Julia Butler Hansen National Wildlife Refuge: Post-Construction Assessment of Fishes, Habitats, and Tide Gates in Sloughs on the Mainland

2011 Annual Report

Prepared By:

Jeffrey Johnson

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, WA 98683

I. INTRODUCTION

A. GOAL

The primary goal of this study is to assess the effect of habitat restoration on fish, fish communities and aquatic habitat at Julia Butler Hansen National Wildlife Refuge. Habitat restoration is focused on replacement of traditional style tide gates with side-hinged, self-restrained tide gates and installation of these new style tide gates at sloughs without connection to the Columbia River.

B. OBJECTIVES

1. Assess the periods, frequency, and duration that tide-gates (as presently configured, after modifications, and newly installed) are conducive to passage by juvenile and adult salmonids, specifically during October-June.

2. Describe presence, distribution, and biological characteristics (e.g., species, size) of fish inhabiting mainland sloughs at Julia Butler Hansen NWR (pre-and-post construction) and compare to that observed at reference sloughs.

3. Characterize habitats of mainland sloughs at Julia Butler Hansen NWR and compare to that observed at reference sloughs (pre-and post-construction).

4. Quantify changes in fish community and habitat quality with the re-introduction and/or improvement of the return of tidal exchange.

C. RELATIONSHIP TO COLUMBIA ESTUARY ECOSYSTEM RESTORATION PROGRAM (CEERP)

1. CEERP Goal, Objectives and Management Questions

Within the context of the CEERP, the goal of this project is to understand, conserve, and restore ecosystems in the lower Columbia River and estuary. The CEERP objectives addressed by this project are 1. Conserve and restore factors that control ecosystem structures/processes, e.g., hydrodynamics, water quality. 2. Increase quantity, quality of ecosystem structures, e.g., estuarine habitat for juvenile salmonids; 3. Maintain and enhance LCRE food webs to benefit salmonid performance; and 4. Improve salmonid performance in terms of life-history diversity, foraging success, growth, and survival. Results from these objectives help provide answers to these CEERP management questions 1) What are the limiting factors or threats, i.e., stressors and controlling factors, in the estuary preventing the achievement of desired habitat or fish performance? 2) Which actions are most effective at addressing the limiting factors preventing achievement of habitat, fish, or wildlife performance objectives? 3) Are the estuary habitat actions achieving the expected biological and environmental benefits, e.g., SBU targets? 4) What factors should be included or refined to improve the ability of the SBU crediting method to predict benefits to ESA-listed fish from ecosystem restoration in the LCRE?

2. FCRPS BiOp Estuary/Ocean RPA sub-actions

This ongoing project directly addresses actions in RPA 60 and provides information applicable to RPAs 37, 58, 59, and 61.

- RPA 37 Estuary Habitat Implementation 2010-2018 – Achieving Habitat Quality and Survival Improvement Targets. “FCRPS RM&E results will actively inform the relationship between actions, estuary habitat change and salmon productivity and new scientific information will be applied to estimate benefits for future implementation.”

- RPA 58 Monitor and Evaluate Fish Performance in the Estuary and Plume. “Monitor and evaluate juvenile salmonid growth rates and prey resources at representative locations in the estuary and plume. Monitor and evaluate temporal and spatial species composition, abundance, and foraging rates of juvenile salmonid predators at representative locations in the estuary and plume.”

- RPA 59 Monitor and Evaluate Migration Characteristics and Estuary/Ocean Conditions. “Evaluate migration through and use of a subset of various shallow-water habitats from Bonneville Dam to the mouth toward understanding specific habitat use and relative importance to juvenile salmonids. Monitor habitat conditions periodically, including …substrate characteristics, dissolved oxygen, temperature, and conductivity, at representative locations in the estuary as established through RM&E.”

- RPA 60 Monitor and Evaluate Habitat Actions in the Estuary. “Evaluate the effects of selected individual habitat restoration actions at project sites relative to reference sites and evaluate post-restoration trajectories based on project–specific goals and objectives.”

- RPA 61 Investigate Estuary/Ocean Critical Uncertainties. “Continue work to define the ecological importance of the tidal freshwater, estuary, plume, and nearshore ocean environments to the viability and recovery of listed salmonid populations in the Columbia River Basin.”

