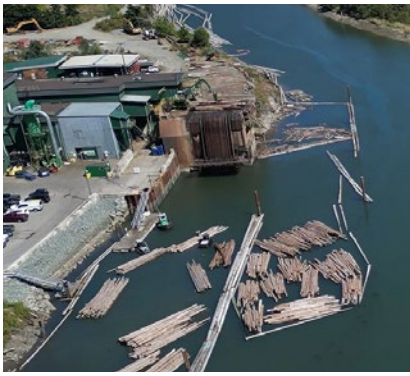
PACIFIC SALMON FOUNDATION



RESILIENT COASTS FOR SALMON

Nature-based solutions for climate change

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MARINE SCIENCE PROGRAM

resilientcoasts.ca

SALMON AND COASTAL MODIFICATION

Pacific salmon are a vital part of our coastal ecosystem and our way of life in BC. As British Columbians, many of us have grown up fishing and eating salmon, appreciating salmon-centric art and witnessing the annual migrations and spawning events as salmon return to our local rivers—salmon are woven into our cultures and our way of life on the coast. In British Columbia there are five well known species of Pacific salmon: Chinook, coho, sockeye, chum and pink. Each species has unique features, but they all have a similar life cycle starting with hatching from eggs laid in freshwater streams, migrating to sea and returning as adults to their natal streams to spawn and die (Figure 1). This journey of Pacific salmon has shaped the way our freshwater and marine ecosystems function, contributing to their incredible diversity and productivity. Unfortunately, Pacific salmon are being increasingly impacted by coastal modification and associated habitat loss during their coastal phase of life.

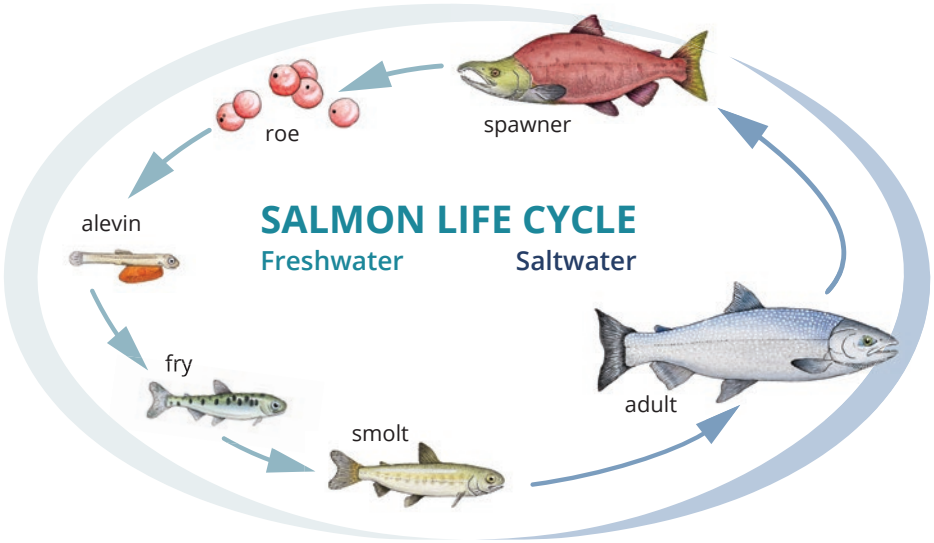


Figure 1. *The life cycle of anadromous Pacific salmon, starting in fresh water of rivers, streams and creeks, moving into estuaries and the open ocean, and ending back in the waters where they were born. Illustrations by Anisha Parekh*

Cover photos by Ryan Miller (top), Eiko Jones (left), Bob Oxborrow (centre) and Mitch Miller (right)

HOW DO SALMON USE THE NEAR SHORE?

