Leque
3rd-year Post-Restoration
Tidal Marsh Fish Monitoring Report

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Oblique view of the Leque restoration site. Photo courtesy of Loren Brokaw, WDFW.

Summary

This technical memorandum summarizes the monitoring activities from February to September 2022, under WDFW contract number 21-18843. This includes Leque Island and surrounding areas but excludes the separate project in North Leque Island. Fish capture, (Henrichs et al 2021), study design rational and water level, vegetation, and channel monitoring methods (Henrichs et al 2020) have already been previously described. As such, in this technical memo, we focus on results from the 2022 monitoring season. After a brief description of data analysis methods, this technical report summarizes the second year of post-project monitoring of fish use and water parameters in the restoration area and associated reference areas as well as vegetation and channel development monitoring.

Methods

For the purposes of describing our 2022 results, we aggregated our data into groups based on hypotheses formed in the Leque Island Monitoring and Adaptive Management Plan (Henrichs et al 2020). A Before-After-Control-Impact (BACI) (Underwood, 1994) study design was proposed to evaluate potential impacts of the restoration actions. With respect to fish and water data, observations were grouped into two strata to facilitate comparison. The first stratum contains sites within the restoration area in constructed channels of the restoration project (Restoration). The second stratum contains sites immediately surrounding Leque Island that experience similar biological and physical conditions as the restoration area (Reference).

Water Level and Water Level Monitoring

Four level loggers were deployed in and around Leque Island for the 2022 monitoring season, two in the restoration site and two in nearby reference sites (Table 1). These loggers logged over the period of salmon outmigration from February to August and provided a continuous record on a 15-minute timestep of salinity, temperature, and geo-referenced Water Surface Elevations (WSE) in a common vertical datum (NAVD88 (cm)). Methods for level logger deployment are detailed in the Leque Island Monitoring and Adaptive Management Plan (Henrichs et al 2020).

Table 1. Name, location, and logging duration of the four level loggers.

Name	Latitude	Longitude	Strata	Duration
Davis Slough	48.24010000	-122.3948100	Reference	Feb 5th to August 22nd
Leque 2	48.23154478	-122.3862186	Restoration	Feb 5th to August 22nd
Leque 1	48.23031710	-122.3835056	Restoration	Feb 5th to August 22nd
West Pass Blind	48.24121728	-122.3853097	Reference	Feb 5th to August 22nd

Continuous water level loggers directly measured the water level above a pressure sensor. We knew when a level logger is no longer covered by water and could more accurately represent water conditions by determining when a logger was wet and when a logger was dry. We filtered level logger data to include only a wetted state so summary statistics only include parameters when the sensors are fully submerged. Once the logger state (wet vs. dry) was known, we aggregated and visually examined our level logger results by month and strata to determine if

there were any differences in tidal inundation, temperature or salinity between the two strata. We also recorded spot measurements using a YSI ProSolo at each seine set as well as a depth measurement. Water temperature (^{o}C), dissolved oxygen (mg/L) and salinity (PSU) were recorded at the top and bottom of the water column before the seine was deployed. Top and bottom spot measurements were averaged and then aggregated and visually examined across month and strata to determine if there were differences in water quality between the two strata.

Fish Catch and Fish Density

For all species, we report raw catch totals to represent species richness and relative differences in quantities of each fish species encountered. Estuarine systems can encompass both fresh water and marine fishes. Many of these fishes are euryhaline and can occupy a large salinity gradient. We aggregate species by groupings of marine and freshwater, with salmon being distinctly salmon, as described by Wydoski and Witney (2003) and Piestch and Orr (2015).

For each seine set, the number of fish caught was divided by set area to established catch per unit effort (CPUE) for each sampling location. Set area for the small beach seine was calculated by multiplying the average area of a small beach seine (96 m^2) by the total percentage of the net deployed. For example, if the end of the net was not returned to the beach but instead had to be towed in by the wader/boat, the amount of the net deployed was estimated to be above 100 percent. From these site specific CPUE estimates, we expanded to report fish per hectare by multiplying CPUE in m2 by 10,000 to get CPUE in hectares (# fish per hectare).

Fyke net catches were summed over the entire daily set that encompassed most of the ebb tide and divided by the amount of time that the net was fishing. For the 2022 monitoring season there was a single fyke trapping site so catch and CPUE (# fish/hr) are presented. For seine sets, we aggregated our results by channel and strata and then compared the mean and standard error of the resulting densities To compare salmon densities between restoration and reference locations, we provided initial comparisons of densities between similar gear types since fyke trap recapture efficiency estimates and wetted area calculations are still being developed.

