Julia Butler Hansen National Wildlife Refuge:

Assessment of Fishes, Habitats, and Tide gates in Sloughs on the Mainland

2007, 2008 Progress Report

Prepared By:

Jeffrey Johnson
Jennifer Poirier
Sara Ennis
Timothy A. Whitesel

U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
Population & Habitat Assessment Program
1211 S.E. Cardinal Court, Suite 100
Vancouver, Washington 98683

May 2009

Table of Contents

List of Figures

List of Tables

Abstract

In spring 2007 and 2008, the U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office monitored biological and physical attributes of eight sloughs on the Julia Butler Hansen National Wildlife Refuge (JBHNWR). Our study assessed and described baseline conditions within four sloughs with existing tide gates and four sloughs without water control structures, prior to habitat restoration work tentatively scheduled to begin in summer 2009. Preliminary data was gathered March through June and yielded pre-construction information concerning: adult salmonid presence, tide gate function and accessibility, fish presence, community structure, habitat use and aquatic habitat conditions within the sloughs.

A total of three adult coho salmon were observed spawning in Nelson Creek, a former tributary of Indian Jack slough. Seining directly outside of tide gates (or within remnant outlets) detected the presence of juvenile salmon in close proximity to six mainland sloughs. Hoop nets installed directly in front or behind tide gate culverts captured a total of 200 juvenile salmon entering three mainland sloughs through existing tide gates. Fish sampling within mainland sloughs detected a total of 151 juvenile salmon within one closed slough and three gated sloughs. Aquatic habitat conditions for fish (i.e., temperature and dissolved oxygen) may be more limiting in closed and gates sloughs when compared to reference sloughs.

Comparisons between pre and post construction data will made to evaluate the effectiveness of the restoration work, to improve our understanding of how juvenile salmon use Columbia River backwater habitats and to provide important information

that may be used to assist in the development and implementation of similar projects in the Lower Columbia River Estuary.

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 (NOAA 2008). 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 (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 tidally-influenced wetlands to improve conditions for juvenile anadromous salmonids has been included in recovery and management plans and regulatory requirements including the Subbasin Plan for the Columbia Main Stem and Estuary (Lower Columbia Fish Recovery Board (LCFRB) 2004) and NOAA Fisheries' FCRPS Biological Opinions (NOAA 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.* 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.

The Julia Butler Hansen National Wildlife Refuge (JBHNWR) consists of island and mainland areas of the lower Columbia River. These areas are managed primarily for the protection of the endangered Columbian White tailed deer. Refuge islands adjacent to mainland JBHNWR are relatively pristine. Sloughs are not diked or controlled by tide gates and have unimpeded connection to surrounding waters and tidal action. Aquatic habitats on the mainland portion of JBHNWR historically included the lower reaches of three tributaries (i.e., Risk Creek, Nelson Creek, and an unnamed creek), wetlands, and eight tidally-influenced sloughs to which adult and juvenile salmonids likely had access. Presently, accessibility of slough habitats is largely impeded by dikes and tide gates. Tide gates control access to four of the eight sloughs. The tide gates currently in use are of four different styles. One of the four is designed to allow a controlled level of water to enter the slough during tidal cycles. The others 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 the sloughs to times when water is flowing out of the slough. Dikes supporting county roads isolate the other four mainland sloughs. These closed sloughs have no direct connectivity with the Columbia River. A series of drainage ditches provides some water movement among all mainland JBHNWR sloughs. Current conditions reduce tidal influence on sloughs and likely cause poor habitat conditions for native salmonid species.

To improve fish passage, ingress and egress, in 2003 the USACOE replaced a failing culvert and traditional top-hinge wooden tide gate (W201+30) with a new culvert and a side-hinge aluminum gate. The gate is equipped with a float and cam system that holds the gate partially open during incoming tides until the buoyancy of the floats rotate the cams and close the gate. Operation of this culvert and tide gate is now compromised by damage to the culvert caused by 2006 winter flooding.

In 2007, the USACOE initiated a hydrologic and hydraulic feasibility study to analyze options for modifying existing tide gates to improve flood control, increase fish passage into sloughs and improve slough habitat quality on the refuge (NMFS, 2008). The feasibility study focused on eight sloughs, four with existing tide gates, and four sloughs that are isolated from the Columbia River by dikes without tide gates. Resulting from this study, the USACOE has proposed installing tide gates at the four sloughs currently blocked by dikes and replacing tide gates in three other sloughs. The replacement gates would be side-hinge aluminum and equipped with a hydraulic arm assembly that controls gate closing. This assembly blocks the gate at a fully open position until water level within the slough rises to a predetermined elevation at which point the hydraulic arm allows the gate to close. The highest water elevation will be

established as that which maximizes tidal inflow and does not flood Columbia White-tailed Deer habitat. It is unclear whether these modifications will result in improved fish passage into and out of the sloughs or aquatic habitat conditions.

The U. S. Fish and Wildlife Service, Columbia River Fisheries Program Office (CRFPO) has initiated an evaluation project with the goal of assessing the effects of the USACOE restoration actions at JBHNWR. This project will compare slough conditions before and after restoration and among treatment and reference sites. Activities in 2007 and 2008 focused on collecting baseline data before construction activities began. The following objectives were addressed during the 2007 and 2008 field seasons: 1. Determine whether adult anadromous salmonids are present in the upper reaches of Risk Creek and Nelson Creek during fall spawning; 2. Assess accessibility through tide gates (as presently configured), specifically during March through June when juvenile salmon are likely in the area; 3. Describe the presence and distribution of salmonids and other fish species inhabiting treatment sloughs and compare to that observed in reference sloughs; 4. Characterize aquatic and riparian habitats in treatment sloughs and compare to that observed in reference sloughs.

Methods

Study Area

Julia Butler Hansen Refuge for the Columbian White-Tailed Deer

JBHNWR was established in 1972 for the protection and management of endangered Columbian white-tailed deer. The refuge complex contains over 5,600

acres of pastures, forested tidal swamps, brushy woodlots, marshes and sloughs along the Columbia River in both Washington and Oregon. The mainland portion of JBHNWR (mainland JBHNWR) is located near the town of Cathlamet, Washington at Columbia River Kilometer (Rkm) 54.7-57.9. Mainland JBHNWR is bordered by the Columbia River to the west, the Elochoman River to the south, Brooks Slough and the town of Skamokawa to the north, and Washington Highway 4 to the east. The refuge has been altered through homesteading, wetland drainage, agricultural production, flood control construction, and grazing by cattle. There are eight sloughs on mainland JBHNWR, formerly influenced by tides that are interconnected by a series of drainage ditches and channels. Four gated sloughs, Brooks, Duck Lake, W201+30, and W259+50 have tide gates that control the discharge of water from the mainland interior. Brooks Slough has three 1.5 x 1.5 meter, top-hinge aluminum tide gates. Duck Lake has a single 1.8 meter diameter, top-hinge steel tide gate. W201+30 has a 1.2 meter diameter side-hinge aluminum tide gate equipped with a cam and float system that holds the gate partially open during incoming tide until the float system disengages the cams and allow the gate to close completely. W259+50 has a 1.5 x 1.5 meter, top-hinge wooden tide gate. Four closed sloughs, Ellison, Hampson, Indian Jack and Winter are not connected to the Columbia River and its side channels because of flood control levees (Figure 1).

JBHNWR includes islands that do not have dikes and that are adjacent to mainland JBHNWR. The Hunting Islands are a group of three islands on the Washington side of the Columbia River immediately downstream of the town of Cathlamet at Rkm 54.7. The natural tidal marsh habitat on South Hunting Island is relatively pristine with no evidence of human habitation or landscape alterations. The

slough on the eastern edge of South Hunting Island was selected as a reference site (Figure 1). Price Island is also part of the JBHNWR. The island is located on the Washington state side of the Columbia River at Rkm 56.3. Steamboat slough separates the Island from mainland JBHNWR on the Washington shore. The native tidal marsh and tidal spruce swamp habitat remain intact with no apparent evidence of human settlement. There are no water control structures on the island. The large slough on the north (interior) side of the island was selected as a reference site on Price Island (Steamboat Slough) (Figure 1).

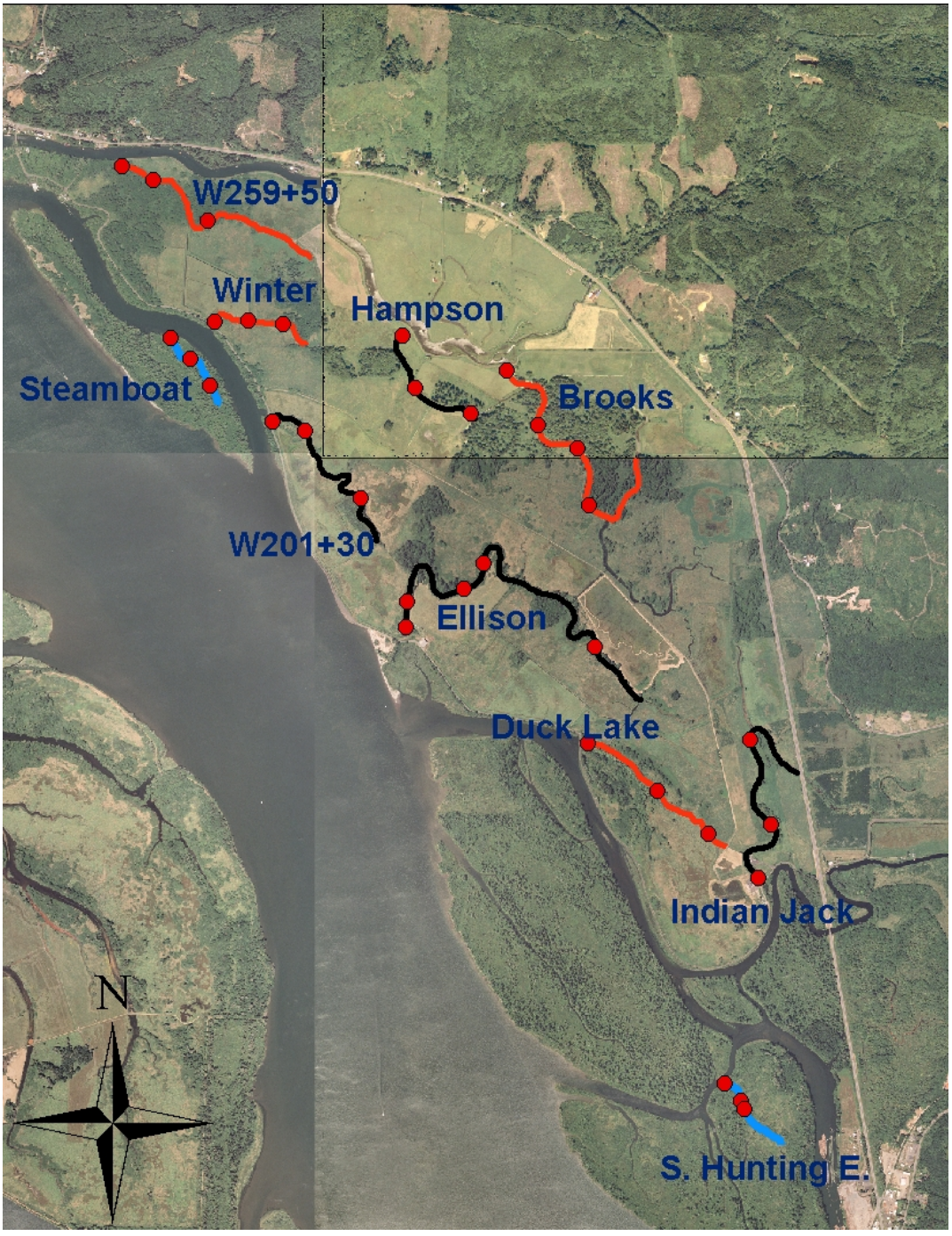

Figure 1. Area map of JBHNWR National Wildlife Refuge showing the location of sloughs and sample reaches (red circles) surveyed in 2007 and 2008. Black, green and blue lines indicate closed, gated and reference sloughs, respectively.

