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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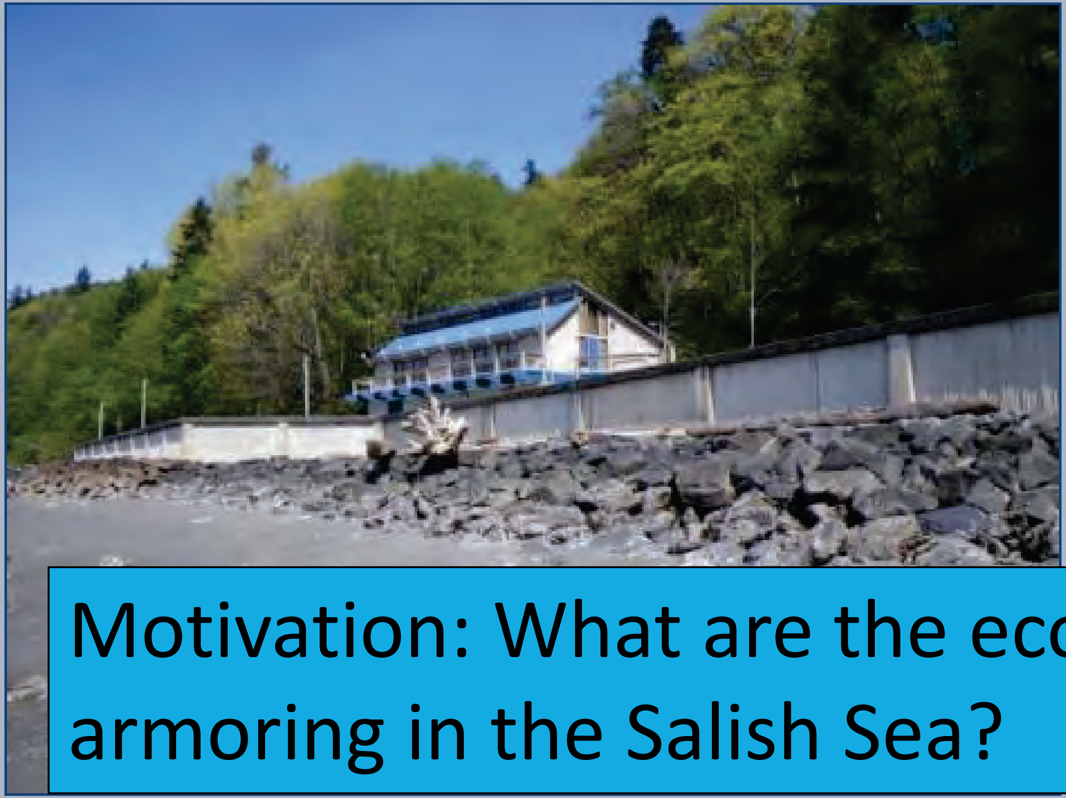
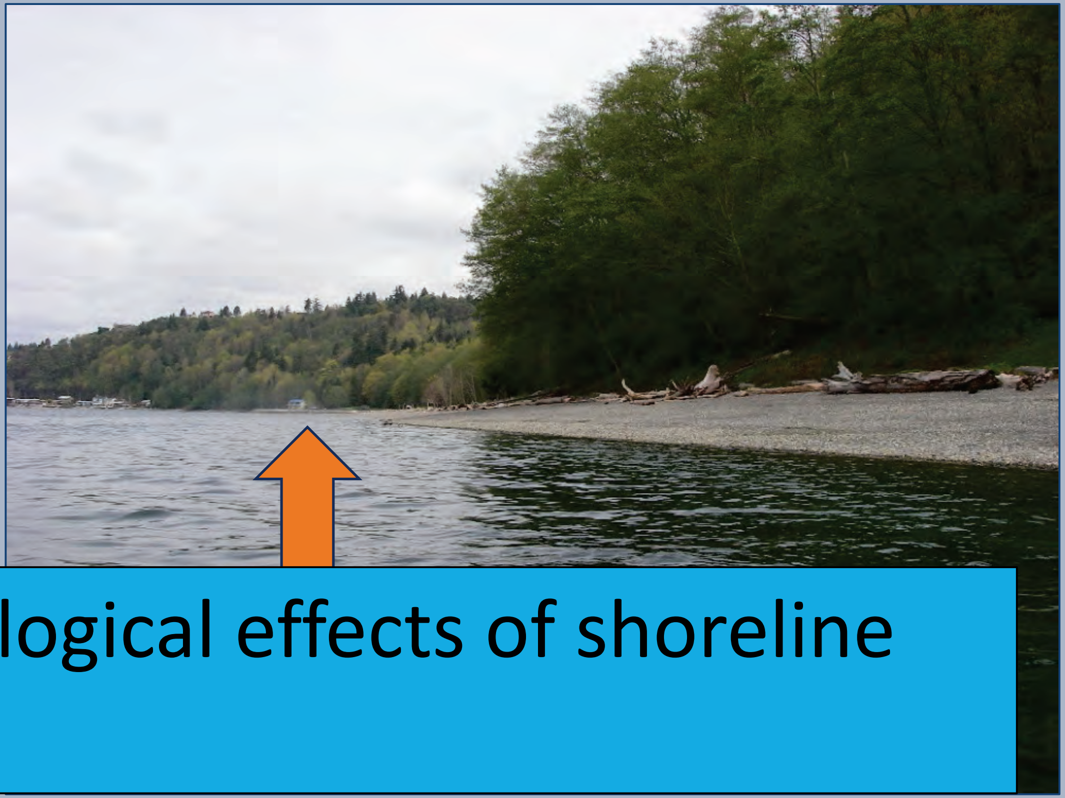
2014 Salish Sea Ecosystem Conference

