Restoration Effectiveness in Puget Sound:

Shoreline Monitoring Case Study Report

April 2021

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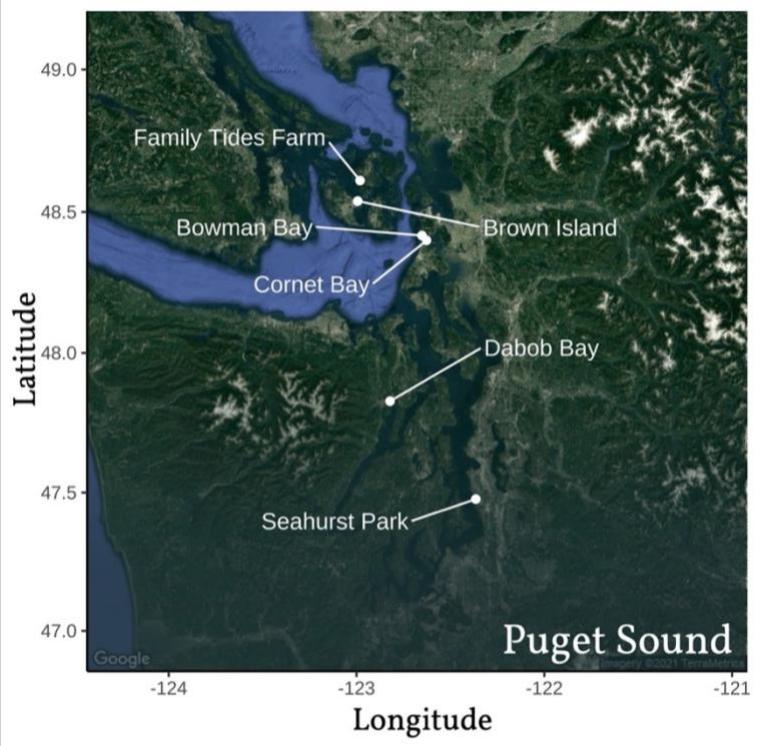
Introduction

Nearly one third of Puget Sound's shorelines are artificially armored (e.g., with seawall, bulkhead, or riprap). Armoring has negative impacts on the flora and fauna of intertidal beaches. Recent beach restoration efforts have focused on removing armor to recover natural function. Through regular monitoring, we can evaluate the effectiveness of these restoration efforts and their value to the nearshore ecosystem, applying what we learn to future management scenarios.

The Puget Sound Ecosystem Monitoring Program (PSEMP) Nearshore work group has compiled a list of sites restored and monitored since 2005 with a focus on areas where shoreline armor has or will be removed. The list details 54 sites, of which 38 had armor removed as of February 2020. Thus far, a total of 21,132 feet of armor has been removed. This case study report details some of the sites that have been consistently monitored.

Why Use These Sites as Case Studies?

We have chosen **six sites** – a selection of the first beaches to be monitored using consistent protocols outlined in the Shoreline Monitoring Database – as representative case studies for evaluating the effectiveness of restoration on different physical and biological variables. These sites are unique in that they have several years of monitoring data (between three and six years), and in most cases, these data span before and after restoration (specifically, de-armoring) efforts. All sites include at least one "Natural," never armored area, and at least one "Restored" area. Many also include areas that are "Unrestored," and still have armoring along the shoreline. These different spatial and temporal treatments are extremely useful in comparing local variability and the long-term effects of armoring – and restoration – through time.



The six sites monitored herein represent diverse shore types, are both privately and publicly owned beaches, and span a large area within the Puget Sound: from Deception Pass, to the San Juan Islands, to Hood Canal, and the city of Burien. They represent urbanized and state-preserved shorelines. As such, they in part represent a diversity of responses to restoration.

Why These Protocols?

Researchers and community science groups monitor many different biological and physical attributes at shoreline sites to gauge restoration effectiveness (a full list can be found here). In this document we present the results of four of these protocols – beach wrack, logs, riparian vegetation, and insects. These four protocols represent the first that were incorporated into the database and therefore contain the most complete data (often both pre- and post- restoration efforts). Within each protocol, we present the results of one variable: total percent wrack cover, total number of logs, total number of fallen trees, and insect family diversity. Details pertaining to these variables are outlined in the Methods below.

Predictions & Interpretation

Predictions

We predict natural sites to have the highest levels and unrestored sites to have the lowest levels of all response variables. We predict restoration, in the form of armor removal, to lead to increases in all variables, which should reach levels similar to those of the natural (reference) sites.

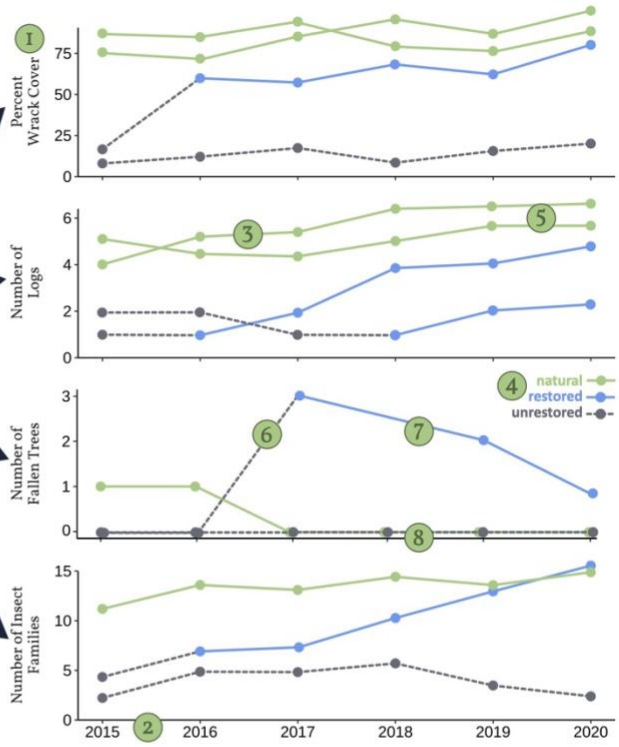
Percent Wrack Cover: Armor built low on the shore limits the deposition of wrack with the receding tide, thus we expect unrestored sites to have low wrack cover and natural sites to have high wrack cover. Wrack should accumulate quickly after armor is removed.

Number of Logs: Armor built low on the shore limits the receding tide from leaving behind logs, thus we expect unrestored sites to have fewer logs and natural sites to have more logs. After armor removal, logs should collect more slowly than wrack, but once present, will be less variable through time.

Number of Fallen Trees: Armor can prevent both growth of riparian vegetation and erosion of sediment, thus we expect there to be very few fallen trees at unrestored sites and more at natural sites. Fallen trees might increase initially when armor is removed and then decrease gradually with time as they become logs or are carried away by tides.

Number of Insect Families: Armor decreases heterogenity of the backshore habitat, which supports diverse insect families, thus unrestored sites should be less diverse than natural sites. We expect number of insect families to increase after wrack, logs, and vegetation accumulate at the shore.