Coastal and estuarine areas are vital stop-over habitats where young salmon grow, adjust and prepare for their life at sea. As they make their way out of their natal rivers, juvenile Pacific salmon use estuaries and marine coastal areas as rearing habitat to rest, grow and eat before they begin their great open ocean journey. Tidal wetlands are critical habitat where salmon can also take their time to transition from freshwater to the salt water of the ocean. Lush vegetation and narrow tidal channels provide refuge for juveniles (Figure 2). Terrestrial insects are a major food source for salmon when they fall from trees, overhanging sedges and shrubs. As they venture further, natural marine shorelines provide safe areas for the growing juveniles to continue their growth and catch nutritious prey (Figure 3).

Figure 2. *Healthy estuarine wetlands provide excellent habitat for out-migrating juvenile Pacific salmon. Photo by Nicole Christiansen.*

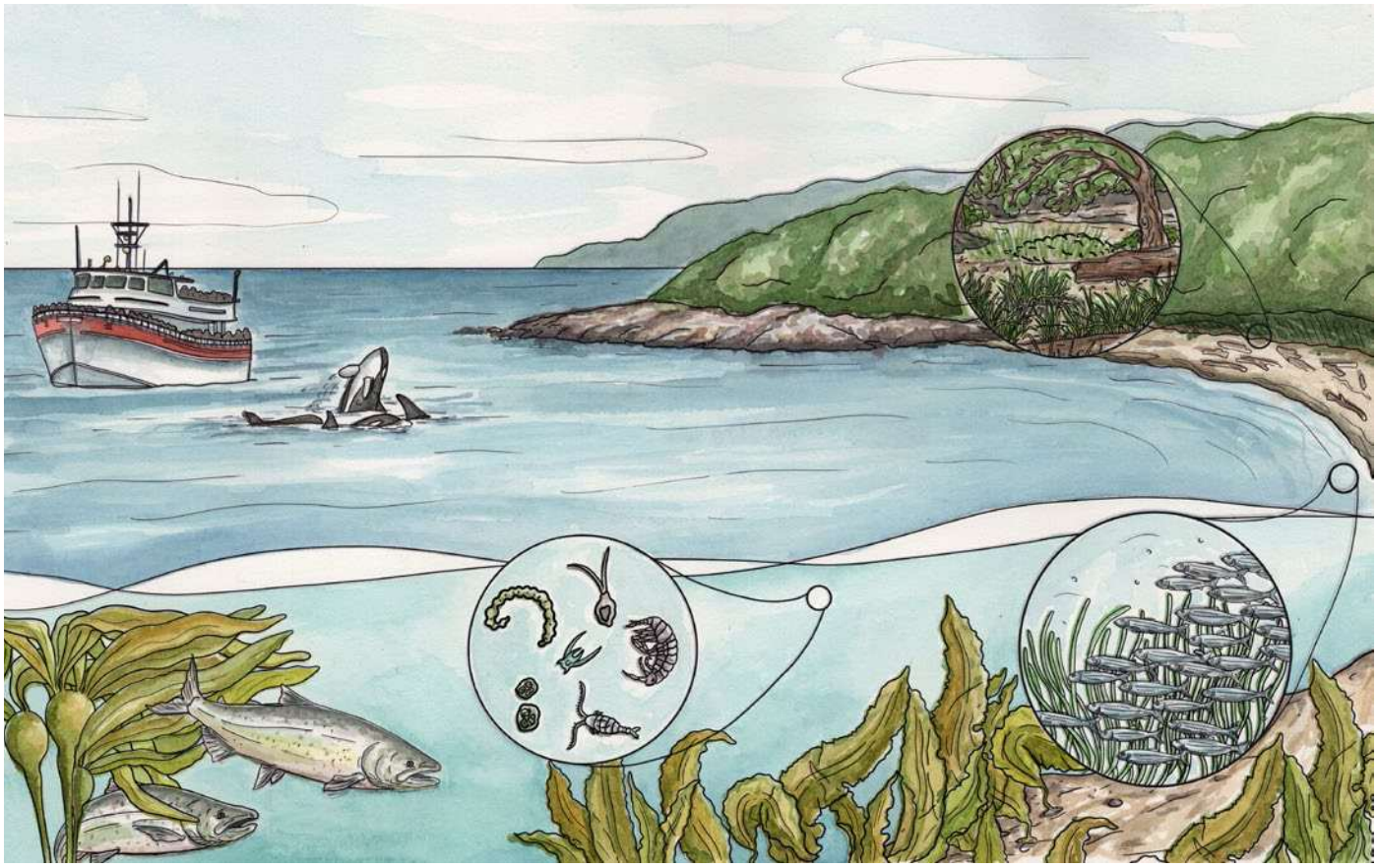


