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

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

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

**Ecological framework**

**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*)

Ecological framework/Beach survey results

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

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

*Fish and snorkeler not to scale!*
Conclusions

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

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• WA Dept. of Natural Resources: Helen Berry, Jeff Gaecke
• 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

- Loss of terrestrial vegetation
  (Romanuk & Levings 2003)

- Lower density and diversity of insects
  (Romanuk & Levings 2003)

- Greater microclimate variability
  (Rice 2006; Morley et al. 2012)

- Altered fish distribution
  (Toft et al. 2007; Bilkovic & Roggero 2008)

- Wave reflection
  (Pilkey & Wright 1988; Griggs 2005)

- Suspended sediment

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

- No sediment source
  (Pilkey & Wright 1988; Griggs 2005)
Results: wrack “assemblage”

Amount of algae, eelgrass, and terrestrial wrack

AMOUNT AND COMPOSITION OF WRACK SIGNIFICANTLY DIFFERENT

(by type)

(pairied 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)
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

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**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

Intro/Hypotheses, Approach, Methods/Beach survey results/Conceptual model/Primary consumers/Secondary consumers
Conceptual model: Armored nearshore

Terrestrial

Marine riparian – trees and shrubs

Riparian insects

Leaf litter

Fallen trees

Zone of armoring

Beach wrack

Wrack invertebrates

Driftwood

Logs

Eelgrass

Algae

Marine/estuarine water

Estuarine

Juvenile salmon

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

Ecotone: upper intertidal
Marine riparian – trees and shrubs

Eelgrass

Algae

Marine/estuarine water

Wrack

invertebrates

Beach wrack

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

Juvenile salmon

Marine/estuarine water

Algae

Eelgrass

Beach wrack