data for water surface elevations corresponding to the sock net sets exist for 204 hours. Tide gates were assumed to be open for 71 hours of the 204-hour period (i.e., 35% of the time; see Appendix B). Culverts were not "perched" at any time during sets of the hoop net or sock net. As previously described, salmonids were collected entering the slough only during the 22 April fish passage trial.

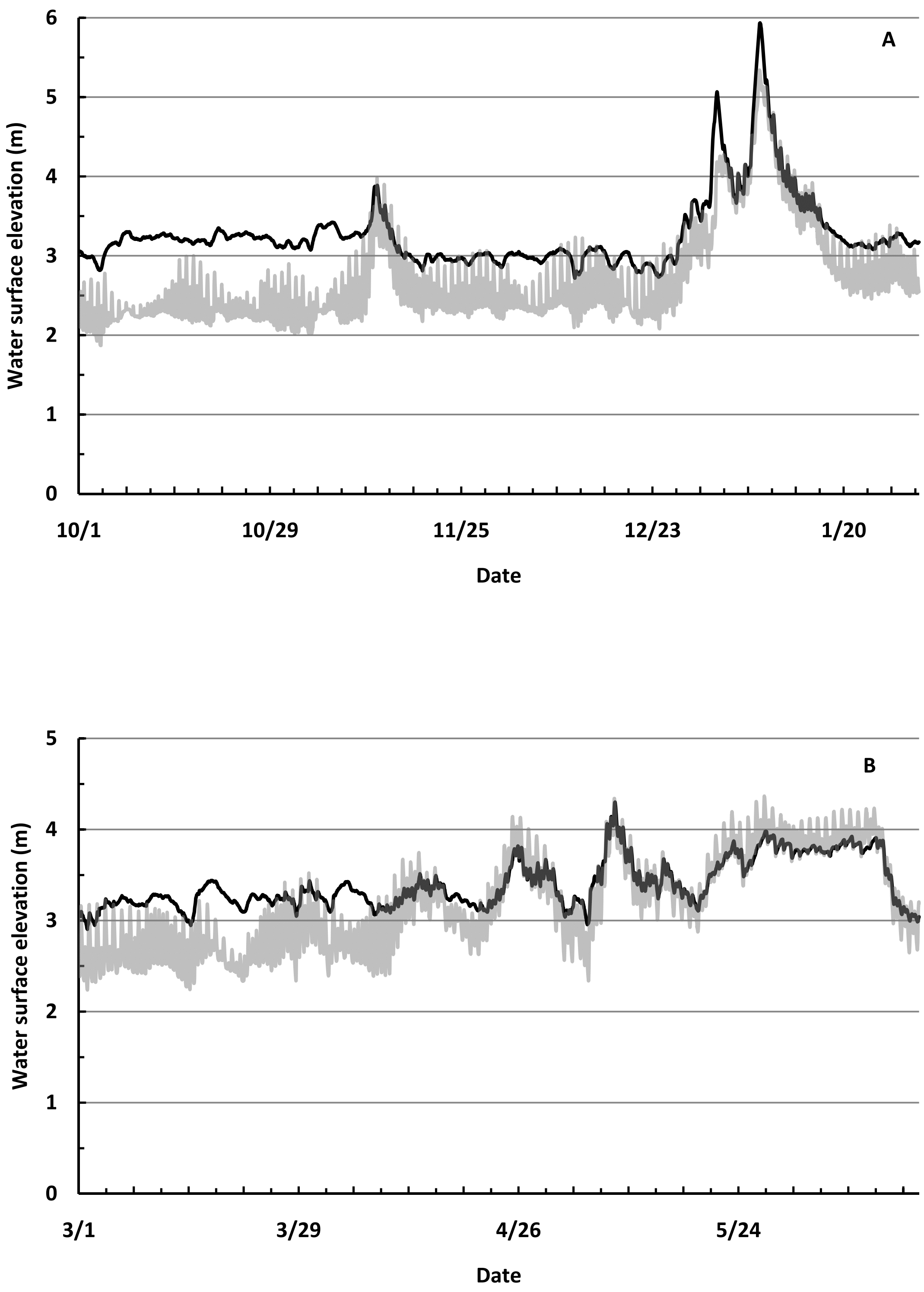

Figure 5. Water surface elevations inside South Deer Island Slough (black line) and outside tide gates (gray line) for 1 October 2008-31 January 2009 (A) and 1 March 2009-15 June 2009 (B). Elevation of the lowest-most culvert outside of the slough is 2.41 m.

Fish Community

North Deer Island Slough—A total of 14 hoop net sets, 40 minnow trap sets, and 30 crayfish trap sets were made in 7 sample reaches in North Deer Island Slough. A total of 10,125 fish, representing 13 taxa were captured during the entire field season (Table 2). Of the total, 81.5% of fish were captured in hoop nets and 18.5% were captured in minnow and crayfish traps. Threespine stickleback was the most abundant species captured in all reaches, making up 97.5% of the total catch (Table 2). Oriental weatherfish was the second most abundant fish species captured in all sample reaches, making up 0.7% of the total catch. Four of the 13 species captured in North Deer Island Slough were native taxa comprising 97.7% of the total fish catch (Table 3). Excluding threespine stickleback, native taxa comprised 9.0% of the total fish captured in North Deer Island Slough. No salmonids were captured in North Deer Island Slough.

South Deer Island Slough.—A total of 70 seine hauls, 14 hoop net sets, 33 minnow trap sets, and 42 crayfish trap sets were made in 7 reaches in South Deer Island Slough. A total of 4,104 fish representing 20 taxa were captured during the entire field season (Table 2). Of the total, 74.8% of fish were captured in hoop nets, 21.2% were captured in seines, and 18.5% were captured in minnow and crayfish traps. Threespine stickleback was the most abundant species captured in South Deer Island slough, making up 84.5% of the total catch (Table 2). Sculpin was the second most abundant taxa captured, making up 3.0% of the total catch (Table 2). Ten of the 20 species captured in South Deer Island Slough were native taxa comprising 94.3% of the total fish catch (Table 3). Excluding threespine stickleback, native taxa comprised 63.0% of the total fish captured in South Deer Island Slough.