Figure 3. *Salmon utilize complex and diverse shoreline habitats as they grow in the coastal environment. They are supported by habitats such as eelgrass meadows, kelp forests and shallow beaches for refuge and abundant food sources. Overhanging riparian vegetation moderates beach temperatures for spawning forage fish and for rearing salmon, and provides terrestrial food inputs. Illustration by Holly Sullivan*

Figure 4. *In many estuaries, logging operations tend to result in implementation of hardened shorelines and both these and the presence of the log booms themselves will impact salmon habitat. Photo by Mitch Miller.*

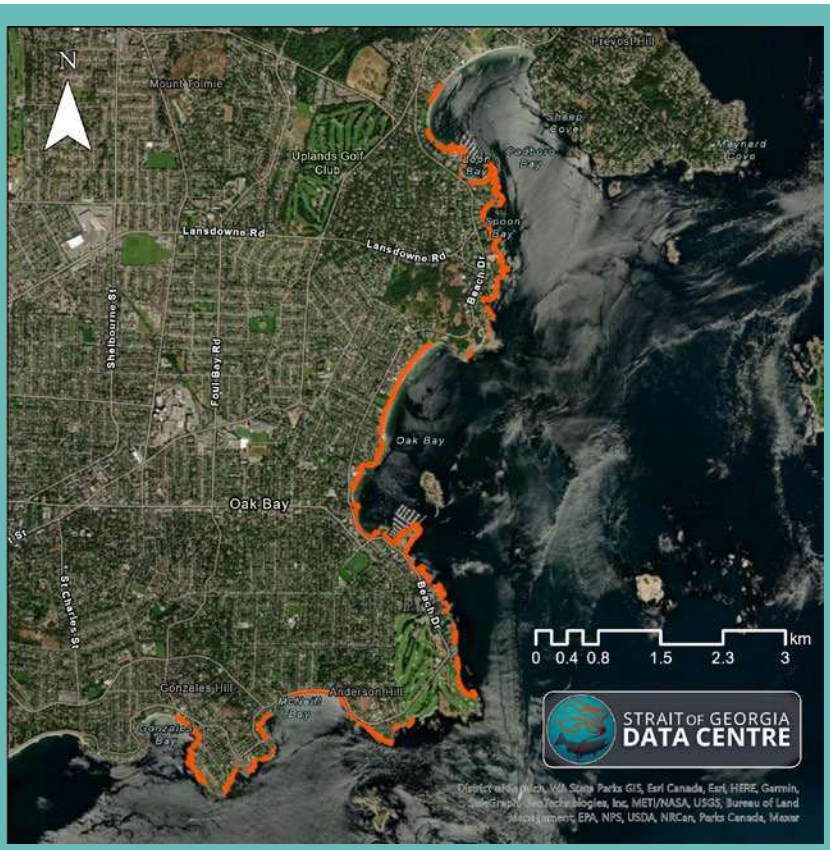
How well salmon grow during their time in coastal areas is directly linked to their success out at sea, and ultimately, whether they make it back to spawn the next generation. When Pacific salmon first migrate out to coastal habitats, they preferentially use shallow areas and shift along the depth gradient and between habitats as they grow. The natural slope of beaches creates a gradient of habitats, where the underwater habitat becomes shallower as the water approaches the shore. Here, the smallest salmon can hug the shoreline where the water is too shallow for predators to reach them. Coastal development has unfortunately made an impact on these vital habitats.