Results

Hypothesis 1: Tidal fluctuations inside the restoration site will be similar to those in reference marshes.

Hypothesis 1 is supported with data from four continuous water level loggers in the two strata.

The four level loggers were wetted for 56,790 of 77,727 records (73.1%). Water Surface Elevations (WSE) were similar between reference and restoration sites (Fig. 1) for the monitoring period, except that Leque 2 lacked the lower 95% CI because the mouth of the channel had a large impoundment that kept the channel from completely draining throughout the tidal cycle. While the upper limits of tidal inundation were similar across all sites, Leque 2 was muted on the lower edge of the tidal cycle.

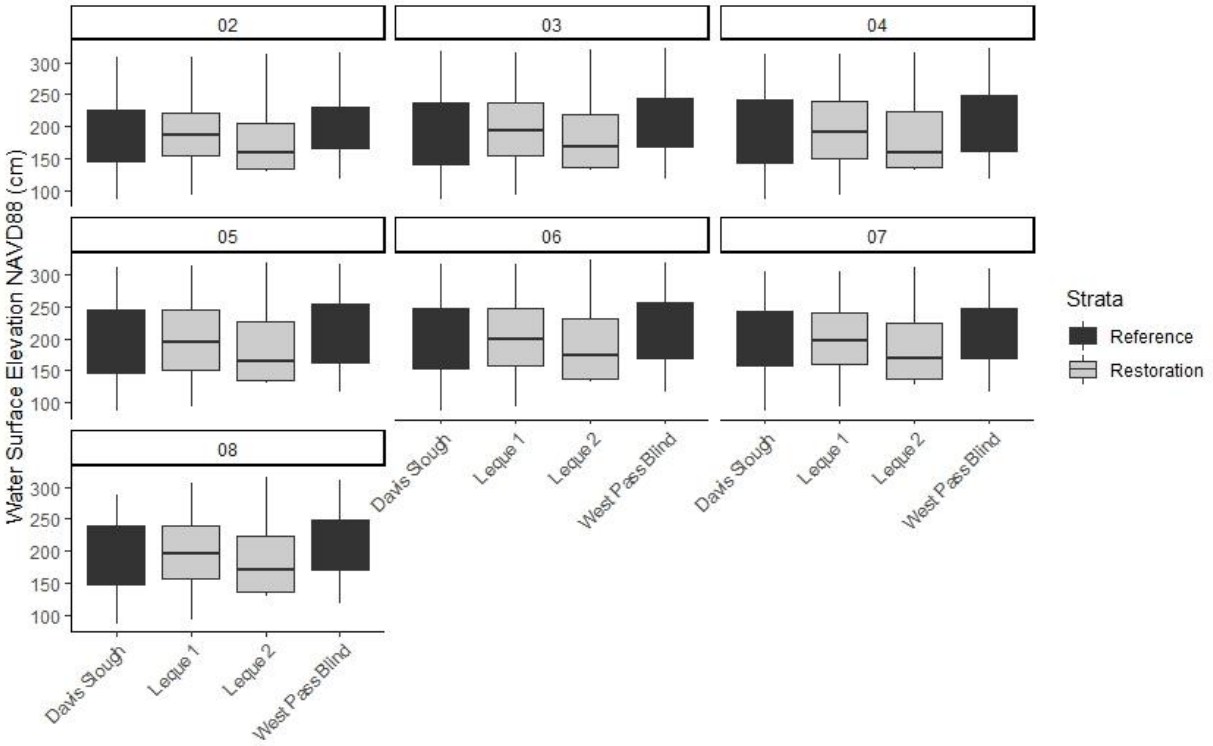

Figure 1. Boxplots of Water Surface Elevation (cm, NAVD88) by each month (2= February, 8=August) over the 2022 monitoring period. Central line of the box represents the median, the shaded box represents the inter-quartile range (25%-75%) and the whiskers represent the 95% Confidence Interval. Dots are outliers of the 95% distribution.

Hypothesis 2: Dissolved oxygen (DO), salinity and water temperature within the restoration site will be comparable to the of nearby reference marshes.

Hypothesis 2 is supported with level logger data and spot measurements at beach seine sites.