Identification of Study Sloughs and Sample Reaches

All sloughs proposed for restoration actions were included in this study. Treatment sloughs included four gated and four closed sloughs enclosed by dikes and tide gates on mainland JBHNWR. Reference sloughs selected for this study showed no evidence of human impact, no water control and were within one kilometer of treatment sloughs. One natural (unmodified) slough from Price Island (Steamboat slough) and one from South Hunting Island (S. Hunting E.) were designated as reference sloughs (Figure 1). All treatment and reference sloughs are located within two kilometers of the others on the Washington side of the Columbia River shipping channel and therefore, likely witness the same pool of migrating fish.

The goal of sample reach selection was to assure random and spatially balanced data collection from ten percent of the total slough length. Each treatment and reference slough was divided into 50 meter sample reaches. If ten percent of these reaches was less than two reaches, then the slough was split into 25 meter reaches. The sample reach closest to the mouth, tide gate or historic connection to the Columbia River was sampled in each slough. Additional sample reaches (within each slough), were selected using a random, spatially-balanced approach to insure that various habitats and conditions were represented. Three 25 m sample reaches were established in W201+30 and Hampson sloughs, three 50 m sample reaches were established in Indian Jack, Duck Lake, W259+50, and Winter sloughs, four 50 m reaches were established in Brooks slough, and five 50 m reaches were established in Ellison slough (Figure 1). In reference sloughs, three 25 m sample reaches were established in S. Hunting E. and Steamboat sloughs (Figure 1). The result was that ten

percent of slough length was represented and at least three reaches were sampled in each slough. Sampling effort in 2007 and 2008 focused on the same sets of reaches.

Sampling Schedule

To minimize any spatial or temporal-bias, the order in which reaches were sampled was randomized. Sampling effort was distributed evenly throughout the field season (approximately five reaches surveyed per week, March through May or June). This sampling regime was employed to ensure the various habitats and conditions present within each slough were represented, as well as to capture the seasonal variation and changes in fish community composition and distribution. In spring 2007, all sample reaches were surveyed once (for fish and habitat) during the season. In 2008, two reference sloughs and four sloughs slated for 2008 construction on mainland JBHNWR (Indian Jack, Duck Lake, Winter and W259+50), were surveyed once early in the juvenile salmonid out-migration season (March/April) and again later in the season (May/June). A single survey (habitat only) was conducted on the four remaining sloughs slated for construction after 2008 (Ellison, Hampson, Brooks and W201+30) to establish base-line conditions.

Adult Salmonid Presence

To determine fish presence and navigability potential through existing tide gates (chiefly Brooks Slough) and tributaries, a single adult salmonid spawning ground survey was performed on 24 October, 2007 in Risk Creek, Nelson Creek and an unnamed creek,. The survey was conducted outside of JBHNWR, upstream of Washington Highway 4. (Figure 2). Surveyors walked along stream margins inspecting areas for live

fish, redds and carcasses. All observed live fish, redds and carcasses were enumerated.

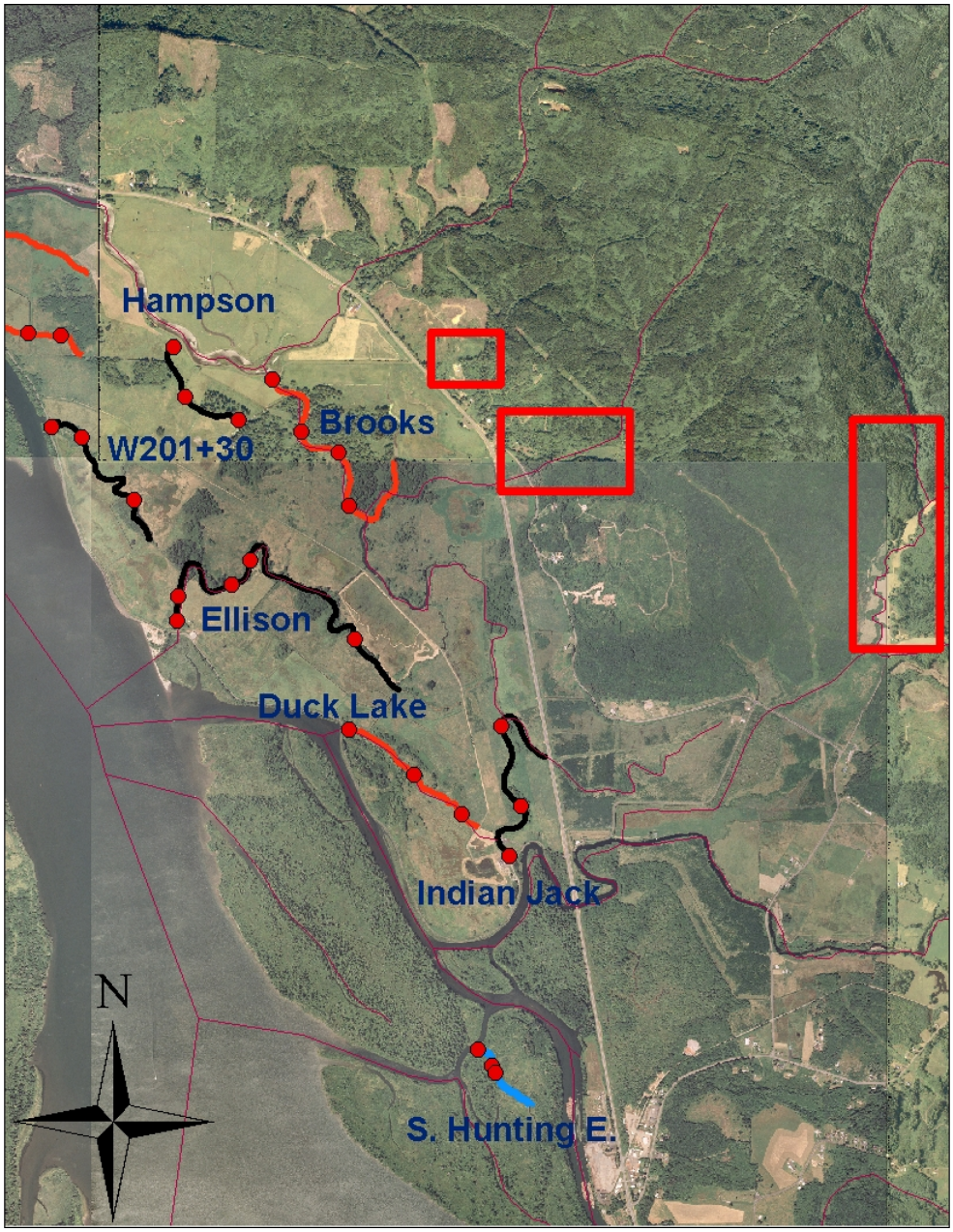

Figure 2. Area map of JBHNWR National Wildlife Refuge and surrounding area showing the locations of adult salmon spawning ground surveys within rectangles in 2007 and 2008.

Juvenile Salmon passage at gated sloughs

In 2007, fish passage trials were performed at all sloughs with existing tide gates (Duck Lake, W201+30, W259+50 sloughs), in the two reference sloughs (S. Hunting E. and Steamboat), and outside two sloughs with no direct connectivity to the Columbia River (Winter and Ellison sloughs). In 2008, fish passage trials were conducted at two sloughs slated for construction in 2009 (Duck Lake and W259+50), and the two reference sloughs.

To assess physical operation and passage potential through existing tide gates, these trials consisted of operating fish traps at slough mouths twice each year. Trials occurred March 19 to April 11 and May 7 to May 10 in 2007 and March 27 to May 15 and June 2 to June 4 in 2008. During each trial, one to five seine hauls were performed immediately outside of the tide gate to determine the presence of juvenile salmonids. In Duck Lake, W201+30 and W259+50 sloughs, a 1.2 m circular hoop net was attached either directly to or within 2 m behind the tide gate culvert to capture fish attempting to enter into sloughs through tide gates. In reference sloughs, hoop nets were set at the mouth, oriented to sample the incoming tide. All hoop nets were set for one or two tidal cycles.

Juvenile Salmon Passage at Reference Sloughs

In 2007 and 2008, a 1.2 m circular hoop net with 4.6 m wings was used to fish the mouth of both reference sloughs. Hoop nets were set overnight (fishing incoming or outgoing tide), in areas with sufficient water depth to submerge the trap (minimum 60 cm).

Fish Distribution

Seines and circular hoop nets were the primary fish sampling methods utilized during the 2007 and 2008 field seasons. In 2007, seines were used to sample fish in all reaches of all sloughs (including reference sloughs). In 2008, seines were used to sample fish in four sloughs slated for construction in 2008 (Indian Jack, Duck Lake, Winter and W259+50, and the two reference 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. Each seine was held on shore and either walked by foot or towed into the channel by boat making a sweep along the shore. The size of the encircled area was estimated and documented (effort). In reaches where near-shore aquatic vegetation or woody debris would not allow effective seine use, the seine was fed into the slough from the boat in a 360 degree sweep and pulled back into the boat. One to three seine hauls were performed in each reach in 2007. A minimum of five seine hauls were performed in each sample reach in 2008.

All captured fish were placed in an aerated live well, identified, enumerated and released. In addition, fork length and weight of salmonids was 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 Passive Integrated Transponder (PIT) tag. Prior to release, fish were allowed to recover in an aerated live well for 15 to 30 minutes.

Habitat Characterization

In reference sloughs, water temperature and depth was recorded hourly in the lowest reach of both sloughs using Onset HOBO water level loggers during 23 March through 13 June (2007) and 19 March through 9 July (2008). 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. In the four gated and four closed treatment sloughs, a single logger (Onset StowAway Tidbit), recording temperature only was placed at the mouth or mid-point of each slough to record hourly water temperature during 16 March through 14 June (2007) and 18 March 2008 through February 2009 (Figure 3). Water temperature loggers are currently still installed in eight mainland sloughs. Temperature data collected using a YSI meter was used in the 2008 analysis. 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). 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.

Habitat surveys occurred during the sampling schedule described above. In 2007, habitat surveys were conducted once within each reach in four gated, closed and reference sloughs. In 2008, habitat surveys were conducted twice in each reach in reference sloughs and four treatment sloughs (Indian Jack, Duck Lake, Winter and W259+50), and once in the remaining sloughs (Ellison, Hampson, W201+30,and Brooks).

Dissolved oxygen 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. Qualitative 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 mainland 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, a minimum of 20 times, 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.

Results

Adult Presence

A total of three adult coho salmon and one redd were observed in upper Nelson Creek on 24 October, 2007. Surveyors walked a 2 Km section of Nelson Creek upstream of Risk Road and observed two male and one female coho salmon in close proximity to a single redd. There were no adult salmon observed in Risk Creek or the unnamed tributary. Risk Creek was a series of braided swamps upstream of Washington State Highway 4, and a large beaver dam likely rendered the unnamed tributary impassable to adult salmonids at the upstream end of the Highway 4 culvert.

Juvenile Salmon passage

2007

A total of 839 juvenile salmonids were captured during fish passage trials between March 19 and May 10, 2007 (Tables 1 & 2). Juvenile salmon were captured in all five sampling areas, with the majority being captured in reference sloughs (71.6% of total) (Tables 1 & 2). Three species of salmon and a single steelhead trout were captured during trials. Chinook were the most abundant salmonid species making up 74.3% of the total salmonid catch. A total of 24 seine hauls were performed in five

sample areas during trials. Seine hauls detected presence of salmonids within 50 meters of all five slough mouths (Tables 1 & 2). A total of 128 salmon (15.3%), were captured by seine net. Of these, 43.8% were captured at the mouth of gated sloughs. Eleven of 47 (23%) Chinook captured at the mouth of gated sloughs were adipose fin clipped (hatchery origin). Nine of 72 (13%) Chinook captured at the mouth of reference sloughs were adipose fin clipped. No coho captured at the mouth of sloughs were adipose fin clipped. A total of 23 hoop nets were set to capture fish entering or exiting through tide gates or reference sloughs. Hoop nets captured fish successfully entering and exiting all five sloughs (Tables 1 & 2). A total of 711 salmon were captured in hoop nets. Of the total, 529 salmon (74.4%) were captured in reference sloughs, while 182 salmon (25.6%) were captured entering/exiting mainland sloughs through tide gates. Of fish entering mainland sloughs through tide gates, the majority of salmon were captured in W259+50 slough (49.5%) and W201+30 slough (34.6%). Forty-one of 96 (43%) Chinook captured entering gated sloughs were adipose fin clipped. One of 84 (1%) coho captured entering gated sloughs was adipose fin clipped. Eighty-two of 409 (20%) Chinook captured entering reference sloughs were adipose fin clipped. No coho captured entering reference sloughs were adipose fin clipped.