When estuaries and marine shores are highly modified with industrial activities such as logging, milling, or otherwise, it can threaten the survival of salmon (Figure 4).

Historically, we have built right up to the shoreline and imposed structures like seawalls, docks and piers to allow for recreation at the water's edge. The unfortunate downside is that these structures impact salmon behaviour, cut off habitat or reduce habitat quality, and interrupt coastal processes. We are at risk of losing valuable habitat for Pacific salmon and other creatures.

Did you know that in many urban locations around the world, more than 50% of the shoreline has been "hardened" by coastal armouring structures (Gittman et al. 2016)? Not to mention, our coasts are often hubs for industry such as shipping and logging. The Resilient Coasts for Salmon project has mapped the shorelines of the east coast of Vancouver Island, building a dataset of the extent of coastal modification. Check out the data to see how much of your community is armoured. In this aerial map of Oak Bay in Victoria BC, orange highlighting depicts areas of shoreline modification with coastal infrastructure such as seawalls, marinas, groynes and more. Within the municipal boundaries of Oak Bay, approximately 51.6% of the shoreline has been modified.

To learn more, visit:
resilientcoasts.ca/community-mapping



HOW DOES COASTAL INFRASTRUCTURE AFFECT HOW SALMON USE THE NEARSHORE?

Overwater Structures

Overwater structures such as piers and docks shade the environment below, which has cascading impacts on the coastal food web (Figure 5). Along the highly developed Elliott Bay waterfront in Seattle, it was found that there were significantly more abundant and diverse salmon prey (epibenthic invertebrates and zooplankton) in the areas not covered by piers, than directly under those structures (Cordell et al. 2017a). While some species of epibenthic invertebrates may be found under piers and docks, many that are important prey for juvenile salmon tend to live in areas where there are algae, seagrasses and phytoplankton, but due to the lack of light under piers and docks, these seagrasses and those associated species tend to be missing (Cordell et al. 2017b). This results in a reduced availability of food for salmon under structures like docks and ferry piers.

Salmon also tend to avoid overwater structures like piers and docks (Munsch et al. 2014); the lack of l ight makes it more difficult to see their predators, properly orient themselves, or school together. Salmon are visual hunters, so piers are less desirable habitat as the lack of light impacts their ability to detect prey (Munsch et al. 2014). Overwater structures that extend from the zone above the high tide line into the subtidal zone tend to have the greatest effect on fish that use this nearshore habitat (Toft et. al 2007). Because many fish tend to avoid areas under docks, their presence can disrupt movement patterns of migratory fish, causing them to swim out further resulting in greater physical exertion and possibly more exposure to predators (Munsch et al. 2014, Munsch et al. 2017, Toft et al. 2007). Particularly for juvenile salmon, the presence of overwater structures in estuaries could impact the success of their outmigration (Toft et al. 2007). The environment below overwater structures is so different from natural shorelines, that it impacts the community of species who use that habitat. For example, researchers in Puget Sound, WA have found that the areas under piers tend to have a much higher proportion of critters like crabs, and very little algae or kelp, and only some fish species (Cordell et al. 2017b, Munsch et al. 2014).

Image credit: still shot from video: National Oceanic and Atmospheric Administration and Pacific Northwest College of Art, Beryl Allee and John Summerson vimeo.com/89795956

Figure 5. *Overwater structures make the habitat underneath dark and inhospitable for species like Pacific salmon. Photo by Kyla Sheehan.*

Figure 6. *Seawalls are fixed structures on our coasts, preventing habitat from adjusting with changing conditions. Photo by Maria Catanzaro.*

OTHER CONSEQUENCES OF MODIFICATIONS

Coastal Squeeze

When shorelines are hard armoured, with seawalls and riprap, habitats cannot naturally migrate landward with sea level rise; this phenomenon is known as coastal squeeze. This restricts or interrupts coastal processes and reduces the adaptive nature of our shorelines. Coastal squeeze also means a direct loss of intertidal habitat and the species that rely upon those areas. As sea levels rise (Figure 6), our vital coastal habitats such as wetlands will need to shift and migrate landward, but they can't do so when modifications like seawalls are in the way. If we don't give our coasts the room to adjust to changing conditions, we could lose valuable habitat.

