Summary of Discussions from Breakout Groups

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As outlined in the Introduction to these Proceedings, the overall objectives of the Workshop were (1) to summarize the 'state of the science' on the physical changes and ecological impacts of shoreline armoring, (2) to assess the levels of certainty of this knowledge, and (3) to identify information and data needs that will advance the understanding of the impacts of armoring on Puget Sound beaches. These objectives are addressed through synthesis of the information provided in the individual papers of these Proceedings along with summaries from small-group discussions in breakout groups, and by full group discussions prior to conclusion of the workshop. Workshop participants were divided into three groups, with each group composed of representatives from each of the major scientific disciplines related to understanding the biology and geology of beaches and the impacts of shoreline armoring. The following sections on Armoring Impacts, Research Needs, and Conclusions represent the outcomes from these breakout groups and the plenary group discussions during the Workshop.

Armoring Impacts

The underlying conceptual model used throughout the Workshop was that shoreline armoring can alter processes (for example, sediment or groundwater delivery to the beach), which can lead to changes in beach structure (such as beach width or sediment grain size), which in turn causes ecological impacts to natural beach functions. The levels of certainty about these connections vary widely; we often have the poorest documentation of how changes in structure actually affect ecological functions. One of the difficulties in understanding and predicting the ecological impacts of shoreline armoring is that physical (morphological and hydrodynamic) responses to armoring depend on the setting: types of sediment, beach morphology, position in a drift cell, and local wave and current regimes.

Many of the impacts of armoring were demonstrated in the presentations and were reinforced in discussions among scientists from different regions. In addition, as noted in the literature review by J.M. Coyle and M.N. Dethier in appendix C of this Proceedings, armoring impacts may occur via combinations of at least five direct and indirect mechanisms: (1) placement loss, (2) land-beach disconnection, (3) sediment impoundment, (4) passive erosion, and (5) active erosion. For each of these, the response time can vary widely. The workshop break-out sessions resulted in four conceptual models (figs. 1-4) that illustrate the diversity of processes that may be altered by armoring, and give some indication of how well each has been demonstrated through field studies. In addition, each of these conceptual models lists some of the constraints that may influence the importance or magnitude of a mechanism, as well as how feasible or useful armoring removal or other related management measures would be at a given location.

Placement Loss

Impacts associated with placement loss occur when armoring encroaches onto the beach (fig. 1). In the Workshop's group discussions, this was viewed as the most rapid and best demonstrated impact, but often the least widely recognized. Many impacts increase when bulkheads are located seaward of ordinary high water. Some of these impacts are direct, such as truncating the beach and thus reducing area for forage fish to spawn, invertebrates to live, and logs to accumulate. In addition, there are many indirect effects of placement loss that relate to the disconnection that armoring usually causes between terrestrial and marine processes (fig. 2). Bulkheads often change the land-sea transition zone from a complex, broad ecotone to a simple line. This land-beach disconnection can occur with armoring placed at any elevation on the shore, but is most severe with structures placed at lower elevations on the beach profile. A key issue, documented in some areas of Puget Sound, is the associated loss of natural backshore riparian vegetation landward of the armoring, such as the overhanging trees that characterize local unmodified shorelines (for example, see photographs in the paper by J.D.Toft and others in this Proceedings). Data from Puget Sound demonstrate that this combination of placement loss and loss of riparian vegetation may reduce the quantity and diversity of invertebrates, many of which are preyed on by juvenile salmon during their shoreline migration (see the paper by J.D. Toft and others in this Proceedings).

