May 1st, 1:30 PM - 3:00 PM

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

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Heerhartz, Sarah; Dethier, Megan; Toft, Jason; Cordell, Jeff; and Ogston, Andrea, "Shoreline armoring disrupts marine-terrestrial connectivity in the Salish Sea, with consequences for invertebrates, fish, and birds" (2014). *Salish Sea Ecosystem Conference*. 225.


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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

Logs

Marine

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*)

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

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

ARMORING = FEWER INVERTEBRATES AND DIFFERENT TAXA
• 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

**FEWER BIRDS AND DIFFERENT TAXA AT ARMORED BEACHES**
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?
Conclusions

- Aquatic-terrestrial connectivity is important for Salish Sea ecosystem health
- Armoring disrupts connectivity – landward and seaward impacts
Acknowledgements – thank you!

Field and lab support:
• WA Dept. of Natural Resources: Helen Berry, Jeff Gaeckle
• UW Wetland Ecosystem Team: Erin Morgan, Katie Dowell, Claire Levy, Beth Armbrust
• 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

- Hypothetical unarmored profile
- Armoring structure
- Water
- Beach

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)

No sediment source
(Pilkey & Wright 1988; Griggs 2005)

Wave reflection

Suspended sediment

Lower density and diversity of invertebrates on bottom substrates
(Chapman 2003)

Encroachment on upper beach
Results: wrack “assemblage”

Amount of algae, eelgrass, and terrestrial wrack

AMOUNT AND COMPOSITION OF WRACK SIGNIFICANTLY DIFFERENT

(LESS WRACK)

Eelgrass

Terrestrial

(MORE WRACK)

2D Stress: 0.12

Type

Armored

Unarmored

Wrack assemblage

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

Physical predictor variables

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

Invertebrate taxa correlations

Variation between points explained by physical variables (6 out of 12 possible)

Ecological framework/Beach survey results/Primary consumers
Secondary consumers: juvenile salmon

- PRIMARY BEHAVIOR: FORAGING AT SURFACE
- INSECTS?

Straightness index: 
Net/Total = 0.57

Total distance: 87 m

Net distance: 50 m
Secondary consumers: juvenile salmon

- FEEDING RATES, MOVEMENT RATES, STRAIGHTNESS INDEX CONSISTENT BETWEEN ARMORED-UNARMORED
- DIFFERENCES IN DEPTH DISTRIBUTION
Secondary consumers: juvenile salmon

ST: Net/Total = 0.57

Total distance: 87 m

Net distance: 50 m

Feeding behavior affects movement paths

Intro/Hypotheses, Approach, Methods/Beach survey results/Conceptual model/Primary consumers/Secondary consumers
Marine riparian – trees and shrubs
Eelgrass
Algae
Marine/estuarine water
Wrack
invertebrates
Beach wrack

Terrestrial

Zone of armoring

Ecotone: upper intertidal

Conceptual model: Armored nearshore

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

Juvenile salmon

Birds