Riparian Connection

Coastal modification also disrupts overall land and sea connectivity. Removal of trees and shrubs on modified shores results in loss of a valuable nutrient source from leaves and insects that fall into the water. Surf smelt, a prized prey item for rearing juvenile salmon in coastal areas, also suffer from the removal of overhanging coastal vegetation. Without the shade of trees and shrubs, the beaches where surf smelt deposit their eggs can reach extreme temperatures. Along streams and shorelines, trees stabilize riparian zones and keep the waters cool, clean and clear, which is vital for Pacific salmon (Figure 7). Sadly, riparian vegetation is often removed to make room for infrastructure, or because it is seen as obstructing waterfront views.

Seawalls

The presence of structures like seawalls below the highwater mark means that for a lot of the time, there is deep water right up to the shoreline, rather than a natural slope where the water gets shallower as you approach the shore. This allows for larger predators to get close to the shore and hunt smaller fish like juvenile salmon and forage fish.

Seawalls also tend to change the availability of prey (Munsch et al. 2014). Studies have found that shoreline armouring like sea walls reduced the number and diversity of epibenthic invertebrates (critters that reside on or above the rock, sand and mud of the seafloor) and the availability of terrestrial insects compared to unarmoured areas (Cordell et al. 2017b). As a result, when young salmon are next to artificial structures, they end up feeding on alternative prey types such as planktonic prey that might be harder to catch and less nutritious.

Figure 7. *Maintaining a healthy riparian area with overhanging branches from trees and shrubs can provide a huge benefit to young salmon. The shade helps cool the shallow nearshore waters where it is safest for them to be, and the branches provides a food source from the terrestrial insects that drop into the water. Photo by Nicole Christiansen.*

Reduced Habitat Complexity

You might notice that on a natural shoreline, there is often variation in the critters that reside at different levels in the intertidal — this is known as bio-banding (Figure 8). Depending on where the habitat is located along the intertidal gradient, it will be submerged for different periods of time, resulting in different plants and animals finding their niche. Shoreline armouring such as seawalls reduce the habitat complexity — there are fewer nooks and crannies compared to a natural shoreline, and they often cut off intertidal areas where we would normally see those diverse bio-bands of species (Figure 9). Compared to natural and restored beaches, some key elements of the intertidal, such as beach wrack, logs, and supratidal invertebrates, are often less abundant and less diverse on shores with seawalls (Des Roches et al. 2022). Biological diversity in an ecosystem is well known to be a marker of health and resilience to changing conditions.

Figure 8. *Bio-banding can often be seen on rocky outcrops where the habitat and species present vary depending on factors like the time it is not covered by the tide. Photos by Kyla Sheehan.*

Figure 9. *Armoured shorelines tend to cut off the intertidal habitat, reducing diversity of the shore.*

NATURAL SHORELINES, A SOLUTION FOR SALMON:

With much of British Columbia's population concentrated along the coast, we have a lot to lose as sea levels rise, including vital habitat for Pacific salmon. When kept natural, rather than hardened with seawalls or other structures, shorelines will buffer wave energy and provide quality complex habitat that supports the entire coastal food web (Figure 10).

Figure 10. *On a natural shoreline (right side of image), the water gradually gets shallower as you approach the beach. This gradient in habitats means that smaller fish can be protected in the nearshore where larger predators cannot access them. They also benefit from the shade of overhanging tree branches and shrubs in these areas. Meanwhile, a human-made seawall (left) is static, providing little habitat to support biodiversity, while also causing the wave energy to intensify, potentially overtop the wall, and create erosion at the base.*

Figure 11. *Below the surface, the VIM docks are teeming with life! Anemones, tube worms, kelps, sponges and more! Photos by Kyla Sheehan.*

SO HOW CAN WE BALANCE THE NEED FOR COASTAL INDUSTRY AND COMMUNITIES WITH HEALTHY HABITAT FOR SALMON?