Level logger data showed similarity in water temperature between reference and restoration locations throughout the monitoring period (Fig. 2). Salinity was similar across both strata from February to June but trended higher in the restoration channel sites in July and August (Fig. 3). The restoration site level loggers directly face Port Susan Bay and are influenced by marine water. The reference level logger sites directly face the South Fork of the Skagit River and are more influenced by freshwater from the South Fork of the Skagit River.

There were 263 spot measurements of depth and water quality. Salinity and temperature showed similar trends and magnitudes over the monitoring period (Figure 4a and 4b). DO was similar across strata except for June and July, where Restoration sites trended lower then then Reference sites (Figure 4c). Reference sites generally had greater variability in depth and greater depth then Restoration sites (Figure 4d). This shift is due to sampling constraints. Restoration sites have a narrow tidal window (6.5 ft – 9 ft MLLW) where they can be effectively sampled while Reference sites could be sampled over a wider range of tidal heights. Despite suggestive trends, all confidence intervals overlap indicating a lack of statistical support for aforementioned trends.

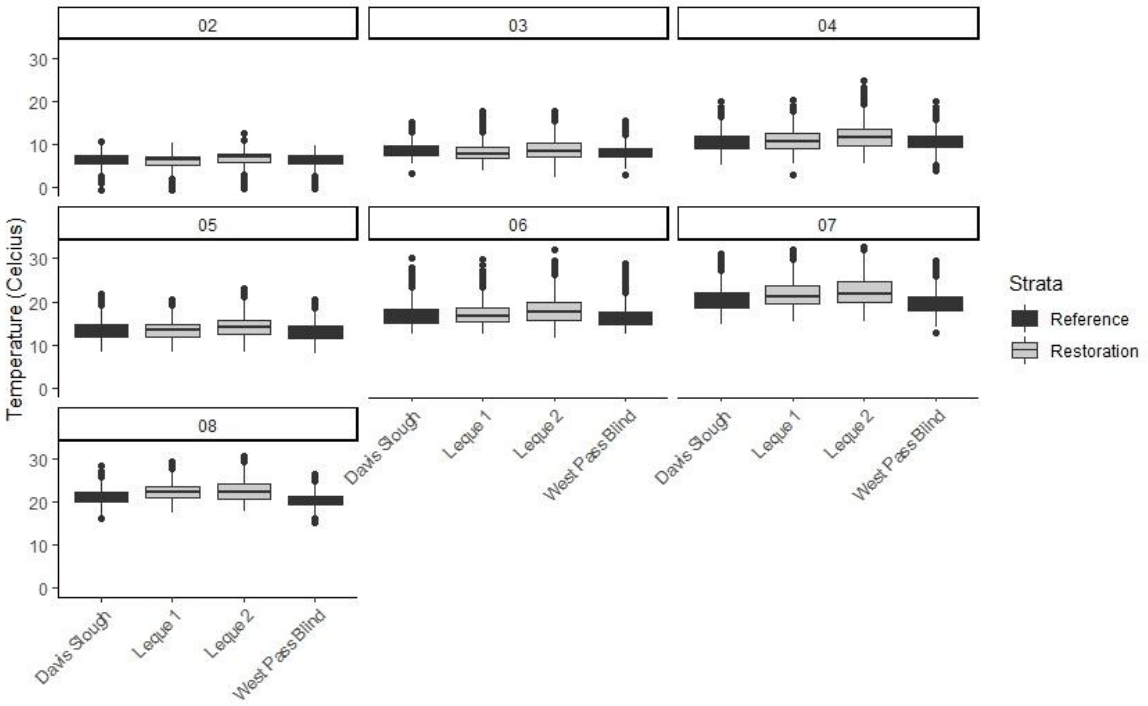

Figure 2. Boxplots of temperature (° C) by month (2= February, 8=August) over the 2022 monitoring period. Central line of the box represents the median, the shaded box represents the inter-quartile range (25%-75%) and the whiskers represent the 95% Confidence Interval. Dots are outliers of the 95% distribution.