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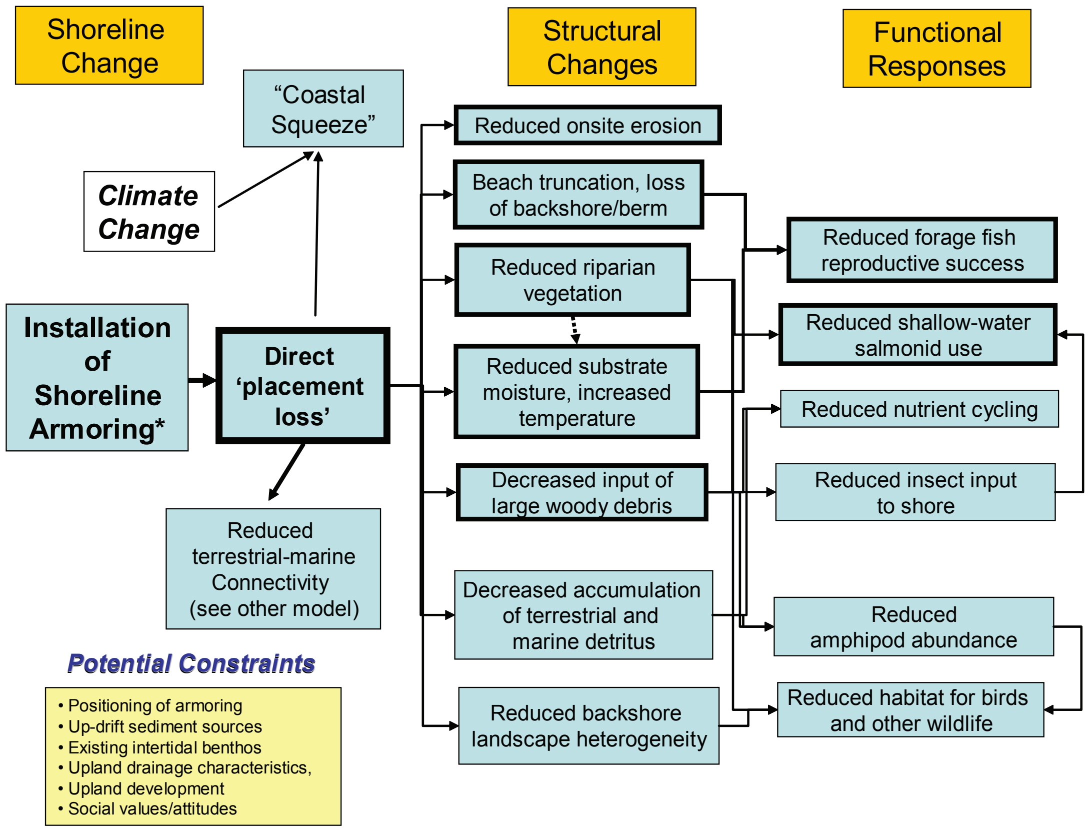

Figure 1. Conceptual model of the impacts associated with *placement loss*, which occurs when armoring encroaches onto the beach. The thicker black lines represent increased certainty in the response. Thinner black lines could represent less certainty in general or a lack of data for Puget Sound.

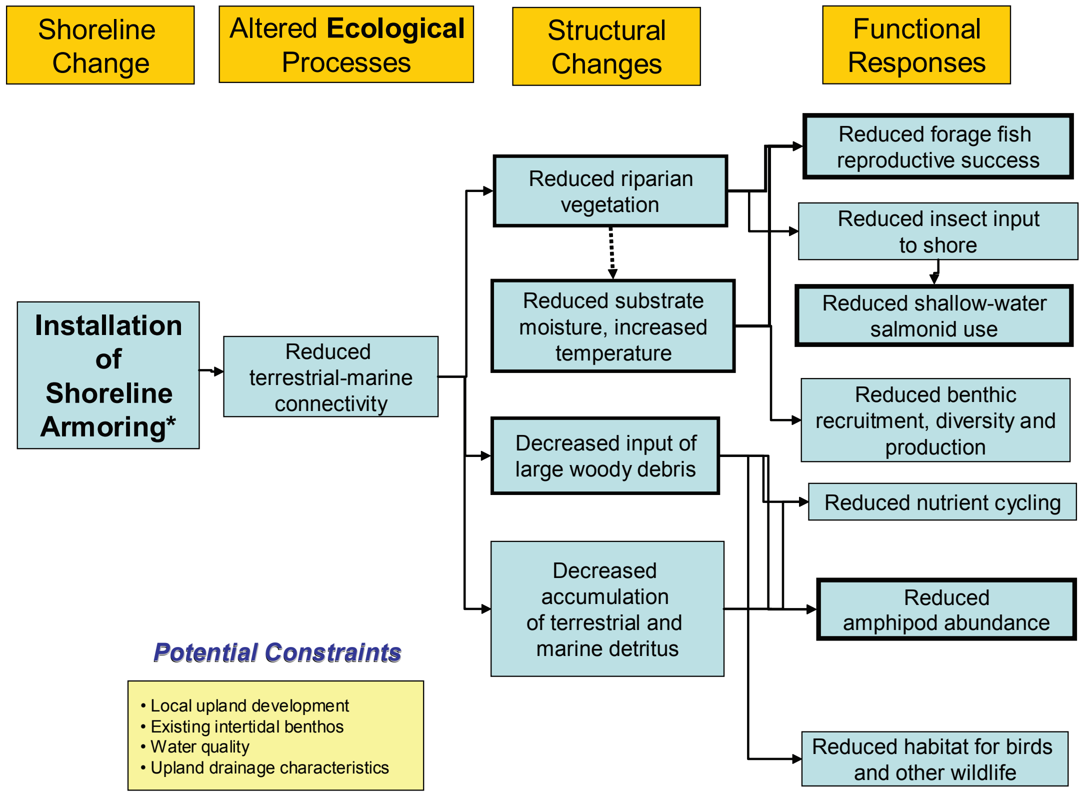

Figure 2. Conceptual model of *ecological processes* altered after installation of shoreline armoring. The thicker black lines represent increased certainty in the response. Thinner black lines could represent less certainty in general or a lack of data for Puget Sound.