Table 2. Percentage for each taxa (all methods combined) of total fish captured in North Deer Island Slough, South Deer Island Slough, and lower Tide Creek, 2009. Values in parentheses are numbers of individuals.

Species		N. Deer Slough	S. Deer Slough	Tide Creek
Threespine stickleback		97.5 (9,869)	84.5 (3,468)	63.0 (788)
Amur goby		0.0 (0)	0.2 (9)	0.0 (0)
Bluegill		0.3 (35)	0.4 (16)	0.0 (0)
Brown bullhead		0.0 (0)	0.1 (3)	0.1 (1)
Chinook salmon	Total	0.0 (0)	1.1 (47)	0.0 (0)
	Adipose clipped	0.0 (0)	1.0 (40)	0.0 (0)
	Unmarked	0.0 (0)	0.1 (7)	0.0 (0)
Coho salmon		0.0 (0)	0.6 (24)	18.8 (235)
Common carp		0.4 (45)	0.0 (2)	0.0 (0)
Cutthroat trout		0.0 (0)	0.0 (0)	0.5 (6)
Oriental weatherfish		0.7 (66)	0.6 (26)	4.0 (50)
Banded killifish		0.1 (9)	0.7 (27)	0.4 (5)
Largescale sucker		0.0 (0)	0.1 (5)	0.3 (4)
Northern pike minnow		0.0 (0)	0.4 (15)	0.1 (1)
Pacific lamprey		0.0 (0)	0.0 (1)	0.2 (3)
Peamouth		0.0 (2)	2.6 (105)	0.0 (0)
Pumpkinseed		0.2 (22)	2.0 (83)	0.3 (4)
Redside shiner		0.0 (5)	1.9 (77)	0.1 (1)
Sculpin		0.2 (16)	3.0 (125)	10.0 (125)
Steelhead		0.0 (0)	0.0 (0)	0.2 (2)
Unknown cyprinid[a]		0.0 (1)	0.0 (1)	0.0 (0)
Unknown lamprey[a]		0.0 (0)	0.0 (1)	0.0 (0)
Unknown sunfish[a]		0.3 (30)	0.5 (21)	0.0 (0)
Warmouth		0.0 (1)	0.0 (0)	0.0 (0)
Western book lamprey		0.0 (0)	0.0 (1)	1.5 (19)
White crappie		0.1 (8)	0.1 (4)	0.0 (0)
Yellow bullhead		0.1 (6)	0.8 (32)	0.5 (6)
Yellow perch		0.1 (10)	0.3 (11)	0.0 (0)

[a]Not included in species composition.

Table 3. Percentages of native and non-native taxa of total fish captured in North Deer Island Slough, South Deer Island Slough, and lower Tide Creek, 2009.

Area	Species, including threespine stickleback		Species, excluding threespine stickleback	
	Native	Non-native	Native	Non-native
North Deer Island Slough	97.7	2.3	9.0	91.0
South Deer Island Slough	94.3	5.7	63.0	37.0
Lower Tide Creek	94.7	5.3	85.7	14.3

A total of 71 salmonids, representing two taxa, were captured among reaches of South Deer Island Slough (Table 2). Chinook salmon were the most abundant species making up 66.2% of the total catch of salmonids. The majority of salmon were captured during May-June in seine hauls (81.7%), followed by hoop nets (12.7%), and crayfish traps (5.6%). Both adipose-fin clipped and unmarked Chinook salmon were captured. Adipose-fin clipped Chinook salmon composed 85.1% (40 of 47) of Chinook captured in South Deer Island Slough. No adipose-fin clipped coho salmon were captured in South Deer Island Slough. Range in fork lengths was 71-125 mm for adipose-fin clipped Chinook salmon, 40-79 mm for unmarked Chinook salmon, and 39-152 mm for coho salmon (Figure 6). The length frequency distribution of coho salmon captured in South Deer Island Slough suggests two age classes of fish, fingerling/pre-smolt (age 0) and smolts (age 1). The majority of coho salmon captured in South Deer Island slough were pre-smolts (66.7%).

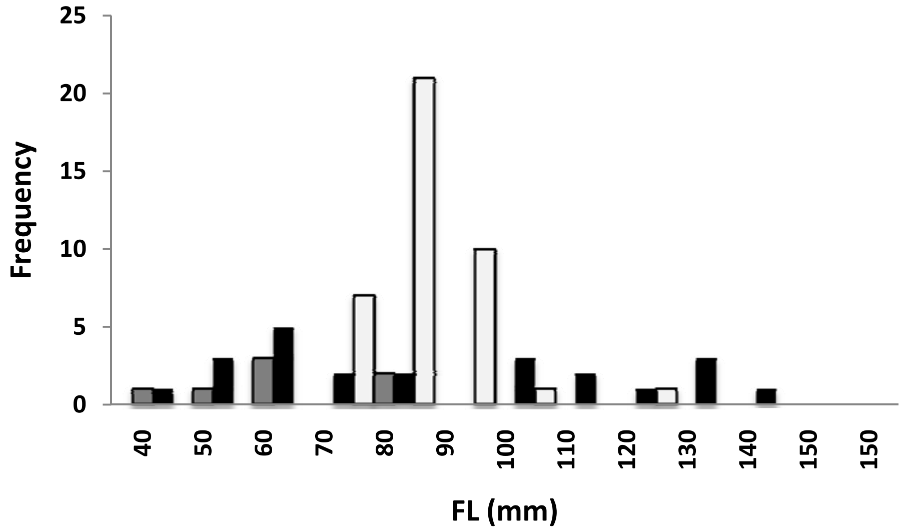

Figure 6. Length frequency of juvenile adipose-fin clipped chinook salmon (open bars), unmarked (wild) Chinook salmon (gray bars), and coho salmon (black bars) captured in seines, hoop nets, and crayfish traps in South Deer Island Slough, 2009.