II. Study Description

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B. BACKGROUND

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 2008). 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. 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 (NMFS 2008). Presently, accessibility of slough habitats is largely impeded by dikes and tide gates. 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 at slough W201+30 with a new culvert and a side-hinge aluminum gate. The gate is equipped with a float and cam system that is designed to hold the gate partially open during incoming tides until the buoyancy of the float rotates the cams and closes the gate. Operation of this culvert and tide gate was 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 (Figure 1). As a result of this study, the USACOE has proposed installing tide gates at three sloughs currently blocked by dikes (Hampson, Indian Jack, and Winter) and replacing tide gates in two other sloughs (Brooks and Duck Lake). 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 actually result in improved fish passage into and out of the sloughs or aquatic habitat conditions.

III. Methods

A. 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, historically influenced by tides and currently interconnected by a series of drainage ditches and channels. Until 2009, four of these sloughs were connected to the Columbia River by culverts with tide gates and four were not connected because of flood control levees. The four gated sloughs, Brooks, Duck Lake, W201+30, and W259+50 had tide gates that controlled the discharge of water from the mainland interior. Brooks Slough had three 1.5 x 1.5 meter, top-hinge aluminum tide gates. Duck Lake had 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. The four closed sloughs, Ellison, and Hampson, Indian Jack and Winter were not connected to the Columbia River and its side channels because of flood control levees but were interconnected to other sloughs on the JBHNWR by drainage ditches. Construction in 2009 installed culverts and the new tide gate design at Hampson and Winter Sloughs, replaced one of the three gates at Brooks Slough with the new tide gate design and fixed a heaved culvert at W201+30 that was thought to effect tide gate operation (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 control 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 control site on Price Island (Steamboat Slough) (Figure 1).