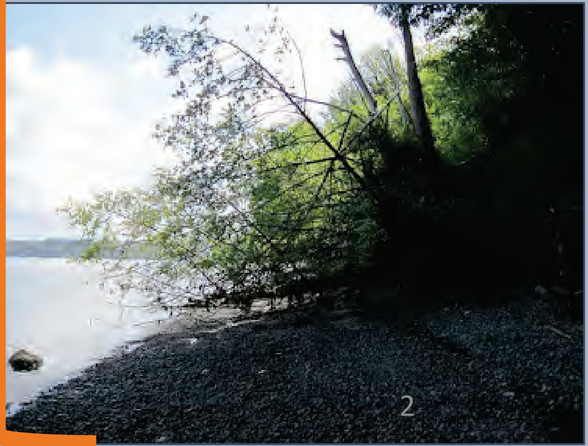




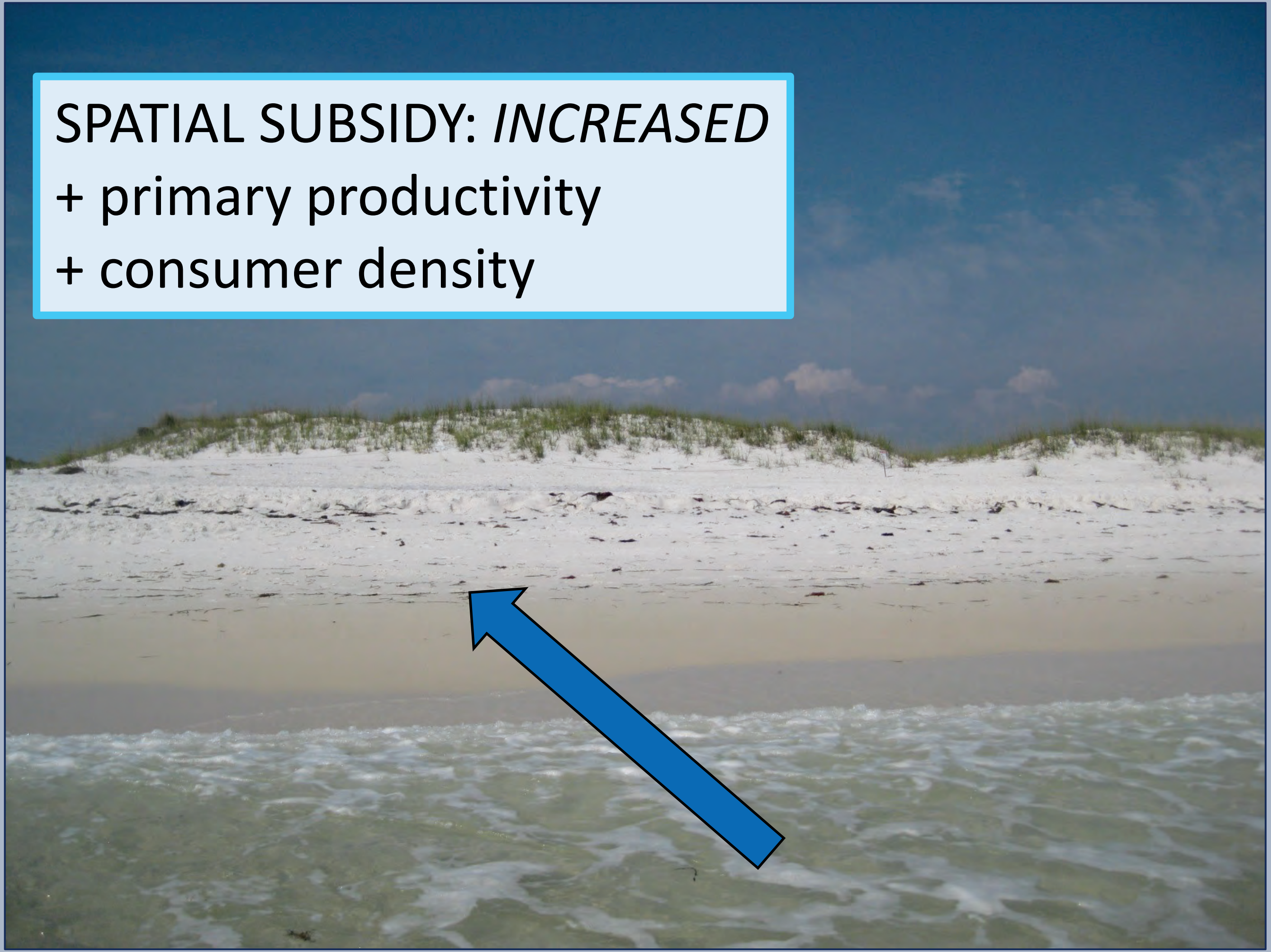
Motivation: What are the ecological effects of shoreline armoring in the Salish Sea?

