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Shoreline armoring disrupts marine-terrestrial connectivity in the Salish Sea, with consequences for invertebrates, fish, and birds

Sarah Heerhartz  
*University of Washington, sarah.heerhartz@gmail.com*

Megan Dethier  
*University of Washington*

Jason Toft  
*University of Washington*

Jeff Cordell  
*University of Washington*

Andrea Ogston  
*University of Washington*

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Shoreline armoring disrupts marine-terrestrial connectivity in the Salish Sea, with consequences for invertebrates, fish, and birds

Sarah Heerhartz, Megan Dethier, Jason Toft, Jeffery Cordell, and Andrea Ogston

2014 Salish Sea Ecosystem Conference

Motivation: What are the ecological effects of shoreline armoring in the Salish Sea?
Outline

1. Ecological framework:
   a) Ecotones and spatial subsidies
   b) Beach wrack
2. Results: Beach surveys
   a) Physical characteristics
   b) Beach wrack and logs
3. Results: Primary consumers (beach invertebrates)
4. Results: Secondary consumers:
   a) Terrestrial birds
   b) Juvenile salmon
5. Conclusions
   a) Ecological context of shoreline armoring
   b) Restoration and conservation implications
Well-studied aquatic-terrestrial ecotones: sandy coasts, forested streams

**SPATIAL SUBSIDY: INCREASED**
+ primary productivity
+ consumer density

(Polis & Hurd 1996; Dugan et al. 2003)

(Nakano & Murakami 2001)
Beach wrack

Romanuk & Levings 2010 – terrestrially derived carbon in chum salmon in Howe Sound

Terrestrial

Marine

Logs

Dipterans (Flies)

Coleopterans (Beetles)

Talitrids (Beach hoppers)

Ecological framework
Shoreline armoring

How does armoring affect:

• Aquatic-terrestrial connectivity?
• Permeability of boundary?
• Fluxes of material and organisms?
• Subsidies for primary consumers?
Physical parameters

Armored differences (N = 29 pairs):
- Lower maximum elevation (*paired t-test, p < 0.01*)
- Narrower beach width (*paired t-test, p < 0.01*)

ARMORING = REDUCED SIZE OF ECOTONE, LOWER ELEVATION OF AQUATIC-TERRESTRIAL INTERFACE

Ecological framework/Beach survey results
logs and wrack

spring n = 24 pairs
fall n = 27 pairs

armored differences:
• significantly fewer logs (paired t-test, p < 0.01)
• width of log line significantly smaller (paired t-test, p < 0.01)

ecological framework/beach survey results

armoring = removal of log zone habitat
Beach wrack

- Spring N = 24 pairs
- Fall N = 27 pairs
- Less wrack in spring than in fall (ANOVA, \( p < 0.01 \))

Armored differences:
- Less wrack (paired t-test, \( p < 0.01 \))
- Lower proportion of terrestrial material in wrack (paired t-test, \( p < 0.01 \))

ARMORING = REDUCED TERRESTRIAL-AQUATIC FLUX OF ORGANIC MATERIALS
Wrack invertebrates

ARMORING = FEWER INVERTEBRATES AND DIFFERENT TAXA

Includes some insect taxa that have been found in juvenile salmon diets (e.g. Toft et al. 2007; Romanuk & Levings 2010)
Wrack invertebrates

- Overall invertebrate assemblage significantly different between armored and unarmored
- Differences explained by combination of physical predictor variables
- Unarmored assemblage correlated with talitrid amphipods, flies, and beetles
- Armored assemblage correlated with aquatic isopods and bivalves
Secondary consumers: birds

Abundance and species composition

• Fewer birds overall at armored beaches
  • Armored beaches: crows most common, no shorebirds
  • Unarmored beaches: sparrows most common, no seagulls
Secondary consumers: birds

Behavior (terrestrial birds)

- DIFFERENCES IN HABITAT USE BETWEEN ARMORED AND UNARMORED BEACHES
- FEWER PREY? OR REDUCED FORAGING OPPORTUNITY?
Secondary consumers: juvenile salmon

More observations at unarmored beaches

Juvenile salmon in deeper water along armored shorelines

• DIFFERENCES IN DISTRIBUTION BETWEEN ARMORED AND UNARMORED BEACHES
• FEEDING RATES CONSISTENT
• FEWER PREY?