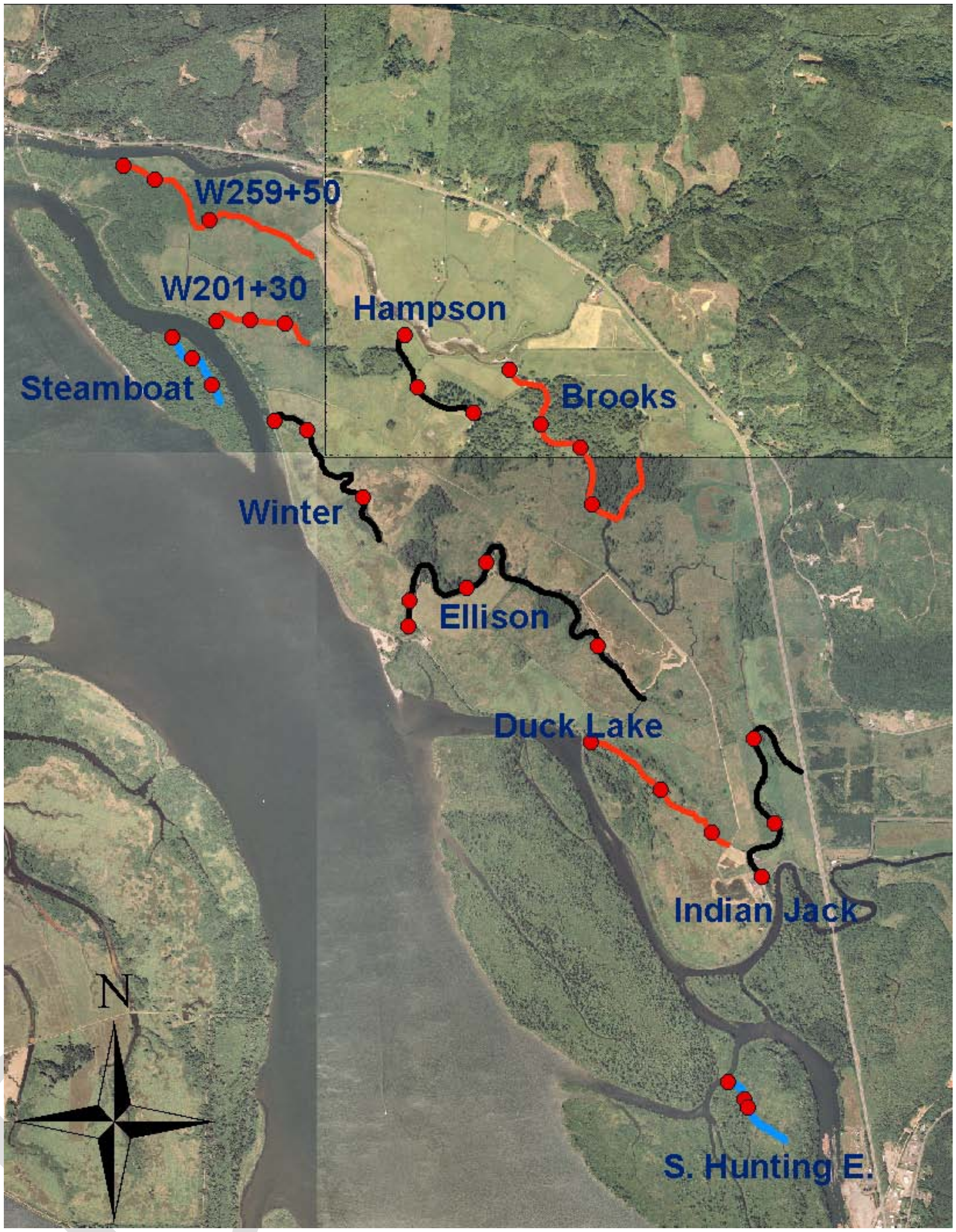

Figure 1. Area map of JBHNWR National Wildlife Refuge showing the location of sloughs and sample reaches (red circles) surveyed in 2007, 2008 and 2010. Black, red and blue lines indicate closed, gated and reference sloughs, respectively.

A. Identification of Study Sloughs and Sample Reaches

All sloughs proposed for restoration actions were included in this study. Treatment sloughs included three gated and three closed sloughs enclosed by dikes and tide gates on mainland JBHNWR. Two control sloughs, W259+50 and Ellison were to receive no modifications during the study. Reference sloughs selected for this study showed no evidence of human impact, no water control and were within two kilometers of treatment sloughs. One natural (unmodified) slough from Price Island (Steamboat slough) and one from South Hunting Island (S. Hunting E.) were designated as control sloughs (Figure 1). All treatment, control and reference sloughs are located within a two kilometer reach of the Columbia River on the Washington side of the shipping channel and therefore, likely witness the same pool of migrating fish. Though the inclusion of unimpacted, mainland control sloughs would have been preferred for this study, none are available within the vicinity (within 2 kilometers) of the treatment sloughs. As such we selected control sloughs that experience full tidal influence and would likely represent conditions that treatment sloughs would approach without tide gate influences. In addition, Ellison slough (closed) and W259+50 slough (gated) will not be modified during this project and as such function as additional controls.

Sample reach selection was designed to assure random and spatially-balanced data collection representing at least 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 (see Stevens and Olsen 2004). 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 a minimum of ten percent of slough length was represented and at least three reaches were sampled in each slough. Sampling effort in 2007 and 2008 (pre-construction) and 2010 (post-construction) focused on the same sets of reaches.

B. Study Design and Analysis

Our study design is based upon comparing fish community and habitat conditions in treatment sloughs to reference sloughs and control sloughs before and after treatment. In this study, we have selected two reference studies and two control studies. One control, W259+50 is a gated slough and the other, Ellison is a closed slough. W259+50 we refer to as a "positive control" and Ellison we refer to as a negative control. The expectation is that conditions at closed sloughs that receive a new tide gate will move toward those of the positive control and further away from the negative control. Selection of sloughs and slough reaches are explained above. The reference sloughs are considered the ideal condition and are expected to be independent of treatments on the mainland. Conditions in the reference sloughs are assumed to reflect natural or system wide variation in estuary quality. We would expect conditions at treatment sloughs to trend toward that at reference sloughs but fall short of ideal conditions. The difference between conditions at reference sloughs and treatment sloughs post construction might reflect the extent that the new tide gates allow sloughs to reach ideal conditions (e.g. what level of restoration has occurred).

C. FIELD METHODS AND PROTOCOLS

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 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 2011, all sample reaches were surveyed twice (for fish and habitat) during the season.

Juvenile Salmon passage at gated sloughs

In 2011, fish passage trials were performed at Winter slough (previously closed slough that received self-restrained tidegate in summer 2009). To assess physical operation and passage potential through existing tide gates, these trials consisted of operating fish traps inside the slough (upstream of the tide-gate) oriented to capture fish entering the slough. Trials occurred May ? to May ? 2011. In Winter Slough, a 1.2 m circular hoop net was attached within 5 m behind the tide gate culvert to capture fish attempting to enter into the slough through the tide gate. The wings covered the entire cross section of the slough. All hoop nets were set for one tidal cycle.

Juvenile Salmon Passage at Reference Sloughs

In 2011, a 1.2 m circular hoop net with 4.6 m wings was used to fish the mouth of Steamboat slough. Hoop nets were oriented to sample the incoming tide, in areas with sufficient water depth to submerge the trap (minimum 60 cm). The fish trap, including the wings, covered approximately fifty percent (by width) of the slough mouth. All hoop nets were set for one tidal cycle. Fish passage trials in the reference slough were conducted May ? to May ? 2011, concurrently with Winter Slough (described above).