Tide Creek.—A total of 50 seine hauls, 14 hoop net sets, 2 minnow trap sets, and 3 crayfish trap sets were made in 7 reaches in lower Tide Creek. A total of 1,250 fish, representing 15 taxa, were captured during the entire field season (Table 2). Of the total, 92.3% of fish were captured in hoop nets, 6.7% were captured in seines, and 1.0% was captured in minnow and crayfish traps. Threespine stickleback was the most abundant species captured in lower Tide Creek, making up 63.0% of the total catch (Table 2). Coho salmon was the second most abundant species captured, making up 18.8% of the total catch (Table 2). Ten of the 15 species captured in lower Tide Creek were native taxa, comprising 94.7% of the total fish catch (Table 3).

A total of 243 salmonids representing three taxa were captured in lower Tide Creek (Table 2). Coho salmon was the most abundant species, making up 66.2% of the total salmonid catch, followed by coastal cutthroat trout (6 individuals) and steelhead (2 individuals). Juvenile coho salmon were captured in all reaches, with the majority of individuals (93.6%) captured during May-June. Coastal cutthroat trout were captured in four reaches, during May-June only, whereas steelhead were captured in two reaches during March-April and May-June. The majority of coho salmon was captured in hoop nets (90.5%), and the remaining by seines (9.5%). No adipose-fin clipped salmonids were captured in lower Tide Creek. Ranges in fork lengths of salmonids were 37-142 mm for coho salmon (Figure 7), 120-217 mm for coastal cutthroat trout, and 176 and 180 mm for the two steelhead (Figure 7). The length frequency distribution of coho salmon captured in lower Tide Creek suggests two age classes of fish, fingerling/pre-smolt (age 0) and smolt (age 1). The majority of fish captured in lower Tide Creek were pre-smolts (55.7%).

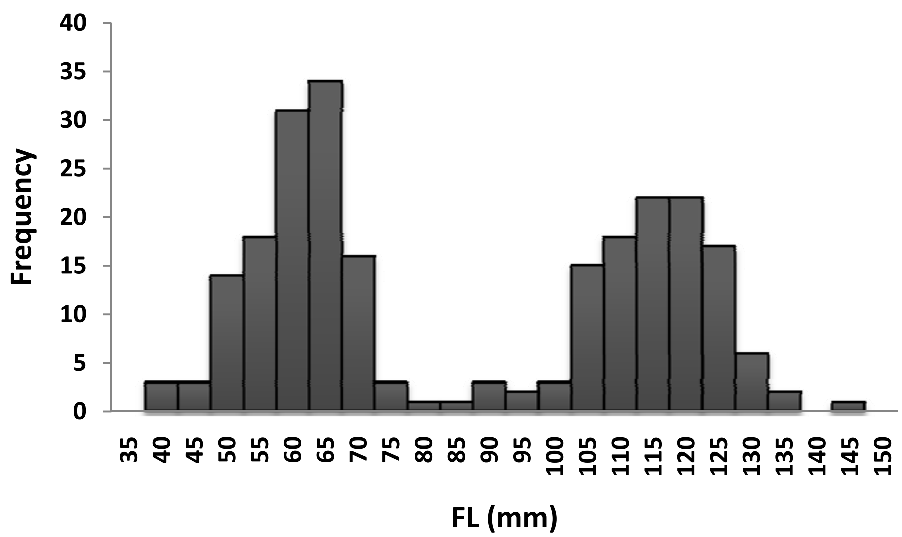

Figure 7. Length frequency of juvenile coho salmon captured in seines and hoop nets in lower Tide Creek, spring 2009.

Habitat Characterization

Physical Habitat.—In North Deer Island Slough, range in wetted width and mean water depth among sample reaches was 36.5-62.5 m and 0.63-1.18 m, respectively. Silt and sand were the dominant substrate types in all sample reaches (Table 4). Riparian vegetation was primarily shrubs (50.0%) and deciduous trees (35.7%). Shade averaged 16%, ranging from 2 to 40% among reaches. Physical channel cover was provided primarily by aquatic vegetation and large pieces of submerged woody debris. Range in water surface elevation was 2.24-3.48 m, with a mean daily range (daily maximum minus daily minimum) of 0.10 m during 13 March-15 June.

In South Deer Island Slough, range in wetted width and mean water depth among sample reaches was 8.5-75 m and 0.63-1.68 m, respectively. Water depth exceeded our 2-m probe at five of the seven reaches, and a 2-m depth was assigned to these points. Silt was the dominant substrate type in 100% of sample reaches (Table 4). Riparian vegetation was predominantly shrubs (57.1%) and deciduous trees (28.6%). Shade averaged 9%, ranging from 1 to 40% among reaches. Physical channel cover was provided primarily by overhanging trees and shrubs, and submerged woody debris. Range in water surface elevation was 2.95-4.30 m, with a mean daily difference of 0.18 m during 13 March-15 June.

In lower Tide Creek, range in wetted width and mean water depth among sample reaches in lower Tide Creek was 4.2-10.5 m and 0.41-1.56 m, respectively. Silt and sand were the dominant substrate types in all sample reaches (Table 4). Riparian vegetation was grasses/forbs in 100% of reaches. Shade averaged 13% ranging from 1 to 40% among reaches. Physical channel cover was provided primarily by reed canary grass.

Water Quality.—Mean water temperatures did not significantly differ ($P>0.05$) among North Deer Island Slough, three sites in South Deer Island Slough, and a site immediately outside the tide gates at South Deer Island Slough during 13 March-15 June (Table 5). Mean water temperatures varied by 1.0°C or less among the five sites. Daily range in water temperature was lowest at North Deer Island Slough and highest immediately inside the tide gate at South Deer Island Slough (medians of 0.6 and 1.6°C, respectively; Table 6). Overall, significant differences in daily range existed among several sites ($P<0.001$), with North Deer Island Slough significantly lower than all other sites.

Table 4. Summary of physical habitat (percentage of reaches with physical habitat feature) within North Deer Island Slough, South Deer Island Slough, and lower Tide Creek, 2009.