Outline

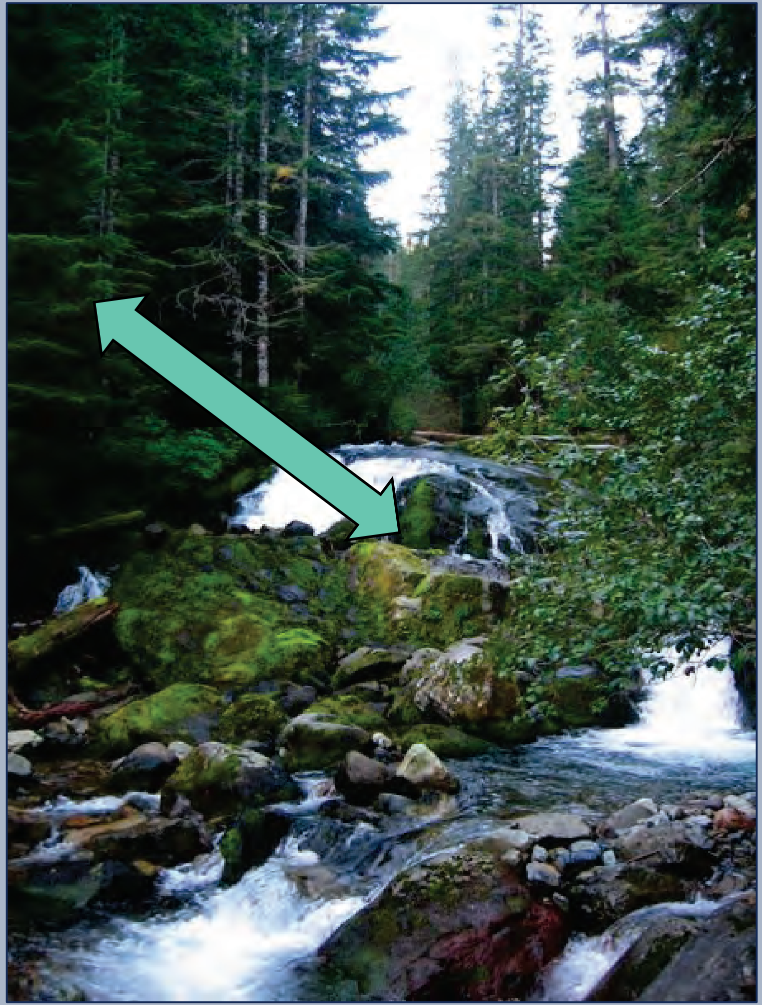
1. Ecological framework:
   a) Ecotones and spatial subsidies
   b) Beach wrack
2. Results: Beach surveys
   a) Physical characteristics
   b) Beach wrack and logs
3. Results: Primary consumers (beach invertebrates)
4. Results: Secondary consumers:
   a) Terrestrial birds
   b) Juvenile salmon
5. Conclusions
   a) Ecological context of shoreline armoring
   b) Restoration and conservation implications



Well-studied aquatic-terrestrial ecotones: sandy coasts, forested streams



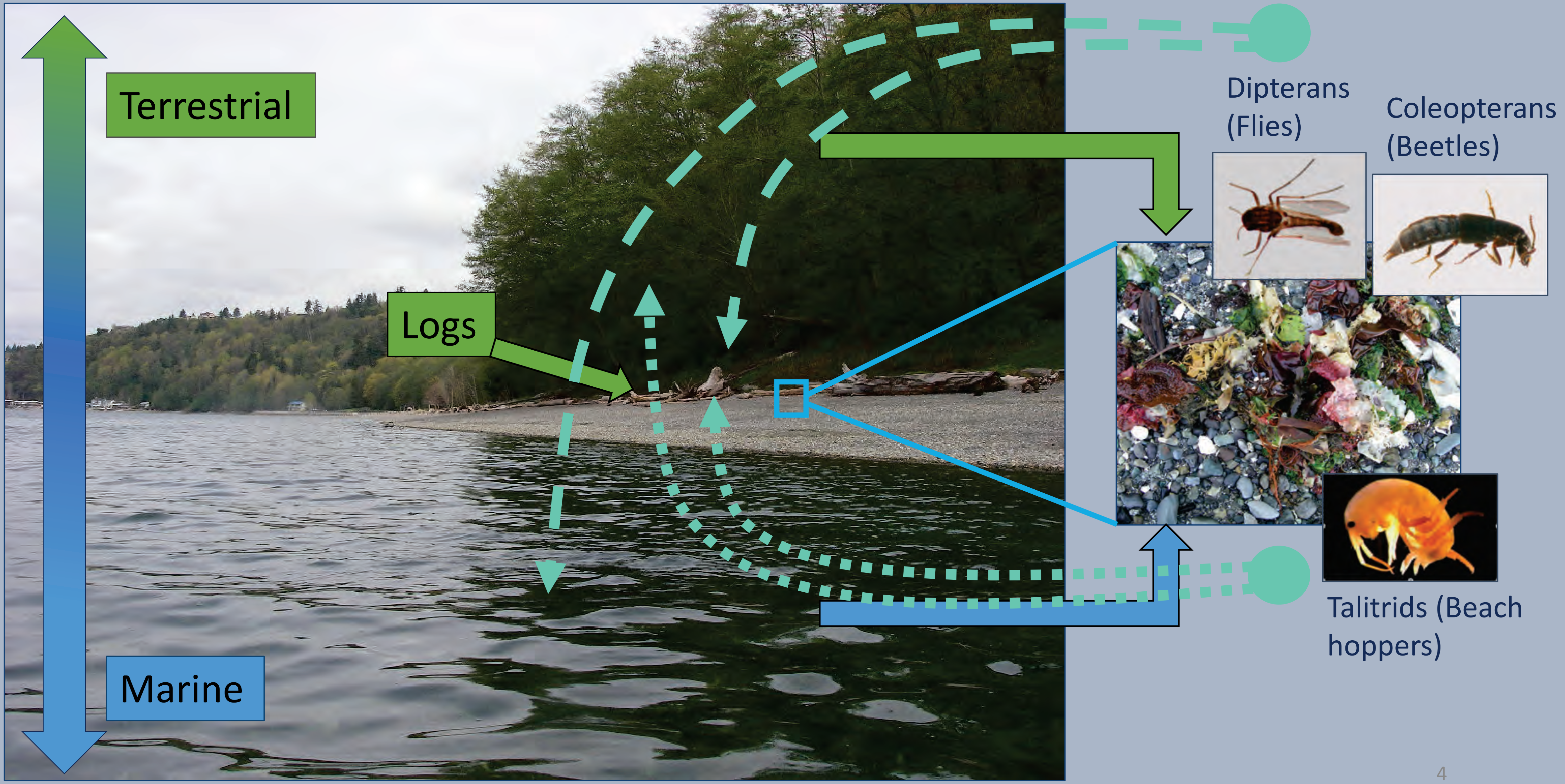
(Polis & Hurd 1996; Dugan et al. 2003)