Fish Community and Distribution

Beach seines (15 m x 1.8 m with 0.6 cm mesh) were the primary fish sampling method utilized during the 2011 field season. 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 while the boat was rowed in a circle back to the first deployed end of the seine. A minimum of five seine hauls were performed in each sample reach in 2011.

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.

Sorensen Similarity Index (SSI) was calculated from seining data collected 2007 through 2011. We used species captured within each slough (all reaches combined for each year) and compared treatment sloughs to reference or control sloughs. SSI's were calculated using:

SSI = 2*A/(B+C)

Where :

A = number of common species between the sloughs

B = the number of species in slough B

C = the number of species in slough C

SSI's were calculated for each treatment and reference/control pair. As an example, species collected from Winter and Steamboat sloughs in 2007 to calculate a SSI for pre condition treatment vs. reference condition. So, similarity was calculated between each treatment slough and each reference and control slough for each year that collections were conducted. We grouped treatment sloughs by pre-treatment conditions with "closed" sloughs and "gated" sloughs as different treatment groups (see Johnson et al 2009). Resulting SSI values were tested for significance using ANOVA with treatment (pre vs. post) as the factor (Table 1).

Table 1. Sorensen Similarity index were calculated using these comparisons:

Winter Hampson Indian Jack	Vs.	South Hunting Steamboat (reference)
Winter Hampson Indian Jack	Vs.	W259+50 (positive control)
Winter Hampson Indian Jack	Vs.	Ellison (negative control)
Duck Lake Brooks	Vs.	South Hunting Steamboat (reference)
Duck Lake Brooks	Vs.	W259+50 (positive control)
Duck Lake Brooks	Vs.	Ellison (negative control)

Habitat Characterization

Water temperature was recorded hourly in the lowest reach of each slough using Onset StowAway Tidbits. Recorders were deployed in April, 2011. Unfortunately, all of these loggers were lost likely due to theft or deterioration of mounting cables. Data presented here is data from previous years or data acquired form USACE loggers. Seven-day average daily maximums (7-DADM) were calculated from the temperature logger data. Seven-DADM levels were compared to threshold criteria above which juvenile salmonids exhibit sub-lethal effects (Richter and Kolmes 2005, EPA 2003). Daily temperature range (maximum – minimum daily temperature) was calculated for each slough. Median daily temperature range was compared between sloughs using Kruskal-Wallis ANOVA on ranks followed by Dunn's multiple comparison procedure.

Habitat surveys occurred during the sampling schedule described above. In 2011, habitat surveys were conducted twice within each reach in all sloughs between March 17 and June 23, 2011. Dissolved oxygen and conductivity were measured in each sample reach using an YSI meter. Mean slough DO% was calculated by averaging the point measurements from all slough reaches. Slough mean DO% was tested among sloughs for significance using ANOVA followed by Bonferroni multiple comparisons.

IV. RESULTS

A. JUVENILE SALMON PASSAGE

A total of 532 juvenile salmonids were captured during fish passage trials at Winter and Steamboat sloughs in 2011 (Appendix 1). Juvenile Chinook, coho and Chum salmon were captured entering both sloughs. As in 2010, juvenile Chinook salmon were captured entering both sloughs in all passage trials. Fourteen fish species were captured during 2011 fish passage trials. Nine of 12 fish species captured entering Steamboat slough were native, whereas eight of eleven were native in Winter slough.

The most abundant fish species in all trials were three-spine stickleback followed by juvenile Chinook salmon. This is matches data collected during fish passage trials in 2010. Unlike trial in 2010, no juvenile steelhead or western brook lamprey were captured during passage trials. One pacific lamprey juvenile was captured in 2011 (Steamboat). Juvenile Chinook salmon, peamouth and three-spine stickleback were captured in both sloughs, during each trial in 2010 and 2011. Eastern Banded Killifish was the most abundant non-native species captured in both 2010 and 2011 passage trials. Largemouth bass was the second most abundant non-native species captured in 2010 but were absent from captures in 2011.

B. Fish Community and Distribution

Three hundred thirty-five seine hauls were performed in 35 sample units between March 17 and June 23, 2011. A total of 5,710 fish representing 25 taxa were captured in five main land and two reference sloughs (Appendix 2**.** Seven of the eight (88%) species captured in reference sloughs Steamboat and South Hunting were native. Nine of sixteen (56%) species captured in Winter, Hampson and Indian Jack Sloughs (gated sloughs previously closed) were native. Five of eight (63%) species captured in Brooks and Duck Lake Sloughs (gated sloughs retrofitted with new gate design) were native. In Ellison, a slough that has remained closed at its historical mouth, six of fifteen (40%) species were native. Three-spine stickleback was the most prevalent species in all sloughs.