Area	Dominant substrate [a]	Sub-dominant substrate [a]	Dominant riparian vegetation [b]	Sub-dominant riparian vegetation [b]	Percent shade (SD, range) [d]	Physical cover [c, e] (%, range)
North Deer Island	Silt (71.4%) Sand (28.6%)	Silt (92.9%) Sand (7.1%)	Shrub (50.0%) Tree (35.7%) Grass/Forb (14.3%)	Trees (57.1%) Shrub (35.7%) Grass/Forb (7.1%)	16.0 (12.4, 2.0-40.0)	Overhanging Tree/Shrub (100.0, 0.0-10.0) Woody Debris (100.0, 1.0-18.0) Aquatic Vegetation (85.7,0.0-85.0)
South Deer Island	Silt (100%)	Silt (71.4%) Sand (28.6%)	Shrub (57.1%) Trees (28.6%) Grass/Forb (14.3%)	Trees (64.3%) Shrub (28.6%) Grass/Forb (7.1%)	9.0 (9.6, 1.0-40.0)	Overhanging Tree/Shrub (85.7, 0.0-5.0) Woody Debris (85.7, 0.0-6.0) Aquatic Vegetation (21.4,0.0-5.0) Reed Canary Grass (21.4, 0.0-5.0)
Lower Tide Creek	Silt (71.4%) Sand (28.6%)	Silt (35.7%) Sand (28.6%) Gravel (21.4%) Pebble (14.3%)	Grass/Forb (100%)	Trees (57.1%) Grass/Forb (42.9%)	13.0 (15.7, 1.0-40.0)	Reed Canary Grass (100.0, 0.0-50.0) Woody Debris (28.6, 0.0-3.0) Overhanging Tree/Shrub (7.1%, 0.0-5.0)

[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.
[d] Mean percent shade.
[e] Percent of reaches with each category of physical cover and range among individual reaches.

Table 5. Mean water temperature (SD, range) recorded at 30-minute intervals at temperature-depth loggers in North Deer Island Slough, South Deer Island Slough, and outside the south Deer Island Slough tidge gates, and two additional reaches in South Deer Island Slough during 13 March-15 June 2009.

North Deer Slough (Berm)	South Deer Slough (Reach 1)	South Deer Slough (Reach 2)	South Deer Slough (Inside Tide Gates)	South Deer Slough (Outside Tide Gates)
13.0°C (3.1, 6.2-19.0)	13.4°C (4.5, 5.9-23.3)	12.5°C (4.2, 5.2-20.7)	13.5°C (4.7, 5.1-23.3)	13.1°C (4.1, 5.1-22.3)

Table 6. Median daily temperature range (°C) in North Deer Island Slough, South Deer Island Slough, and outside the South Deer Island Slough tide gates. “X” denotes significant differences (P<0.05).

Sites (increasing temperature range)	Sites (decreasing temperature range)				Temperature range (°C)
	South Deer (inside)	South Deer (outside)	South Deer (Reach 1)	South Deer (Reach 2)	
North Deer	X	X	X	X	0.6
South Deer (Reach 2)	X	X			0.9
South Deer (Reach 1)	X				1.1
South Deer (outside)					1.4
South Deer (inside)					1.6

The 7-DADM in North Deer Island Slough and South Deer Island Slough remained below the upper threshold level of 16.8°C until the end of May. Temperatures rose to and remained greater than 16.8°C by 20 May in South Deer Island Slough and by 31 May in North Deer Island Slough (Figure 8).

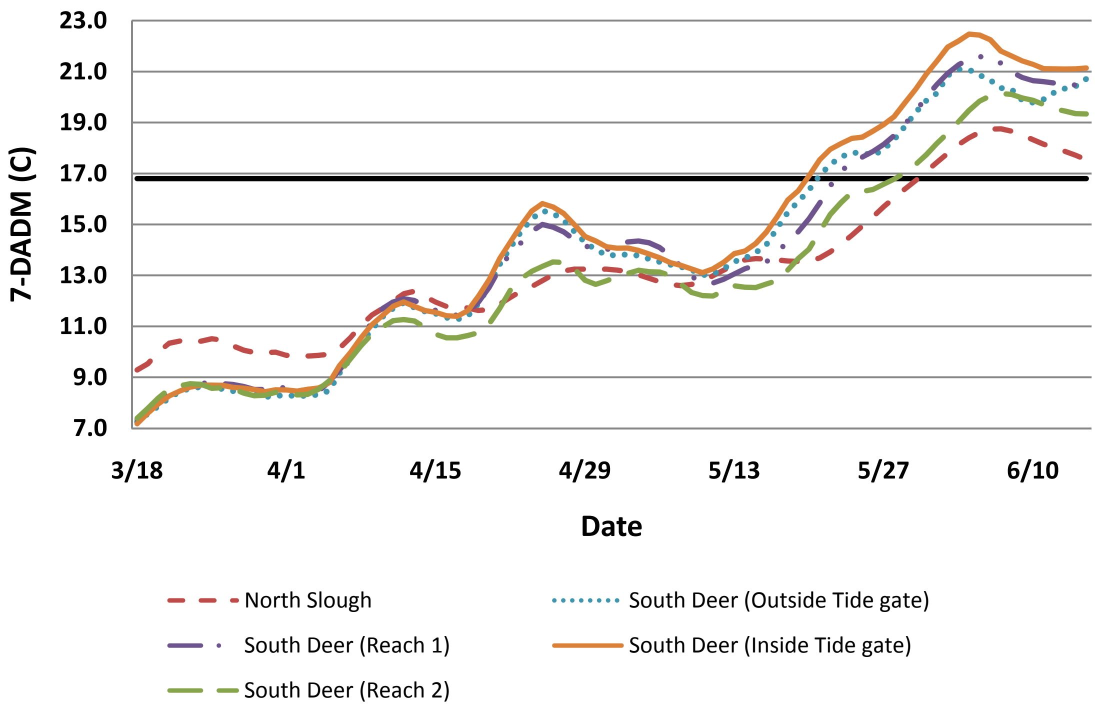

Figure 8. Seven-day average daily maximum water temperature (7-DADM) for North Deer Island Slough and South Deer Island Slough during 18 March-15 June 2009.

Instantaneous measurements of water quality variables (water temperature, dissolved oxygen, conductivity, pH, turbidity, and water transparency) recorded at fish and habitat survey sites throughout the field season varied among some areas (Table 7). Water temperature and conductivity were significantly higher at North Deer Island Slough than both South Deer Island Slough and lower Tide Creek, and did not differ between the latter two areas. Dissolved oxygen (percent saturation and concentration) was significantly lower at North Deer Island Slough than both South Deer Island Slough and lower Tide Creek, and did not differ between the latter two areas. Turbidity was significantly lower at lower Tide Creek than North Deer Island Slough and South Deer Island Slough, and did not differ between the latter two areas. Water transparency and pH did not differ among the areas.