Table 1. Number per hour (count) of salmonids captured in hoops nets entering sloughs and number per square meter (count) of salmonids captured in seines outside of sloughs during March 3 through April 11 fish passage trials in mainland JBHNWR and reference sloughs, 2007.

Species	Trap Type	S. Hunting E.	Steamboat	Duck lake	W201+30	W259+50
Chinook Salmon	hoop	0.958 (67)	3.415 (265)	0.024 (1)	0.169 (8)	0.758 (57)
	seine	0.015 (7)	0.017 (7)	0.008 (1)	0.028 (7)	0.002 (1)
Coho Salmon	hoop	0.057 (4)	0.129 (10)	0.071(3)	0.570 (27)	0.160 (12)
	seine	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)
Chum Salmon	hoop	0.000 (0)	0.026 (2)	0.000 (0)	0.000 (0)	0.000 (0)
	seine	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)

Table 2. Number per hour (count) of salmonids captured in hoops nets entering sloughs and number per square meter (count) of salmonids captured in seines outside of sloughs during May 7 through May 10 fish passage trials in mainland JBHNWR and reference sloughs, 2007.

Species	Trap Type	S. Hunting E.	Steamboat	Duck lake	W201+30	W259+50
Chinook Salmon	hoop	0.747 (37)	0.914 (40)	0.692 (17)	0.189 (9)	0.172 (4)
	seine	0.083 (31)	0.194 (27)	0.000 (0)	0.251 (35)	0.043 (2)
Coho Salmon	hoop	1.515 (75)	0.594 (26)	0.285 (7)	0.398 (19)	0.688 (16)
	seine	0.000 (0)	0.000 (0)	0.007 (5)	0.007 (1)	0.000 (0)
Chum Salmon	hoop	0.000 (0)	0.069 (3)	0.000 (0)	0.000 (0)	0.043 (1)
	seine	0.000 (0)	0.000 (0)	0.000 (0)	0.029 (4)	0.000 (0)
Steelhead Trout	hoop	0.000 (0)	0.000 (0)	0.041 (1)	0.000 (0)	0.000 (0)
	seine	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)

The fork length (FL) of juvenile Chinook salmon captured by seine at the mouth of sloughs ranged from 35 to 124 mm (Figure 3). Fork length of juvenile Chinook salmon captured in hoops nets entering sloughs ranged from 33 to 165 mm (Figure 4). The six juvenile coho captured by seine at the slough mouths ranged from 48 to 56 mm FL. Juvenile coho salmon captured entering sloughs ranged from 32 to 143 mm FL (Figure 5). The six juvenile chum salmon captured in hoop nets at Steamboat and W259+50 ranged from 41 to 53 mm FL and the four captured in seines at W201+30 mouth ranged from 48 to 53 mm FL. A single juvenile steelhead captured entering Duck Lake slough had a fork length of 57mm.

Length frequency distribution of Chinook salmon captured during fish passage trials suggest a size class separation at 110mm FL (see Figures 5 though 7). Fourteen percent of juvenile Chinook salmon captured entering reference sloughs were greater than 110 mm FL. Of the 18 juvenile Chinook captured entering (gated) Duck Lake slough, 16 (89%) were greater than 110 mm FL. In the other two gated sloughs, 10 % (W259+50) and 23% (W201+30) of juvenile Chinook captured were greater than 110 mm FL.

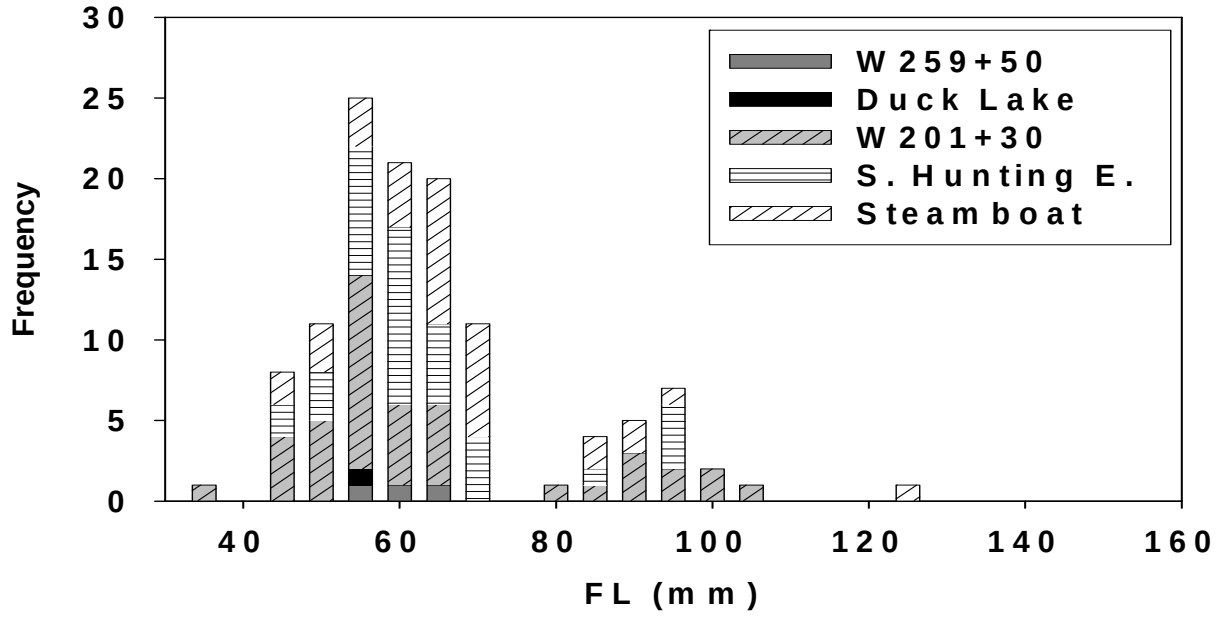

Figure 3: Length frequency of juvenile Chinook salmon captured in seines at the mouth of sloughs during fish passage trials in mainland JBHNWR, 2007.

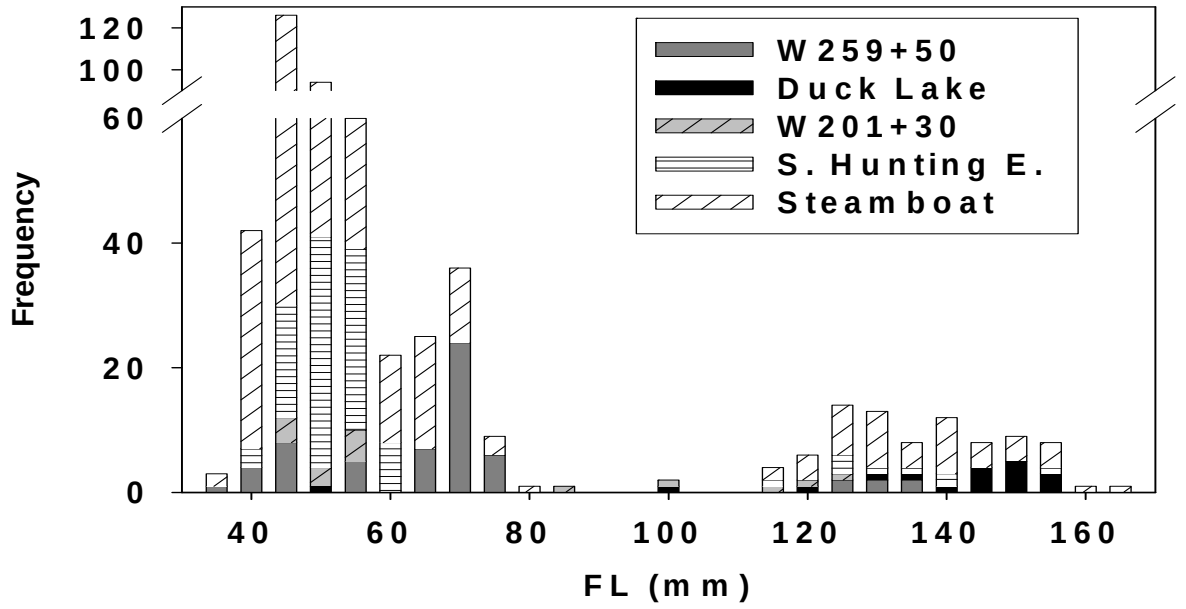

Figure 4: Length frequency of juvenile Chinook salmon captured in hoops nets entering sloughs during fish passage trials in mainland JBHNWR, 2007.

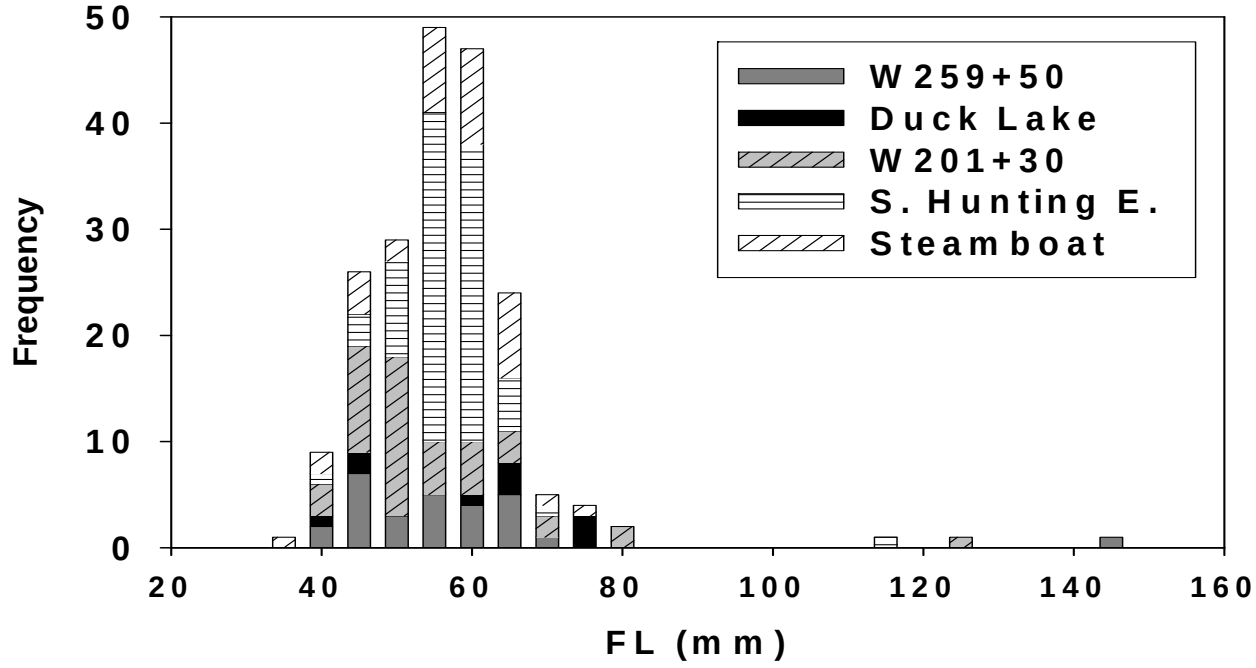

Figure 5: Length frequency of juvenile coho salmon captured in hoops nets entering sloughs during fish passage trials in mainland JBHNWR, 2007.