Juvenile salmon were captured throughout mainland JBHNWR. They were captured in every treatment, control and reference slough. Salmonid species captured include juvenile Chinook, coho, chum salmon and coastal cutthroat trout. Juvenile salmonids were capture in all sample reaches of treatment sloughs, Hampson, Indian Jack and Winter (previously closed) except the mid-reach of Indian Jack Slough. Juvenile salmon were captured in all reaches of treatment sloughs Brooks and Duck Lake (previously gated to new gates). This is similar to reference sloughs where juvenile salmonids were captured in all sample reaches. Juvenile salmon were also captured throughout W259+50 and W201+30. Interestingly, juvenile Chinook salmon were captured in three of the five sample reaches in the control slough Ellison (closed at historical connection to the Columbia River). Ellison, as with all other sloughs within the flood levee, is connected to adjacent sloughs through drainage channels.

Seine collections conducted in treatment sloughs before tide gate installation and retrofit, when compared to post construction collections, include fewer juvenile salmonids. Juvenile salmonids were captured in reaches post-construction where they were not captured pre-construction. In fact, there were no reaches where juvenile salmonids were captured pre-construction where they were not subsequently captured post construction. No salmon were captured in Hampson or Winter sloughs pre-construction but were captured in all reaches post-construction. No juvenile salmon were captured in Indian jack slough pre-construction but were captured in two of the three reaches in the one year of sampling post-construction. In Duck lake and Brooks slough, juvenile salmon were captured in reach one (nearest the tide gate) during pre-construction sampling, but have been captured in all reaches post- construction. There were two juvenile salmon captured in Ellison slough pre-construction, but have been captured in all sloughs between 2010 and 2011 collections.

Table 2: Number of sample reaches in treatment, control and reference sloughs where juvenile salmonids were captured during pre- or post-treatment collections.

Slough condition	Pre-treatment	Post-treatment
Treatment (n=16) [1]	2	15
+control (n=3) [2]	3	3
-control (n=5) [3]	2	5
Reference (n=4, 6) [4]	4	6

1. Includes previously closed and tide gated sloughs that received new style gates.
2. Positive control slough that was gated pre and post treatment that did not receive knew style gate (W259+50).
3. Negative control slough that remained closed at its historical connection to the Columbia River. This slough is connected to other Refuge sloughs through drainage canals.
4. Two reaches in Steamboat slough was not sampled pre treatment. Juvenile salmonids were collected from every reach that was sampled pre and post treatment.

There was significant SSI value increases post-construction (Table 2) in previously closed sloughs (Winter, Hampson and Indian Jack) when compared to reference sloughs (Steamboat and South Hunting; $p < 0.001$), and both positive (W259+50; $p = 0.014$) and negative control sloughs (Ellison; p = 0.018). There were no significant SSI value increases post-construction in previously gated treatment sloughs when compared to reference sloughs or either positive or negative control sloughs (Table3).

Table 3. Average pre and post treatment SSI of previously closed or gated treatment sloughs and reference, positive, or negative control sloughs. The asterisk marks significant changes between pre and post SSI values.

	Pre treatment	Post treatment
Closed vs.		
Reference*	.340	.673
Positive Control*	.417	.635
Negative Control*	.269	.640
Gated vs.		
Reference	.474	.638
Positive Control	.612	.556
Negative Control	.620	.571

C. Habitat Characterization

All USFWS temperature loggers were lost in 2011. Presented here is temperature data collected from USACE temp loggers installed in Winter, Hampson and Ellison sloughs. USACE loggers were not installed at either reference sloughs. Data was only available until April 22nd of 2011.