(Nakano & Murakami 2001)

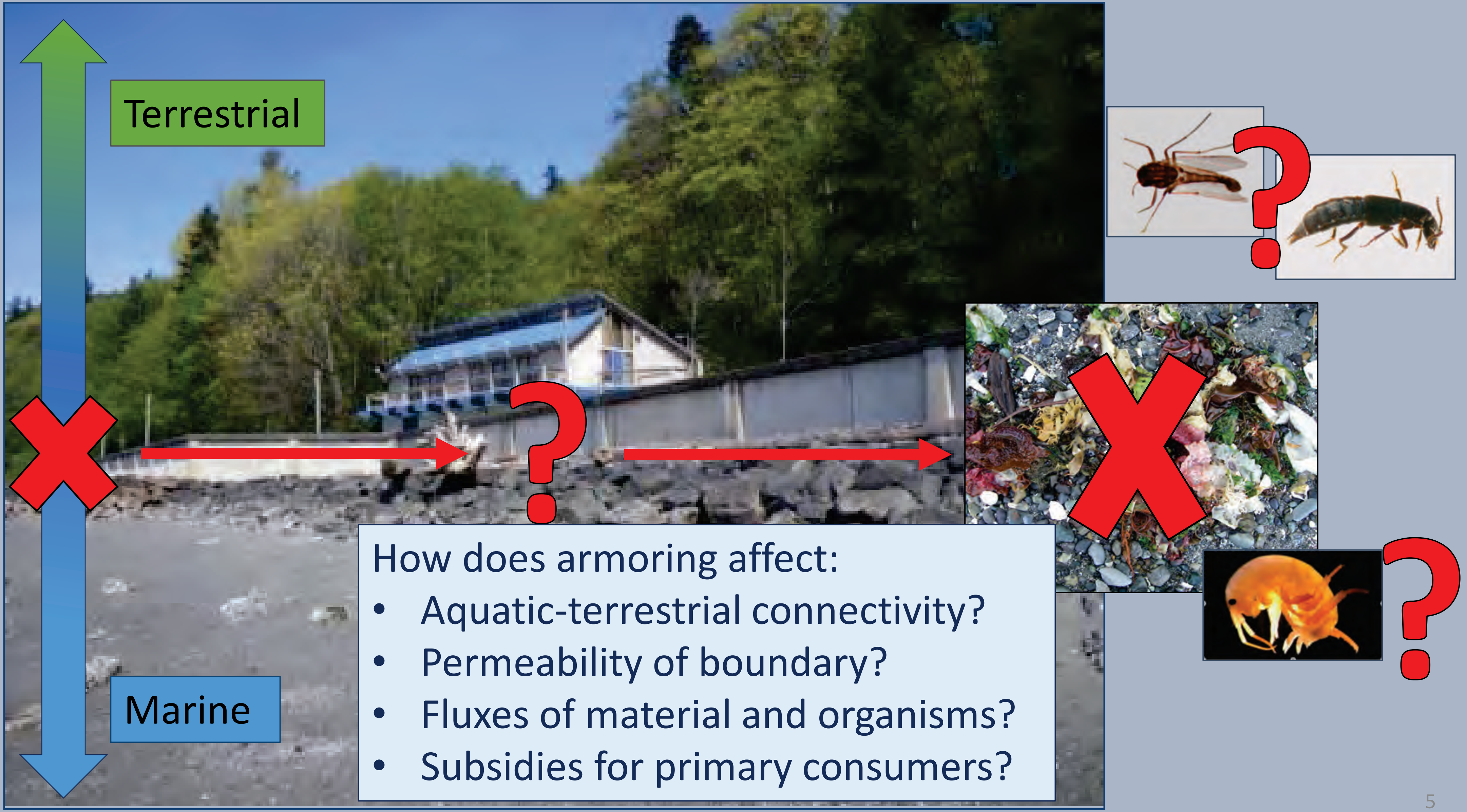
Beach wrack

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



Ecological framework

