

**Benthic and epibenthic invertebrate community two years after dike
breach, in restored salt marsh on Fir Island, Skagit delta,
Washington State**

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Abstract

The listing of Chinook salmon (*Oncorhynchus tshawytscha*) as a threatened species prompted the restoration of estuaries in the Pacific Northwest, including the Snow Goose Reserve in the Skagit River delta, Washington. The 2015 restoration consisted of a dike setback and the conversion of 93.5 hectares of farmland back to original salt marshes. Here I investigate the success of the restoration through the examination of the benthic and epibenthic invertebrate community. The results of this study show a 1626% increase in the number of organisms from 2017 to 2018. The family Enchytraeidae constitutes 66% of the individuals identified in 2018, mostly present in the adjacent site. The results of the study also reveal low numbers of chironomids and other diptera, and crustaceans compared to other estuarine studies from the region. The next most abundant taxa, and probably the highest biomass, were Nereidae and Ampharetidae which had about the same number of individuals on the restored site and on the adjacent site. The study also discovered the presence of the invasive New Zealand mud snail (*Potamopyrgus antipodamus*) in 2018.

Key words

Salt marsh restoration; salt marsh succession; benthic and epibenthic invertebrates; dike removal; Chinook recovery.

Introduction

Historically, human development has flourished on the coasts of waterbodies and around estuaries because of the ease of fluvial transport, the nutrient-rich soils, and the availability of recreation and other ecosystem services (Barbier, 2016). To protect human infrastructures against wave action, flooding and storms, and to farm periodically flooded land, communities have constructed shoreline armoring along most of the available coasts with detrimental consequences (Lee et al., 2018). Tidal restrictions such as dikes, drainage ditches and sea walls, eliminate the inflow of sediments, affect the abundance and diversity of most species, alter the food web, and often result in increased shoreline erosion and decreased water quality (Roman & Burdick, 2012; Barbier 2016). Historically, half of the Skagit delta was comprised of tidal marsh, fresh-water marsh, or open channels. 73% of the historical tidal marsh habitat has been lost since the 1800s. This loss was driven by urbanization, the transformation of delta lands into farmlands using armoring structures, and the logging and draining of the soils (Collins et.al., 2003; Friebe, 2018).

In recent decades, tidal wetland restoration has been motivated around the world by the will to regain ecosystem services provided by nearshore ecosystems, including biodiversity, water quality, and protection from erosion, flood and sea level rise. With the acceleration of climate change and sea level rise, natural salt marshes can help protect shorelines through sediment accretion (Weinstein & Kreeger, 2000), and help attenuate and reduce the height of storm surge (Barbier, 2016). In the Pacific Northwest, an important motivation for tidal wetland and estuarine restoration consists in the rehabilitation of habitat for salmonid species (Lee et al. 2018). Salt marshes provide food such as invertebrates and small fish, nursing grounds, and shelter for many species of fish, birds and mammals (Mann, 2000). They support the fastest growth of salmon of all types of estuarine habitats. Out of the six salmon species in the Pacific Northwest, Chinook salmon (*Oncorhynchus tshawytscha*), are the most dependent on estuaries in their life cycles, using coastal marshes for rearing and transitioning into saltwater habitat through smoltification (Furlong, 2017). The historical reduction in the area occupied by salt marshes has greatly affected the survival rate of juvenile Chinook salmon (Beamer et al., 2005b) and has prompted the listing of the species under the Endangered Species Act (Beamer et al., 2005a). The listing of Chinook salmon as a threatened species brought forth The Skagit Chinook Recovery Plan (Beamer et al., 2005a), which states that the recovery of the species should start with the salt marsh restorations of Fir Island and the Swinomish Channel, and include the removal of dikes and setbacks and the reestablishment of migration corridors (Furlong, 2017).

The success of a restoration of a tidal marsh can be evaluated by the presence and abundance of the biota on site (Staszak & Armitage, 2013). Macroinvertebrates are an important food source not only for salmon but also for other nekton, birds and epifauna. Simenstad and Cordell (2000) studied the stomach content of chinook salmon in several Pacific Northwest estuaries and found that the dominant preys of the salmonid were benthic and epibenthic organisms. Macroinvertebrates are also at the base of the detrital food web and link primary production to higher trophic levels (Mann, 2000). The type and abundance of benthic and epibenthic organisms can help determine how well and how fast the land is returning to a functioning ecosystem (Staszak & Armitage, 2013).

The colonization of invertebrates may take a very long time. According to Ferguson and Rakocinski (2008), and Moseman et al. (2004), it can take more than 25 years for the invertebrate community to recover after restoration of a salt marsh. The recovery is dependent on the soil and flora development,

the amount of detritus available, and the predation and competition interactions, although the invasion of exotic species may alter the succession patterns (Simenstad & Cordell, 2000).

Studies concerned by benthic and epibenthic invertebrate communities in restored tidal marshes have not been carried out in the Skagit delta. On the West coast of the US a few studies stand out. The work of Gray (2011) on benthic invertebrates of tidal wetlands in Oregon was designed to help researchers understand the relationship between habitat drivers (elevation, inundation regime, salinity, groundwater level) and physical and biological characteristics (soil characteristics, vegetation cover, woody stem density and basal area, and invertebrate assemblages) on restored sites. Howe et al. (2014) studied the interior marsh of San Francisco Bay. Moseman et al. (2004) examined the Tijuana Estuary in California. Gray et al. (2002) surveyed the Salmon River Estuary in Oregon. Each of these ecosystems is unique due to its latitude, geomorphology and location within the larger landscape; therefore, different communities should live in the Skagit Delta, and perhaps different succession processes.