2008

A total of 295 juvenile salmon were captured during fish passage trials between March 27 and June 4, 2008. Juvenile salmon were captured in all four sampling areas, with the majority of fish being captured in reference sloughs (91.5% of total) (Tables 3 & 4). Three species of salmon were captured during these trials. Chinook were the most abundant species making up 96.6% of the total salmon catch. A total of 40 seine hauls were performed in four sample areas. Seine hauls detected presence of salmonids within 50 meters of all four slough mouths (Tables 3 & 4). A total of 114 salmon (38.6%), were captured by seine net. Of these, 93.9% were captured at the mouth of reference sloughs. No Chinook captured at the mouth of gated sloughs were adipose

fin clipped. Thirteen of 102 (13%) Chinook captured at the mouth of reference sloughs were adipose fin clipped. No coho captured at the mouth of sloughs were adipose fin clipped. A total of eight hoop nets were set to capture fish entering through tide gates or reference sloughs. Hoop nets captured fish successfully entering sloughs in three of four locations (Tables 3 & 4). A total of 181 salmon (61.4%), were captured in hoop nets. Of this total, 163 salmon (90.1%) were captured in reference sloughs, while 18 fish (9.9%) were captured entering mainland sloughs through tide gates. Of fish entering mainland sloughs through tide gates, 100% were captured in W259+50 Slough (Tables 3 & 4). Two of16 (13%) Chinook captured entering W259+50 Slough were adipose fin clipped. One of 161 (1%) Chinook captured entering reference sloughs were adipose fin clipped. No coho captured entering sloughs were adipose fin clipped.

Table 3. Number per hour (count) of salmonids captured in hoops nets entering sloughs and number per square meter (count) of salmonids captured in seines outside of sloughs during March 27 through May 15 fish passage trials in mainland JBHNWR and reference sloughs, 2008.

Species	Trap Type	S. Hunting E.	Steamboat	Duck lake	W259+50
Chinook Salmon	hoop	0.880 (27)	1.649 (40)	**	0.277 (5)
	seine	0.029 (20)	0.066 (68)	0.000 (0)	0.000 (0)
Coho Salmon	hoop	0.065 (2)	0.000 (0)	**	0.055 (1)
	seine	0.000 (0)	0.001 (1)	0.000 (0)	0.000 (0)
Chum Salmon	hoop	0.000 (0)	0.000 (0)	**	0.000 (0)
	seine	0.001 (1)	0.003 (3)	0.000 (0)	0.000 (0)
Unidentified Salmonid	hoop	0.000 (0)	0.000 (0)	**	0.000 (0)
	seine	0.000 (0)	0.000 (0)	0.006 (1)	0.000 (0)

** Hoop trap and data was lost due to high water event.

Table 4. Number per hour (count) of salmonids captured in hoops nets entering sloughs and number per square meter (count) of salmonids captured in seines outside of sloughs during June 2 through June 4 fish passage trials in mainland JBHNWR and reference sloughs, 2008.

Species	Trap Type	S. Hunting E.	Steamboat	Duck lake	W259+50
Chinook Salmon	hoop	2.126 (57)	1.446 (37)	0.000 (0)	0.419 (11)
	seine	0.011 (10)	0.007 (4)	0.004 (2)	0.008 (4)
Coho Salmon	hoop	0.000 (0)	0.000 (0)	0.000 (0)	0.038 (1)
	seine	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)

The fork length of juvenile Chinook salmon captured by seine at the mouth of sloughs ranged from 39 to 153 mm (Figure 6). Fork length of juvenile Chinook salmon captured in hoops nets entering sloughs ranged from 35 to 142 mm (Figure 7). The one juvenile coho captured by seine (Steamboat slough) was 109 mm FL. Of the four juvenile coho salmon captured entering sloughs, the two entering S. Hunting E. were 56 and 64 mm FL and the two entering W259+50 were 72 and 130 mm FL. The four juvenile chum captured by seine net ranged from 43 to 64 mm FL. All juvenile Chinook salmon captured entering reference sloughs were less than 110 mm FL, whereas 25% of juvenile Chinook captured entering W259+50 were longer than110 mm FL.

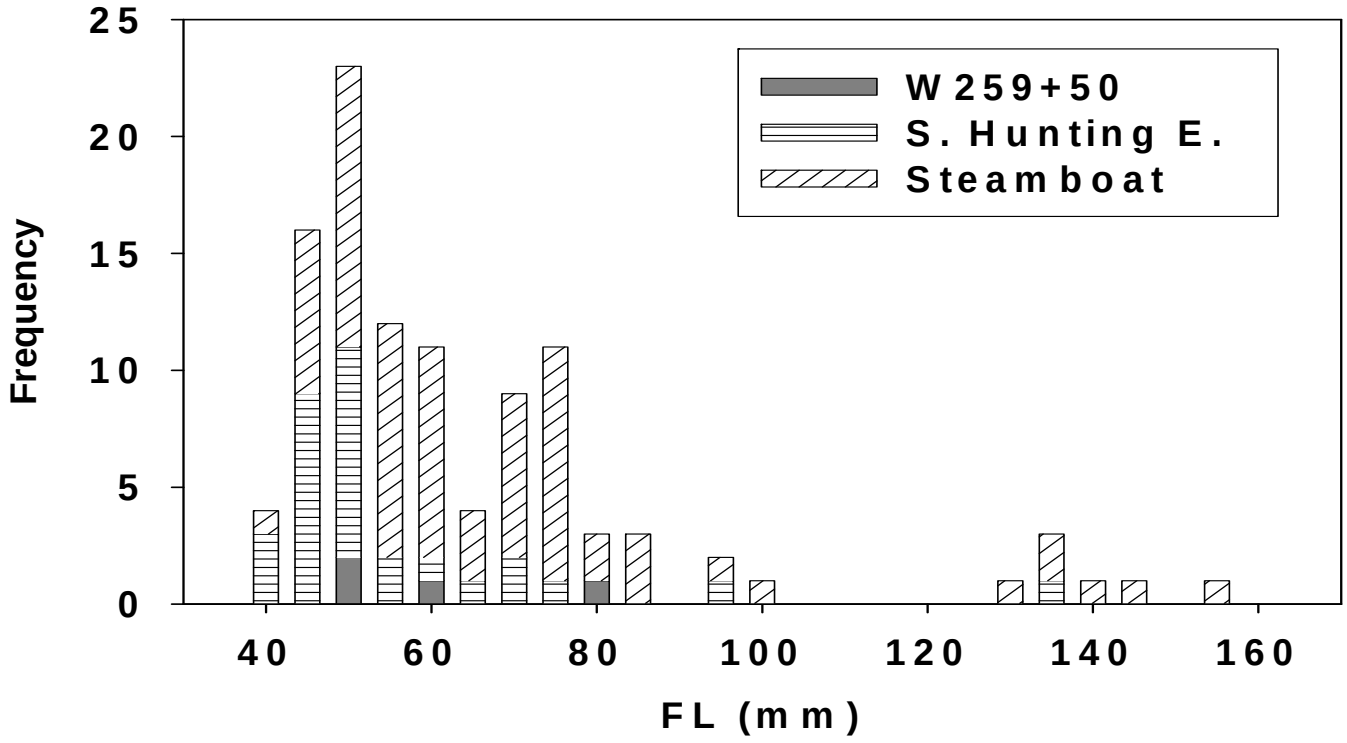

Figure 6: Length frequency of juvenile Chinook salmon captured in seines at the mouth of sloughs during fish passage trials in mainland JBHNWR, 2008.

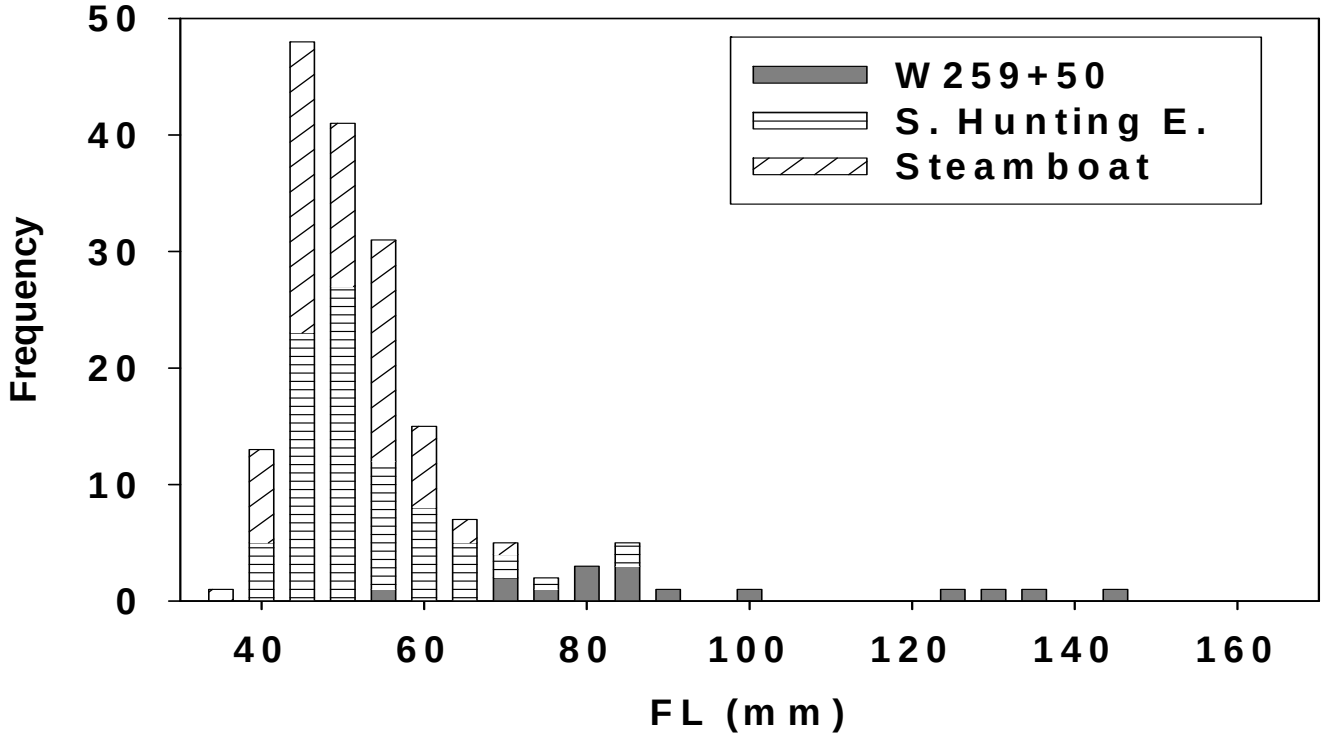

Figure 7: Length frequency of juvenile Chinook salmon captured in hoops nets entering sloughs during fish passage trials in mainland JBHNWR, 2008.

Fish Distribution

2007

Three hoop nets were set, and 53 seine hauls were performed in 32 sample reaches in spring 2007. A total of 869 fish representing 16 taxa were collected in eight main land and two reference sloughs (Table 5). All fish capture in reference sloughs were native species. In gated sloughs, five of the ten species were non-native and in closed sloughs, seven of the thirteen species were non-native. Of the total, 90.7% of the fish captured were native species, and 9.3% were non-native. Three-spine

Stickleback was the most abundant species in all locations, making up 69.6% of the total catch (Table 5). Chinook salmon were the second most abundant fish species captured, making up 16.7% of the total catch (Table 5). A total of 171 salmonids representing 3 taxa were captured. Chinook salmon were the most abundant species making up 90.1% of the total salmon catch. Both adipose fin clipped and unmarked Chinook were captured. Adipose fin clipped Chinook composed 11.5 % (10 of 87) of Chinook captured in gated sloughs and 7.5% (5 of 66) of Chinook captured in reference sloughs. No adipose fin Chinook were captured in closed sloughs and no adipose fin clipped coho were captured in any slough. Juvenile salmonids made up 1.5% of total catch in closed sloughs, 25.8% in gated and 19.1% in reference sloughs. Salmon made up the highest proportion of total fish captured in W201+30 Slough (33%), followed by Steamboat (23%) and S. Hunting E. (17%). Ellison Slough had the most species captured in any sloughs in 2007 with ten total taxa. Ellison Slough was the only closed slough where salmonids were captured (Appendix A).

Table 5. Species type and percentage (number) of total fish captured (all sampling methods combined) in four closed sloughs (Indian Jack, Ellison, Winter and Hampson), four gated (Duck Lake, W201+30, W259+50 and Brooks) and two reference sloughs, 2007.