Predicted Patterns



How to Interpret the Results

1. Response variable measured is shown on the vertical **y-axis**
2. One sampling event/year is shown on the horizontal **x-axis**; years labelled only on bottom plot; *e.g., here yearly sampling occurred , 2015 - 2020*
3. **Lines** connect sampling events - shown as **points** - for a single transect
4. The **legend** shows the color/line type representing each strata; solid green = natural, solid blue = restored; dashed grey = unrestored (armored)
5. **Multiple lines in one color** denote sites with multiple transects/strata; *e.g. here two green lines show two transects for the natural strata*
6. Restoration (armor removal) is shown by a **transition from a grey dashed line to a blue solid line**; *e.g., here it occurred between 2016 and 2017*
7. If a **point is not shown**, that sampling year was missed; *e.g., here, number of logs was not sampled in 2018 for one natural transect*
8. Overlapping points (same year, same response value) are **offset**; *e.g., here, the number of fallen trees is zero for multiple transects in multiple years*

Methods

To determine restoration effectiveness, researchers and community (citizen) science groups monitored physical and biological response variables along 50-meter (shore-parallel) transects at three location types: **natural** (never armored), **unrestored** (currently armored), and **restored** (previously armored). Groups used standard protocols to measure beach wrack, logs, riparian vegetation, and insects. Below we describe the main variables measured in each protocol for which data are plotted for each site in this report. Full protocol details can be found at the Shoreline Monitoring Database.

1. Beach wrack: percent cover of beach wrack in a 0.1 square-meter quadrat at 10 random points along the 50-meter transect (wrack type, depth, and width of wrack line also measured but not shown here)
2. Logs: number of logs intersected by a transect perpendicular to the shoreline at 5 random points along the 50-meter transect (log size class, terrestrial/marine/human use also recorded but not shown here)
3. Riparian vegetation: the total number of fallen trees within the 50-meter transect (canopy cover, backshore cover, and vegetation types also recorded but not shown here)
4. Insects: the number of insect families (richness) in fallout trap per square meter per day at 5 points along the 50-meter transect (total insect density, life stage also recorded but not shown here)

Monitoring at Bowman Bay

Authorship & Citation

This case study report was prepared by Simone Des Roches and Jason Toft (University of Washington), Jason Morgan (Northwest Straits Foundation), and Hannah Faulkner (Washington Department of Fish and Wildlife).

Citation:

Des Roches, S, Toft, J, Faulkner, H, Morgan, J. 2021. Restoration Effectiveness in Puget Sound: Shoreline Monitoring Case Study Report. University of Washington.

Acknowledgements & Funding

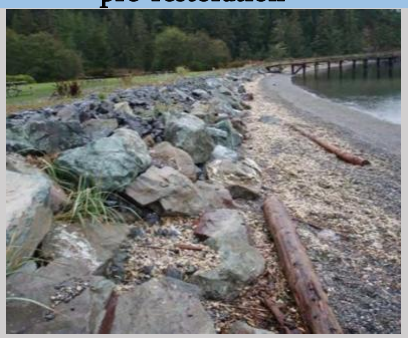
This work was made possible through the participation of fourteen different groups, a striking demonstration of the breadth of participation across Puget Sound: The University of Washington School of Aquatic and Fisheries Sciences, The Northwest Straits Foundation, Washington Department of Fish and Wildlife, Washington State Parks, Washington Sea Grant, Skagit Conservation District, Skagit Fisheries Enhancement Group, Skagit County Marine Resources Committee, Salish Sea Stewards, Island County Marine Resources Committee, Sound Water Stewards, Washington Department of Natural Resources, Washington Department of Ecology, The Northwest Watershed Institute, Friends of the San Juans, The City of Burien, Whidbey Island Conservation District, Washington State University Beach Watchers, and the US Department of Agriculture.

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement PC-01J22301 through the Washington Department of Fish and Wildlife. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency or the Washington Department of Fish and Wildlife, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

We acknowledge that restoration and monitoring activities occurred on occupied Coast Salish territories

Case Study 1: Bowman Bay

Deception Pass, WA

pre-restoration	initial restoration	post-restoration
		

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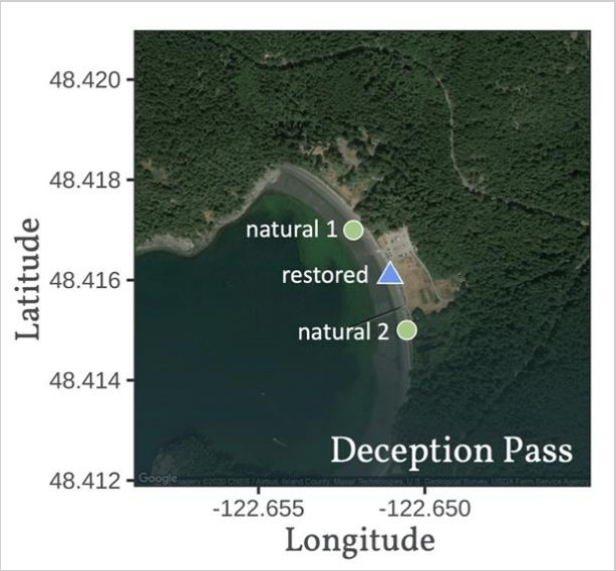
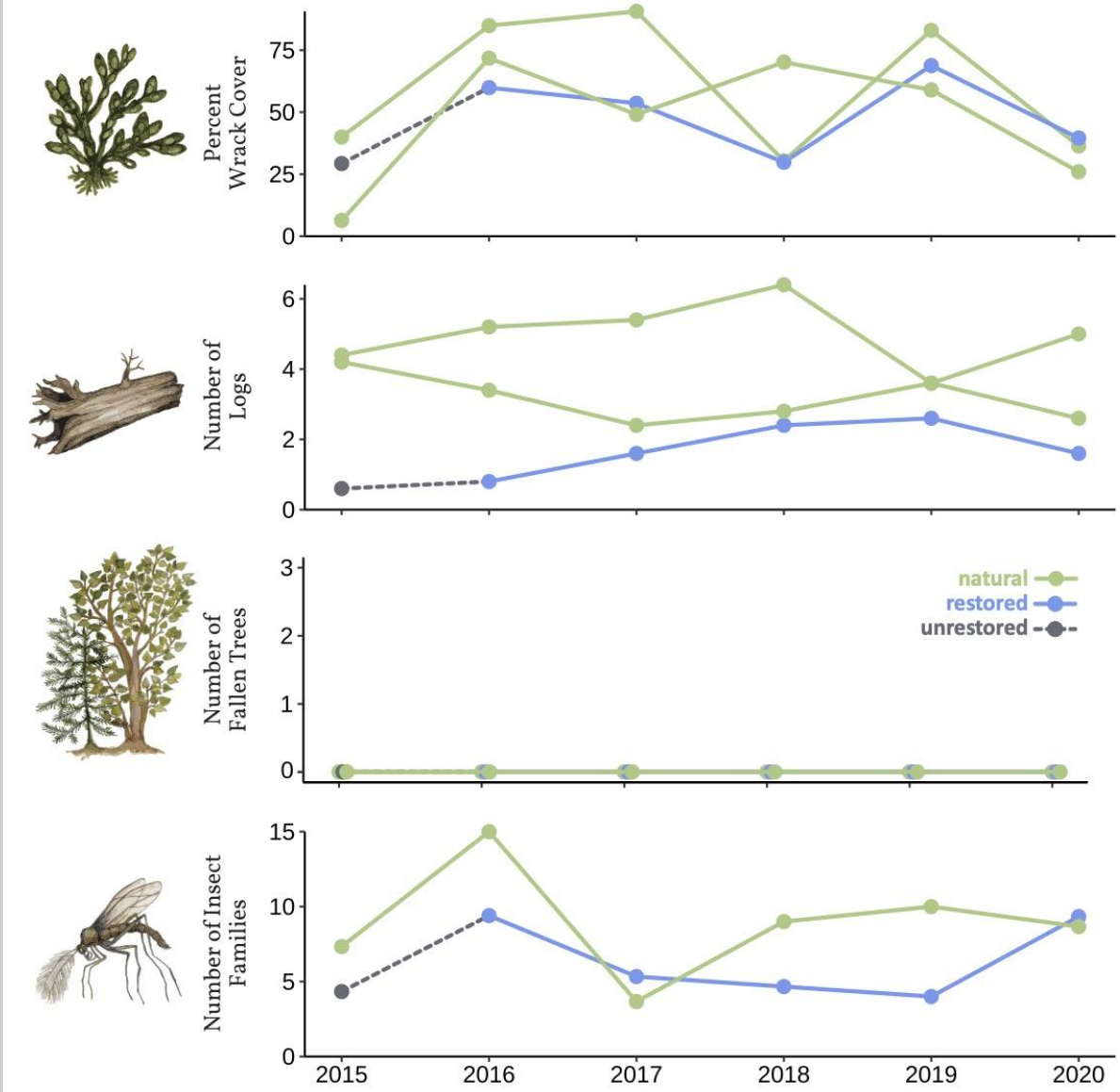