Table 7. Mean (SD, range) of water quality variables within North Deer Island Slough, South Deer Island Slough, and lower Tide Creek, 2009.

Area	Water Temperature (°C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/l)	Conductivity (µS)	pH	Turbidity (JTU)	Transparency (cm)
North Deer Island	16.6 (3.7, 9.0-21.2)	64.7 (14.7, 37.4-88.4)	6.2 (1.5, 3.9-9.1)	128.9 (38.8, 38.2-166.9)	5.8 (1.2, 4.0-7.0)	11.0 (5.9, 5.0-25.0)	85.0 (38.8, 37.0-170.0)
South Deer Island	13.0 (4.0, 7.4-20.9)	86.8 (9.2, 76.6-100.9)	9.2 (1.2, 7.5-11.8)	52.7 (14.9, 38.7-89.0)	6.9 (0.3, 6.4-7.1)	10.0 (7.5, 0.0-30.0)	88.0 (29.0, 35.0-147.0)
Lower Tide Creek	12.1 (3.7, 6.3-18.4)	83.7 (11.2, 59.5-99.8)	9.1 (1.8, 5.7-11.7)	53.0 (12.8, 36.6-75.2)	6.7 (0.3, 6.3-7.2)	4.0 (2.7, 0.0-10.0)	96.0 (19.4, 60.0-132.0)

Discussion

To ultimately assist in developing and prioritizing habitat restoration actions for Deer Island Slough and adjacent areas, as well as document baseline conditions prior to implementing restoration actions, the goal of this assessment was to generate biological and physical information relevant to fish presence, aquatic habitats, and fish access to habitats. Relative to fish access, the presence of five species of anadromous fish (Chinook salmon, coho salmon, coastal cutthroat trout, steelhead, and Pacific lamprey) at various locations in South Deer Island Slough and lower Tide Creek indicates that fish are able to pass from the Columbia River into South Deer Island Slough through the existing tide gates. Moreover, we collected hatchery-produced juvenile Chinook salmon actively entering the slough through a culvert in April when hatchery-produced juveniles and wild juveniles were also collected both immediately inside and outside the tide gates. Juvenile salmon actively entering the slough were not collected during May and June even though juveniles were also collected both immediately inside and outside the tide gates.

We used difference in water surface elevations immediately inside and outside tide gate culverts to determine when tide gates were likely open, and estimated frequency of opening on a daily basis and overall duration of opening over longer time periods. During the time we sampled for fish actively entering the slough, tide gates were estimated to be open daily, and for about a third of the total time that nets were set at a tide gate culvert. Lack of collecting juvenile salmon during the later sampling may potentially be related to several factors, such as differential fish abundance and sampling efficiency over time, and conditions associated with specific tide gates affecting a fish's ability to pass (i.e., opening size and water depth and velocity may not be conducive to fish passage). Thus, we are uncertain of how efficiently fish are able to pass the tide gates. Because other factors may influence fish passage when a tide gate is open, we believe differences in water surface elevation likely overestimate the opportunity for fish passage.

Although we do not have data for specific conditions at each tide gate, tide gates were assumed to be open almost daily and for the majority of the fall and spring. When adult salmon were returning in October 2008-January 2009, we assumed tide gates were open for 95% of the time and perched for 46%. When juvenile salmon were migrating in the Columbia River in March-June 2009, we assumed tide gates were open for 70% of the time and perched for 5%. When perched, the concrete pad, which is about 0.61 m below the tide gates, may affect the ability of adult fish to enter the slough when opening size and water depth and velocity are conducive to passage at the tide gates.

Salmonids in South Deer Island Slough and lower Tide Creek appear to use the areas for various life history requirements. Because we know of no accounts of Chinook salmon spawning in Tide or Merrill creeks, or of any hatchery out-planting there, we believe that juvenile hatchery and wild Chinook salmon migrating down the Columbia River are using South Deer Island Slough as rearing habitat. Coho salmon spawning has been documented in Tide and

Merrill creeks (ODFW unpublished data). We collected two age classes of juvenile coho in both South Deer Island Slough and lower Tide Creek, for which sub-yearlings were presumed to have been produced in the Tide Creek drainage and yearlings may have been produced in the drainage, entered the drainage from elsewhere to rear, or a combination of both sources of fish. Coastal cutthroat trout occur in upper portions of the Tide Creek drainage (USFWS unpublished data) and individuals may be using habitats in South Deer Island Slough and lower Tide Creek for various purposes (e.g., rearing, maturation and growth, and as a migratory corridor if migratory behavior is expressed). Other than the presence of sub-adult steelhead, we are uncertain about the nature of steelhead use in South Deer Island Slough and lower Tide Creek. In addition to salmonids, Pacific lamprey is considered an anadromous species of concern, and we are uncertain whether spawning routinely occurs within the Tide Creek drainage.

Fish communities observed at each of the three areas primarily differed relative to prevalence of non-native species. Non-native species were dominant in North Deer Island Slough for species composition (9 of 13 taxa) and relative abundance (91% non-native individuals when threespine stickleback was excluded). Non-native species made up a third and a half of all species observed at lower Tide Creek and South Deer Island Slough, respectively, and their relative abundance slightly exceeded a third, at most, of all species when threespine stickleback was excluded. Prevalence of non-native species in North Deer Island Slough is likely due to gross differences in aquatic habitat and associated attributes, and perhaps limited opportunities for access into the slough.