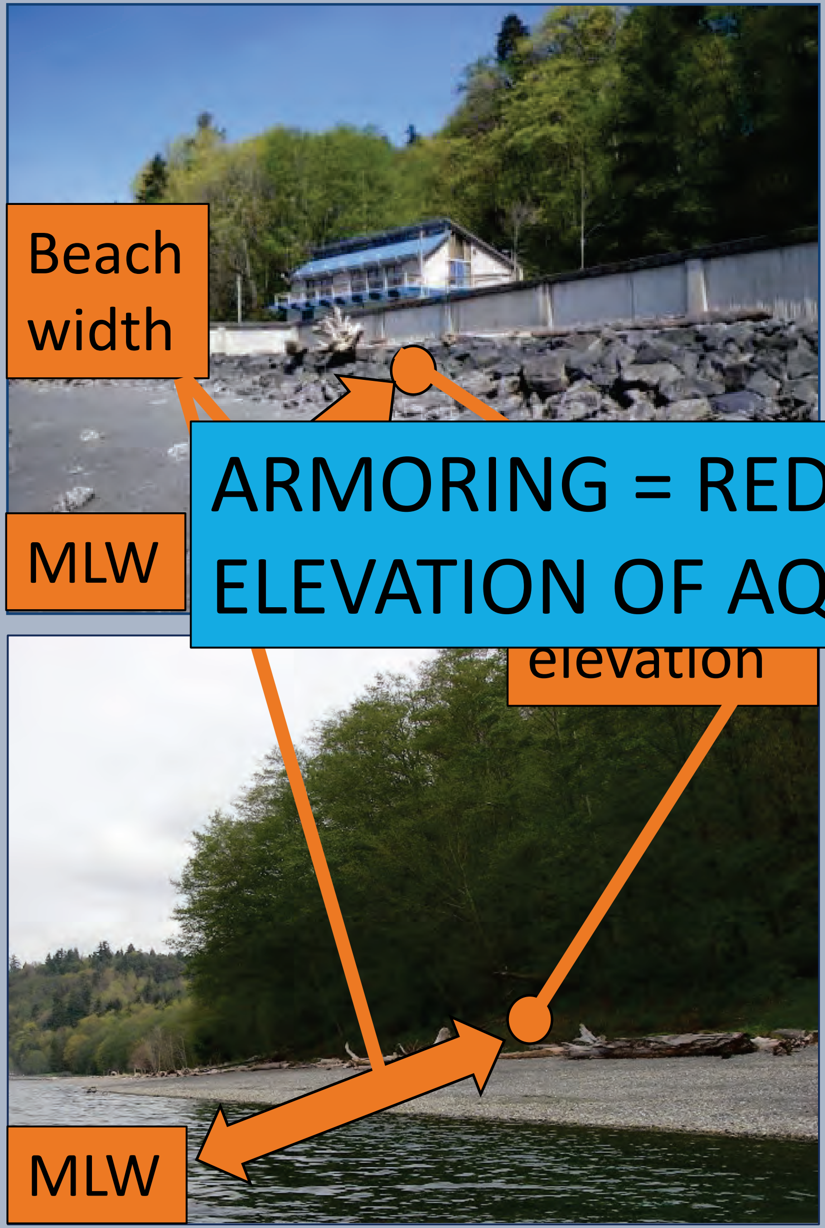
Shoreline armoring

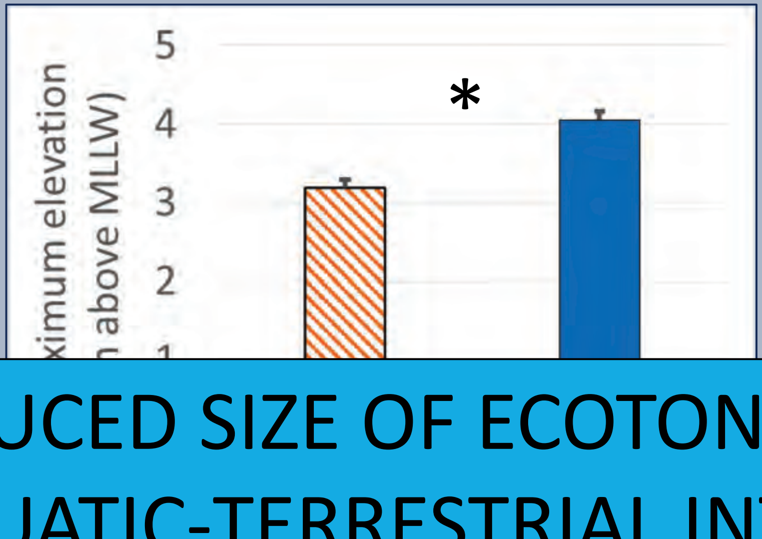


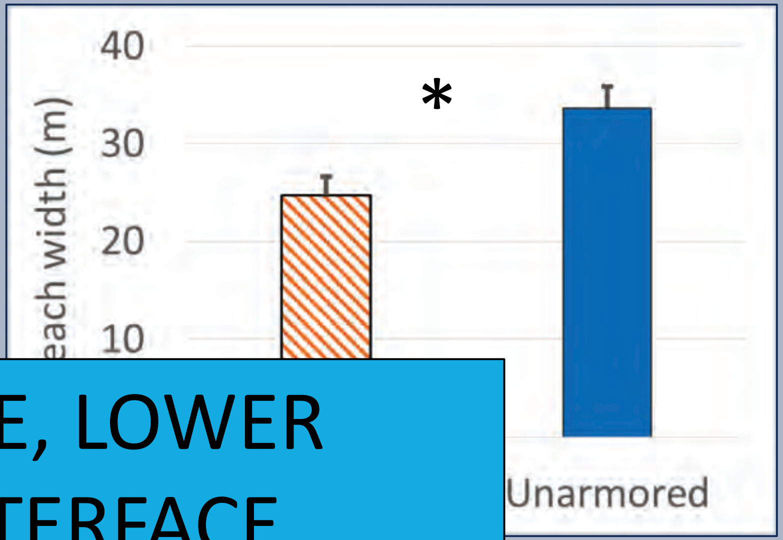
How does armoring affect:

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

Physical parameters





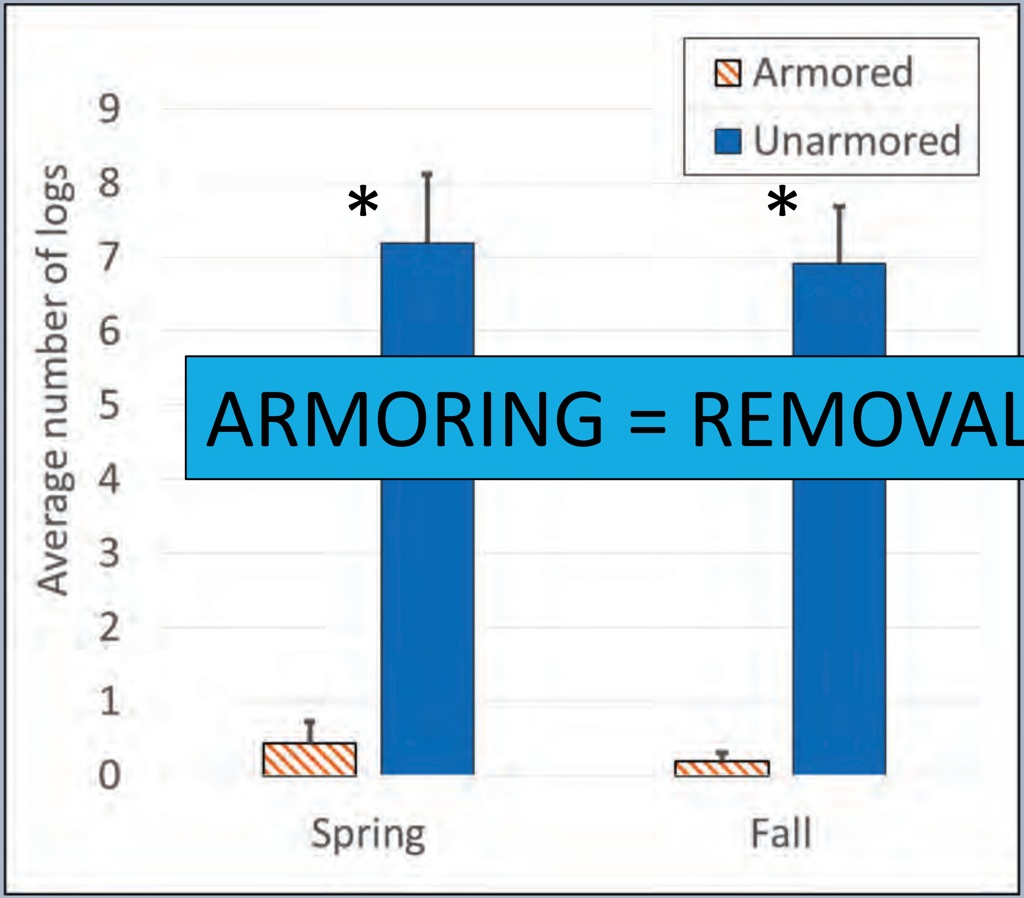


ARMORING = REDUCED SIZE OF ECOTONE, LOWER ELEVATION OF AQUATIC-TERRESTRIAL INTERFACE

Armored differences (N = 29 pairs):

- Lower maximum elevation (*paired t-test, $p < 0.01$*)
- Narrower beach width (*paired t-test, $p < 0.01$*)