Species		Closed	Gated	Reference
3-spine Stickleback		73.9 (99)	57.3 (220)	80.4 (295)
Bluegill		2.2 (3)	1.3 (5)	0.0 (0)
Chinook Salmon	Total	0.7 (1)	22.7 (87)	18.0 (66)
	Unmarked	0.7 (1)	20.1 (77)	16.6 (61)
	Adipose clipped	0.0 (0)	2.5 (10)	1.3 (5)
Chum Salmon		0.0 (0)	0.0 (0)	0.3 (1)
Coho Salmon		0.7 (1)	3.1 (12)	0.8 (3)
Dace		0.0 (0)	0.0 (0)	0.3 (1)
E. Banded Killifish		3.0 (4)	7.6 (29)	0.0 (0)
Large Mouth Bass		1.5 (2)	1.3 (5)	0.0 (0)
Largescale Sucker		0.7 (1)	0.0 (0)	0.0 (0)
N. Pike Minnow		2.2 (3)	0.0 (0)	0.0 (0)
Peamouth		6.7 (9)	0.2 (1)	0.0 (0)
Pumpkinseed		0.0 (0)	1.6 (6)	0.0 (0)
Sculpin		0.0 (0)	0.5 (2)	0.3 (1)
Small Mouth Bass		0.7 (1)	0.0 (0)	0.0 (0)
Unknown Sunfish		5.2 (7)	4.4 (17)	0.0 (0)
Yellow Bullhead		0.7 (1)	0.0 (0)	0.0 (0)
Yellow Perch		1.5 (2)	0.0 (0)	0.0 (0)

Juvenile salmonids were captured in all sampled reaches of reference sloughs. Three species, Chinook, coho and chum were captured in reference sloughs. In all gated sloughs, juvenile salmon were captured in the reach nearest the tide gate (within 50 meters). These consisted of Chinook and coho in all sloughs. Salmon were not captured in other reaches of Duck Lake slough (gated, 2 additional reaches) or Brooks

slough (gated, 3 additional reaches). Coho and Chinook juveniles were captured in the highest (furthest from tide gate) of the two additional reaches in W201+30. Juvenile Chinook were captured in all three reaches of W259+50 and coho were captured in the lowest and highest (furthest from tide gate) reaches. Of the closed sloughs, juvenile salmon were captured only in Ellison slough. One Chinook (middle of five reaches) and one coho (reach furthest from historical mouth) were captured in Ellison slough. Chinook captured in reference sloughs ranged from 37 to 124 mm FL (Figure 8). Chinook captured in gated sloughs ranged from 54 to 130mm FL. The one Chinook captured in Ellison slough (closed slough) was 155mm FL. Coho salmon captured in reference sloughs was 39mm FL (Figure 9). Coho captured in gated sloughs ranged from 55 to 112mm FL. Ten of the twelve coho captured in gated sloughs were from W201+30. The one coho captured in Ellison slough (closed slough) was 71mm FL. The one chum salmon captured in S. Hunting E. was 38mm FL.

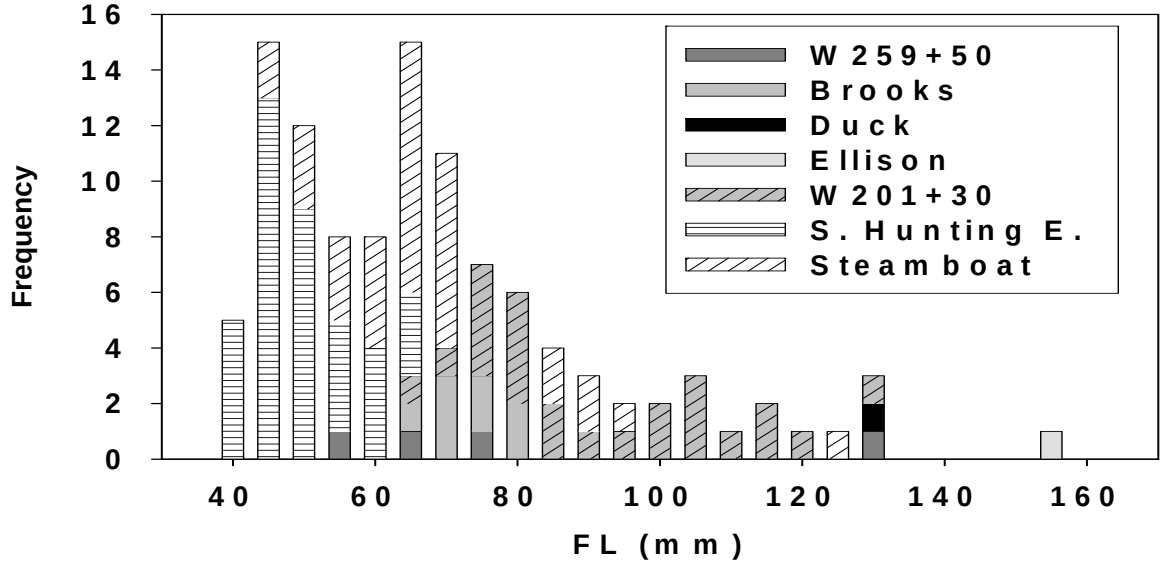

Figure 8: Length frequency of juvenile Chinook salmon captured in hoop nets and seines during fish distribution sampling on mainland JBHNWR, 2007.

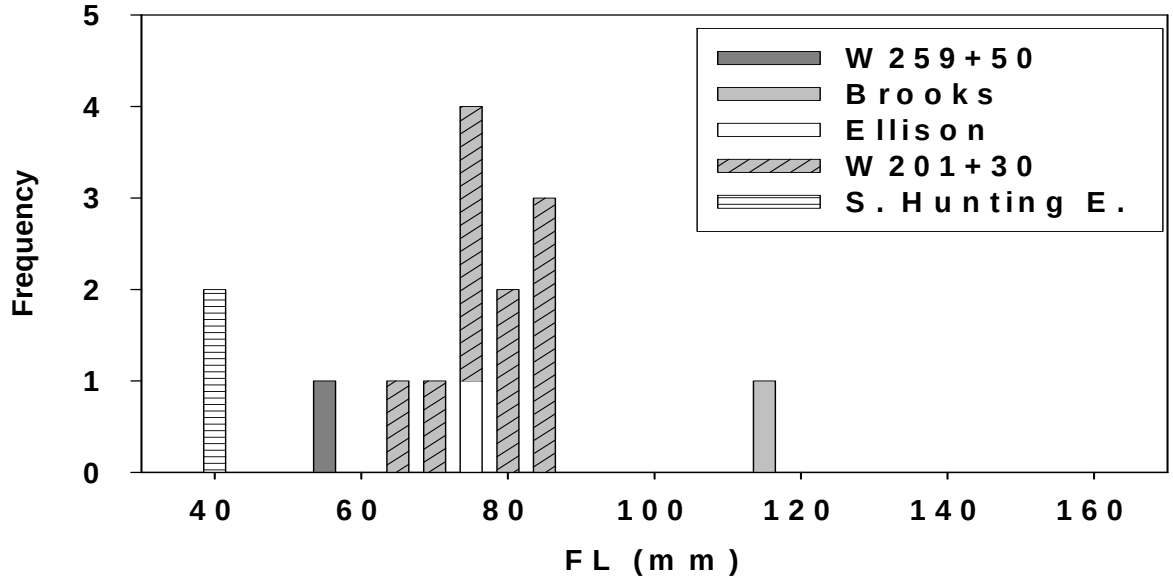

Figure 9: Length frequency of juvenile coho salmon captured in hoop nets and seines during fish distribution sampling on mainland JBHNWR, 2007.

2008

A total of 155 seine hauls were performed in 16 sample reaches in spring 2008. A total of 3,789 fish representing 15 taxa were captured in four main land and two reference sloughs (Table 6). All fish captured in reference sloughs were native species. Five of the thirteen species captured in gated sloughs were non-native and six of the nine species captured in closed sloughs were non-native. Of the total, 96.6% of the fish captured were native species, and 3.4% were non-native. Duck Lake Slough had the most species captured of all sloughs in 2008 with 11 total taxa (Appendix B). Three-spine Stickleback were the most prevalent and most abundant species in all locations, making up 90.5% of the total catch (Table 5). Chinook salmon were the second most abundant fish species captured, making up 2.4% of the total catch (Table 6). A total of 92 salmonids representing 2 taxa were captured in two mainland and two reference sloughs (Appendix B). Chinook salmon were the most abundant species making up 98.9% of the total salmon catch. Both adipose fin clipped and unmarked Chinook were captured. Adipose fin clipped Chinook composed 1.7% (1 of 58) of Chinook captured in gated sloughs and 10% (3 of 33) of Chinook captured in reference sloughs. No adipose fin clipped coho were captured in any slough. No salmon were captured in closed sloughs. Juvenile salmonids made up 5.1% of total catch in gated sloughs and 1.5% in reference sloughs. The highest proportion of salmon were captured in W259+50 slough (63.0%), followed by Little Steamboat (23.9%) and S. Hunting E. (12.0%) sloughs.

Table 6. Species type and percentage (number) of total fish captured (all sampling methods combined) in two closed sloughs (Indian Jack and Winter), two gated sloughs (Duck Lake and W259+50) and two reference sloughs, 2008.

Species		Closed	Gated	Reference
3-spine Stickleback		79.6 (296)	84.2 (976)	95.6 (2158)
Bluegill		0.8 (3)	0.2 (2)	0.0 (0)
Brown Bullhead		0.5 (2)	0.0 (0)	0.0 (0)
Chinook Salmon	Total	0.0 (0)	5.0 (58)	1.5 (33)
	Unmarked	0.0 (0)	4.9 (57)	1.3 (30)
	Adipose clipped	0.0 (0)	0.1 (1)	0.1 (3)
Coho Salmon		0.0 (0)	0.1 (1)	0.0 (0)
Common Carp		0.0 (0)	0.4 (5)	0.0 (0)
E. Banded Killifish		2.7 (10)	1.6 (18)	0.0 (0)
Largemouth Bass		0.3 (1)	0.0 (0)	0.0 (0)
Largescale Sucker		0.0 (0)	0.3 (3)	0.2 (5)
Northern Pikeminnow		0.0 (0)	0.5 (6)	1.3 (30)
Peamouth		0.3 (1)	1.2 (14)	0.9 (20)
Pumpkinseed		2.4 (9)	1.2 (14)	0.0 (0)
Sculpin		0.0 (0)	3.1 (36)	0.3 (7)
Shiner		3.0 (11)	0.1 (1)	0.0 (0)
Starry Flounder		0.0 (0)	0.0 (0)	0.2 (5)
Unknown Sunfish		10.5 (39)	2.2 (25)	0.0 (0)

Juvenile Chinook salmon were captured in all sampled reaches of reference sloughs. No other salmon species were captured in reference sloughs. Juvenile Chinook were captured in all sampled reaches of W259+50 and the lowest most reach (within 50 m of tide gate) of Duck Lake slough. One juvenile coho salmon (FL = 60mm) was captured in the highest reach of W259+50. No juvenile salmon were captured in the two closed sloughs sampled in 2008 (Indian Jack and Winter sloughs). Chinook salmon captured ranged from 36 to 97mm FL (Figure 10). Chinook captured in reference sloughs ranged from 36 to 74mm FL and though from gated sloughs ranged

from 41 to 97 mm FL. One of the 58 Chinook captured in gated sloughs was from Duck Lake slough (62mm FL).