North Deer Island Slough appears to consist of more lentic (i.e., pond- or lake-like) habitat without water flow from a perennial tributary as is the case for South Deer Island Slough. Lower dissolved oxygen and higher instantaneous water temperature, conductivity, and cover from aquatic vegetation in North Deer Island Slough compared to South Deer Island Slough are indicative of lentic conditions. These conditions are likely more conducive to the suite of non-native species observed in North Deer Island Slough than native species inhabiting the other two areas. Relative to differences in water temperature measurements (instantaneous versus continuous) between North Deer Island Slough and South Deer Island sloughs, we are uncertain why continuous measurements in North Deer Island Slough exhibited the lowest daily range relative to South Deer Island Slough. We assume that locations of data loggers in each slough (i.e., upper most portion of a relatively closed slough versus the lower end of a slough receiving flowing water) and perhaps the slightly greater amount of shading in North Deer Island Slough may be contributing factors.

In summary, Deer Island Slough and lower Tide Creek are altered aquatic habitats, for which the combined areas of South Deer Island Slough and lower Tide Creek are used by five species of anadromous fish. The existing tide gates allow adult and juvenile fish passage to an unknown extent. North Deer Island Slough is largely isolated, primarily providing habitat for non-native species. Although various habitat restoration actions are applicable to modify conditions in South Deer Island Slough and lower Tide Creek, gaining a better understanding of prevailing conditions at the tide gates relative to fish passage and how and when anadromous fish use specific areas of the slough would benefit the development of overall restoration strategies, which should consider these areas in the context of the drainage basin. Restoration actions to improve water exchange with the Columbia River and flow within North Deer Island Slough appear to be appropriate to improve habitat for native fishes.

Recommendations

The following recommendations are based on data collected and observations made in conducting this assessment. They are intended to contribute to the development of habitat restoration strategies focused on fish and aquatic habitats. The relative importance of each should be determined in consideration of explicit objectives and priorities for the land management, uses, and habitat restoration of the Deer Island area.

- Determine the water surface elevation above which current land uses are impaired in the three areas of Deer Island, and evaluate whether tide gates could remain open without impairing current land use. During this evaluation, consider how holding tide gates open may modify aquatic habitat and channel conditions (e.g., inhibit fish passage).
- Assess feasibility of reducing incidence of perched culverts at South Deer Island Slough (e.g., through constructing a slotted-sill on the concrete pad outside the tide gates).
- Increase water exchange with the Columbia River and flow within North Deer Island Slough to improve dissolved oxygen and water temperature (i.e., based on instantaneous measurements). Conduct feasibility study of strategies that increase water exchange and drainage without impairing land uses. Assess effects of channel constrictions on water flow, material routing, and fish passage.
- Establish native woody vegetation in appropriate areas that are presently dominated by non-native herbaceous vegetation (e.g., at lower Tide Creek where reed canary grass is prevalent).
- Develop a spatially representative data set for water temperature throughout Deer Island Slough and lower Tide Creek.

- Develop an understanding of hydraulic conditions at existing tide gates in North Deer Island Slough and South Deer Island Slough relative to fish passage and water exchange.
- Develop a better understanding of how and when anadromous fish use specific areas of South Deer Island Slough, Tide Creek, and Merrill Creek to assist in identifying and prioritizing potential restoration actions (e.g., focus on fish passage at tide gates versus habitat conditions upstream). Specific objectives might include:
    - Evaluate whether Pacific lamprey spawn in the Tide Creek drainage;
    - Determine if and when juvenile coho salmon and cutthroat trout leave upper creek reaches and enter South Deer Island Slough;
    - Determine how long coho salmon and cutthroat trout rear in the creeks and slough;
    - Determine when coho salmon and cutthroat trout leave the slough;
    - Determine whether fish that leave the slough and return to the creek or enter the Columbia River; and
    - Begin to monitor survival rates of coho salmon and cutthroat trout relative to use of Deer Island Slough.
- So that activities can be integrated, consider the entire Tide Creek and Merrill Creek drainages in the context of developing restoration strategies at Deer Island Slough.