Logs and wrack



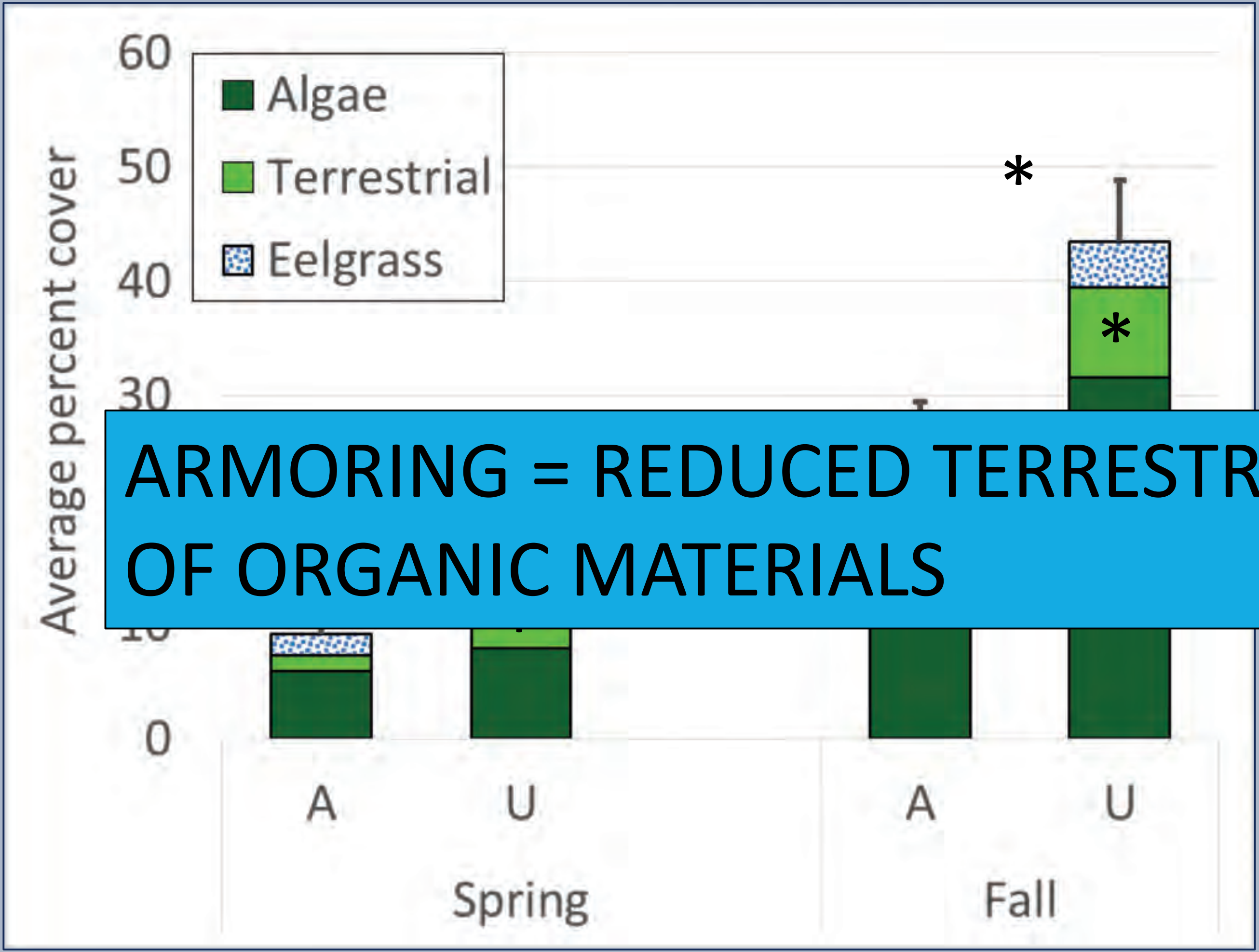
ARMORING = REMOVAL OF LOG ZONE HABITAT

Spring N = 24 pairs
Fall N = 27 pairs

<u>Armored differences:</u>

- Significantly fewer logs (*paired t-test,*
- Width of log line significantly smaller (*paired t-test, p* < *0.01*)

Beach wrack



Spring N = 24 pairs

Fall N = 27 pairs

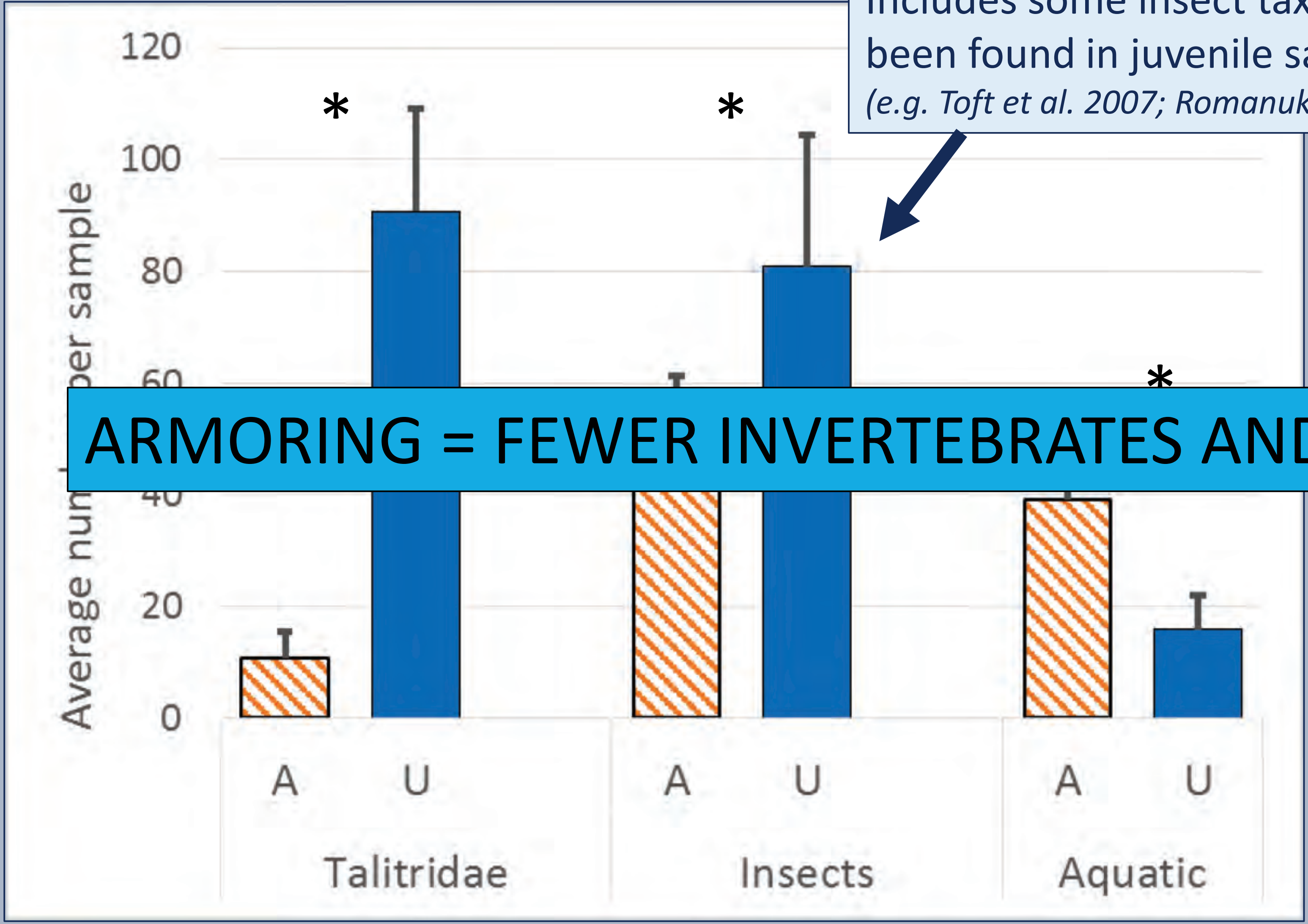
- Less wrack in spring than in fall (*ANOVA, p < 0.01*)