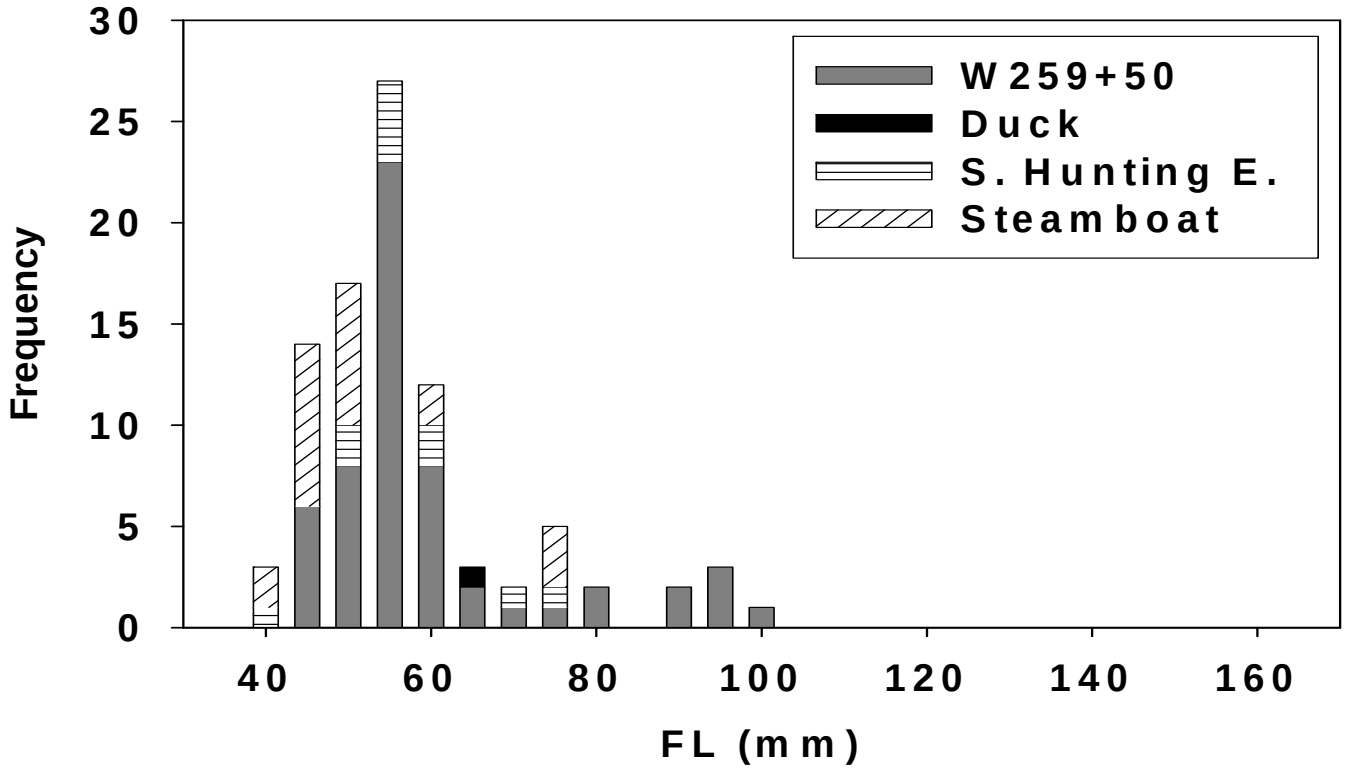

Figure 10: Length frequency of juvenile Chinook salmon captured in seines during fish distribution sampling on mainland JBHNWR, 2008.

Habitat Characterization

Physical Habitat

Closed Sloughs

A total of 14 reaches were sampled within four closed sloughs (Indian Jack, Ellison, Winter and Hampson) in 2007 and 2008. Silt and sand were the dominant substrate types in 100% of reaches. Riparian vegetation was primarily grassy forb and deciduous trees (Tables 7 & 8). Shade averaged 17% ranging from zero to 50% among reaches. Physical channel cover was dominated by aquatic vegetation (Tables 7 & 8).

Gated Sloughs

A total of 13 reaches were sampled within four sloughs with tide gates (Duck Lake, W201+30, W259+50 and Brooks) in 2007 and 2008. Silt and sand were the dominant substrate types in 100% of reaches. Riparian vegetation was primarily grassy forb and deciduous trees. Average percent shade was 27% in 2007 and 2008 (Tables 7 & 8). Aquatic vegetation provided the majority of physical cover and averaged 24 % and 19% in 2007 and 2008, respectively.

Reference Sloughs

A total of six reaches were sampled within the two reference sloughs in 2007. A total of four reaches were sampled within reference sloughs in 2008. Silt and sand were the dominant substrate types in 100% of reaches. Riparian vegetation was primarily woody shrubs and grassy forb (Tables 7 & 8). Percent shade averaged 20% and 10% in 2007 and 2008, ranging from 5-40% among reaches. Submerged large

woody debris and overhanging trees and shrubs provided the majority of cover in both 2007 and 2008 (Tables 7 & 8).

Table 7. Summary of physical habitat features (percentage of reaches with physical habitat feature) within four closed sloughs (n=14 reaches), four gated sloughs (n=13 reaches) and two reference sloughs (n=7 reaches) on mainland JBHNWR and neighboring Hunting and Price Islands, 2007(all reaches combined).

Slough	Dominant Substrate [a]	Sub-Dominant Substrate [a]	Dominant Riparian Veg. [b]	Sub-Dominant Riparian Veg. [b]	Mean % Shade (SD, range)	Percent Physical Cover [c] (average, range)
Closed	Silt	Silt (71.4%) Sand (28.6%)	Grass Forb (78.6%) Tree (14.3%) Shrub (7.1%)	Grass Forb (42.9%) Tree (35.7%) Shrub (21.4%)	17.0 (16.6, 0.0-50.0)	Aquatic Vegetation (44%, 10.0-70.0) Woody Debris (14%, 0.0-40.0) Overhanging Tree/Shrub (11.1%, 0.0-50.0)
Gated	Silt	Silt (69.2%) Sand (30.8%)	Grass Forb (84.6%) Tree (7.7%) Shrub (7.7%)	Grass Forb (46.2%) Tree (46.2%) Shrub (7.7%)	27.0 (23.4, 0.0-70.0)	Aquatic Vegetation (24%, 0.0-75.0) Overhanging Tree/Shrub (9%, 0.0-50.0) Woody Debris (8%, 0.0-35.0)
Reference	Silt	Silt (57.1%) Sand (42.9%)	Shrub (85.7%) Grass Forb (14.3%)	Grass Forb (71.4%) Tree (14.3%) Shrub (14.3%)	20.0 (14.4, 5.0-40.0)	Aquatic Vegetation (3%, 0.0-10.0) Overhanging Tree/Shrub (8%, 0.0-20.0) Woody Debris (9%, 0.0-20.0)

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

Table 8. Summary of physical habitat features (percentage of reaches with physical habitat feature) within four closed sloughs (n=20 reaches), four gated sloughs (n=19 reaches) and two reference sloughs (n=8 reaches) on mainland JBHNWR and neighboring Hunting and Price Islands, 2008 (all reaches combined).

Slough	Dominant Substrate [a]	Sub-Dominant Substrate [a]	Dominant Riparian Veg. [b]	Sub-Dominant Riparian Veg. [b]	Mean % Shade (SD, range)	Percent Physical Cover [c] (percent, range)
Closed	Silt	Silt	Grass Forb (75.0%) Shrub (25.0%)	Tree (65.0%) Shrub (20.0%) Grass Forb (15.0%)	12.0 (10.1, 0.0-40.0)	Aquatic Vegetation (37%, 10.0-90.0) Woody Debris (10%, 0.0-30.0) Overhanging Tree/Shrub (7%, 0.0-40.0)
Gated	Silt	Silt (89.5%) Cobble (10.5%)	Grass Forb (89.5%) Tree (5.3%) No Veg. (5.3%)	Tree (65.8%) Grass Forb (21.0%) Shrub (7.9%) No Veg. (5.3%)	27.0 (31.1, 0.0-40.0)	Aquatic Vegetation (19%, 0.0-80.0) Woody Debris (9%, 0.0-40.0) Overhanging Tree/Shrub (9%, 0.0-40.0)
Reference	Silt	Silt	Shrub (87.5%) Grass Forb (12.5%)	Grass Forb (87.5%) Shrub (12.5%)	10.0 (6.6, 5.0-20.0)	Aquatic Vegetation (5%, 0.0-10.0) Woody Debris (10%, 5.0-20.0) Overhanging Tree/Shrub (9%, 0.0-20.0)

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

Water Quality

The 7-DADM reached 16ºC and remained above this threshold starting on May 26 in Steamboat slough, whereas this threshold was never reached in the other reference slough, S. Hunting E. (Figure 3). The dates that the closed sloughs Hampson and Ellison reached and remained above this threshold were May 28 and May 31, respectively (Figure 4). Indian Jack slough (a closed slough) reached the threshold level two times during monitoring (May 12 – May 20 and May 31 – June 11) but dropped below 16ºC the final three days of data collection. Gated sloughs reached and stayed above 16ºC threshold between May 10 and June 2 (Figure 5).

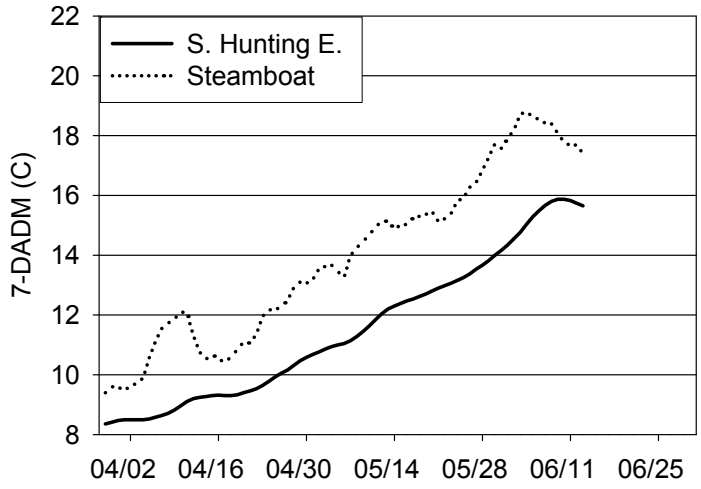

Figure 11. Seven-day average daily maximum water temperature (7-DADM) for lower most sampling reach within reference sloughs S. Hunting E. and Steamboat at JBHNWR, 2007.

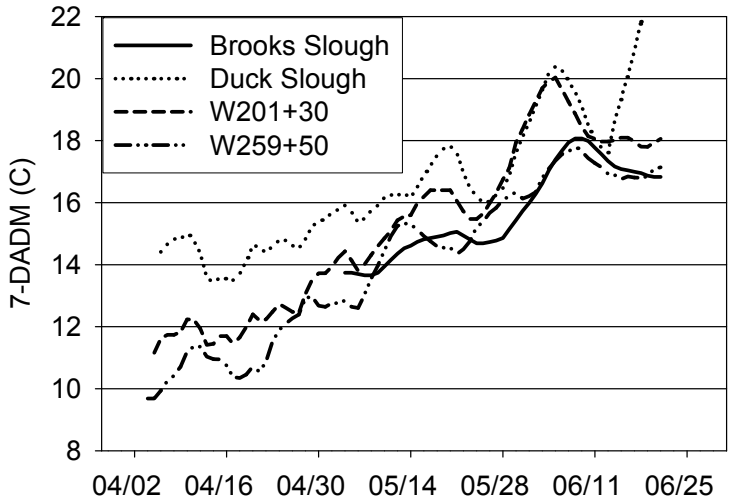

Figure 12. Seven-day average daily maximum water temperature (7-DADM) for lower most sampling reach within gated sloughs Brooks, Duck, W201+30 and W259+50 at JBHNWR, 2007.

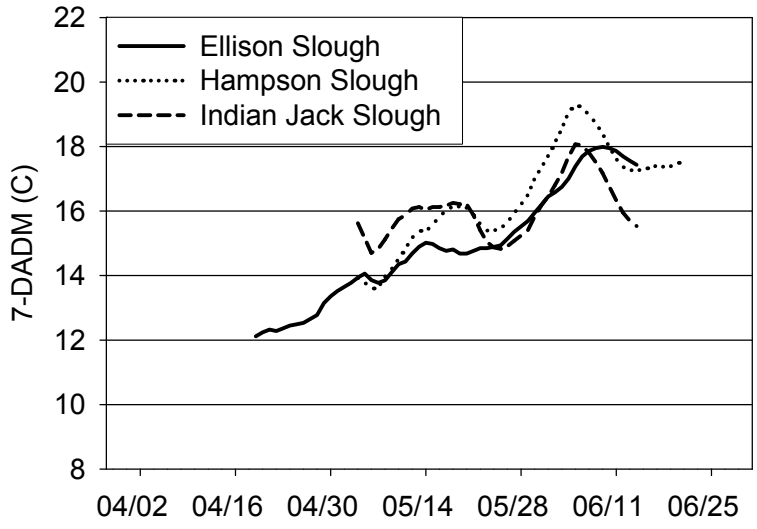

Figure 13. Seven-day average daily maximum water temperature (7-DADM) for lower most sampling reach within closed sloughs Ellison, Hampson and Indian Jack at JBHNWR, 2007.