Bowman Bay is a pocket beach in the Whidbey Basin at Deception Pass State Park. Before 1979, hard shoreline riprap armoring was built to protect a now dismantled fish hatchery and marine biology station. This armoring impeded sediment transport processes, leading to beach sediment coarsening and degradation of nearshore habitat. Together, the Skagit County Marine Resources Committee, Northwest Straits Foundation, Skagit Fisheries Enhancement Group, Salish Sea Stewards, and Washington State Parks combined to remove ~ 540 feet (2,000 tons) of shoreline armoring. This project, completed in November 2015, restored natural sediment transport processes and improved around 0.6 acres of nearshore habitat for forage fish spawning, juvenile salmon migration. Restored ecosystem resilience will further allow for lateral shifts in seagrass beds in response to sea level rise. Armor removal has also improved beach access for park visitors.

Site Characteristics

Location	Deception Pass (48.41608, -122.65104)
Shore Type	pocket beach
Land Ownership	public
Date Restored	2015
Restoration Type	armor removal, nourishment, log addition, vegetation planting
Length Armor Removed	540 ft
Years Monitored	2015-2020
Protocols	beach wrack, logs, insects, vegetation

Results



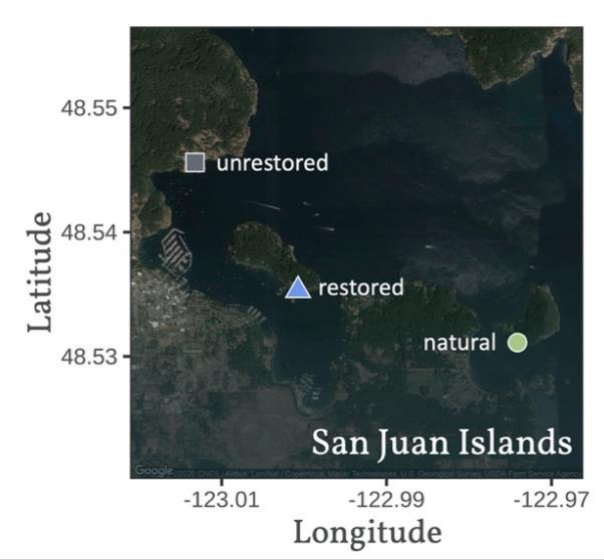
As predicted, armor removal appeared to have steadily positive effects on beach wrack cover and the number of beached logs. Wrack cover fluctuated over the years in both restored and natural locations. The number of logs was more stable, but typically higher in the location that was never armored. Fallen trees did not accumulate at any location regardless of whether they were previously armored. Restoration appeared to have subtly positive effects on the number of insect families. Still, recent samples show comparable diversity of insect families between natural and restored locations. Because there is no unrestored armored "control" location, true impact of armor removal is difficult to assess. Raw data can be downloaded at the Shoreline Monitoring Database.

Case Study 2: Brown Island

San Juan Islands, WA

pre-restoration	initial restoration	post-restoration
		

Background

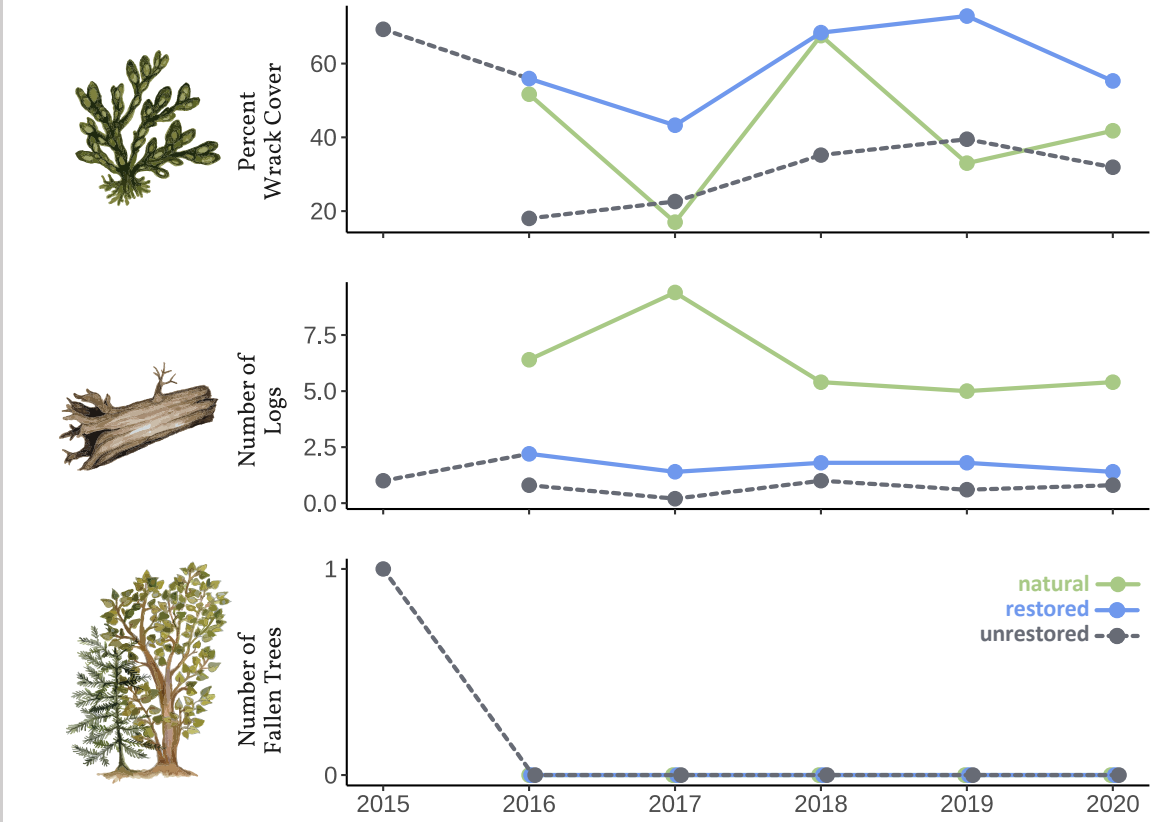


Brown Island, a small island in the San Juan archipelago, formerly had bulkhead armor spanning three adjacent private beaches. When the three landowners became aware of the harmful environmental effects of shoreline armoring, they reached out to Friends of the San Juans for help coordinating and funding restoration. In 2015, 175 cubic yards of rock were removed, followed by the replenishing of the upper beach with sand and gravel and the planting of native vegetation, including dune grass and snowberry. Today, the three neighboring landowners can now enjoy access to a healthy beach. Wrack, logs, and vegetation are compared to nearby armored and natural sites on San Juan Island.