A few macroinvertebrate studies have been carried out in the vicinity of the Skagit delta. Cordell et al. (1998) conducted a post-dike breach study of the macroinvertebrate community in a tidal brackish wetland on Spencer Island, in the Snohomish River estuary. Their research was motivated by the investigation of the availability of sufficient prey species for salmonids. The authors found a dominance of tolerant taxa, probably because the restoration was in its early stage. Lee et al. (2018) examined the effects of armoring removal in six Puget Sound sites. They found a strong response of macroinvertebrate recovery in all sites; though initially slow during the first three to four years, peak diversity seemed to be reached after eight years in the region. The authors warn that the process may take longer depending on the sediment deposition rate, grain size and beach profile.

The Fir Island Estuary restoration project on the Washington Department of Fish and Wildlife Snow Goose Reserve was initiated to restore tidal processes, allowing water, sediment, and nutrients to re-enter the marsh, and to reestablish wildlife habitat (Friebel, 2018). This study focused on the re-establishment of benthic and epibenthic invertebrate communities on the Fir Island site as an index of successful restoration. It had two objectives. The first was to estimate the success of the restoration process by evaluating the diversity and richness of the benthic and epibenthic invertebrate community. The second objective was to report the re-colonization succession of benthic and epibenthic communities specific to the Skagit delta ecosystem. Two years after the breaching of the dike on the Snow Goose Reservation, I expected to find a difference in the type and number of organisms found on site compared with the findings of the previous year. I also expected to find a similar community on the restored site compared to the adjacent site.

Study Site

The Fir Island Estuary restoration project is located in the Skagit delta (48° N, 122° W), on the Washington Department of Fish and Wildlife Snow Goose Reserve (Figure 1). Its restoration was completed in 2016 (Figure 2).



Figure 1: Skagit delta, Washington, and study site (Snow Goose Reserve) outlined in yellow (Friebel, 2018)

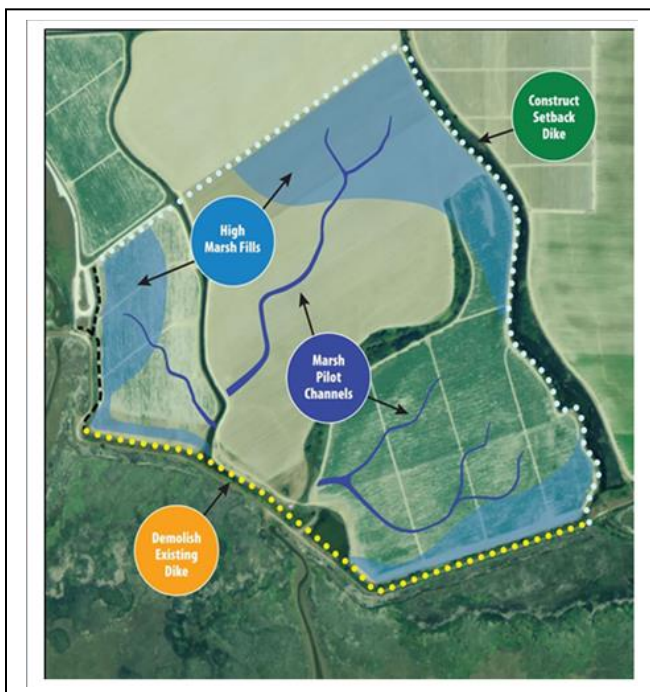


Figure 2: Fir Island Farm Project, Snow Goose Reserve, Skagit County, Washington (Friebel, 2018).

The restoration of the site consisted of setting back the existing dikes which converted 93.5 hectares of farmland into 53 hectares of estuarine emergent marsh and 40.5 hectares of snow goose habitat. In

addition, 7 hectares of tidal channels were reestablished (Furlong, 2017). The newly restored site was first sampled in 2017, one month after completion, to establish a baseline data for the restored site and the adjacent quasi-reference site. I sampled both restored and adjacent site in July of 2018.

Method

72 samples were taken (figure 3), 36 in the restored site, and 36 in the adjacent site.



Figure 3: Location of samples in the restored area (blue) and the adjacent area (yellow) on the Snow Goose Reserve, Skagit delta, Washington.

Each set of 72 samples were taken at three elevations, high, medium and low. The sampling was carried out during low tide with an 8 centimeters auger, at a depth of 10 cm. 240 cm³ of each sample was used to evaluate invertebrate presence. Samples were washed through a 0.5 mm sieve to remove as much of the fine sediments as possible. Using a dissecting microscope, invertebrates were counted and identified with Kozloff & Price (1996) and online websites for additional pictures.

The comparison between the 2018 and 2017 taxonomic groups was used to establish a recolonization succession trajectory for the restored site. The comparison between the adjacent site and the restored site informed on the direction and stage of the recolonization.

For each sample and habitat type, taxonomic richness and abundance was computed. I also calculated the Shannon-Weiner index for each site, and the percent composition for each taxonomic group. A t

test and a Chi Square test were used to compare richness and abundance between sites, and between the two sampling events (2017 and 2018).

Statistical analysis

For each sample and habitat type, percentages, taxonomic abundance, t test and Chi Square test were computed using MS Office Excel. The t test was used to compare the number of each taxon between the adjacent site and the restored site, and between the 2017 and 2018 sampling events. The Chi Square test was used to compare the taxa distribution for the communities found in 2017 and 2018.

The Shannon-Weiner Species Diversity Index (H'), a measure of both richness and evenness of a community, was used to compare data from different habitats and time period. "The Shannon-Weiner Species Diversity Index is calculated by taking the number of each species, the proportion each species is of the total number of individuals, and sums the proportion times the natural log of the proportion for each species (Nolan & Callahan, 2006, p334)."

$$H' = - \sum_{i=1}^s p_i \ln p_i$$

In the above formula, s is the number of species, and p_i is the proportion of individuals of each species belonging to the i th species of the total number of individuals. The index increases as both richness and evenness increase, with values usually between 1.5 and 3.4, rarely above 4.