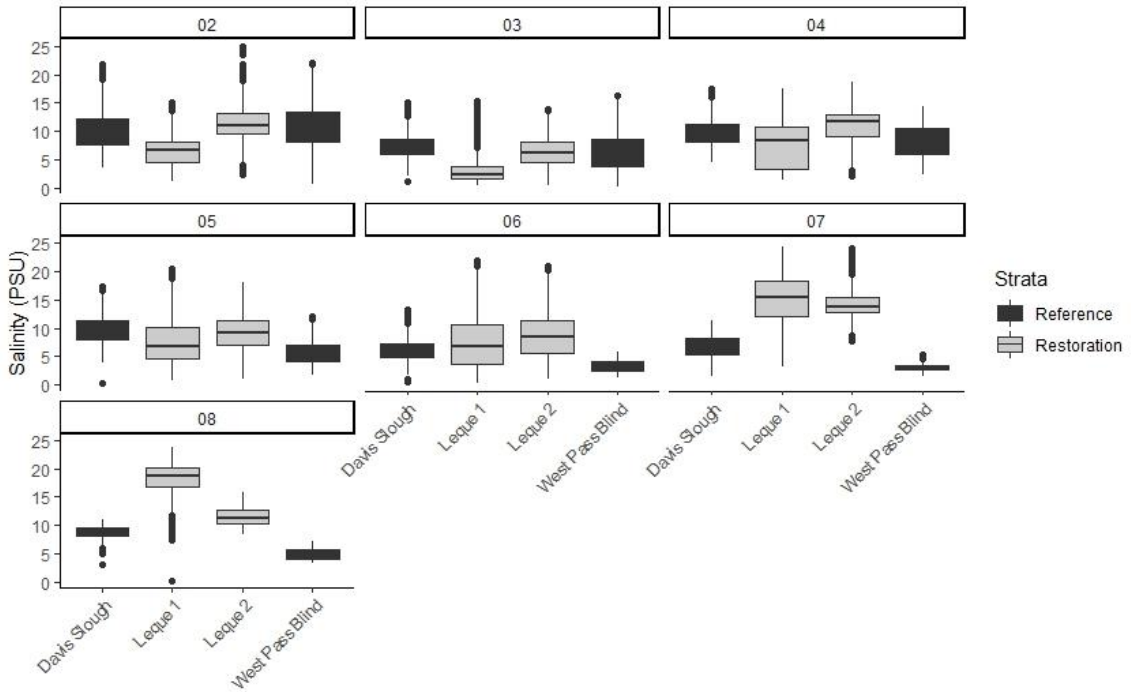

Figure 3. Boxplots of Salinity (PSU) by month (2= February, 8=August) over the 2022 monitoring period. Central line of the box represents the median, the shaded box represents the inter-quartile range (25%-75%) and the whiskers represent the 95% Confidence Interval. Dots are outliers of the 95% distribution.