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Appendices

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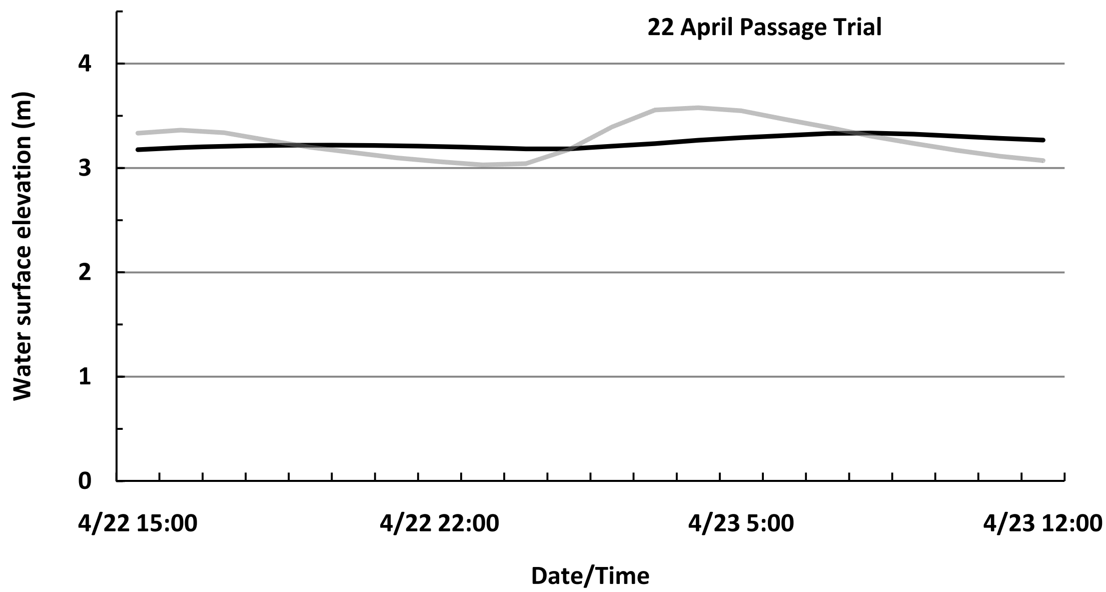
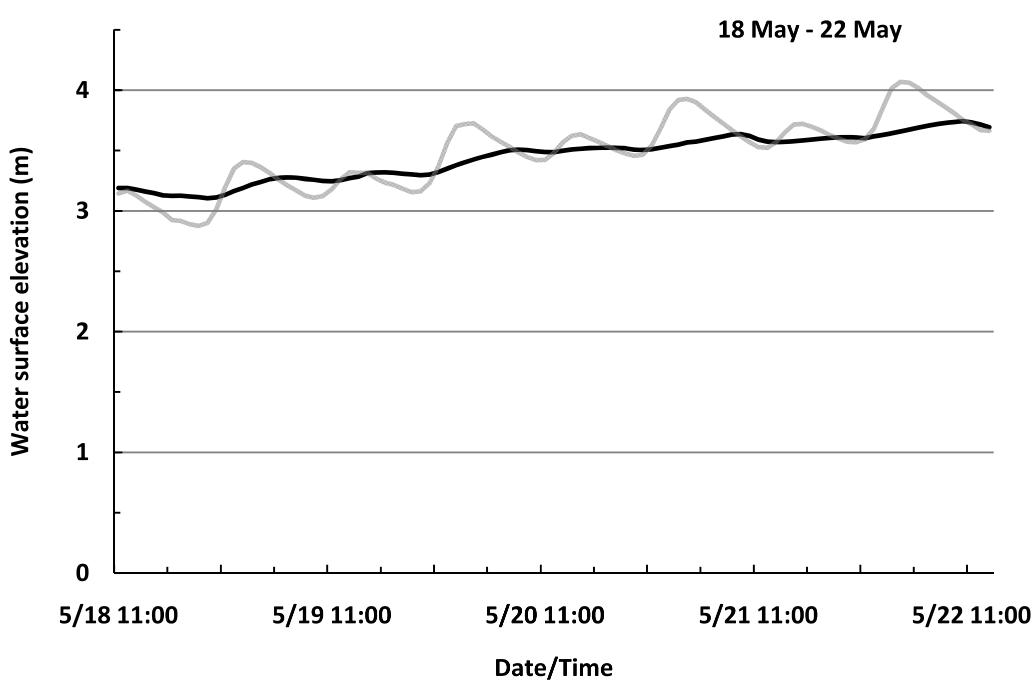
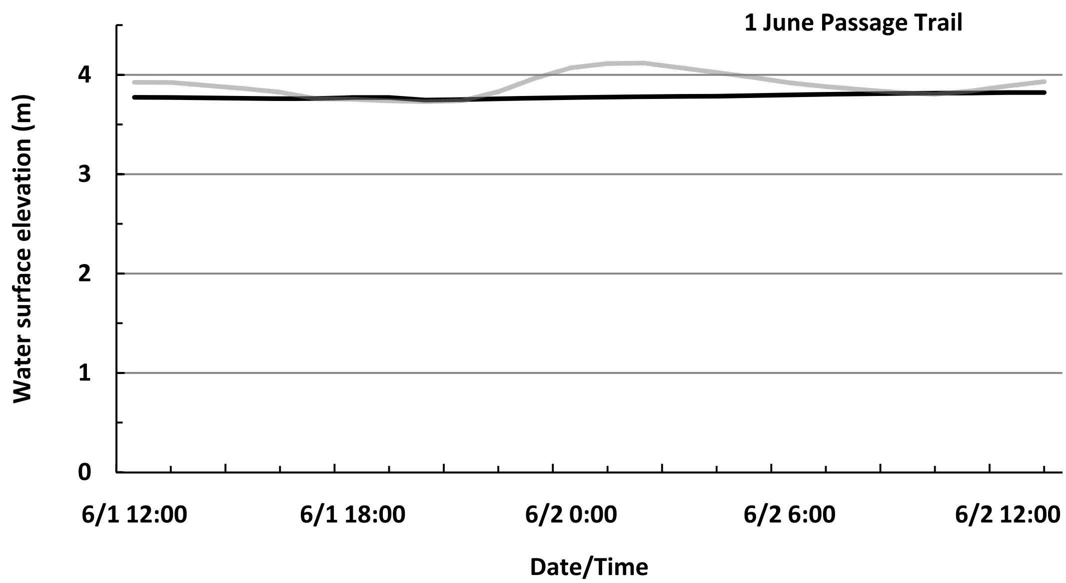
Appendix A. Species, number of individuals, and percentage of total fish captured in South Deer Island Slough sock net, 2009.

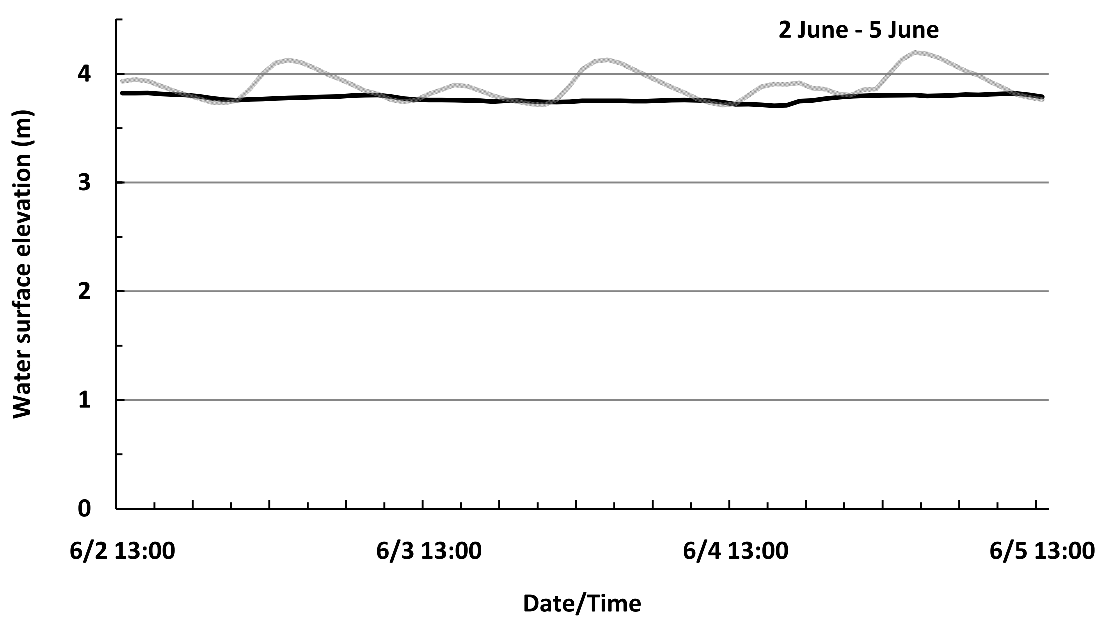
Species	Number of individuals	Percent of total
Threespine stickleback	69	94.5
Amur goby	1	1.4
Banded killifish	1	1.4
Yellow bullhead	2	2.7
Total	73	

