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Vignette 11: Ecological Consequences of Built Shorelines in the Salish Sea

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Waterfronts are important ecosystems and busy places. Shallow waters are often productive and densely inhabited by fish. Along shore, terrestrial, aquatic, and benthic realms provide a diversity of habitats for primary producers, invertebrates, and fishes. Indeed, ecologists often characterize nearshore ecosystems as fish nurseries because they provide small fish with plentiful, diverse food sources and protection from predators (Beck et al. 2001).

However, the world's population is disproportionately located near water, where people aggregate industrial, residential, and commercial activities. Consequently, many nearshore ecosystems are highly modified. This is the case in the Salish Sea where many species rely on shoreline habitats, but people have modified shorelines. By appreciating habitat impacts and how to mitigate them, we may steer toward a future that enables people and nearshore ecosystems to coexist.

One of the major modifications to the Salish Sea's shoreline is armoring (e.g., seawalls, riprap). Armoring is hard, heavy material such as concrete or boulders that prevent erosion and allow people to build close to shore. Over 25% of Puget Sound's shorelines are armored, approaching 100% in urban areas (Simenstad et al. 2011). Armoring can replace backshore vegetation, truncate intertidal zones, simplify benthic substrates, and eliminate transition zones connecting land and sea.

The ecology of armored shorelines is different from their unarmored counterparts. Severing the connection between land and sea prevents mutual exchange of nutrients and energy (e.g., seagrass, logs, leaf litter) across shore (Dethier et al. 2016;

Heerhartz et al. 2014). The limited, less diverse habitats of armored shorelines are inhabited by less abundant and diverse invertebrate assemblages (Sobocinski et al. 2010; Heerhartz et al. 2016). This translates to a limited prey field available to fish, and fish along armored shorelines must switch from their primary prey of terrestrial (e.g., flies) or epibenthic invertebrates (e.g., harpacticoids) to presumably less valuable plankton (Toft et al. 2007; Morley et al. 2012; Munsch et al. 2015a).

Armoring also influences fish composition. Along armored shorelines, species that prefer deep, rocky waters are present, while species preferring sandy substrates are absent (Toft et al. 2007; Morley et al. 2012; Munsch et al. 2015b). Additionally, along intact shorelines, tiny fish use the shallowest waters to avoid predators before they grow large enough to use deeper waters. However, these tiny fish avoid armored shorelines, presumably because their deeper waterfronts do not offer extreme shallows and predator refuge (Munsch et al. 2016). In addition to removing predator refuge, armored waterfronts attract small fish predators (Munsch et al. 2015b). Another issue is that armored beaches lack backshore vegetation, which keeps intertidal zones cool and damp. As a result, survival of beach spawning fish embryos is lower along armored shorelines compared to vegetated shorelines (Rice 2006). Overall, there are many ecological impacts of armoring on the Salish Sea, and these effects are primarily negative.

Another common modification to shorelines is overwater structures (e.g., bridges, docks, piers). Overwater structures shade shallow waters, limiting photosynthetic species and creating areas too dark for fish to see. This can reduce abundances

of invertebrates that associate with algae and seagrasses, including invertebrates common in fish diets (Cordell et al. 2017a). In addition, fish avoid shaded areas under large piers (Munsch et al. 2014; Ono et al. 2014). This is particularly concerning for juvenile Pacific salmon, which migrate along shore but often swim in circles next to piers rather than under them. When salmon do use areas under piers, they rarely feed (Munsch et al. 2014). Similarly, large floating bridges are physical barriers that can disrupt migratory movements of salmonids and increase their risk of predation, potentially by attracting predators to migratory bottlenecks (Moore et al. 2013). Overwater structures are thus another stressor to the Salish Sea's nearshore ecosystems.

By appreciating negative effects of shoreline modifications, we can mitigate them, even along shores heavily used by people (Munsch et al. 2017). Restoring shorelines by removing armoring can recover many lost habitat functions (Toft et al. 2014; Lee et al. 2018). Indeed, many of the Salish Sea's shorelines are not exposed to rapid erosion and do not require conventional armoring. In such cases, property owners may employ alternative shoreline designs that are more aesthetic than armoring, allow people to access the beach, and retain

habitat functions (Washington Department of Fish and Wildlife 2016). Where true restoration is not practical, built pocket beaches and artificial intertidal zones can mimic some habitat functions of intact shorelines (Toft et al. 2013). These efforts to improve habitat can directly benefit people, for example by providing recreational beach space within urbanized landscapes. In areas where conventional armoring is necessary, seawalls can be textured to provide habitats for algae and invertebrates including fish prey (Cordell et al. 2017b). Similarly, where large overwater structures are necessary, people can construct them using translucent surfaces to avoid shading (Cordell et al. 2017b). Pocket beaches, artificial intertidal zones, textured seawalls, and translucent pier materials have recently been employed along the downtown Seattle waterfront to enhance habitats without reducing the waterfront's utility to people. Ongoing research is examining their effectiveness. Overall, we may protect the Salish Sea's nearshore ecosystems by appreciating ecological consequences of building along shore, conserving shorelines where human use constraints are low, and developing and employing approaches to mitigate negative effects of built shorelines in urban areas.



Railroad tracks and rip rap armoring along the shoreline at Marine Park, Bellingham WA
Photo: Ginny Broadhurst