I used a t test developed by Hutcheson to compare the Shannon Diversity Indices and estimate how significantly different they were (Zar, 2010).

$$t = \frac{H_a - H_b}{\sqrt{s_{H_a}^2 + s_{H_b}^2}}$$

H represents the Shannon Diversity Index for each of the two samples a and b . The denominator in the formula represents the variance (s^2) of the samples.

Results

The number of individuals in 2018 amounted to 907 in the adjacent site and 164 in the restored site (Table 4 in Appendices). I examined the relative dominance for each taxon on each site (adjacent and restored) and for three elevations (high, medium, low) in 2018. Figure 4 was difficult to examine because of the high numbers of Enchytraeidae, so I created Figure 5 which graphs the same data as figure 4 but without the Enchytraeidae taxon. The adjacent site exhibits higher numbers than the restored site for all taxa except for Nereidae (or Nereididae) and Bivalvia. Nereidae, Enchytraeidae,

Pyramidellidae and Ampharetidae have the highest numbers of individual organisms compared to all other taxa. Nereidae and Ampharetidae have comparable numbers on both sites. Enchytraeidae taxa strongly dominate in the adjacent site, followed by Nereidae, Pyramidellidae and Ampharetidae. Nereidae and Ampharetidae taxa dominate in the restored site.

Both the adjacent site and the restored site have a total of 8 identified taxa. The restored site lacks Ostracoda and Flabellifera, taxa found in low numbers in the adjacent site (9 and 2 respectively). The adjacent site lacks *Phascolosoma agassizii* and Bivalvia, but their numbers were extremely low in the restored site (1 and 3 respectively). We can infer from these results that the diversity on both sites is comparable in the type of benthic and epibenthic taxa identified. The difference between the two sites is relative to the number of individuals counted for each taxon.

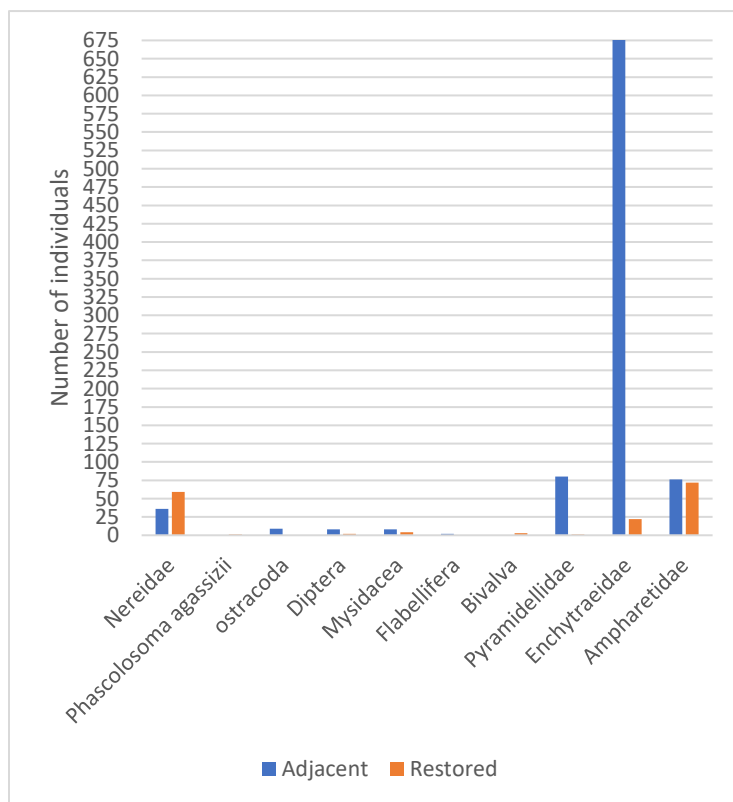


Figure 4: Number of individuals for each taxon in the restored site versus the adjacent site for the 2018 sampling of nearshore habitat on Fir Island, Skagit River Delta, Washington.

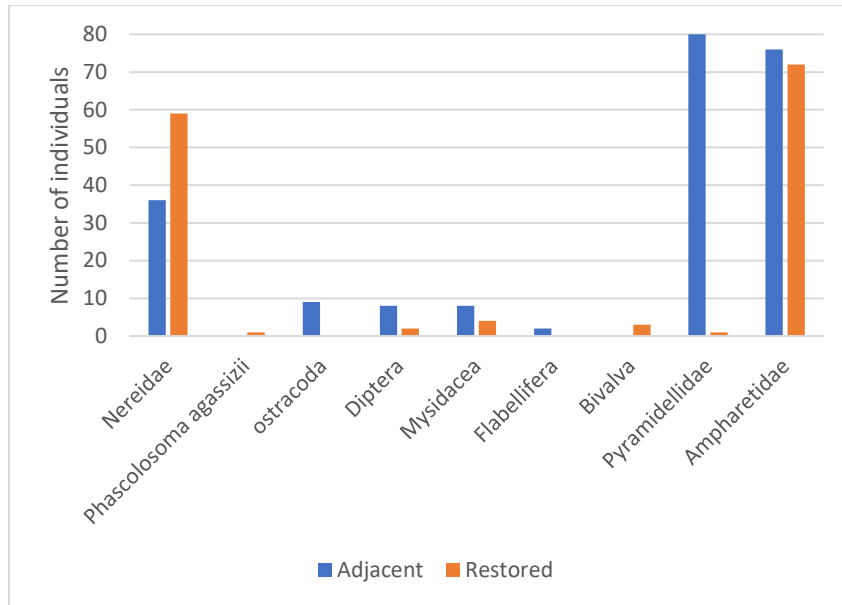


Figure 5: Number of individuals for each taxon (excluding Enchytraeidae) in the restored site versus the adjacent site for the 2018 sampling of nearshore habitat on Fir Island, Skagit River Delta, Washington.

Figure 6 illustrates the number of individuals for each taxon depending on the habitat elevation and site location.