Sediment Impoundment

Although sometimes difficult to quantify, another important impact of armoring involves changes to nearshore sediment processes (fig. 3), including sediment impoundment. Armoring often is constructed to prevent shoreline or bluff erosion; however, in doing so the structure reduces sediment supply from the bank or bluff onto the beach and into the shoreline drift cell. Even though most sediment on Puget Sound's beaches is believed to have originated from eroding bluffs, both historical and current rates of sediment supply are poorly quantified, in large part because of the difficulty of measuring such episodic and long-term processes. Participants agreed that not all armoring impounds sediment equally—a seawall that reduces sediment supply to the beach from an actively eroding bluff which supplied most of the sediment to a drift cell is more critical than one on a relatively stable, heavily wooded or low bluff that was only a minor source of sediment to that shoreline.

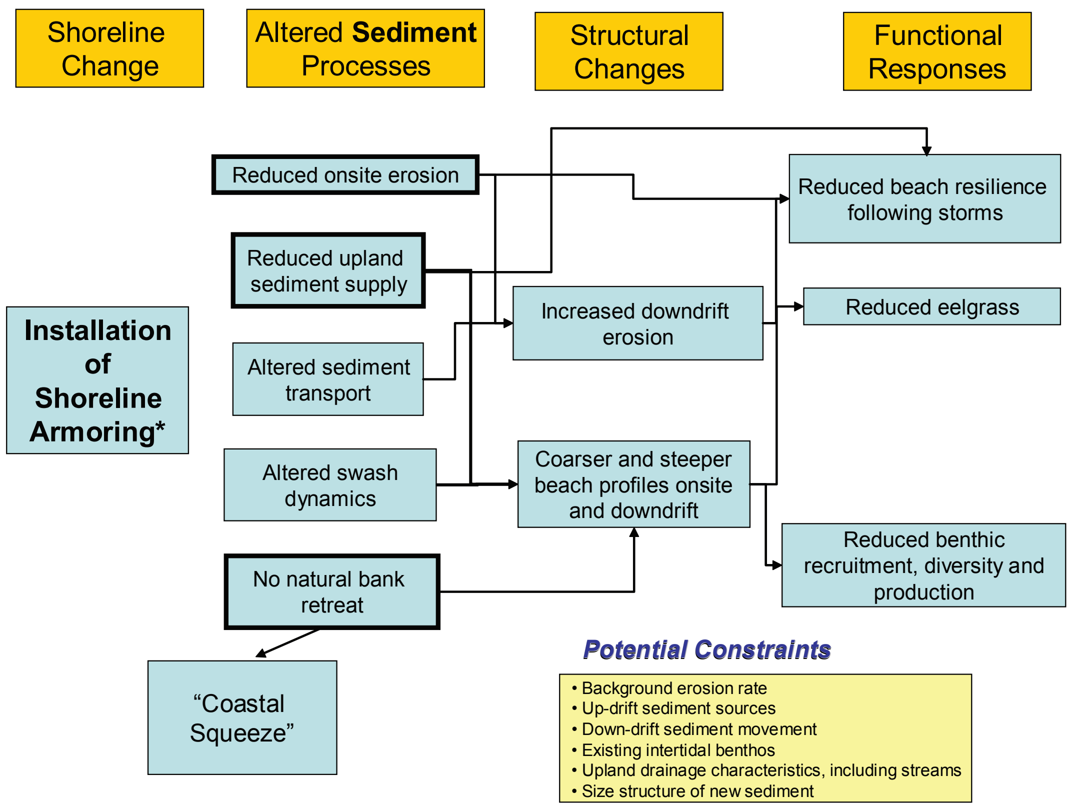

Figure 3. Conceptual model of *sediment processes* altered after installation of shoreline armoring. The thicker black lines represent increased certainty in the response. Thinner black lines could represent less certainty in general or a lack of data for Puget Sound.