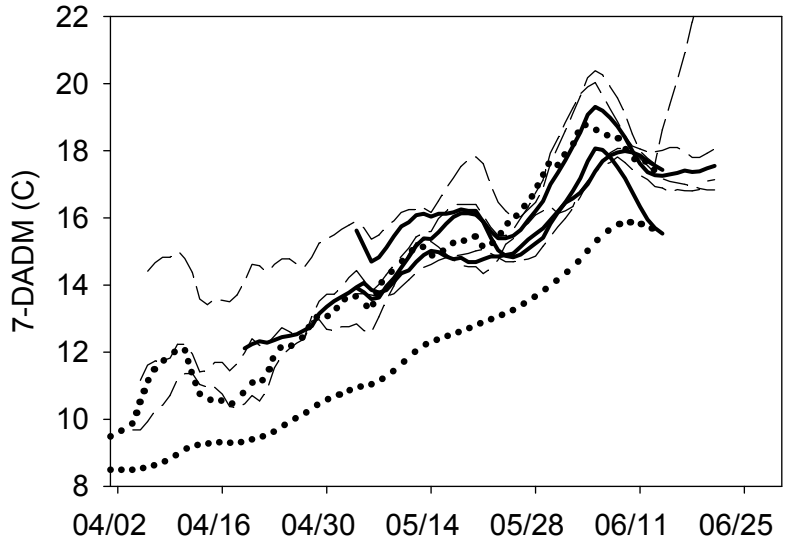

Figure 14. Seven-day average daily maximum water temperature (7-DADM) for lower most sampling reach within closed sloughs (solid lines), gated sloughs (dashed lines) and reference sloughs (dotted lines) JBHNWR, 2007.

Daily temperature range varied among sloughs. Median daily temperature range varied from 0.2ºC and 3.95ºC (Table 9). Significant differences were found among sloughs in 27 of 36 pair wise comparisons. S. Hunting E. showed the lowest daily temperature range (0.02ºC) and the other reference slough, Steamboat had the highest (3.95ºC). Closed slough daily temperature range varied from 0.58 ºC in Ellison to 1.04 ºC in Hampson. Gated slough daily temperature range varied from 0.30 in Brooks slough to 2.37 ºC in W021 slough.

Table 9. Median daily temperature range (ºC) of Julia Butler Hansen NWR sloughs, 2007. "X" signifies significant differences among sloughs as determined using Kruskal-Wallis ANOVA on Ranks followed by Dunn's multiple comparison procedure.

	Steamboat	W201	Duck	W259	Hampson	Indian	Ellison	Brooks	ºC
S.HuntingE.	x	x	x	x	x	x	x		0.20
Brooks	x	x	x	x	x	x			0.30
Ellison	x	x	x	x	x	x			0.58
Indian	x	x	x						1.02
Hampson	x	x							1.40
W259	x								1.74
Duck Lake	x								2.32
W201	x								2.37
Steamboat									3.95

Closed slough DO% measured levels ranged from 17.2-98.1% (mean = 65.2%) in 2007 and 15.1-80.2% (mean = 48.4%) in 2008 (Tables 11&12). In 2007, the lowest

level was found in Winter Slough and the highest in Indian Jack Slough. Indian Jack slough had the lowest and Ellison the highest closed slough DO% measured in 2008.

Gated slough DO% measured levels ranged from 29.2-102.2% (mean = 73.3%) in 2007 and 10.1-107.3% (mean = 70.1%) in 2008 (Tables 11&12). In 2007, the lowest DO% measured was in Duck Lake and the highest in Brooks slough. In 2008 the lowest level DO% measured was in Duck Lake slough and the highest was in W259+50.

In reference sloughs, DO ranged from 50.9-105.9% (80.2%) in 2007 and 72.4-101.3% (87.1%) in 2008 (Tables 11&12). Steamboat slough had the highest and lowest measured DO% among reference sloughs in 2007. In 2008 Steamboat had the highest DO% measured and S. Hunting E. had the lowest.

Table 10. Mean (standard deviation, range) of water quality variables within four closed sloughs (n=14), four gated sloughs (n=13) and two reference sloughs (n=7) on mainland JBHNWR and neighboring Hunting and Price Islands, 2007.

Slough	% Dissolved Oxygen	Dissolved Oxygen (mg/l)	Conductivity (µS)	Turbidity (JTU)	Transparency (cm)
Closed	65.2 (2.6, 17.2-98.1)	6.4 (2.0, 2.2-9.8)	208.9 (150.9, 60.5-602.0)	8.2 (4.2, 5.0-15.0)	71.8 (24.6, 38.0-110.0)
Gated	73.3 (24.7, 29.2-102.2)	7.7 (2.9, 1.8-11.4)	106.1 (28.8, 56.3-172.1)	8.1 (5.2, 0.0-15.0)	88.0 (27.1, 41.0-132.0)
Reference	80.2 (19.7, 50.9-105.9)	9.7 (1.6, 7.2-12.3)	77.5 (26.9, 37.7-101.3)	5.7 (3.5, 0.0-10.0)	50.6 (43.0, 10.0-132.0)

Table 11. Mean (standard deviation, range) of water quality variables within four closed sloughs (n=20 reaches), four gated sloughs (n=19 reaches) and two reference sloughs (n=8 reaches) on mainland JBHNWR and neighboring Hunting and Price Islands, 2008.

Slough	% Dissolved Oxygen	Dissolved Oxygen (mg/l)	Conductivity (µS)	pH	Turbidity (JTU)	Transparency (cm)
Closed	48.4 (20.9, 15.1-80.2)	5.2 (2.3, 1.5-8.3)	136.4 (71.6, 70.9-377.1)	6.07 (0.2, 5.7-6.5)	8.2 (4.0, 5.0-15.0)	77.0 (22.0, 45.0-134.0)
Gated	70.1 (28.0, 10.1-107.3)	7.7 (3.2, 1.0-12.5)	107.3 (44.7, 70.4-215.1)	6.15 (0.6, 3.9-6.8)	7.0 (3.0, 5.0-15.0)	85.0 (20.0, 43.0-125.0)
Reference	87.1 (8.9, 72.4-101.3)	9.8 (1.3, 8.1-12.2)	71.8 (19.8, 41.3-92.9)	6.7 (0.4, 6.1-7.4)	7.5 (5.3, 5.0-20.0)	103.0 (30.0, 55.0-130.0)

No significant differences among individual sloughs or among closed, gated and reference slough types were found in 2007. Significant differences in DO% were found

in 2008 among slough types, with closed sloughs having significantly lower DO% levels than either gated sloughs or reference sloughs. No difference was found between gated and reference sloughs in 2008.

When compared individually, Indian Jack slough had significantly lower DO% levels than both reference sloughs and all gated sloughs except Duck Lake slough (Table 13). Duck Lake had significantly lower DO% levels than both reference sloughs as well as W259+50 and W201+30 gated sloughs.

Table 12. Mean DO% of Julia Butler Hansen NWR sloughs, 2008. "X" signifies significant differences among sloughs as determined using ANOVA followed by Bonferroni multiple comparison procedure.

	Steamboat	W259+50	W201+30	S.HuntingE.	Brooks	Winter	Hampson	Ellison	Duck	DO%
Indian	x	x	x	x	x					34.7
Duck	x	x	x	x						37.4
Ellison										53.7
Hampson										54.1
Winter										54.7
Brooks										74.3
S.HuntingE										83.3
W201+30										87.3
W259+50										91.3
Steamboat										98.2

Average conductivity in reference sloughs ranged from 37.7- 101.3µS (mean = 77.5 µS) in 2007 and from 41.3-92.9µS (71.8 µS) in 2008. In closed sloughs, average specific conductivity ranged from 60.5-602.0µS (208.9µS) in 2007 and from 70.9-377.1µS (136.4µS) in 2008. Average conductivity in gates sloughs ranged from 56.3-

172.1µS (106.1µS) in 2007 and from 70.4-215.1µS (107.3µS) in 2008 (Tables 11&12). Among slough types, average pH ranged from 6.1 and 6.7 in 2008 (Table 12). Measurements of pH were not collected in mainland or reference sloughs in 2007. Turbidity in closed sloughs ranged from 5-15 JTU's (mean = 8.2) in 2007 and 2008. In gated sloughs, turbidity ranged from 0-15 JTU's (mean = 8.1) in 2007 and from 5-15 JTU's (mean = 7.0) in 2008. In reference sloughs, water turbidity ranged from 0-10 JTU's (mean = 5.7) in 2007 and from 5-20 JTU's (mean = 7.5) in 2008 (Tables 11&12). Water transparency in closed sloughs ranged from 38.0-110.0 cm (mean = 71.8 cm) in 2007 and from 45.0-134.0 cm (mean = 77.0 cm) in 2008. In gated sloughs, visibility ranged from 41.0-132.0 cm (mean = 88.0 cm) in 2007 and from 43.0-125.0 cm (mean = 85.0 cm) in 2008. Visibility in reference sloughs ranged from 10.0-132.0 cm (mean = 50.6 cm) in 2007 and from 55.0-130.0 cm (mean = 103.0 cm) in 2008 (Tables 11&12).

Summary

Adult Salmonid Presence

Adult salmon were found upstream of the JBHNWR. The adult salmon seen in Nelson Creek likely by-pass refuge sloughs by way of a constructed channel connecting the Elochoman River to Nelson Creek. No evidence was found of adult salmonids passing existing tide gates or through JBHNWR.

Juvenile salmon passage

Juvenile salmon are able to enter through existing tide gates. Numbers of juvenile salmonids captured entering through these tide gates are fewer than numbers captured entering into reference sloughs. However, sampling efficiency may be different among sloughs and slough types. Thus, while tide gates do not prevent juvenile salmon from entering sloughs, it is unclear whether the tide gates influence the number of juvenile salmon entering sloughs.

Juvenile Chinook salmon enter both reference and gated sloughs. Of Chinook captured entering gated sloughs, the proportion longer than 110mm FL was more than that entering reference sloughs. This suggests that smaller fish may have more difficulty entering gated sloughs.

Fish Distribution

Reference sloughs appeared to contain more salmon species than either closed or gated sloughs. Three species of salmon (Chinook, coho and chum salmon) were captured in reference sloughs whereas chum salmon were not captured in closed or gated sloughs. Both hatchery origin (adipose fin clipped) and unmarked Chinook salmon were captured in gated and reference sloughs. Gated and closed sloughs appeared to contain more total fish species, specifically non-natives species, than reference sloughs. All ten species captured in reference sloughs were native species. In gated sloughs, 6 of 14 species were non-native and in closed sloughs 10 of 16 species were non-native. Non-native species captured include those known to prey on juvenile salmonids (e.g. Smallmouth Bass). Juvenile salmon were captured in Ellison

Slough (closed slough) indicating that salmon can move among sloughs using interconnecting ditches.

Habitat Characterization

Water temperatures in gated sloughs may be more limiting to juvenile salmon than temperatures in reference sloughs. This was evidenced by the 7-DADM, a rolling average of 7 consecutive daily maximum temperatures recorded within a stream (Hicks, 2000). Water temperature levels in W259+50, W201+30, Brooks, Hampson, Ellison and Steamboat sloughs remained below the upper threshold level (16C°) until late May or early June. Temperature in Indian Jack and Duck Lake exceeded 16C° in early May. Water temperature in S. Hunting E. was still within the acceptable range when the temperature logger was removed on 13 June.

Oxygen concentrations in closed sloughs and one gated slough (Duck Lake) may be more limiting to juvenile salmon than in reference sloughs. Four of the five lowest mean DO% were measured in closed sloughs. Duck slough (top-hinge, steel gate) mean oxygen concentration was the second lowest of all sloughs, whereas, W201+30 (side-hinge with cam system gate) and W259+50 (top-hinge wooden gate that allows some inflow) are the third and second highest. These findings are based on point measurements collected during daytime and may not adequately reflect diurnal fluctuations.

References

Bottom, D. L., C. A. Simenstad, A. M. Baptista, D. A. Jay, J. Burke, K. K. Jones, E. Casillas, and M.H. Schiewe. 2005. Salmon at river's end: The role of the estuary in the decline and recovery of Columbia River salmon. U.S. National Marine Fisheries Service. Seattle, Washington.