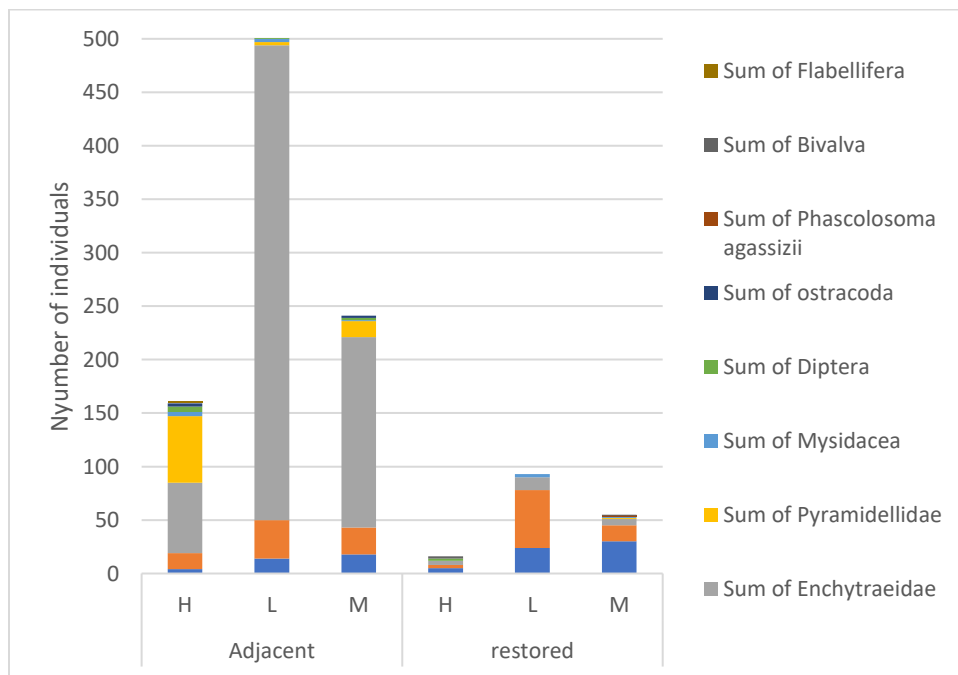


Figure 6: Sum of taxa in each high (H), medium (M), low (L) habitat for the adjacent site versus the restored site, 2018 sampling of nearshore habitat on Fir Island, Skagit River Delta, Washington.

Besides the obvious difference in numbers between the restored and the adjacent sites, a pattern emerges between the different elevations. Low elevations seem to harbor more individuals than the medium elevations, and high elevations seem to carry less. High elevations in the restored site stand out because of their low number of associated organisms. Low elevation in the adjacent site are overwhelmingly occupied by Enchytraeidae. The number of individuals counted in the low elevations of the reference site are more than five times the number of individuals counted in the low elevations of the restored site.

I tested the difference in number of individuals found on both sites for each taxon and found the results summarized in table 1. The null hypothesis is as follows: there is no significant difference between the number of individuals in the restored site versus the adjacent site for each taxon. The only significant difference between the taxa of the two sites concerns the Enchytraeidae taxa.

Table 1: Result of t test for each taxon found in the 2018 adjacent site versus the 2018 restored site.

	Do we reject H_0 ?	P
Nereididae	no	0.16
Ampharetidae	no	0.696
Enchytraeidae	yes	0.000333
Diptera	no	0.147
Crustacea	no	0.523
Isopoda	no	0.16
Bivalvia	no	0.183
Gastropoda	no	0.135
Nematoda	no	0.314
Ostracoda	no	0.071

Comparison between 2017 and 2018 sampling events

The sampling of both sites in 2017 resulted in the identification of 12 taxa (Table 5 in Appendices and Figure 7). The comparison between the data set of 2017 with the data set of 2018 reveals a much lower number of individuals counted in 2017. A total of 62 individual organisms were counted in 2017 compared to a total of 1070 in 2018. Furthermore, the taxa identified are different from one year to the

next. The 2017 samples didn't include Ostracoda, Pyramidellidae and *Phascolosoma agassizi*. It must be noted that, of these three taxa, only Pyramidellidae has a significant presence in the 2018 samples. The 2017 samples include two taxa of the order Terebellida and one taxon from the class polychaeta that were not found in the 2018 sampling. The differences in identification could be attributed partly to the difficulty in identifying the invertebrates, and partly to the succession at work on both sites (the reference site was heavily impacted by the sediments from the dike removal). The comparison between the two sampling events also shows a difference in the numbers and dominance of the common identified taxa (Figures 7 and 8). In 2017, Bivalvia and Nematoda dominate the adjacent site and Terebellida dominate the restored site. Furthermore, the number of individuals in the class Bivalvia is more encountered in 2017 than in 2018. The number of Flabellifera is about the same during both 2017 and 2018 sampling events and is only found in the adjacent site.