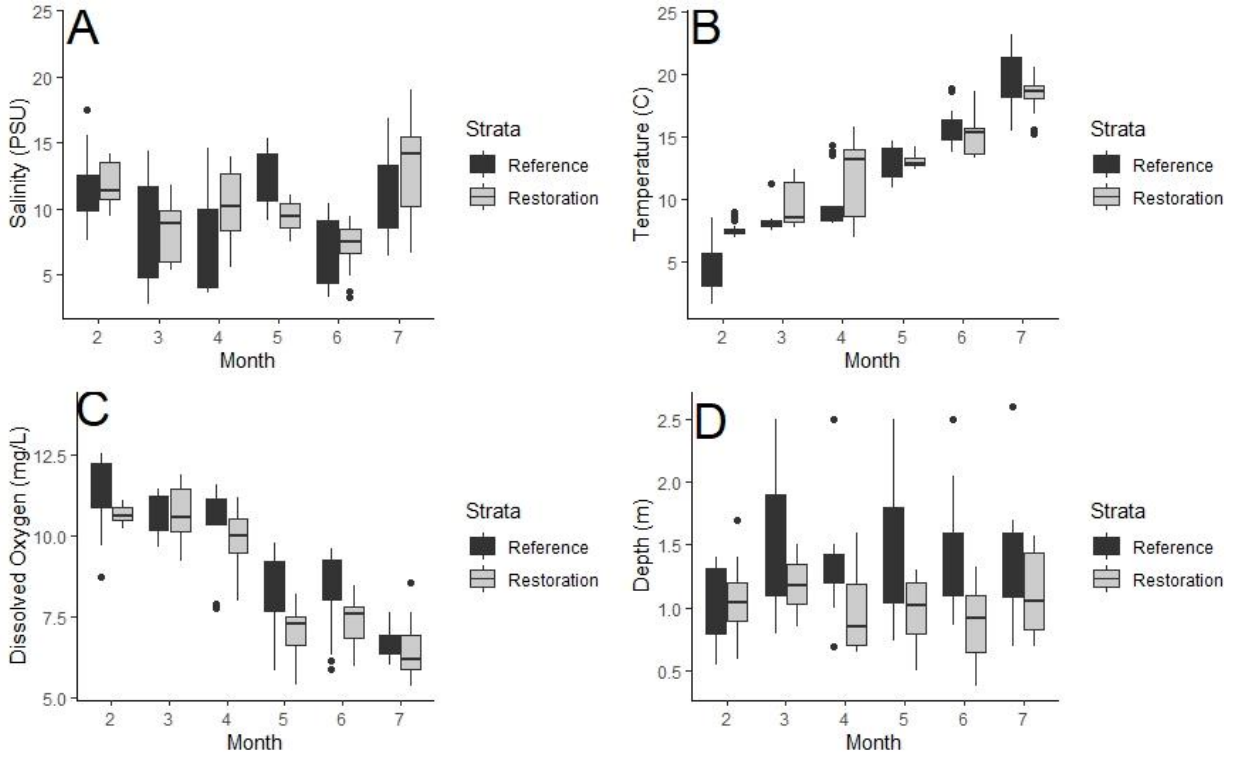

Figure 4. Boxplots of spot measures of salinity (Panel A), temperature (Panel B), dissolved oxygen (Panel C), and water depth (Panel D) at fish monitoring locations aggregated by Reference sites and Restoration (i.e. Treatment) sites for each numeric month (e.g. 2 = February, 7 = July). Central line of the box represents the median, the shaded box represents the inter-quartile range (25%-75%) and the whiskers represent the 95% Confidence Interval. Dots are outliers of the 95% distribution.

Hypothesis 6: Estuarine fish assemblages and juvenile Chinook salmon densities within the restoration site will be comparable to that of nearby reference marshes and similar inside and outside the site. Both Skagit River and Stillaguamish River salmon populations will be detected within the restoration site.

Hypothesis 6 is supported by data collected during fish monitoring.

We sampled five reference locations and four treatment channel networks within the Leque Island restoration area during 2022. In 2022, we completed a total of 261 small beach seines and 11 fyke trapping events. Table 2 summarizes the monitoring effort by strata and month. We made 128 small beach seine sets and 11 fyke trap sets in the Reference Strata and 133 beach seine sets in the Restoration strata. Not all planned sampling events took place due tidal constraints and Covid protocols. For example, during the month of June, we were unable to access Leque 3 due to insufficient tidal height and in April the crew lead was unable to work due to SRSC Covid protocols. Additionally, the last sampling events in August were canceled due to the lack of salmon catches. While there was less effort than planned, actual effort was similar to 2019 pre-restoration monitoring (Henrichs et al 2021).

Table 2. Number of beach seine and fyke sets by month and strata in the Leque Island area.

	Reference		Restoration
Month	**Small beach seine**	**Fyke Trap**	**Small beach seine**
February	11	1	21
March	27	2	28
April	15	1	22
May	21	2	12
June	30	3	17
July	24	2	24
August	0	0	9
Total	128	11	133

We caught 9,558 individual fish across both strata (Tables 3-5), including American Shad, juvenile Pink Salmon, juvenile Chum Salmon, juvenile Coho Salmon, juvenile HOR Chinook Salmon, juvenile NOR Chinook Salmon, Pacific Herring, Surf Smelt, Prickly Sculpin, Pacific Staghorn Sculpin, Peamouth, Threespine Stickleback, Arrow Goby, Shiner Perch, Snake Prickleback, English Sole, Starry Flounder. Of the species present, juvenile Chinook Salmon and juvenile Coho Salmon had natural origin (NOR) and hatchery origin (HOR) individuals. Species richness was similar across strata (Fig. 5a) and similar across months (Fig. 5b).

Table 3. Total fish catch within the Restoration strata for the 2022 monitoring season. DSIT=Davis Slough Inside Tidegate, L1= Leque 1, L2= Leque 2, L3= Leque 3.

Group	Species	DSIT	L1	L2	L3	Species Total
Salmon	Pink Salmon (sub yearling	11	1	5	1	18
	Chum Salmon (sub yearling)	12	12	32	11	67
	Coho Salmon (sub yearling)	10	5	10	1	26
	HOR Chinook Salmon (marked)	0	1	2	1	4
	NOR Chinook Salmon (unmarked)	7	10	14	3	34
	Dolly Varden/Bull Trout	0	1	0	0	1
Marine Forage Fish	Pacific Herring	0	13	665	4	682
	Surf Smelt	1	34	252	160	447
Freshwater Sculpin	Prickly Sculpin	6	1	1	0	8
Marine Sculpin	Pacific Staghorn Sculpin	281	115	47	24	467
Freshwater Minnow	Peamouth	20	197	24	1	242
Common Nearshore/estuarine	Threespine Stickleback	587	350	77	306	1,320
	Arrow Goby	1	7	0	1	9
	Snake Prickleback	0	1	0	0	1
	Shiner Perch	583	144	824	74	1,625
Marine Flatfish	Starry Flounder	203	78	58	48	387
Non-native	American Shad	0	0	1	0	1
	Grand Total	1,722	970	2,012	635	5,339

Table 4. Total fish catch within the Reference strata for the 2022 monitoring season.