Passive Erosion

Another inevitable effect of armoring on shoreline processes, regardless of its elevation, is that it halts the natural shoreline retreat or landward migration of the beach that accompanies sea level rise, land subsidence, or a sediment deficit. Passive erosion is the progressive loss of the beach that occurs when shoreline armoring is built on an already eroding shoreline. Armoring built on a coast that is eroding may provide protection to upland property or structures, but will not provide any protection to the beach seaward of the armoring. The loss of the beach that occurs as a result of passive erosion at modified shorelines is a change that may take years or decades to manifest depending on the background erosion rates, but is certain to occur and has been shown to be a major issue in other locations. Several scientists at the Workshop showed examples of the complete disappearance of beaches on eroding shorelines that contained armoring (see the paper by P. Ruggiero in this Proceedings for example).

Active Erosion

Alteration of hydrodynamic processes that may cause changes in beach geomorphology (fig. 4) were some of the most discussed but least agreed upon effects of shoreline armoring. In some areas, seawalls may increase wave reflection and scouring causing active erosion of beaches, especially when placed below ordinary high water. However, this effect remains an area of uncertainty, especially for the mixed sand and gravel beaches of Puget Sound. Armoring in other regions is believed to cause shorelines to become coarser and steeper. This effect has not been thoroughly investigated in Puget Sound but if it occurs, it could have significant ramifications to the ecology of local beaches. There are some data showing that modified beaches have lower moisture retention in the sediment (either from less shading or from coarser sediments), and this factor can affect forage fish embryos as well as other beach organisms (see the paper by C.A. Rice in this Proceedings).

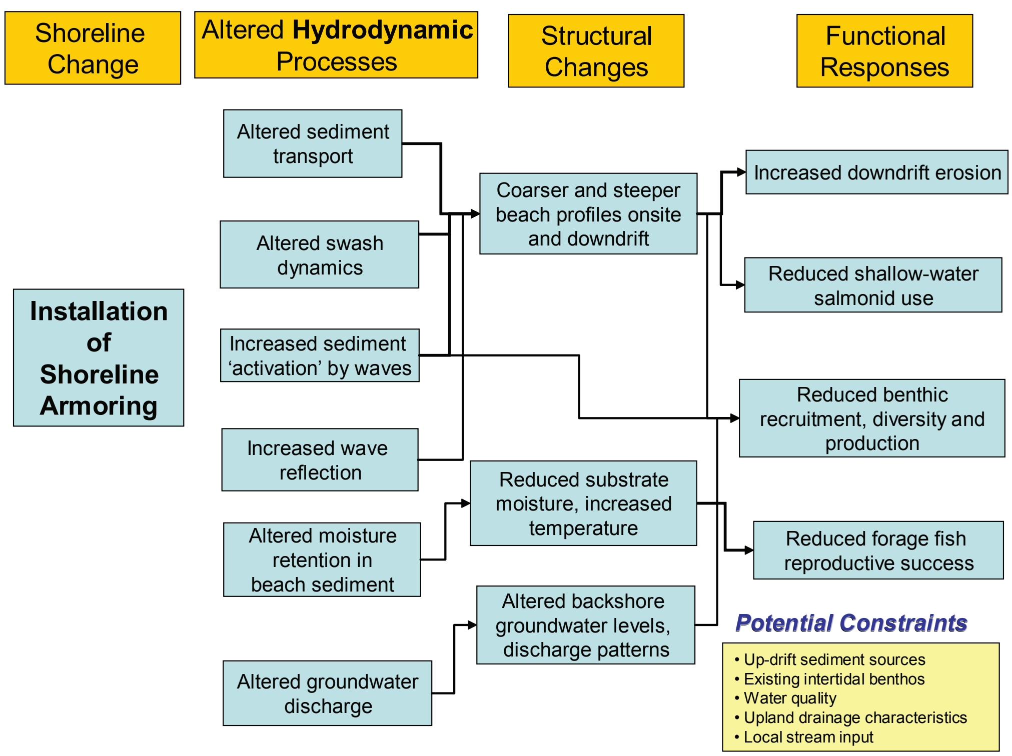

Figure 4. Conceptual model of *hydrodynamic processes* altered after installation of shoreline armoring. The thicker black lines represent increased certainty in the response. Thinner black lines could represent less certainty in general or a lack of data for Puget Sound.

Research Needs

There are local or short-term data sets that document some responses of armoring in Puget Sound, but long-term and cumulative data are lacking. This is particularly true for the hydrodynamic effects of shoreline armoring on beach geomorphology, and for what specific drift cell components produce the greatest effect. For example, it is uncertain whether there are thresholds, beyond which the cumulative loss of sediment supply leads to significantly altered beach structure and biological function. Many of the effects of shoreline armoring occur over variable temporal and spatial scales, depending on parameters such as wave energy or local sediment supply rate. Although it is certain that some changes, such as direct beach loss, will occur in the immediate vicinity of armoring, the alongshore extent of these impacts is uncertain.