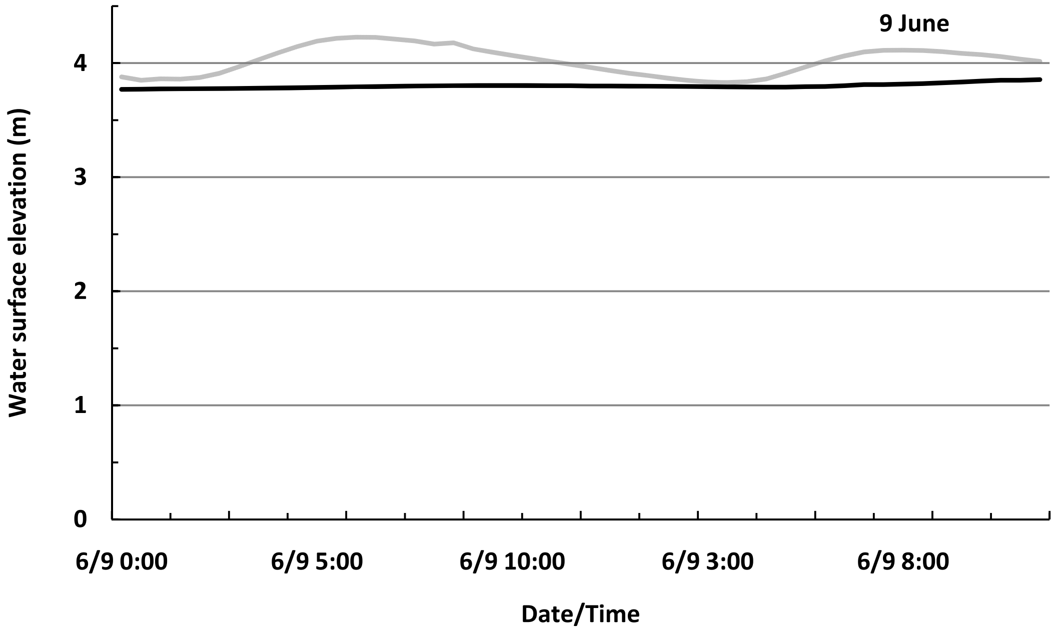
Appendix B. Water surface elevations inside South Deer Island Slough (black line) and outside tide gates (gray line) when hoop net and sock net were fished for fish passage trials and to capture fish entering the slough, 2009. Fish were not sampled on 9 June, but elevations are presented to illustrate a day when the tide gates did not open.






1 June Passage Trail
Water surface elevation (m)
0
1
2
3
4
6/1 12:00
6/1 18:00
6/2 0:00
6/2 6:00
6/2 12:00
Date/Time


2 June - 5 June
Water surface elevation (m)
0
1
2
3
4
6/2 13:00
6/3 13:00
6/4 13:00
6/5 13:00
Date/Time


9 June
Water surface elevation (m)
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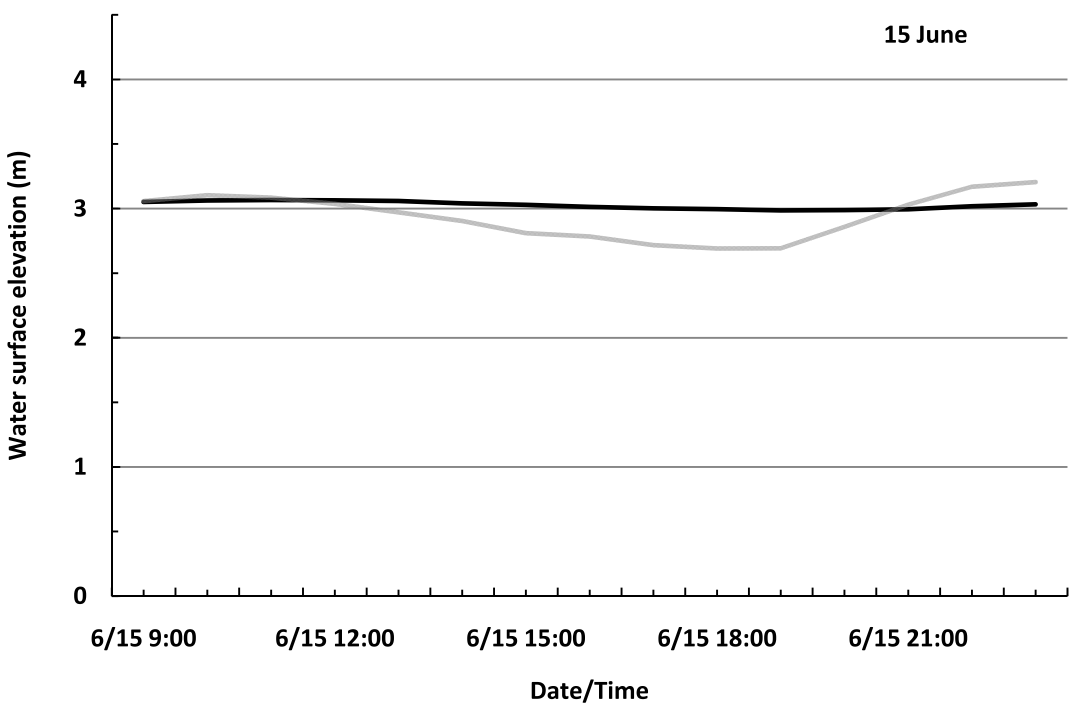
2
3
4
6/9 0:00
6/9 5:00
6/9 10:00
6/9 3:00
6/9 8:00
Date/Time


15 June
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0
1
2
3
4
6/15 9:00
6/15 12:00
6/15 15:00
6/15 18:00
6/15 21:00
Date/Time