Site Characteristics

Location	San Juan Islands (48.53530, -123.00080)
Shore Type	accretion shoreform, transport zone, feeder bluff
Land Ownership	private
Date Restored	2015
Restoration Type	armor removal, nourishment, vegetation planting
Length Armor Removed	200 ft
Years Monitored	2015-2020
Protocols	beach wrack, logs, vegetation

Results



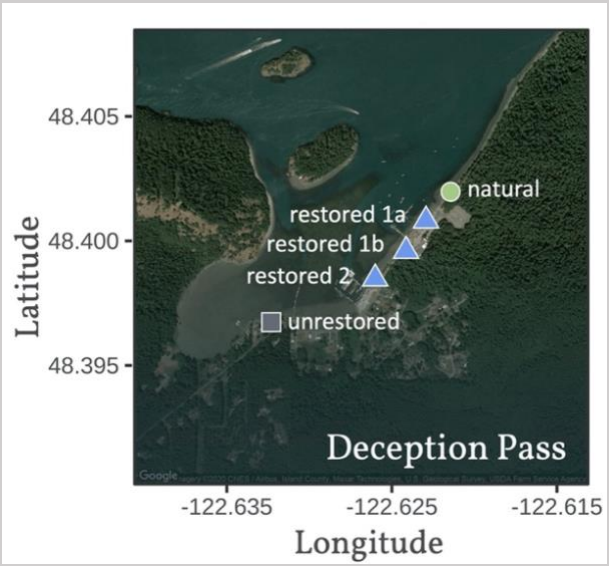
Armor removal had minor effects on beach wrack, the number of logs, and the number of fallen trees. Still, as predicted, armored locations had a consistently lower percentage of wrack cover and fewer logs than both natural and restored locations. Though the natural location typically had a higher number of logs, the restored location had consistently higher wrack cover. The number of fallen trees was steadily low throughout monitoring. Insects were not monitored at this location. Raw data can be downloaded at the Shoreline Monitoring Database.

Case Study 3: Cornet Bay

Deception Pass, WA

pre-restoration	during restoration	post-restoration
		

Background

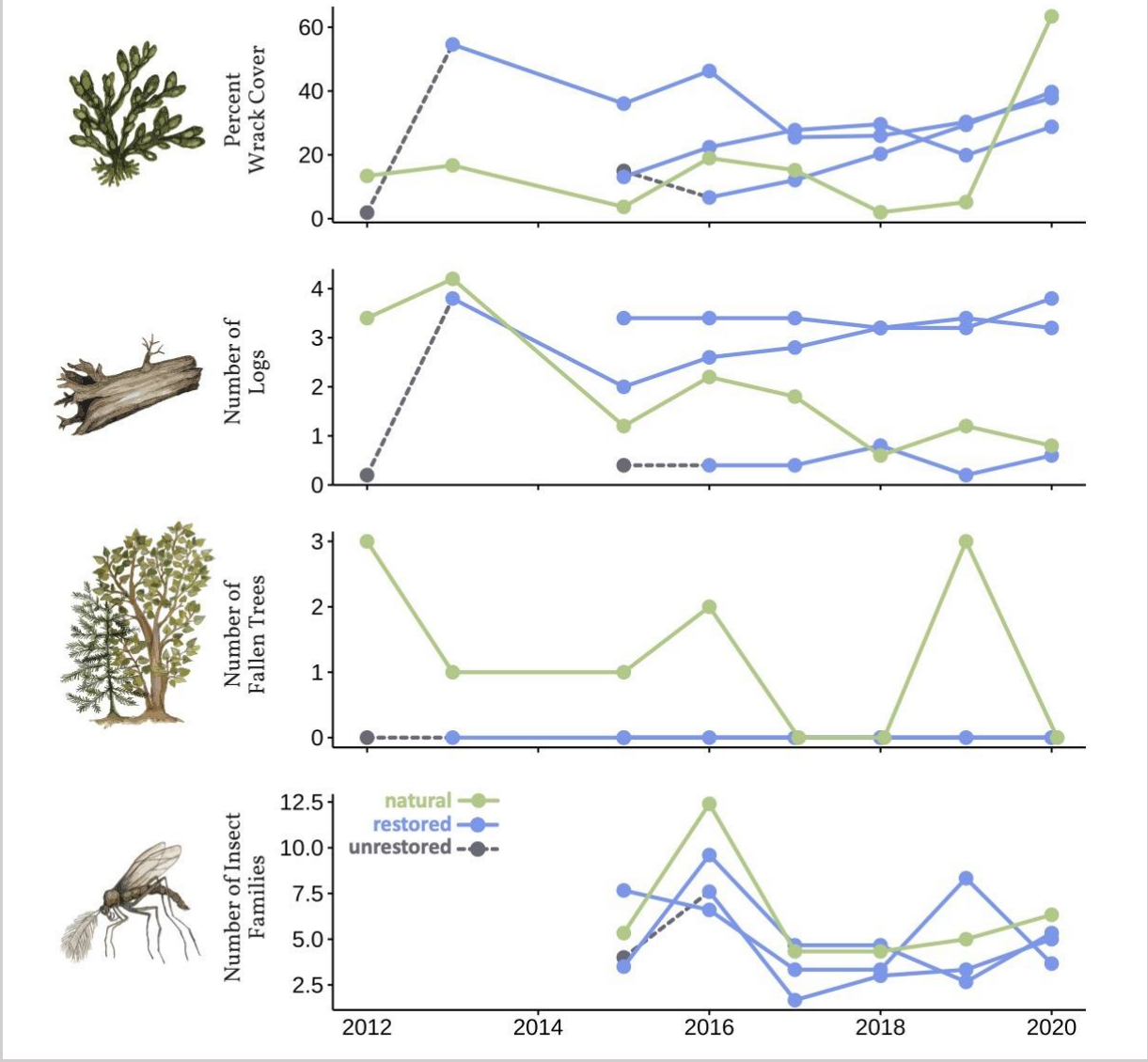


Cornet Bay is an accretion shoreform located on the northern tip of Whidbey Island. In 2012 and 2015, multiple partners, including the Island County Marine Resources Committee, Island County Salmon Recovery Lead Entity, Northwest Straits Foundation, Washington State Parks, Washington State University Island County Beach Watchers, Sound Water Stewards, Whidbey Island Conservation District, and Skagit Fisheries Enhancement Group, came together to dismantle 750 feet of armor, which included removing a creosote bulkhead and the fill material behind it. Post armor removal, the beach was re-graded to a natural slope and then planted with native vegetation. Restoration efforts have improved habitat for forage fish spawning and juvenile salmon migration by eliminating beach scouring and hydrocarbon sources, expanded the intertidal habitat, improved beach composition, and improved riparian vegetation.