Group	Species	Davis Slough	Grand Junction	South Pass	West Pass	Species Total
Salmon	Pink Salmon	5	2	6	1	14
	Chum Salmon	6	1	6	2	15
	Coho Salmon	26	0	6	3	35
	HOR Chinook Salmon	0	0	1	5	6
	NOR Chinook Salmon	4	9	4	3	20
Marine Forage Fish	Pacific Herring	4	4	1	12	21
	Surf Smelt	7	105	201	164	477
Freshwater Sculpin	Prickly Sculpin	2	0	0	0	2
Marine Sculpin	Pacific Staghorn Sculpin	62	23	8	48	141
Freshwater Minnow	Peamouth	29	6	3	288	326
Common estuarine/nearshore	Threespine Stickleback	442	24	41	290	797
	Arrow Goby	1	1	2	3	7
	Shiner Perch	346	23	54	702	1,125
Marine Flatfish	English Sole	0	0	2	1	3
	Starry Flounder	23	26	29	44	122
	Grand Total	957	224	364	1,566	3,111

Table 5. Total fish catch for West Pass Blind Channel fyke trapping site for the 2022 monitoring season. Mean CPUE (fish/hr) and standard error (SE) in parentheses are also presented.

Group	Species	West Pass Blind Channel	Mean CPUE and SE
Salmon	Pink Salmon	4	0.12 (0.05)
	Chum Salmon	38	1.40 (1.21)
	Coho Salmon	5	0.15 (0.08)
	HOR Chinook Salmon	10	0.26 (0.22)
	NOR Chinook Salmon	11	0.33 (0.11)
Freshwater sucker	Largescale Sucker	2	0.07 (0.07)
Forage Fish	Pacific Herring	4	0.12 (0.08)
	Surf Smelt	41	1.03 (0.96)
Freshwater Sculpin	Prickly Sculpin	1	0.03 (0.03)
Marine Sculpin	Pacific Staghorn Sculpin	45	1.35 (0.35)
Freshwater Minnow	Peamouth	170	5.02 (3.04)
Common Nearshore/Estuarine	Threespine Stickleback	339	10.12 (3.97)
	Arrow Goby	1	0.03 (0.03)
	Shiner Perch	433	11.7 (3.97)
Marine Flatfish	Starry Flounder	4	0.13 (0.09)
	Grand Total	1,108	