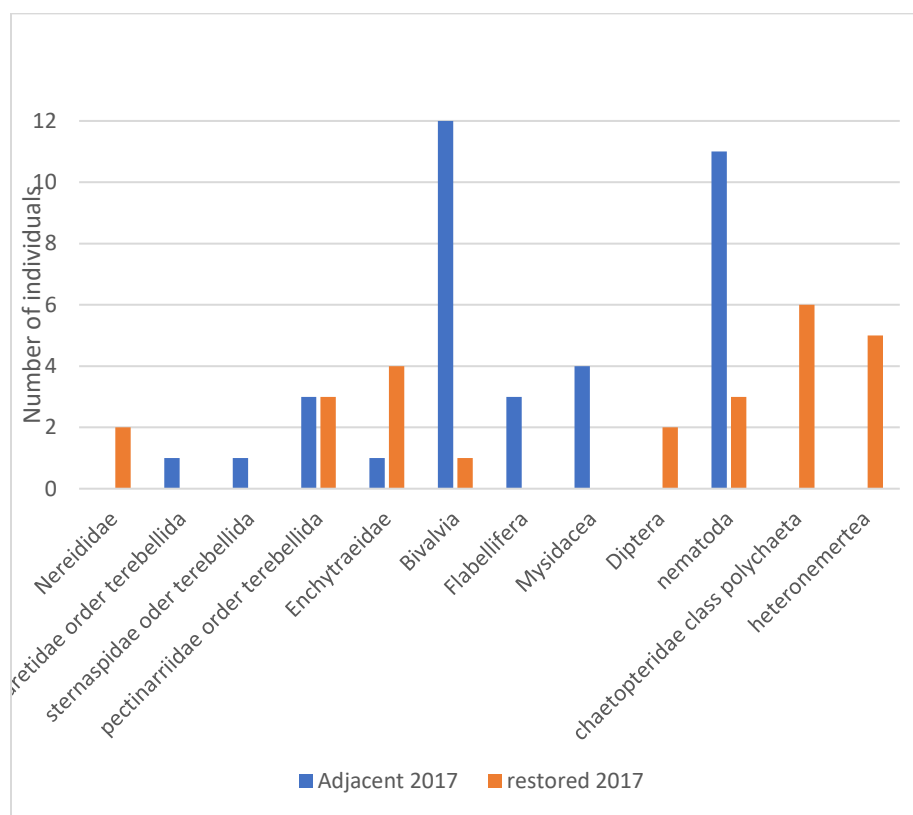


Figure 7: Number of individuals for each taxon in the restored site versus the adjacent site for the 2017 sampling of nearshore habitat on Fir Island, Skagit River Delta, Washington.

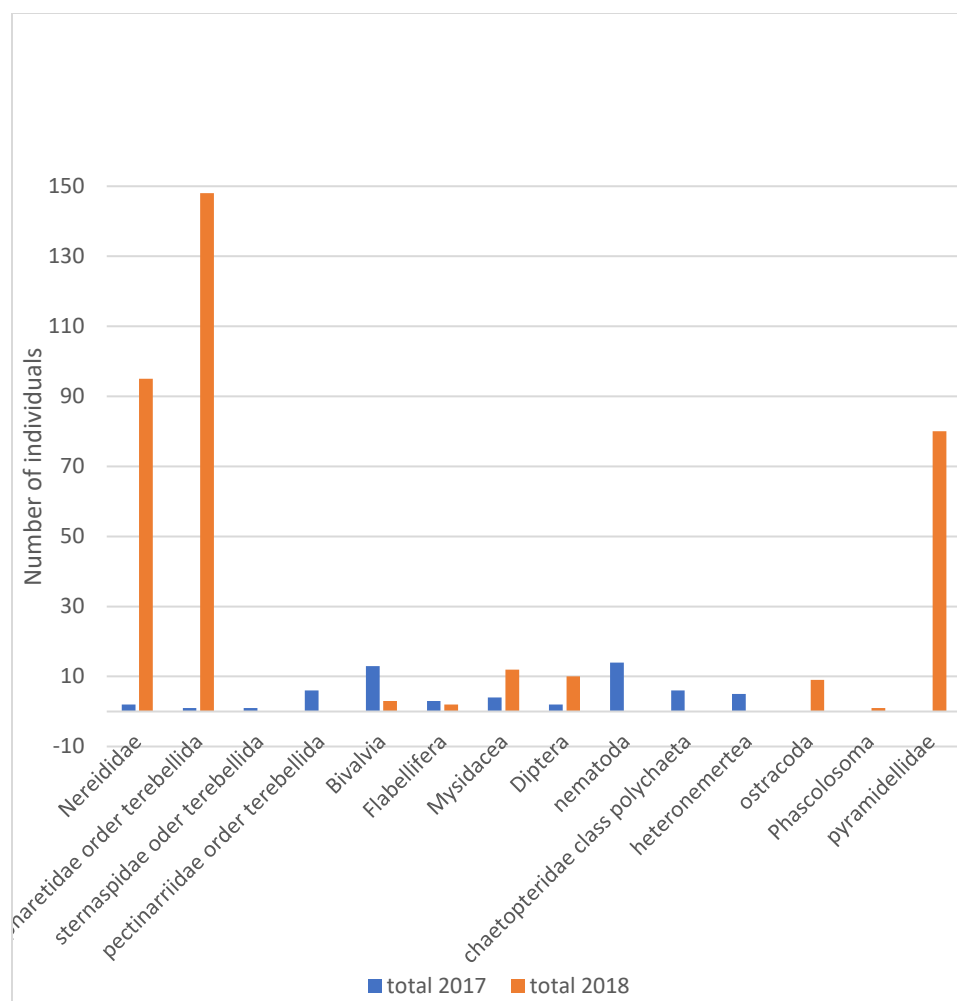


Figure 8: Number of individuals for each taxon in 2018 versus 2017 samplings of nearshore habitat on Fir Island, Skagit River Delta, Washington.

A Chi-Square test revealed a highly significant difference in the fauna between 2017 and 2018 ($P=1.1209E-165$).

The taxa found in 2017 and 2018 are different; I therefore assigned them to higher taxonomic ranks, to be able to compare them. Each phylum or class was tested to establish the significance of the difference in number of individuals between the two sampling events. The null hypothesis was as follow: there is no significant difference between the number of individuals found in 2017 and 2018 for each taxonomic group. The results (table 2) only reflect a significant difference for the phylum Annelida, the taxon that includes the highest number of organisms both in 2017 and 2018.

Table 2: t test result for the comparison of the sampling results of 2018 with the sampling results of 2017 when species were present during both sampling events.