Site Characteristics

Location	Deception Pass (48.40076, -122.62308)
Shore Type	accretion shoreform
Land Ownership	public
Date Restored	Restored 1 a & b: 2012 | Restored 2: 2015
Restoration Type	armor removal, nourishment, log addition, vegetation planting
Length Armor Removed	750 ft
Years Monitored	2012, 2015- 2020
Protocols	beach wrack, logs, insects, riparian vegetation

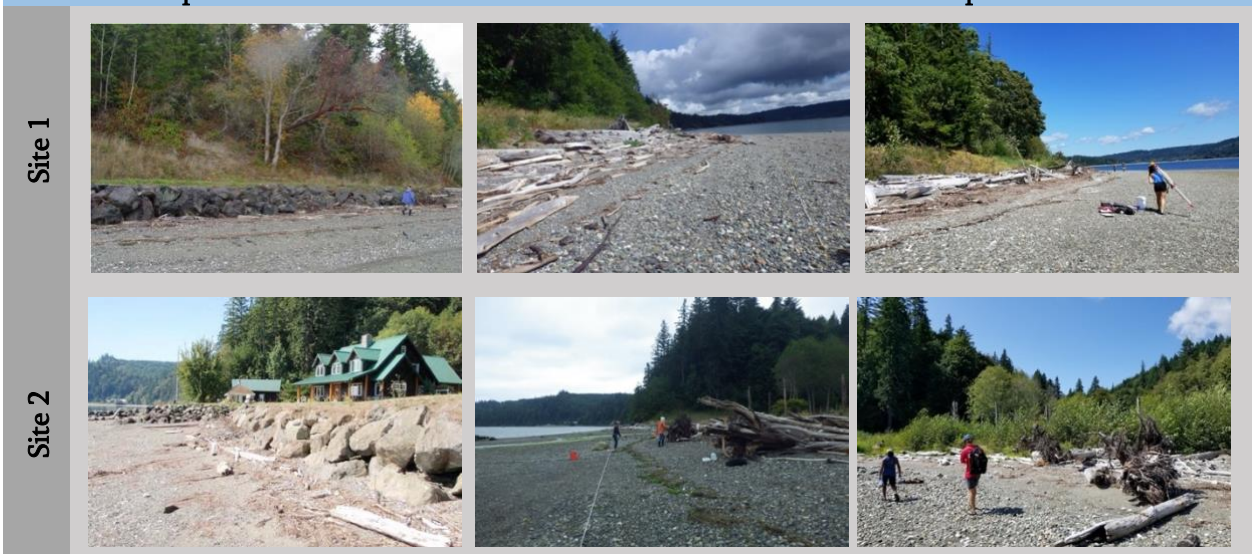
Results



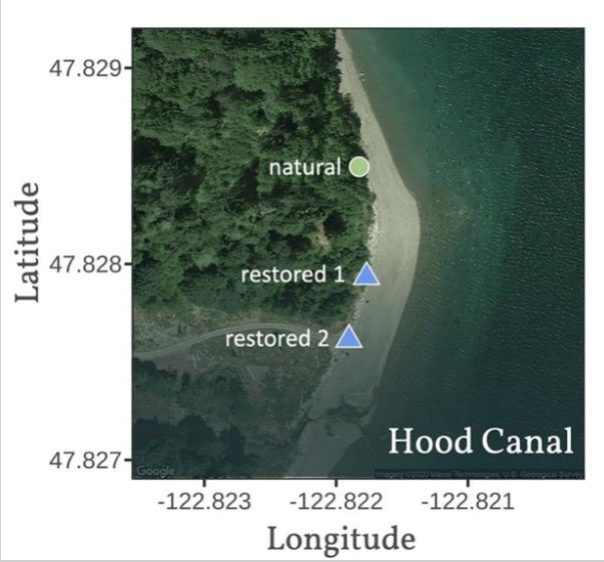
Armor removal seemed to have immediately positive effects on beach wrack cover and number of logs. In particular, wrack coverage was comparable among all three restored locations in 2018 and 2020. Both wrack cover and number of logs were frequently higher than even the natural location, which experienced notable yearly fluctuations. The number of insect families varied considerably over the years but was generally comparable among all the restored locations and the natural location, especially in 2016, 2017, and 2020. Though this site lacked an unrestored control, the location restored in 2012 generally showed higher levels of wrack, logs, and insects, than that restored in 2015, suggesting gradual recovery over the years. Raw data can be downloaded at the Shoreline Monitoring Database.