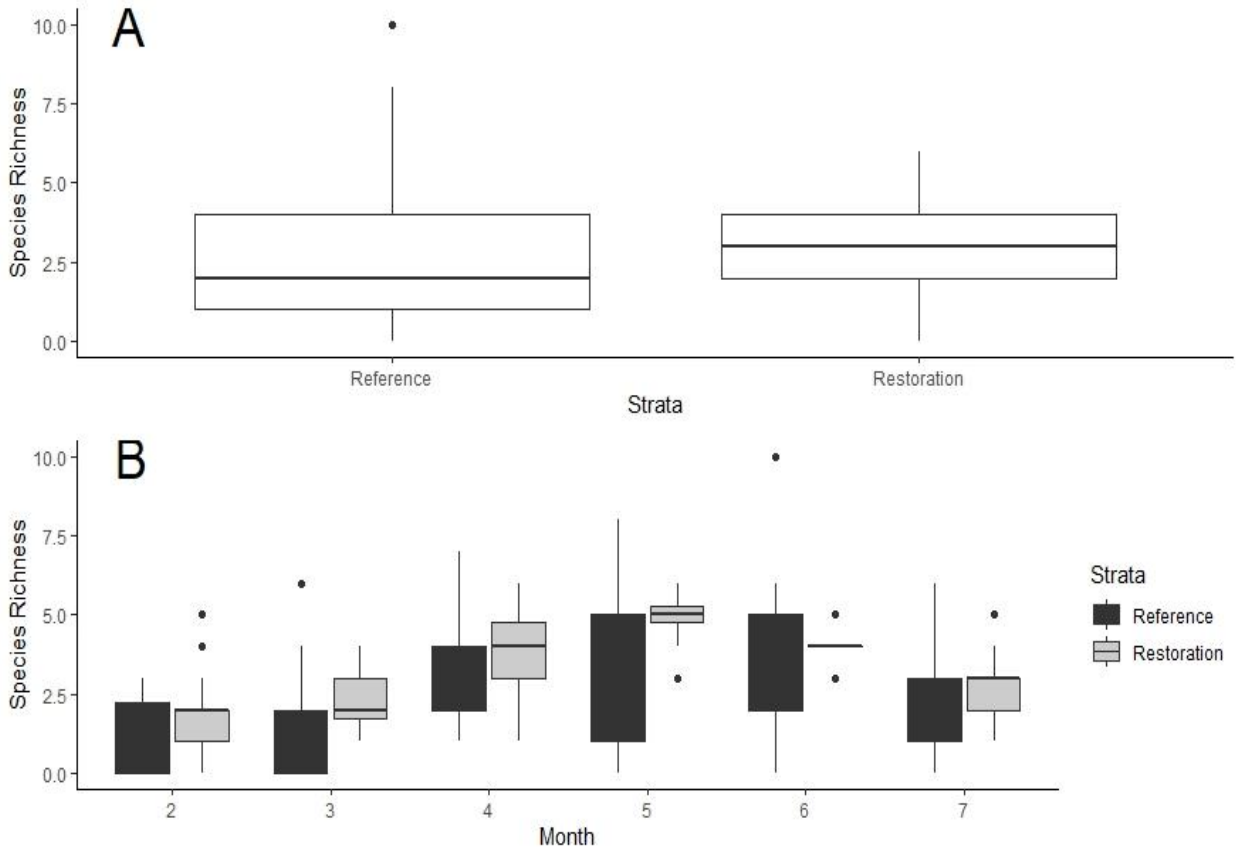

Figure 5. Boxplots of species richness by A) strata and B) numeric month (e.g. 2=February, 7= July) for the Restoration and Reference strata. Central line of the box represents the median, the shaded box represents the inter-quartile range (25%-75%) and the whiskers represent the 95% Confidence Interval. Dots are outliers of the 95% distribution.

For small beach seine sets over the entire monitoring period, mean densities of juvenile chum salmon were higher in the restoration area, while mean densities of juvenile coho salmon were higher in reference areas. Mean densities of juvenile pink salmon and juvenile NOR Chinook salmon were similar in restoration and reference areas (Table 6). There was only a single Dolly Varden/bull trout caught.

We captured 65 NOR juvenile Chinook salmon across all strata in 2022 (restoration= 34, reference= 31). This is compared to the 78 NOR juvenile Chinook Salmon that we caught in 2021 (LeMoine 2021). This represents a 26.7% reduction in catch. We see this reduction reflected in the fact that no NOR juvenile Chinook were caught in the restoration area after week 20 (i.e May 20th) (Fig. 6). The restoration strata had a lower relative, but consistent, density of fish for 4-6 weeks, while the reference sites show transitory peaks. December 2021 saw historic floods in the Skagit and Stillaguamish Rivers, so the outmigration and delta rearing by NOR juvenile Chinook salmon from both rivers was at low levels (Griffiths, personal communication, LeMoine, personal communication). These mitigating factors make any inference about NOR juvenile Chinook salmon use of Leque Island difficult.

Table 6. Mean and standard error (SE) of catch per unit effort (CPUE) in # of fish/ hectare for beach seine sites in the two monitored strata. Each species was grouped by site and then averaged over the year. PK0+= sub yearling Pink Salmon, CH 0+= sub yearling Chum Salmon subyearling, CO 0+ = sub yearling Coho Salmon, CK 0+ HOR = sub yearling Chinook Salmon hatchery origin, CK 0+ NOR = sub yearling Chinook Salmon natural origin, DV/BT = Dolly Varden/ Bull Trout.