	Do we reject H_0 ?	P
Annelida	yes	6.19E-06
Diptera	no	0.0826
Crustacea	no	0.0673
Isopoda	no	0.563
Bivalvia	no	0.108
Gastropoda	no	0.139
Nematoda	no	0.314

The Shannon Weiner indices results (Table 3) indicate that the least diverse community (the smallest index) corresponds to the 2018 reference site, followed by the 2018 restored site and the 2017 reference site, and with the 2017 restored site exhibiting the highest diversity.

The results of the Hutcheson tests for all six combination are negative (Table 6 in Appendices) therefore, all combinations of indices are significantly different.

Table 3: Shannon Weiner diversity Indices and species count for restored and adjacent site in 2017 and 2018.

	Number of species	Shannon Weiner
Adjacent site 2017	8	0.732
Adjacent site 2018	8	0.392
Restored site 2017	8	0.852
Restored site 2018	8	0.555

Discussion

The results of this study show a 1626% increase in the number of organisms from 2017 to 2018. A Chi Square test confirmed the difference between the communities through time. The phylum Annelida represents the only significant difference between the 2017 and the 2018 sampling events as revealed by the t-test carried out for each taxon.

The comparison between the adjacent site and restored site in 2018 shows a higher number of individuals in the adjacent site (907 versus 164), mostly represented by Enchytraeidae and Pyramidellidae taxa. The family Enchytraeidae constitutes 66% of the individuals identified in 2018. Their overwhelming presence is the reason the Shannon Weiner Indices seemed counter intuitive and should therefore be dismissed, even though the Hutchinson test resulted in a significant difference for all paired indices. Cordell & Higgins (1998) also found a strong presence of Oligochaetes on the restored sites of Spencer Island Washington. Oligochaetes of the family Enchytraeidae are worms that feed on detritus and their microbial tissues. Their low numbers in the restored site is probably a result of low accumulation of vegetation detritus. They were absent on both sites in 2017, but their presence in both sites in 2018, albeit in low numbers in the restored site, is a sign this taxon is of paramount importance in the primary succession of the colonization process at work in the Skagit delta.

The number of individuals of the family Nereidae and Ampharetidae was about the same on both sites, which was confirmed by a t-test. It must be noted that the family Nereidae represents by far the largest size of benthic macroinvertebrate present on the Snow Goose Reserve and probably constitutes also the largest biomass even though they amount to relatively low numbers compared to the numerous but very small organisms of the family Enchytraeidae. Nereidae worms are a very important food source for shorebirds and fish (Ambrose, 1986; Shen & Gu 2015), though they might be too large for juvenile salmonids; Simenstad & Cordell (2000) did not find any Nereidae species in the stomachs of juvenile chum and chinook salmon.

Moseman et al. (2004) studied the colonization, succession, and trophic recovery of the benthic macroinvertebrate communities in a restored marsh in the Tijuana Estuary, California. According to their study, the succession was initiated by insects and naidid oligochaete. They were followed by an increase in polychaetes, and the arrival of tubificid and enchytraeid oligochaetes. The authors found little effect of abiotic and biotic factors on macrofaunal communities and suggest that the mode of colonization and the order of arrival might have more of an influence on succession patterns. Contrasting to Moseman et al. (2004), the present study found very little numbers of insects both in 2017 and 2018, but a strong presence of oligochaetes and polychaetes which leads to the conclusion that annelids are the primary succession on the Snow Goose Reserve and should be followed by other species in the future, notably insect larvae.

Simenstad and Cordell's (2000) study revealed a dominance of oligochaetes both in the restored and reference sites of the Pacific Northwest estuaries they examined. Their strong presence in 2018 on the Snow Goose Reserve confirms their key role in the Pacific Northwest tidal wetlands. Simenstad and Cordell (2000) also found that Chironomids were the most common taxa in all sites. The low level of vegetation development and detritus (see Appendices for pictures) might explain the low level of Chironomids numbers on the restored site of the Snow Goose Reserve, but it does not explain the low numbers observed in the adjacent site.

The taxa found on the reference and restored sites on Spencer Island (Cordell & Higgins, 1998) included a high percentage of Ephydriids and Collembolas. The low number of Chironomids and other Diptera larvae and the total absence of Collembola on The Snow Goose Reserve sites are a sign that these marshes are still in their early stages of colonization. It could also be the result of the timing of the sampling events. Diptera larvae tend to emerge into their adult form in early spring and the Snow Goose Reserve sites were sampled in July. Cordell and Higgins (1998) found 5 times more Chironomids individuals in April than at any other time, while Ephydriid flies peaked in May.

Howe et al. (2014) studied the interior marsh macroinvertebrate community in the San Francisco Estuary and found that oligochaete and nematodes were the most abundant taxa in all sites, the next most abundant being polychaetes, the cumacean *Nippoleucon hinumensis*, and ostracods. Other authors (Ferguson & Rakocinski, 2008; Moseman et al., 2004) also found a strong presence of crustaceans. Gray et al. (2002) correlated the presence of Amphipods to the age of the restoration, with young restored sites being the less occupied by the crustacean. The 2017 and 2018 samples reflect low numbers of crustaceans, though they do seem stronger in 2018 notably for the class Ostracoda. This is probably due to the low amount of detritus on the restored site, but this phenomenon is more difficult to explain for the adjacent site. One possible explanation relates to the disturbance from the sediments released during the dike removal. Another explanation is the possibility of low salinity on both sites which is an impediment to marine invertebrate colonization (Cordell & Higgins, 1998).

The 2018 sampling also revealed the rapid development of a Pyramidellidae taxon absent from the 2017 sampling: the invasive New Zealand mud snail (*Potamopyrgus antipodamus*). Though confined to a few sampling areas, and mostly present in the adjacent site (Table 7 in Appendices), this new species might disrupt the natural ecosystem and the future succession of species. According to Gray (2011), New Zealand mud snails may be responsible for low taxonomic richness in areas where they are prevalent. Bersine et al. (2008) studied the diet of juvenile chinook salmon in the Columbia River Estuary where the snail was present in large numbers and found low occurrence of the invasive New Zealand mud snail in the fishes' stomach. Nevertheless, it is possible that, through time, the salmonid diet will shift to increasingly include the species as a prey item (Gray, 2011).