Case Study 4: Dabob Bay

Hood Canal, WA



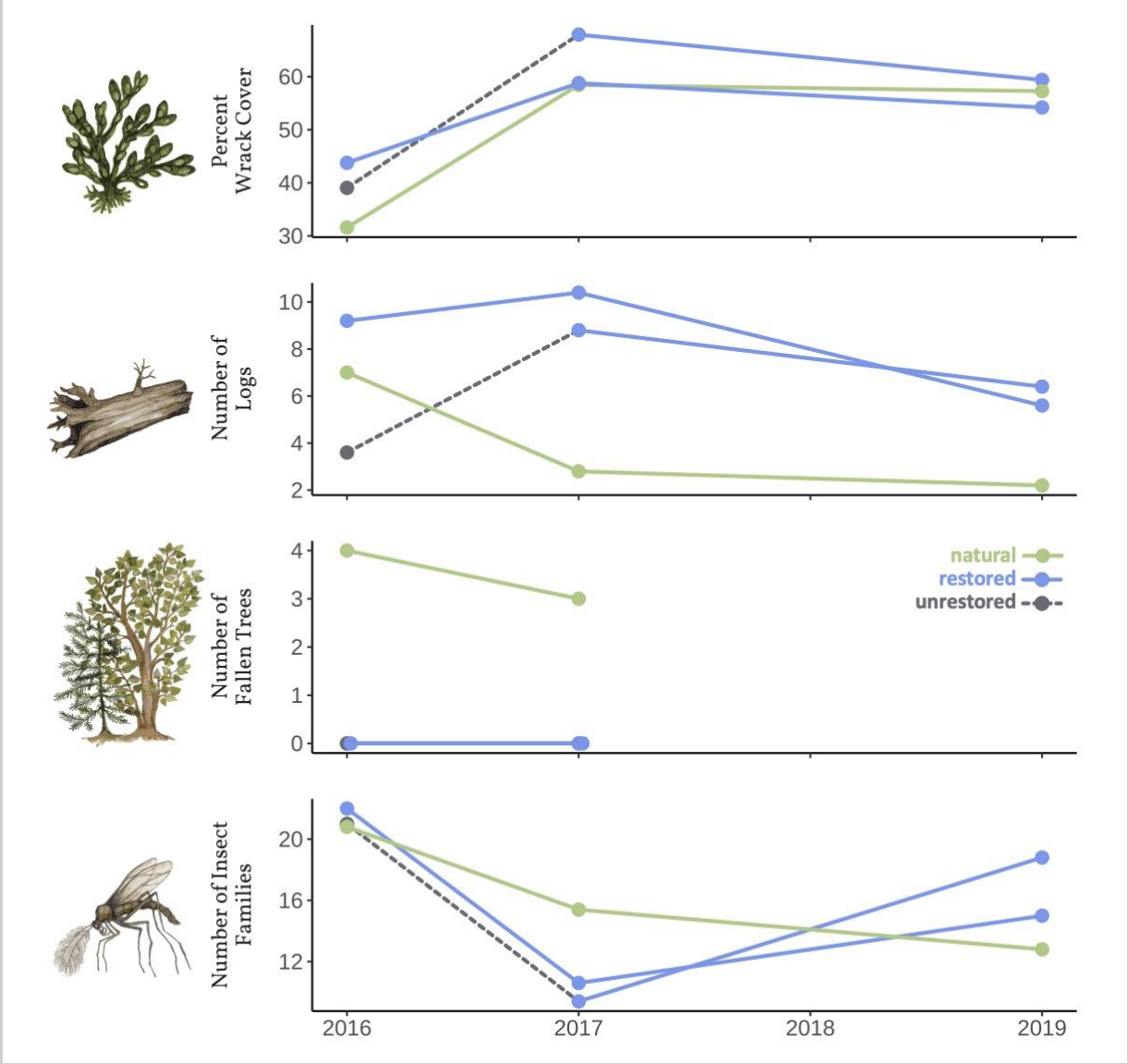
Background



Dabob Bay, located in the Hood Canal region, includes transport zone and accretion shoreform shore types. The bay is surrounded by shoreline owned by public and private landowners. The Washington Department of Natural Resources along with the Northwest Watershed Institute initiated two restoration projects where a total length of 500 feet of bulkheads were replaced with soft shore, logs, and a sloping bank – the first 100 feet in 2009, and the other 400 feet in 2016.

Site Characteristics	
Location	Hood Canal (Restored 1: 47.8276, -122.822 | Restored 2: 47.8279, -122.822)
Shore Type	Restored 1: transport zone | Restored 2: accretion shoreform
Land Ownership	private
Date Restored	Restored 1: 2009 | Restored 2: 2016
Restoration Type	armor removal, log addition (Restored 1), vegetation planting (Restored 2)
Length Armor Removed	Restored 1: 100 ft | Restored 2: 400 ft
Years Monitored	Restored 1 & 2: 2016-2017, 2019
Protocols	beach wrack, logs, vegetation, insects

Results



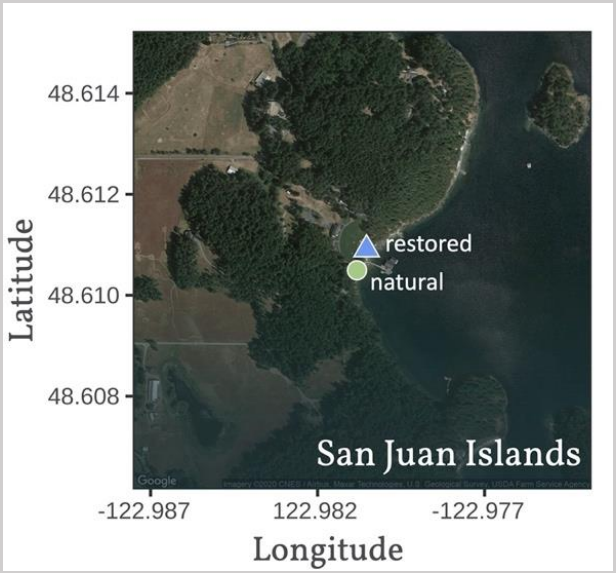
As predicted, restored sites had similar levels of beach wrack, logs, and number of insect families compared to natural locations; however, for wrack cover and insect family richness, levels were comparable prior to restoration. Because there is only one sampling event for one location prior to restoration, it is difficult to make strong conclusions on the effect of restoration. That said, the fact that restored locations had higher numbers of logs and insect families than even the natural locations, indicates the potential effectiveness of restoration. Fallen trees were always greater at the natural location but were not monitored after 2017. Further, no samples were collected in 2020. Raw data can be downloaded at the Shoreline Monitoring Database.

Case Study 5: Family Tides

San Juan Islands, WA

pre-restoration	initial restoration	post restoration
		

Background

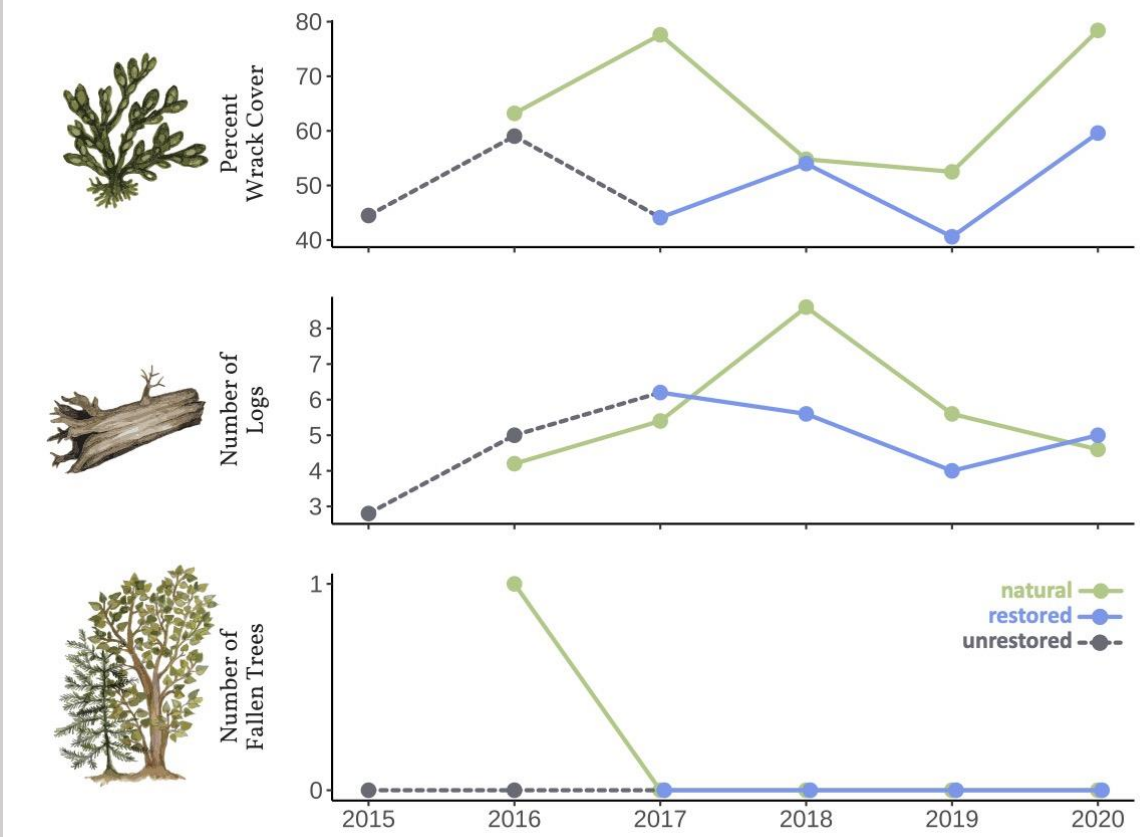


Family Tides is a private pocket beach on Orcas Island, which is part of the San Juan Archipelago. In 2015, private landowners worked with Friends of the San Juans to dismantle a creosote wall armoring the 150 feet of shoreline. The project involved the removal of 27 tons of creosote as well as rock and fill from the beach, the planting of 1,600 native trees and shrubs along the bank, and the restoration of 3,000 square feet of forage fish spawning habitat.