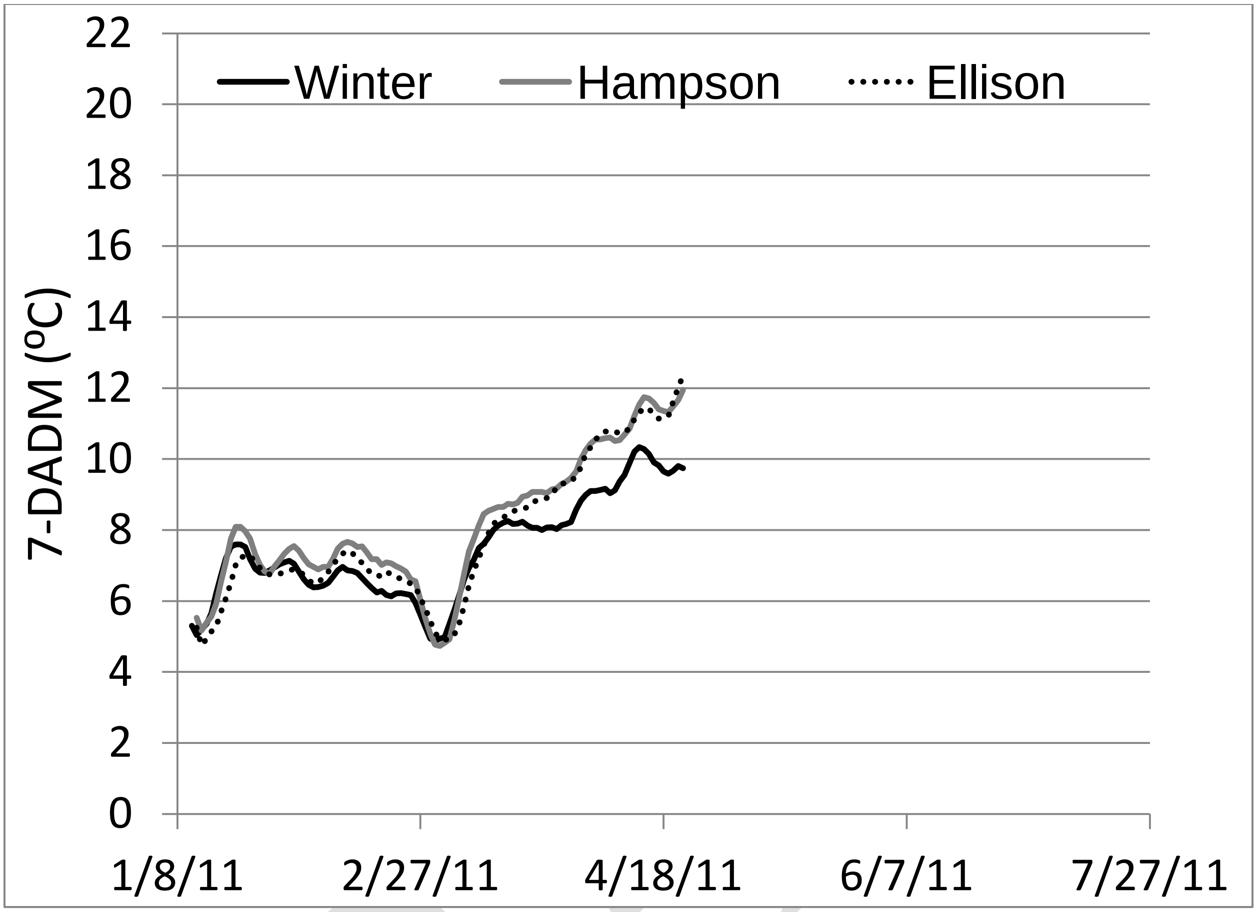

Figure 2: Seven-day average daily maximum water temperature (7-DADM) for lower most sampling reach within Winter and Hampson (treatment sloughs) and Ellison (control) slough, JBHNWR, 2011.