Conclusion

Taxa of the subclass Oligochaeta (family Enchytraeidae) and of the class Polychaeta (families Nereidae and Ampharetidae) are the most abundant taxa and represent the largest biomass on the Snow Goose Reserve on both the restored and the adjacent sites in 2018. Enchytraeidae is the taxa the most abundant in the adjacent site, while Ampharetidae and Nereidae dominate the restored site. Annelids therefore represent the first and most important organisms to recolonize the area after both the disturbance and restoration of the Snow Goose Reserve.

The disturbance caused by the removal of the dike had a strong effect on the adjacent site and pushed its succession age back. It however had the advantage of already being colonized by vegetation and thus is recovering faster than the restored area. Going forward, we might see a quick recovery of all the microbenthic fauna on the adjacent site, followed closely by the restored site. Because of their close location, we might see a similar succession of benthic invertebrate taxa on both sites, including the establishment of communities of crustaceans, bivalves and insect larvae.

According to Simenstad and Cordell (2000), the development trajectory of the marsh invertebrate community is unpredictable and may not have a stable “end point”. Because of the historical and ongoing anthropogenic impacts in most ecosystems, the authors suggest focusing on the restoration of functions rather than on the restoration of an ideal historical condition. I suggest future studies use vegetation development and benthic biomass as parameters for marsh recovery and functionality. Investigating the effect of salinity on the colonization of benthic invertebrate might also offer insight on succession. The evaluation of salmonid presence and stomach content may help evaluate the functionality of the Snow Goose Reserve and could inform on the shift of diet at work during the restoration succession. The full recovery of both sites might take a few years and should be closely monitored because of the presence of the invasive New Zealand mud snail.

Appendix A

Table 4: Organism count in the restored versus adjacent sites for the 2018 sampling of nearshore habitat on Fir Island, Skagit River Delta, Washington.

	2018	Nereidae	Phascolosoma agassizii	ostracoda	Diptera	Mysidacea	Flabellifera	Bivalvia	Pyramidellidae	Enchytraeidae	Ampharetidae
High		4	0	3	5	4	2	0	62	66	15
Medium		18	0	2	2	1	0	0	15	178	25
Low		14	0	4	1	3	0	0	3	444	36
reference total		36		9	8	8	2		80	688	76
High		5	0	0	2	0	0	2	0	4	3
Medium		30	1	0	0	1	0	1	1	6	15
Low		24	0	0	0	3	0	0	0	12	54
restored total		59	1		2	4		3	1	22	72
Grand Total		95	1	9	10	12	2	3	81	710	148

Table 5: Organism count in the restored versus adjacent sites for the 2017 sampling of nearshore habitat on Fir Island, Skagit River Delta, Washington.

	2017	Nereidae	Ampharetidae order terebellida	sternaspidae oder terebellida	pectinariidae order terebellida	Enchytraeidae	Bivalva	Flabellifera	Mysidacea	Diptera	nematoda	chaetopteridae class polychaeta	heteronemertea
Low				1	3		11				10		
Medium			1				1	3	4				
High						1					1		
total reference		0	1	1	3	1	12	3	4	0	11	0	0
Low					3	2						3	3
Medium						2	1			2	3	3	2
High		2											
total restored		2	0	0	3	4	1	0	0	2	3	6	5
Grand total		2	1	1	6	5	13	3	4	2	14	6	5

Table 6: testing H_0 for all pairs of Shannon Weiner indices using a Hutcheson two tailed test, with $\alpha= 0.05$.

	v	s(Hi-Hj)	t	t critical	result
res18 + Adj18	283	0.03414	4.774466	0.675	reject Ho
res18 + res17	62	0.048739	-6.09365	0.679	reject Ho
res18 + Adj17	57	0.064524	-2.74318	0.679	reject Ho
Adj18 + res17	37	0.042239	-10.8904	0.681	reject Ho
Adj18 + Adj17	43	0.059766	-5.68888	0.681	reject Ho
res17 Adj17	59	0.069151	1.735323	0.679	reject Ho



Picture of adjacent site, Snow Goose Reserve, July 2018



Picture of adjacent site, Snow Goose Reserve, July 2018



Picture of restored site, Snow Goose Reserve, July 2018



Picture of restored site, Snow Goose Reserve, July 2018

Table 7: Raw data: Restored versus adjacent site in July 2018 on fir island, Skagit county, Washington.