Site Characteristics

Location	San Juan Islands (48.6164, -122.98079)
Shore Type	pocket beach
Land Ownership	private
Date Restored	2015
Restoration Type	armor removal, vegetation planting
Length Armor Removed	150 ft
Years Monitored	2015-2020
Protocols	beach wrack, logs, vegetation

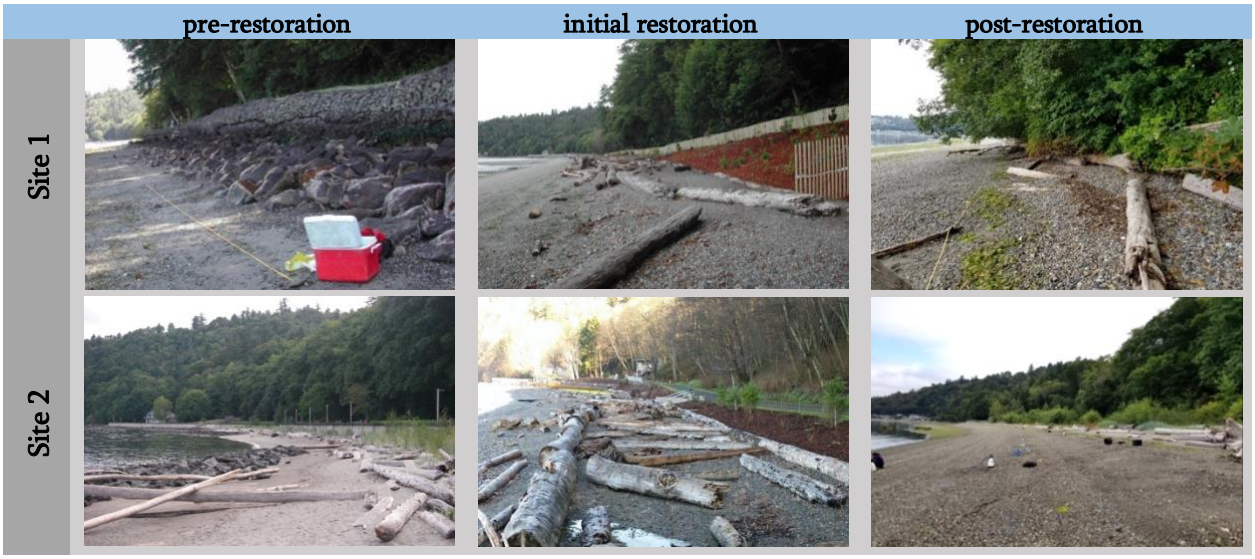
Results



Armor removal had potentially positive effects on beach wrack cover and the number of logs, though both fluctuated substantially through time in both the natural and the restored location. The natural location typically had a higher percentage of wrack cover and a higher number of logs than the restored location. Though there was one fallen tree at the natural location in 2016, no others appeared at either location throughout monitoring. Insects were not monitored at this site. Raw data can be downloaded at the Shoreline Monitoring Database.

Case Study 6: Seahurst Park

Burien, WA



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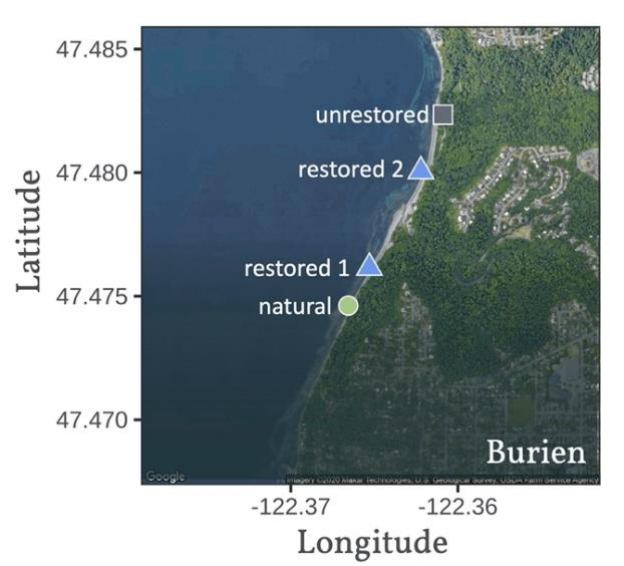
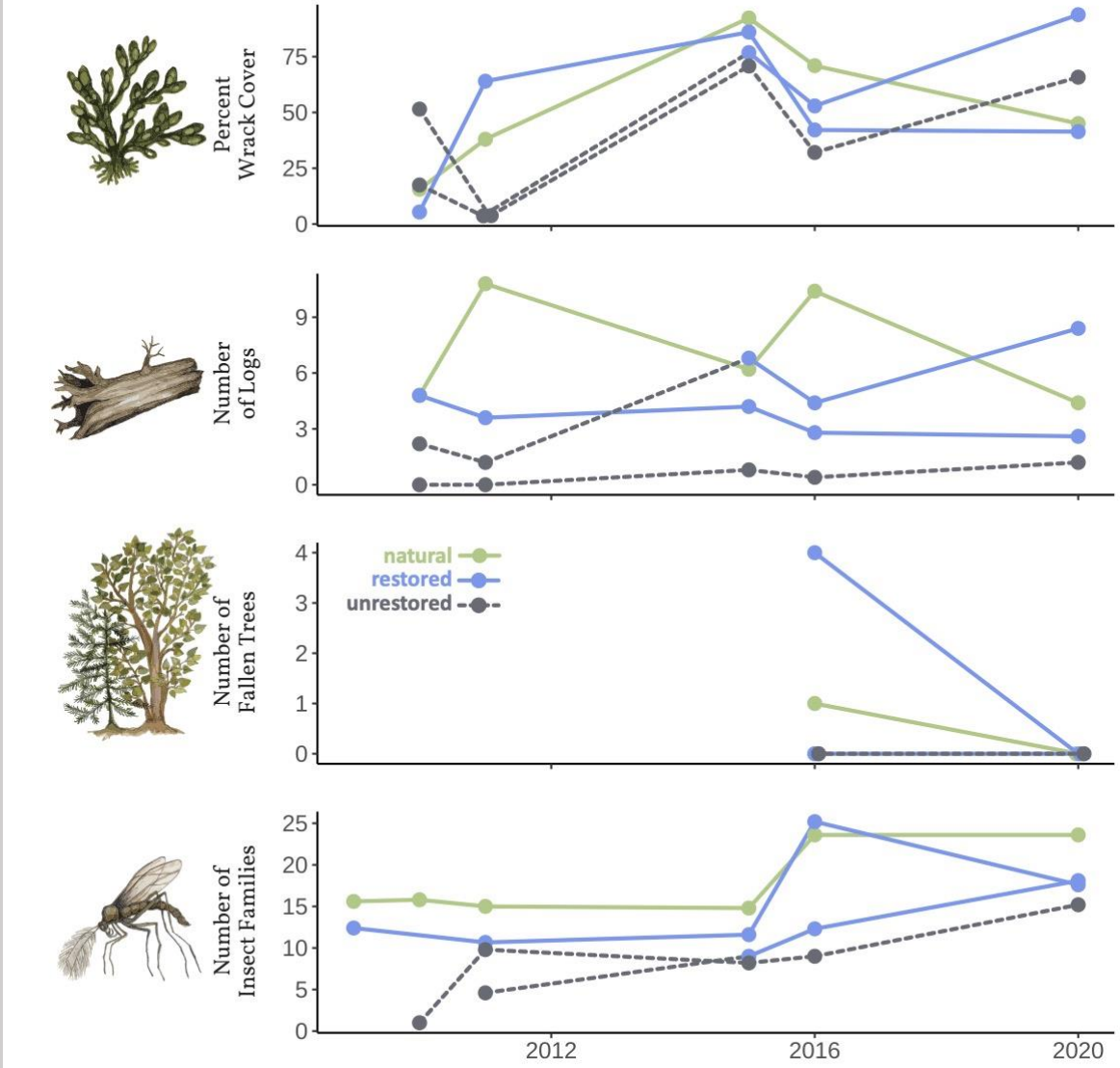