Ecological framework/Beach survey results/Primary consumers/Secondary consumers

Fish and snorkeler not to scale!
Aquatic-terrestrial connectivity is important for Salish Sea ecosystem health.

Armoring disrupts connectivity – landward and seaward impacts.
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• UW Marine Geology Group: Rip Hale, Katie Boldt, Dan Nowacki, Emily Eidam, Julia Marks, Niall Twomey
Restoration and conservation considerations

- Aquatic-terrestrial
- Physical-biological

- Restoring connectivity can restore ecological functions
- Can be stable/self-maintaining over time
Restoration and conservation considerations

- Aquatic-terrestrial
- Physical-biological

- Full restoration of aquatic-terrestrial connectivity sometimes not possible
- Connectivity can be restored for some components or processes within urban constraints
Shoreline armoring – previous research

- Loss of terrestrial vegetation
  - (Romanuk & Levings 2003)
- Lower density and diversity of insects
  - (Rice 2006; Morley et al. 2012)
- Greater microclimate variability
  - (Rice 2006; Morley et al. 2012)
- Altered fish distribution
  - (Toft et al. 2007; Bilkovic & Roggero 2008)
- Wave reflection
- Suspended sediment
- Lower density and diversity of invertebrates on bottom substrates
  - (Chapman 2003)
Results: wrack “assemblage”

Amount of algae, eelgrass, and terrestrial wrack significantly different by type (paired PERMANOVA, fall, $p = 0.001$; spring, $p = 0.002$)

AMOUNT AND COMPOSITION OF WRACK SIGNIFICANTLY DIFFERENT

(MORE WRACK)

(LESS WRACK)

Intro/Hypotheses, Approach, Methods/Beach survey results
Results: wrack “assemblage”

- MORE WRACK CORRELATED WITH WIDTH OF LOG LINE AND MAX ELEVATION/BEACH WIDTH
- SIZE OF ECOTONE IMPORTANT

Amount of algae, eelgrass, and terrestrial wrack

(paired PERMANOVA, fall, $p = 0.001$; spring, $p = 0.002$)
Wrack invertebrates

- Density of invertebrates (how many?)
- Taxonomic composition (what kind?)

Variation between points explained by physical variables (6 out of 12 possible)
Secondary consumers: juvenile salmon

- PRIMARY BEHAVIOR: FORAGING AT SURFACE
- INSECTS?

Total distance: 87 m
Net distance: 50 m

Straightness index: Net/Total = 0.57
Secondary consumers: juvenile salmon

- FEEDING RATES, MOVEMENT RATES, STRAIGHTNESS INDEX CONSISTENT BETWEEN ARMORED-UNARMORED
- DIFFERENCES IN DEPTH DISTRIBUTION

Total distance: 87 m
Net distance: 50 m
Straightness index: Net/Total = 0.57

Intro/Hypotheses, Approach, Methods/Beach survey results/Conceptual model/Primary consumers/Secondary consumers
Secondary consumers: juvenile salmon

ST: Net/Total = 0.57

Total distance: 87 m

Net distance: 50 m

FEEDING BEHAVIOR AFFECTS MOVEMENT PATHS
Marine riparian – trees and shrubs

Eelgrass

Algae

Marine/estuarine water

Fallen trees

Wrack

invertebrates

Driftwood

Logs

Leaf litter

Riparian insects

Birds

Juvenile salmon

Shallow water

Beach wrack

Riparian insects

Wrack invertebrates

Terrestrial

Estuarine

Ecotone: upper intertidal

Intro/Hypotheses, Approach, Methods/Beach survey results/Conceptual model/Primary consumers/Secondary consumers/Conclusions
Intro/Hypotheses, Approach, Methods/Beach survey results/Conceptual model/Primary consumers/Secondary consumers/Conclusions
Marine riparian – trees and shrubs

Eelgrass

Algae

Marine/estuarine water

Wrack

Beach wrack

Wrack invertebrates

Birds

Terrestrial

Zone of armoring

Estuarine

Ecotone: upper intertidal

Conceptual model: Armored nearshore

Intro/Hypotheses, Approach, Methods/Beach survey results/Conceptual model/Primary consumers/Secondary consumers/Conclusions