way point	elevation	location	Nereididae	Ampharetidae	Enchytraeidae	Pyramidellidae	Bivalva	Flabellifera	Mysidacea	Diptera	ostracoda	Phascolosoma agassizii
14	L	Adjacent		14	122						4	
15	L	Adjacent		2	102							
16	L	Adjacent	4	1	44							
17	M	Adjacent	8		59							
18	M	Adjacent			26						2	
19	L	Adjacent		2	15							
20	L	Adjacent			10							
21	L	Adjacent		6	1							
22	L	Adjacent	3	4	41	2			1			
23	M	Adjacent		10	8	4			1			
24	M	Adjacent										
25	M	Adjacent		1	7							
26	M	Adjacent	1	4	17							
27	L	Adjacent		2	1	1						
28	M	Adjacent			16	2				2		
29	M	Adjacent			27							
30	L	Adjacent	2		2				1			
31	M	Adjacent	4	2	3							
32	L	Adjacent	2	1					1			
33	L	Adjacent	3	2	33					1		
34	L	Adjacent		2	73							
36	H	Adjacent										
37	H	Adjacent			12							
38	M	Adjacent	2	1	6							
39	H	Adjacent	1		6			1				
40	H	Adjacent	3	14	17				4			
41	H	Adjacent			11					3		
42	H	Adjacent			1	7					1	
43	H	Adjacent			1	1		1				
44	H	Adjacent										
45	M	Adjacent	3	2	8							
46	H	Adjacent			3					1		
47	H	Adjacent										
48	M	Adjacent		5	1	9						
49	H	Adjacent		1	5	3				1		
50	H	Adjacent			10	51					2	
55	H	restored										
56	H	restored			1							
57	H	restored										
58	M	restored										
59	H	restored	3									
60	M	restored	1	1	2							1
61	M	restored	8						1			
62	M	restored	2	1	3							
63	L	restored		3					1			
64	H	restored			3							
65	L	restored	3	1								
66	L	restored	1	1								
67	L	restored		1	1				1			
68	H	restored										
69	L	restored		9	2							
70	M	restored				1						
71	L	restored	2	4	6							
72	H	restored	1									
73	M	restored	3	3	1							
75	L	restored	2	2								
76	M	restored	1									
77	H	restored		1								
78	L	restored	2	2	1							
79	M	restored	3	3								
80	H	restored		1								
81	M	restored	1									
82	L	restored	2	14								
83	H	restored								1		
84	M	restored	4	5								
85	L	restored	1	5	1							
86	H	restored	1	1			2			1		
87	M	restored	2									
88	L	restored	8	4					1			
89	H	restored										
90	M	restored	5	2			1					
91	L	restored	3	8	1							

Way point coordinates of samples:

14: 48°20'6.68"N 122°24'49.45"W	53: 48°20'2.93"N 122°24'48.10"W
15: 48°20'6.37"N 122°24'49.02"W	54: 48°20'2.93"N 122°24'48.10"W
16: 48°20'4.63"N 122°24'50.99"W	55: 48°20'2.93"N 122°24'48.10"W
17: 48°20'4.23"N 122°24'51.23"W	56: 48°20'2.93"N 122°24'48.10"W
18: 48°20'4.09"N 122°24'51.25"W	57: 48°20'2.93"N 122°24'48.10"W
19: 48°20'3.22"N 122°24'53.73"W	58: 48°20'2.93"N 122°24'48.10"W
20: 48°20'3.00"N 122°24'53.99"W	59: 48°20'2.93"N 122°24'48.10"W
21: 48°20'2.54"N 122°24'54.42"W	60: 48°20'2.93"N 122°24'48.10"W
22: 48°20'2.26"N 122°24'54.66"W	61: 48°20'2.93"N 122°24'48.10"W
23: 48°20'2.26"N 122°24'54.66"W	62: 48°20'2.93"N 122°24'48.10"W
24: 48°20'2.26"N 122°24'54.66"W	63: 48°20'2.93"N 122°24'48.10"W
25: 48°20'2.26"N 122°24'54.66"W	64: 48°20'2.93"N 122°24'48.10"W
26: 48°20'2.26"N 122°24'54.66"W	65: 48°20'2.93"N 122°24'48.10"W
27: 48°20'2.26"N 122°24'54.66"W	66: 48°20'2.93"N 122°24'48.10"W
28: 48°20'2.26"N 122°24'54.66"W	67: 48°20'6.30"N 122°24'34.83"W
29: 48°20'2.26"N 122°24'54.66"W	68: 48°20'6.30"N 122°24'34.83"W
30: 48°20'2.26"N 122°24'54.66"W	69: 48°20'6.30"N 122°24'34.83"W
31: 48°20'2.26"N 122°24'54.66"W	70: 48°20'6.30"N 122°24'34.83"W
32: 48°20'2.26"N 122°24'54.66"W	71: 48°20'6.30"N 122°24'34.83"W
33: 48°20'2.26"N 122°24'54.66"W	72: 48°20'6.30"N 122°24'34.83"W
34: 48°20'2.26"N 122°24'54.66"W	73: 48°20'6.30"N 122°24'34.83"W
35: 48°20'2.93"N 122°24'48.10"W	74: 48°20'6.30"N 122°24'34.83"W
36: 48°20'2.93"N 122°24'48.10"W	75: 48°20'6.30"N 122°24'34.83"W
37: 48°20'2.93"N 122°24'48.10"W	76: 48°20'6.30"N 122°24'34.83"W
38: 48°20'2.93"N 122°24'48.10"W	77: 48°20'6.30"N 122°24'34.83"W
39: 48°20'2.93"N 122°24'48.10"W	78: 48°20'6.30"N 122°24'34.83"W
40: 48°20'2.93"N 122°24'48.10"W	79: 48°20'6.30"N 122°24'34.83"W
41: 48°20'2.93"N 122°24'48.10"W	80: 48°20'6.30"N 122°24'34.83"W
42: 48°20'2.93"N 122°24'48.10"W	81: 48°20'6.30"N 122°24'34.83"W
43: 48°20'2.93"N 122°24'48.10"W	82: 48°20'6.30"N 122°24'34.83"W
44: 48°20'2.93"N 122°24'48.10"W	83: 48°20'6.30"N 122°24'34.83"W
45: 48°20'2.93"N 122°24'48.10"W	84: 48°20'6.30"N 122°24'34.83"W
46: 48°20'2.93"N 122°24'48.10"W	85: 48°20'6.30"N 122°24'34.83"W
47: 48°20'2.93"N 122°24'48.10"W	86: 48°20'6.30"N 122°24'34.83"W
48: 48°20'2.93"N 122°24'48.10"W	87: 48°20'6.30"N 122°24'34.83"W
49: 48°20'2.93"N 122°24'48.10"W	88: 48°20'6.30"N 122°24'34.83"W
50: 48°20'2.93"N 122°24'48.10"W	89: 48°20'6.30"N 122°24'34.83"W
51: 48°20'2.93"N 122°24'48.10"W	90: 48°20'6.30"N 122°24'34.83"W
52: 48°20'2.93"N 122°24'48.10"W	91: 48°20'6.30"N 122°24'34.83"W

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