Coastal industries are a huge part of our economy, and are not going away, but some businesses are leading the charge in building habitat and minimizing impacts on the nearshore!

Victoria International Marina

The Victoria International Marina (VIM)is a world-class hub for large yachts, and renowned for its commitment to environmental stewardship. VIM CEO Craig Norris' background in environmental science drives this commitment, and his curiosity to continue learning. The VIM team endeavors to minimize the marina's impact in the following ways: using materials like high density polyethylene so they are recyclable (unlike creosote or polystyrene), creating surfaces that allow for life to flourish and maintain the functionality of the marina, removing contaminated sediment from the site and adding artificial reefs (Figure 11). They received the Clean Marine BC Certification!

Seattle Seawall

Where there is long-standing infrastructure that promotes tourism such as a seawall walkway, there are opportunities to build habitat without having to start from scratch.

The City of Seattle is a great example. The newly designed pier and seawall beneath it are part of a larger project at Seattle's Waterfront Park (Figure 12). This project aims to create open space for engaging and educational events, plus coastal habitat that supports marine life in the urban location.

Rather than seawalls that plunge into deep water and are covered by solid walkways and structures, which create dark areas lacking habitat complexity, food resources and refugia that young salmon need, the restored areas have a number of modifications so as to retain shallow and complex intertidal zones that receive sunlight.

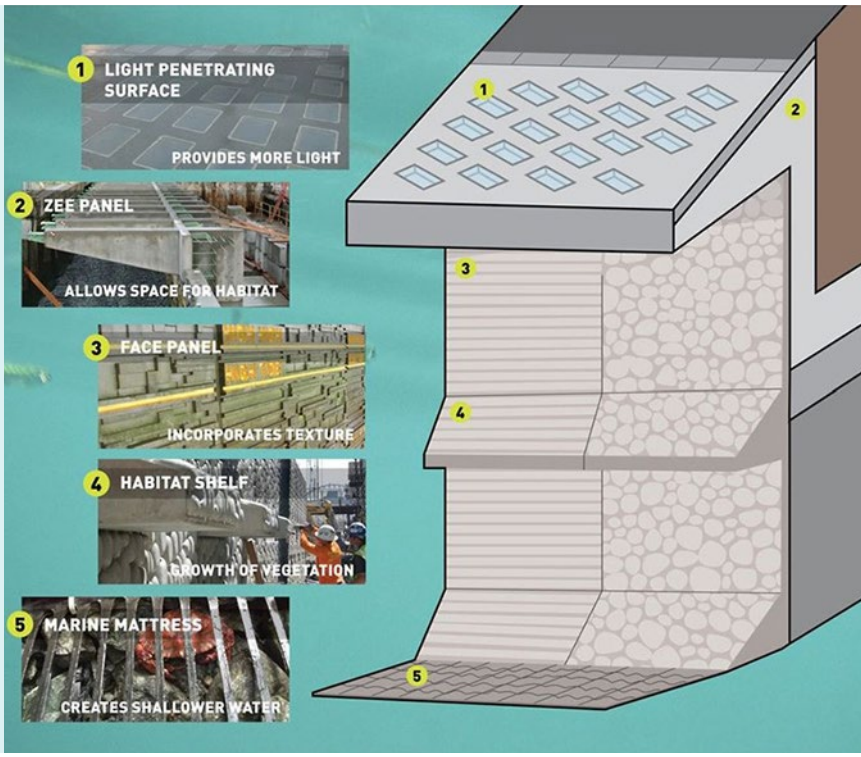
Figure 12. *Seattle's salmon friendly seawalls. Photo by Bob Oxborrow.*

The schematic on the right, from Waterfront Seattle, shows how the seawalls under the walkways and piers have been rebuilt.