Site	Strata	PK 0+	CH 0+	CO 0+	CK 0+ NOR	CK0+ HOR	DV/BT
DSIT	Restoration	39.8 (24.9)	41.7 (26.2)	34.7 (15.3)	25.2 (9.9)	0 (0)	0 (0)
Leque 1		2.9 (2.9)	34.7 (14.9)	14.5 (9.4)	28.9 (10.7)	2.9 (2.9)	2.9 (2.9)
Leque 2		10.6 (7.0)	69.2 (28.5)	21.3 (11.4)	30.9 (13.5)	4.3 (4.3)	0 (0)
Leque 3		5.8 (5.8)	63.7 (37.8)	5.8 (5.8)	17.4 (9.4)	6.4 (6.4)	0 (0)
Grand Junction	Reference	7.2 (5.0)	3.6 (3.6)	0 (0)	32.3 (22.0)	0 (0)	0 (0)
Davis Slough		17.4(11.3)	20.8 (11.6)	90.3 (30.7)	13.9 (6.6)	0 (0)	0 (0)
South Pass		17.8 (13.0)	18.9 (16.0)	18.9 (10.6)	12.6 (6.0)	3.2 (3.2)	0 (0)
West Pass		2.9 (2.9)	6.8 (4.8)	8.7 (4.9)	8.9 (6.4)	14.5 (7.4)	0 (0)

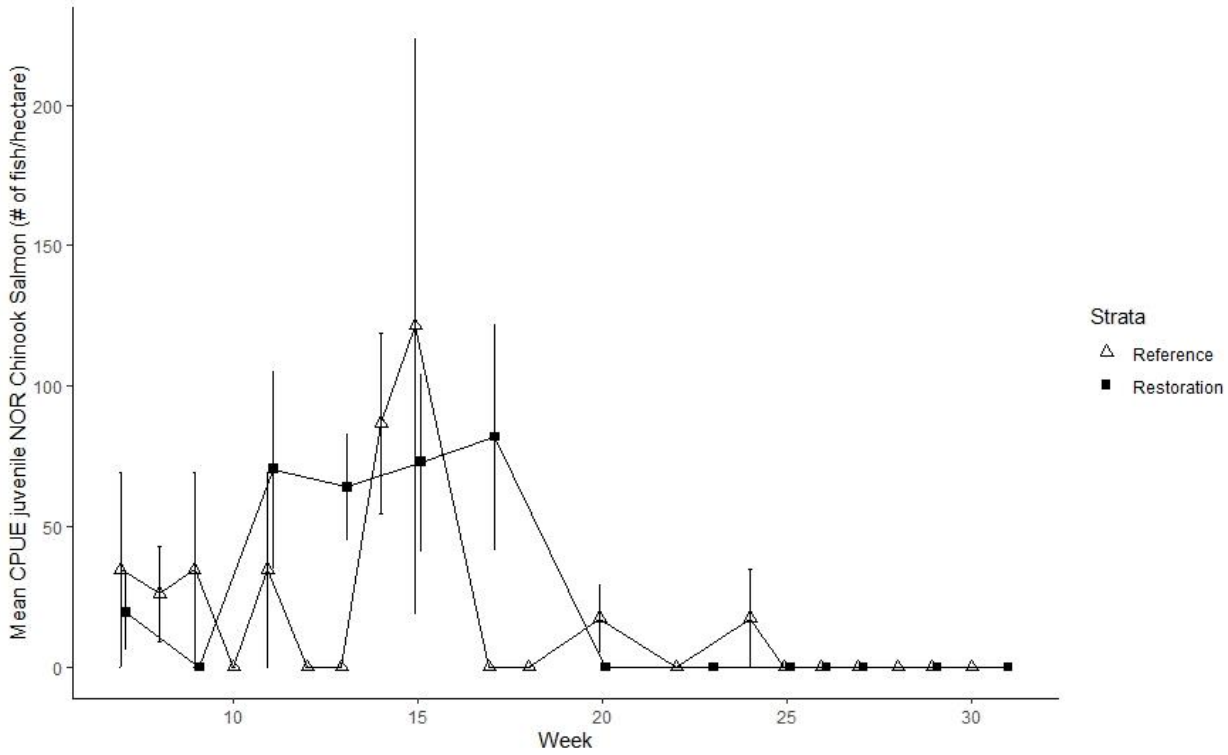

Figure 6. Mean and standard error (SE) of juvenile NOR Chinook Salmon (CPUE = # of fish/hectare) over weeks 7 through 32 in the Restoration and Reference strata.

Hypothesis 7: Juvenile Chinook Salmon utilizing Leque Island restoration area originated from Stillaguamish River and Skagit river and are similar to reference sites.

Hypothesis 7 is still undetermined but is in the process of being evaluated.

Funding has been secured to evaluate genetic samples taken in 2021 and 2022 in the zis a ba and Leuqe restoration areas from a parallel project. Results have been submitted to the WDFW genetics laboratory and are in the process of being evaluated.

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