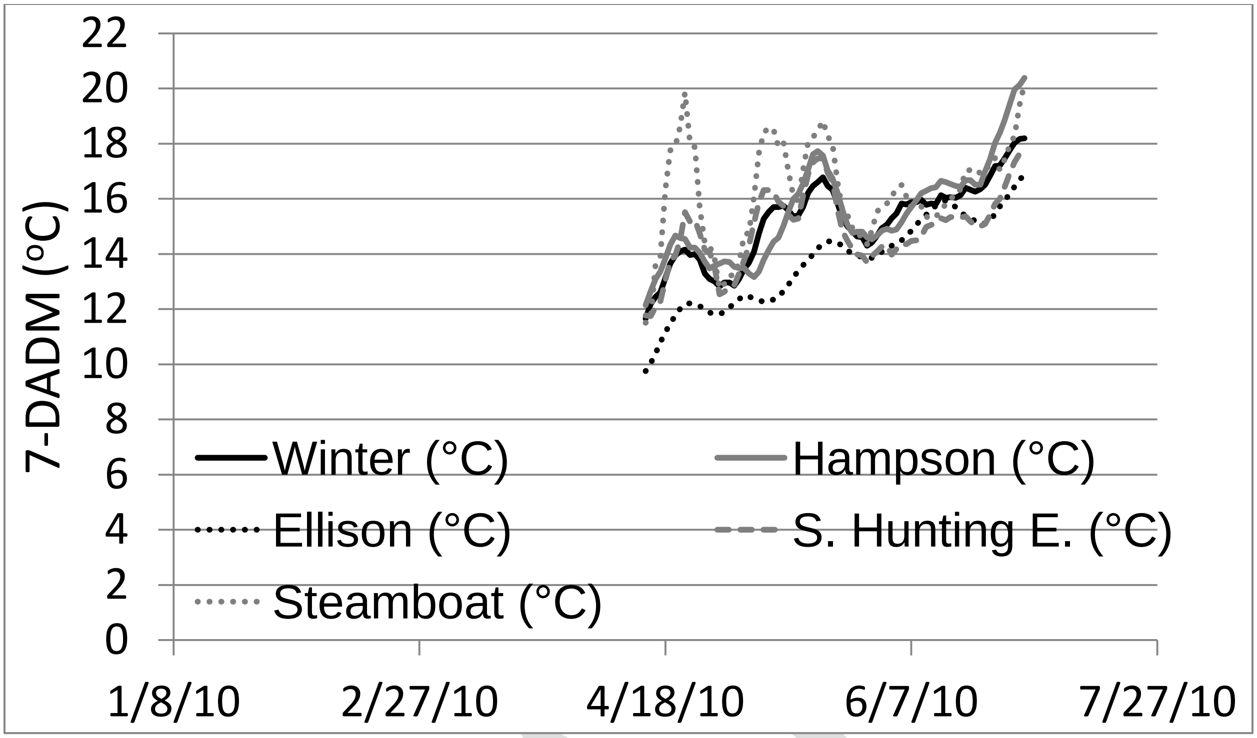

Figure 3: Seven-day average daily maximum water temperature (7-DADM) for lower most sampling reach within Winter, Hampson (treatment), Ellison (control), S. Hunting E. and Steamboat (reference) sloughs, JBHNWR, 2010.

Dissolved oxygen saturation ganged from an average of 44% in Duck Lake to 90% in Steamboat slough (Table 4). Dissolved oxygen concentration ranged from 5.9 mg/l in Duck Lake to 9.59 mg/l in Steamboat slough. There was not a significant difference in dissolved oxygen among individual sloughs. When slough types were grouped, dissolved oxygen concentration was significantly higher in reference sloughs (8.8 mg/l) when compared to treatment sloughs (6.7 mg/l, $p = 0.028$)

Table 4: Average and standard deviation of dissolved oxygen (DO) in Julia Butler Hansen NWR mainland and reference sloughs, 2011. Disloved oxygen is presented in percent saturation (%) and concentration (mg/l).

	Average DO(%)	SD DO(%)	Average DO(mg/l)	SD DO(mg/l)
DUCK LAKE	43.83	16.07	5.87	3.65
BROOKS	61.90	14.07	6.26	1.47
HAMPSON	66.46	14.91	6.77	1.48
ELLISON	70.94	29.82	6.98	2.72
W201+30	65.28	24.87	7.21	2.55
INDIAN JACK	72.42	9.37	7.27	0.74
WINTER	70.02	24.68	7.32	3.05
W259+50	55.95	26.03	7.96	5.28
HUNTING	65.22	34.86	8.01	4.28
STEAMBOAT	90.08	25.68	9.59	3.23

V. Conclusions and Recommendations

A. Summary of Findings

- Installation of self-regulating tide gates at Julia Butler Hansen NWR has allowed juvenile salmon increased access to JBH refuge sloughs.
- Juvenile salmon were captured in more treatment slough sample reaches after self-regulating tide gates were installed.
- The fish community in previously closed treatment sloughs showed increased similarity to reference and both positive and negative control sloughs after tide gate installation.
- Temperature in treatment sloughs Winter and Hampson did not exceed 16C seven day average daily maximum during data collection.
- Dissolved oxygen levels did not fall below critical levels in any slough sampled.

B. Limitations and Constraints

Our ability to witness changes in fish community and salmon densities are limited by the high variance among fish collections. Salmon numbers are relatively low in seine and trap collections. It is not uncommon to capture zero Chinook salmon in multiple seine pulls but then subsequently capture several. In addition, chum and coho salmon captures are rarer than Chinook salmon. It is logical that presence data is presented with high confidence and density data may have such high variance as to be unusable to witness the level of changes that may occur.

Inter annual and month to month variation in weather makes meaningful habitat comparisons difficult on the limited temporal scale of this study. As with salmon density, high inter annual variance makes witnessing meaningful changes difficult on the temporal scale of this study. Two years of pre data and two (at most) post data is not enough to have confidence in temperature or dissolved oxygen change conclusions.