Diefenderfer, H.L., G.C. Roegner, R.M. Thom, E.M. Dawley, A.H. Whiting, G.E. Johnson, K.L.Sobocinski, M.G. Anderson, and B.D. Ebberts. 2005. Evaluating Cumulative Ecosystem Response to Restoration Projects in the Columbia River Estuary. PNNL -15102. Draft Report to the US ArmyCorps of Engineers, Portland District, by Pacific Northwest National Laboratory, Richland,Washington.

Environmental Protection Agency (EPA). 2003. EPA Region 10 Guidance for Pacific Northwest State & Tribal Temperature Water Quality Standards. U.S. EPA, Seattle, WA. 33pp. EPA 910-B-002.

Haskell, C.A., R.C. Koch, K.F. Tiffan, and D.W. Rondorf. 2004. Crims Island Habitat Restoration in the Columbia River Estuary-Fisheries Monitoring and Evaluation, 2003, Draft Report of Research Submitted to U.S. Army Corps of Engineers, Portland District.

Hicks, M. Evaluating Standards for Protecting Aquatic Life in Washington's Surface Water Quality Standards. 2000. Draft discussion paper and literature summary. Revised 2002. Washington State Department of Ecology, Olympia, WA. 197pp.

Johnson, J.R., J. Poirier, and T.A. Whitesel. 2007. Lower Columbia River Channel Improvement: Assessment of Salmonid Populations and Habitat on Tenasillahe

and Welch Islands: 2006 Project Report, Report of Research Submitted to U.S. Army Corps of Engineers, Portland District.

Lower Columbia Fish Recovery Board. 2004. Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan. Volume II. A. Lower Columbia Main stem and Estuary. December 15, 2004.

NMFS (National Marine Fisheries Service). 2008. Endangered Species Act Section 7 Formal and Informal Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Julia Butler Hansen Section 536 Habitat Restoration Project, Lower Columbia River, RM 33.5 – 37.5, (6th field HUC 170800030503), Wahkiakum County, Washington, NOAA Fisheries, Northwest Region, Portland, OR.

NMFS (National Marine Fisheries Service). 2004. Biological Opinion: Operation of the Federal Columbia River Power System, Including the 19 Bureau of Reclamation Projects in the Columbia Basin. NOAA Fisheries, Northwest Region, Portland, OR.

Poirier, J.R., R. Sollee, S. Gainer, S. Lohr, and T. Whitesel. 2006. Lower Columbia River Channel improvement: Assessment of Salmonid Populations and Habitat on Tenasillahe and Welch Islands: 2005 Project Report, Report of Research Submitted to U.S. Army Corps of Engineers, Portland District.

Richter, A., S.A. Kolmes. Maximum Temperature Limits for Chinook, Coho, & Chum Salmon, and Steelhead Trout in the Pacific Northwest. 2005. Reviews in Fisheries Science. 13: 23-49.

U.S. Army Corps of Engineers. 2007. Julia Butler Hansen Columbian White-tailed Deer National Wildlife Refuge Section 536 Habitat Restoration Project Lower Columbia River and Estuary. Draft Integrated Implementation Report and Environmental Assessment. 102pp.

Appendix A. Total fish captured and percentage of total catch (sampling methods combined) in mainland and reference sloughs, 2007.

Species	# individuals Captured	% of Total
Indian Jack		
3-spine Stickleback	5	71.4
E. Banded Killifish	1	14.3
Largescale Sucker	1	14.3
Total	7	
Duck Lake		
3-spine Stickleback	14	53.8
Chinook Salmon	1	3.8
E. Banded Killifish	8	30.8
Large Mouth Bass	1	3.8
Pumpkinseed	2	7.7
Total	26	
Ellison		
3-spine Stickleback	14	31.1
Bluegill	3	6.7
Chinook Salmon	1	2.2
Coho Salmon	1	2.2
E. Banded Killifish	2	4.4
Large Mouth Bass	2	4.4
N. Pike Minnow	3	6.7
Peamouth	9	20.0
Small Mouth Bass	1	2.2
Unknown Sunfish	7	15.6
Yellow Perch	2	4.4
Total	45	
Winter		
3-spine Stickleback	36	97.3
E. Banded Killifish	1	2.7
Total	37	
W201+30		
3-spine Stickleback	151	59.4
Chinook Salmon	74	29.1
Coho Salmon	10	3.9
E. Banded Killifish	18	7.1
Sculpin	1	0.4
Total	254	

Appendix A. continued

W259+50		
3-spine Stickleback	36	80.0
Chinook Salmon	4	8.9
Coho Salmon	1	2.2
E. Banded Killifish	3	6.7
Sculpin	1	2.2
Total	45	
Hampson		
3-spine Stickleback	44	97.8
Yellow Bullhead	1	2.2
Total	*45*	
Brooks		
3-spine Stickleback	19	32.2
Bluegill	5	8.5
Chinook Salmon	8	13.6
Coho Salmon	1	1.7
Large Mouth Bass	4	6.8
Peamouth	1	1.7
Pumpkinseed	4	6.8
Unknown Sunfish	17	28.8
Total	*59*	
South Hunting East		
3-spine Stickleback	204	82.6
Chinook Salmon	38	15.4
Chum Salmon	1	0.4
Coho Salmon	3	1.2
Dace	1	0.4
Total	*247*	
Steamboat		
3-spine Stickleback	91	75.8
Chinook Salmon	28	23.3
Sculpin	1	0.8
Total	120	

Appendix B. Total fish captured and percentage of total catch (sampling methods combined) in mainland and reference sloughs, 2008.

Species	# Individuals Captured	% of Total
W259+50		
3-spine Stickleback	859	88.3
Chinook Salmon	57	5.9
Coho Salmon	1	0.1
Eastern Banded Killifish	3	0.3
Largescale Sucker	1	0.1
Northern Pikeminnow	1	0.1
Peamouth	4	0.4
Sculpin	34	3.5
Unknown Sunfish	13	1.3
Total	973	
Duck Lake		
3-spine Stickleback	117	62.9
Bluegill	2	1.1
Chinook Salmon	1	0.5
Common Carp	5	2.7
Eastern Banded Killifish	15	8.1
Largescale Sucker	2	1.1
Northern Pikeminnow	5	2.7
Peamouth	10	5.4
Pumpkinseed	14	7.5
Sculpin	2	1.1
Shiner	1	0.5
Unknown Sunfish	12	6.5
Total	186	
Indian Jack		
3-spine Stickleback	11	44.0
Eastern Banded Killifish	2	8.0
Peamouth	1	4.0
Pumpkinseed	1	4.0
Shiner	9	36.0
Unknown Sunfish	1	4.0
Total	25	

Appendix B. continued

Species	# Individuals Captured	% of Total
	Winter	
3-spine Stickleback	285	82.1
Bluegill	3	0.9
Brown Bullhead	2	0.6
Eastern Banded Killifish	8	2.3
Largemouth Bass	1	0.3
Pumpkinseed	8	2.3
Shiner	2	0.6
Unknown Sunfish	38	11.0
Total	38	
	S. Hunting E.	
3-spine Stickleback	1969	96.2
Chinook Salmon	11	0.5
Largescale Sucker	5	0.2
Northern Pikeminnow	30	1.5
Peamouth	20	1.0
Sculpin	6	0.3
Starry Flounder	5	0.2
Total	2046	
	Steamboat	
3-spine Stickleback	189	89.2
Chinook Salmon	22	10.4
Sculpin	1	0.5
Total	212	

Appendix C. Total fish captured and percentage total catch (all sampling methods combined) in mainland and reference sloughs during early and late opportunity trials, 2007.

Species	# individuals Captured	% of Total
	Duck Lake	
3-spine Stickleback	185	48.4
Chinook Salmon	19	5.0
Coho Salmon	15	3.9
Common Carp	1	0.3
E. Banded Killifish	43	11.2
Largescale Sucker	3	0.8
N. Pike Minnow	89	23.3
Peamouth	23	6.0
Sculpin	3	0.8
Steelhead Trout	1	0.3
Total	382	
	Mouth Ellison	
3-spine Stickleback	44	46.8
Chinook Salmon	38	40.4
Sculpin	7	7.4
Starry Flounder	5	5.3
Total	94	
	W201+30	
3-spine Stickleback	231	38.1
Bluegill	8	1.3
Brown bullhead	4	0.6
Chinook Salmon	59	9.7
Chum Salmon	4	0.6
Coho Salmon	47	7.7
Common Carp	1	0.2
E. Banded Killifish	26	4.3
Largescale Sucker	3	0.5
N. Pike Minnow	17	2.8
Peamouth	142	23.4
Pumpkinseed	9	1.5
Sculpin	55	9.1
Yellow Bullhead	1	0.2
Total	607	
	Winter	
3-spine Stickleback	10	55.6
Chinook Salmon	3	16.6
Largescale Sucker	5	27.8
Total	18	

Appendix C. continued

Species	# individuals Captured	% of Total
	W259+50	
3-spine Stickleback	1586	89.0
Bluegill	1	0.0
Chinook Salmon	64	3.6
Chum Salmon	1	0.0
Coho Salmon	28	1.6
Dace	1	0.0
E. Banded Killifish	23	1.3
N. Pike Minnow	2	0.1
Peamouth	49	2.7
Sculpin	25	1.4
Starry Flounder	1	0.0
W. Brook Lamprey	1	0.0
Total	1782	
	Brooks	
3-spine Stickleback	48	75.0
Chinook Salmon	14	21.9
Coho Salmon	1	1.6
Large Mouth Bass	1	1.6
Total	*64*	
	South Hunting East	
3-spine Stickleback	5451	78.5
Chinook Salmon	124	1.8
Coho Salmon	81	1.2
E. Banded Killifish	242	3.5
Largescale Sucker	15	0.2
N. Pike Minnow	168	2.4
Peamouth	626	9.0
Sculpin	117	1.7
Starry Flounder	1	0.0
Total	*6948*	
	Steamboat	
3-spine Stickleback	3331	84.2
Chinook Salmon	311	7.9
Chum Salmon	5	0.1
Coho Salmon	36	1.0
E. Banded Killifish	18	0.5
Largescale Sucker	5	0.1
N. Pike Minnow	15	0.4
Peamouth	103	2.6
Sculpin	34	0.8
Starry Flounder	1	0.0
W. Brook Lamprey	1	0.0
Total	3957	

Appendix D. Total fish captured and percentage total catch (all sampling methods combined) in mainland and reference sloughs during early and late opportunity trials, 2008.

Species	# Individuals Captured	% of Total
W259+50		
3-spine Stickleback	1983	95.0
Bluegill	2	0.1
Chinook Salmon	20	1.0
Coho Salmon	2	0.1
Eastern Banded Killifish	34	1.6
Largemouth Bass	1	0.0
Northern Pikeminnow	11	0.5
Pacific Lamprey	1	0.0
Peamouth	20	1.0
Sculpin	13	0.6
Unknown Sunfish	1	0.0
Total	2088	
Duck Lake		
3-spine Stickleback	2307	90.0
Bluegill	7	0.3
Chinook Salmon	2	0.1
Eastern Banded Killifish	22	0.9
Largescale Sucker	14	0.5
Northern Pikeminnow	37	1.4
Peamouth	136	5.3
Pumpkinseed	5	0.2
Sculpin	13	0.5
Shiner	1	0.0
Unknown Lamprey	1	0.0
Unknown Salmonid	1	0.0
Unknown Sunfish	18	0.7
Total	2564	

Appendix D. continued

Species	# Individuals Captured	% of Total
S. Hunting E.		
3-spine Stickleback	2675	84.1
Chinook Salmon	114	3.6
Chum Salmon	1	0.0
Coho Salmon	2	0.1
Eastern Banded Killifish	3	0.1
Largescale Sucker	4	0.1
Northern Pikeminnow	200	6.3
Peamouth	162	5.1
Sculpin	18	0.6
Starry Flounder	1	0.0
Total	3180	
Steamboat		
3-spine Stickleback	15363	97.0
Chinook Salmon	149	0.9
Chum Salmon	3	0.0
Coho Salmon	1	0.0
Eastern Banded Killifish	36	0.2
Northern Pikeminnow	62	0.4
Peamouth	117	0.7
Sculpin	99	0.6
Shiner	1	0.0
Starry Flounder	4	0.0
Total	15835	