Seahurst Park, created in 1975 under King County management, was ceded to the City of Burien from 1993-7. Negative impacts of armor constructed before park creation were clear by the late 1990s when local citizens and the Natural Resources Conservation Service began armor removal, beach nourishment, adding logs, and planting native vegetation. The first major seawall removal restoration effort was in 2005 with another in 2014. Beach nourishment has replenished eelgrass and critical habitat. Seawall removal has improved conditions for forage fish and a crucial migratory corridor for juvenile chinook salmon.

Site Characteristics

Location	Burien (Restored 1: 47.4763, -122.3649 | Restored 2: 47.4801, -122.3619)
Shore Type	Feeder bluff
Land Ownership	Public
Date Restored	Restored 1: 2005 | Restored 2: 2014
Restoration Type	Armor removal, nourishment, log addition, vegetation planting
Length Armor Removed	Restored 1: 1100 ft | Restored 2: 1800 ft
Years Monitored	Restored 1 & 2: 2010-2011, 2015-2016, 2020
Protocols	Beach wrack, logs, insects, vegetation

Results



This site displays some of the most comprehensive evidence for restoration success given that comparisons can be made among existing natural, restored, and unrestored locations. As predicted, armor removal generally had positive effects on beach wrack, logs, and the number of insect families. In particular, in restored locations all variables approached the levels observed at the natural location. Though there was considerable variation among years, armored locations had consistently lower wrack cover, log count, and number of insect families. Most variables were consistently higher at restored and natural locations, with the exception of higher wrack coverage at the armored location in 2020. Raw data can be downloaded at the Shoreline Monitoring Database.

Conclusions

An increasing amount of armored shoreline is being restored across Puget Sound (see the Shoreline Armor Vital Sign Indicator)**.** Partnerships among academics, non/government agencies, organizations, and volunteer groups are making great strides in monitoring the effects of these efforts. Results from six representative sites across Puget Sound show the promising effects of restoration on four response variables: beach wrack (percent cover), logs (number), riparian vegetation (as fallen trees), and insect diversity (number of families).

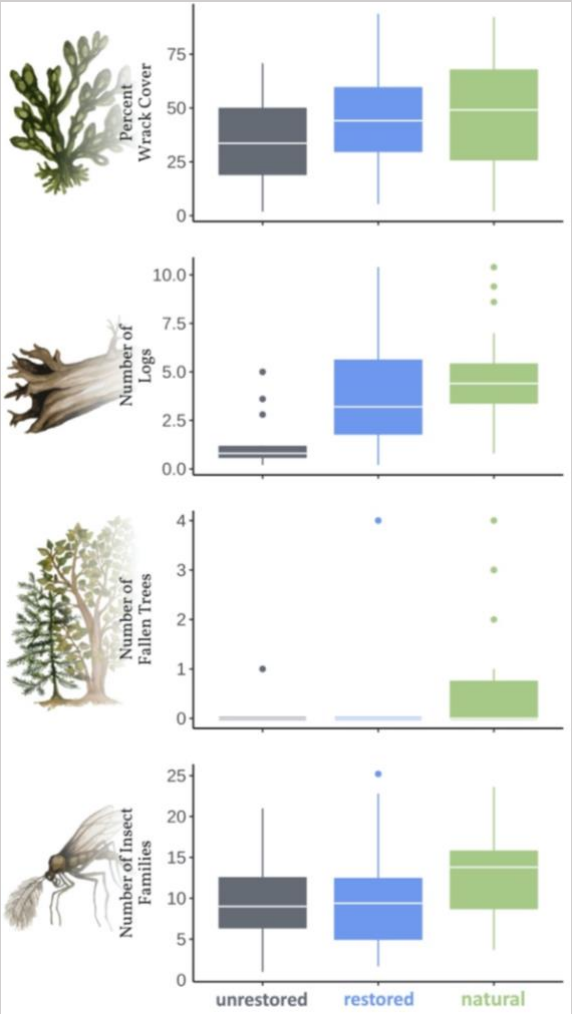


Fig 2: Overall, effects of restoration were positive across six sites for wrack cover, number of logs and fallen trees, and insect family diversity. Box plots summarize data across all transects at all sites across all years.

Fig 1: Effects of shoreline restoration are multifaceted. Armor removal, nourishment, vegetation planting, and log addition have both positive direct (solid lines) and indirect (dashed lines) impacts on shoreline ecosystems.

Results Summary: As with any restoration effort, effects of armor removal are multifaceted, and each biological response variable occurs in the context of many others (Fig 1). Restoring the natural slope of the beach, for example, allows a receding tide to leave behind beach wrack and logs. Some of the first responses to restoration are wrack and driftwood accumulation on the beach (Fig 2). Armor removal can allow native tree growth, which can also contribute to terrestrially-derived beach wrack and logs. Wrack, vegetation, fallen trees, and logs all contribute to a more complex habitat for other organisms including insects, but also marine invertebrates, fish, algae, birds, and even lizards. Our results across six sites in Puget Sound show that, while natural (never armored) sites had the highest levels of wrack, logs, fallen trees, and insect diversity, restored sites were generally improved in many these aspects (particularly wrack cover and log number) and approached "natural" levels, suggesting a positive trajectory for shoreline ecosystems post armor removal.

Future Efforts: Multiple additional protocols and data visualizations available through the database website – including responses such as physical and habitat characteristics are being developed. We plan to further analyze the data presented here along with newly generated data, supplemented with additional sites across Puget Sound. In the future, we will analyze these data in the context of other spatial factors, such as proximity to urban development, public versus private land ownership, and climate.