Many of the data and knowledge gaps discussed during the Workshop and listed below can be informed with dedicated monitoring of beach restoration projects. For this reason, the Estuary and Salmon Restoration Program (ESRP), a Washington State funded effort, is encouraging learning opportunities by funding strategic monitoring of some nearshore restoration projects, including those involving the removal of armoring on beaches. Resolving other uncertainties, and particularly those related to hydrodynamic and geomorphic processes, may require dedicated monitoring and research funding to address the complicated, multi-disciplinary and often long-term processes involved.

Listed below are some of the high priority data and information gaps that exist regarding the impacts of shoreline armoring on sheltered coasts such as Puget Sound:

Geological-Oceanographic Uncertainties

- Does armoring on mixed sand and gravel beaches cause steeping and coarsening of the beach? What does this depend on (how/when/where)?
- What influences sediment composition on the Puget Sound low-tide terrace? How does sediment supply affect the elevation, width, and grain size of the low-tide terrace? Does armoring impact the low-tide terrace and, if so, how?
- What are patterns and rates of bluff erosion in Puget Sound? What local factors affect these rates (for example, rain versus toe erosion)? Can rates and factors be mapped and classified, for example, for each drift cell?
- How does coarse woody debris on beaches affect erosion rates and patterns of erosion?
- What are the patterns and rates of groundwater discharge through beaches locally and Sound-wide, and how are these affected by armoring?
- How do drift cell sediment budgets vary over time? What is the effect of shoreline armoring on drift cell sediment budgets?
- How will Puget Sound beaches with and without armoring respond to sea level rise? What is the anticipated degree of passive erosion that might occur?
- What are the average wave conditions (that is, the wave climate) for Puget Sound beaches? Is wave climate likely to change with climate change? Are simple wave fetch diagrams sufficient to model wave impacts on beaches?
- What are the relative contributions of sediment from streams compared to bluffs?
- What factors influence the effectiveness of ‘soft-shore’ and alternative erosion control techniques?

Biological Uncertainties

- What is the relationship of backshore vegetation to nearshore biota?
- What is the ecological significance of fragmentation of different nearshore ecosystems?
- To what extent do forage fish show beach fidelity for spawning? What is the overall condition of their populations? Is egg production and survival limiting? How might this change over time with sea level rise?
- What effects does armoring have on shorebirds and other seabirds, and how is this effect mediated?
- How does wrack contribute to the nearshore food web?
- What is the food web importance of talitrid amphipods (“beach hoppers”), which appears to be one of the primary biota impacted by shoreline armoring? Are they a major source of shorebird prey?
- What effects, if any, does armoring have on eelgrass, and how is this effect mediated?
- Does shoreline armoring have a significant cumulative effect on juvenile salmonids migrating along the shoreline? Does the spatial distribution of armoring affect this response?

Conclusions

Any gathering of scientists to discuss the 'state of the science' of an important issue will inevitably result in a list of questions that need further research, as above. However, Workshop participants, who came from a wide variety of backgrounds and disciplines, agreed that although there exist significant uncertainties that currently limit our understanding, there is enough known to make some general statements about the impacts of armoring. The breakout groups were not tasked to develop specific recommendations to policy makers, but the following conclusions were clear outcomes of discussions:

- While armoring alters the shoreline in different ways in different ecosystems around the world, almost every study has demonstrated impacts to some beach feature or function that society regards as valuable. These range from loss of space for recreation on the beach, to decreasing the numbers of foraging shorebirds, to erosion on adjacent properties. The benefits accrued by erosion control structures must be weighed against their negative impacts to public resources and to shoreline ecosystems.
- All armoring is not likely to be equally harmful in terms of loss of sediment to the shoreline, because natural sediment supply to the beaches varies so widely. Specific coastal assessments can suggest geomorphic factors or locations (for example, position within a drift cell) that are most valuable for protecting sediment supply.
- Armoring built lower on the shore (that is, lower elevation than extreme higher high water) has increasingly negative impacts, regardless of mechanism. As sea level rises, even structures that were originally built high on the beach may encroach farther into the intertidal.
- Armoring of individual properties is often treated as a benign activity, but the cumulative result of armoring multiple properties may have significant long-term impacts on beaches and drift cells.
- As sea level rises, passive erosion in areas with armored shorelines will result in the progressive loss of beaches around Puget Sound. This will reduce both the recreational benefits and the ecological functions provided by the beaches.

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