Though we have found an increase in presence and distribution of juvenile salmonids in JBH refuge sloughs since tide gate retrofit, we do not know the survival rate or physical condition of these fish or the duration of rearing within the refuge sloughs. From other work at Tenasillahe Island (part of JBHNWR), we found that some juvenile Chinook salmon survive months (during summer) and with high growth rates within refuge sloughs even with high water temperatures (7-DADM >16C). Better information on summer use (duration, growth, prey availability) will allow us to understand juvenile salmon life history and habitat limitation here and throughout the CRE.

VI. References

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VII. Appendix 1 Fish species and number captured entering Winter and Steamboat Sloughs during passage trials.

STEAMBOAT	
3-SPINE STICKLEBACK	9523
CHINOOK SALMON	68
CHUM SALMON	1
COHO SALMON	1
COMMON CARP	2
E. BANDED KILLIFISH	4
LARGESCALE SUCKER	52

N. PIKE MINNOW	7
PACIFIC LAMPREY	1
PEAMOUTH	31
SCULPIN	2
WHITE CRAPPIE	1

WINTER

3-SPINE STICKLEBACK	7385
BLUEGILL	4
CHINOOK SALMON	433
CHUM SALMON	5
COHO SALMON	24
E. BANDED KILLIFISH	72
LARGESCALE SUCKER	4
N. PIKE MINNOW	87
PEAMOUTH	99
PUMPKINSEED	2
REDSIDE SHINER	1
SCULPIN	19

VIII. Appendix 2: Fish species and number captured in reference, control and treatment sloughs.

W259+50

3-SPINE STICKLEBACK	207
BLUEGILL	6
CHINOOK SALMON	2
COHO SALMON	8
CUTTHROAT TROUT	1
PEAMOUTH	1
PUMPKINSEED	1
SCULPIN	7

BROOKS

3-SPINE STICKLEBACK	127
BLUEGILL	4
CHINOOK SALMON	1
COHO SALMON	3
E. BANDED KILLIFISH	6
LARGEMOUTH BASS	2

DUCK LAKE

3-SPINE STICKLEBACK	418
CHINOOK SALMON	36

CHUM SALMON	1
COHO SALMON	11
E. BANDED KILLIFISH	1
PEAMOUTH	2
ELLISON	
3-SPINE STICKLEBACK	363
BLUEGILL	17
CHINOOK SALMON	4
COMMON CARP	1
E. BANDED KILLIFISH	18
GOLDFISH	1
LARGEMOUTH BASS	19
LARGESCALE SUCKER	1
N. PIKE MINNOW	3
PEAMOUTH	9
PUMPKINSEED	5
REDSIDE SHINER	4
WARMOUTH	2
WHITE CRAPPIE	1
YELLOW PERCH	6
HAMPSON	
3-SPINE STICKLEBACK	273
BLUEGILL	65
BROWN BULLHEAD	1
CHINOOK SALMON	7
COHO SALMON	3
COMMON CARP	1
CUTTHROAT TROUT	1
E. BANDED KILLIFISH	1
LARGEMOUTH BASS	2
N. PIKE MINNOW	1
PEAMOUTH	4
PUMPKINSEED	2
REDSIDE SHINER	3
SCULPIN	1
YELLOW PERCH	2
INDIAN JACK	
3-SPINE STICKLEBACK	129
CHINOOK SALMON	5
COHO SALMON	16
E. BANDED KILLIFISH	3
N. PIKE MINNOW	1
PEAMOUTH	1
SCULPIN	6
W201+30	
3-SPINE STICKLEBACK	464
BLUEGILL	39

CHINOOK SALMON	18
CHUM SALMON	1
COHO SALMON	22
E. BANDED KILLIFISH	10
LARGEMOUTH BASS	2
N. PIKE MINNOW	5
PEAMOUTH	4
PUMPKINSEED	12
REDSIDE SHINER	2
SCULPIN	2

SOUTH HUNTING EAST

3-SPINE STICKLEBACK	618
CHINOOK SALMON	48
CHUM SALMON	3
COHO SALMON	2
E. BANDED KILLIFISH	1
N. PIKE MINNOW	1
PEAMOUTH	1
SCULPIN	3

STEAMBOAT

3-SPINE STICKLEBACK	983
CHINOOK SALMON	17
COHO SALMON	2
E. BANDED KILLIFISH	1
SCULPIN	1

WINTER

3-SPINE STICKLEBACK	1481
CHINOOK SALMON	104
CHUM SALMON	1
COHO SALMON	6
E. BANDED KILLIFISH	11
N. PIKE MINNOW	4
PEAMOUTH	4
SHRIMP	1