Starting at the top, walkways were outfitted with light penetrating surfaces (1,2), including grating and glass blocks, to light up the areas below.

Instead of a flat featureless seawall, textured panels and habitat shelves were added to increase surface complexity (3,4). The texture promotes settlement of algae and invertebrates that, in turn, attract small fish. In the build, they have experimented with different types of texture, emulating cobbles in some areas and striated rocks in others.

Towards the low tide mark, so called 'marine mattresses', were installed (5). These added structures create shallow habitat that provide small critters and young salmon refuge from larger predators.



Researchers from the University of Washington's Wetland Ecosystem Team, who provided input, are monitoring the project's success. They are seeing that the steps taken are increasing biodiversity and improving habitat value. As hoped, salmon are using these areas more than they were under traditional structures.

Above it all, in the popular public area, signs about the work provide an excellent learning opportunity for visitors to engage with. A number of articles published in news sites (including an article in Hakai Magazine, and an NPR podcast), also helps create a buzz of interest in the work to a wider audience.

See the students in UW School of Aquatic and Fisheries Sciences present in this work in a seminar hosted by Sound Water Stewards (vimeo.com/511333492).

NATURAL SOLUTIONS AT HOME

On shoreline properties, we can restore and protect our shorelines by:

- **Removing hard armouring** and other coastal modifications that cut off nearshore habitat.
  - > Using nature-based solutions instead that provide benefits to salmon. This could include regrading the beach and backshore, nourishing the beach with sediment, and/or using large woody debris anchored into the sediment to encourage the accumulation of beach sediment.
  - > Using the best practices of the Green Shores® nature-based solution framework, you can turn your waterfront from armoured and bare to lush and natural. The Green Shores principles can help guide the restoration of your shoreline to support healthy coastal habitat.
- **Setbacks.** Where possible, it is best to move infrastructure back from the shore or build new structures set back to plan for sea level rise and allow the shoreline more space to move over time. This allows space for critical salmon habitat such as estuarine wetlands to adjust to changing conditions on our coasts.
- **Manage runoff** to prevent contaminants from entering the marine environment. Salmon rely on clean cool coastal waters. One common contaminant that comes from car tires has been found to be lethal to coho salmon. You can help prevent this and other contaminants from entering the marine environment by having lawns and permeable paving stones, and by planting rain gardens that help filter and hold runoff (Figure 13).
- **Make your dock salmon-friendly** by choosing non-toxic materials, using a grated dock surface so that light can penetrate, and minimize the imprint of pilings and supports.

Figure 13. *An ingenious approach to permeable paving, where car-related contaminants are captured in the vegetation and soil before entering nearby storm drains. Photo by Kyla Sheehan.*

- **Adding complexity** where armouring/structures cannot be removed from the nearshore. This can be done by adding steps, ledges and textured cobble surfaces instead of smooth concrete. In a study comparing structures with different complexity on seawalls, it was found that ecosystem engineer species rockweed (Fucus) and mussels (Mytilus) were more abundant on ledges and steps that were built into seawalls, compared to smooth seawalls (Cordell et al. 2017a).
- **Planting native vegetation** including trees and shrubs along the backshore for shore stabilization and shade. Not to mention, juvenile Pacific salmon love to feed on terrestrial insects that fall from overhanging branches into the water below.

WANT TO LEARN MORE ABOUT HOW WE CAN USE NATURE-BASED SOLUTIONS ON OUR COAST TO SUPPORT PACIFIC SALMON? CHECK OUT THE TOOL KIT AT RESILIENTCOASTS.CA

Sign up for our Marine Science quarterly eNews and never miss a newsletter!

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Canada
PACIFIC SALMON FOUNDATION
RESILIENT COASTS FOR SALMON
STEWARDSHIP CENTRE FOR BRITISH COLUMBIA

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