ARMORING = REDUCED TERRESTRIAL-AQUATIC FLUX OF ORGANIC MATERIALS

p <

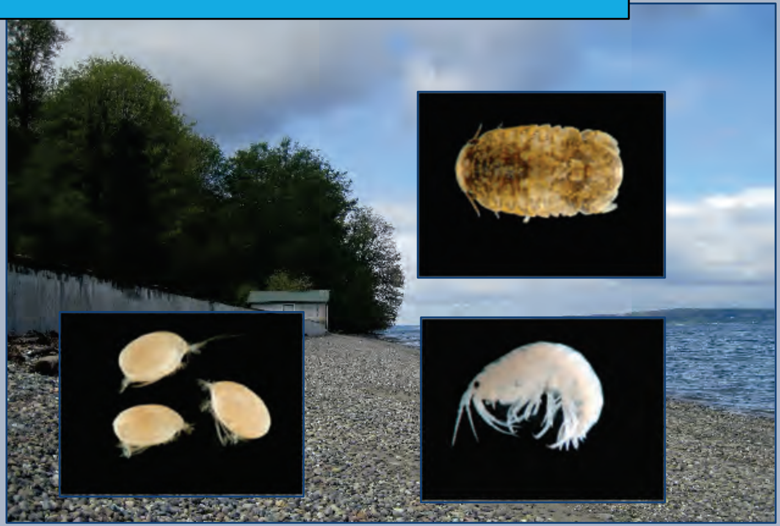
- Lower proportion of terrestrial material in wrack (*paired t-test, p < 0.01*)

Wrack invertebrates

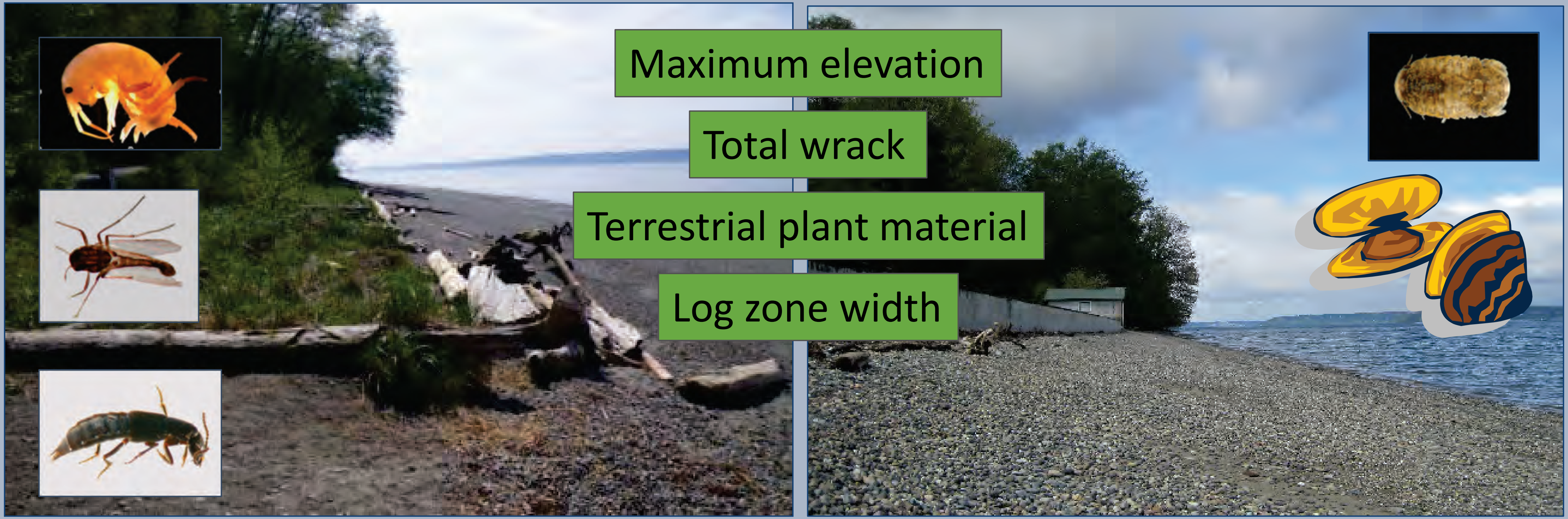


Includes some insect taxa that have been found in juvenile salmon diets
(e.g. Toft et al. 2007; Romanuk & Levings 2010)

ARMORING = FEWER INVERTEBRATES AND DIFFERENT TAXA



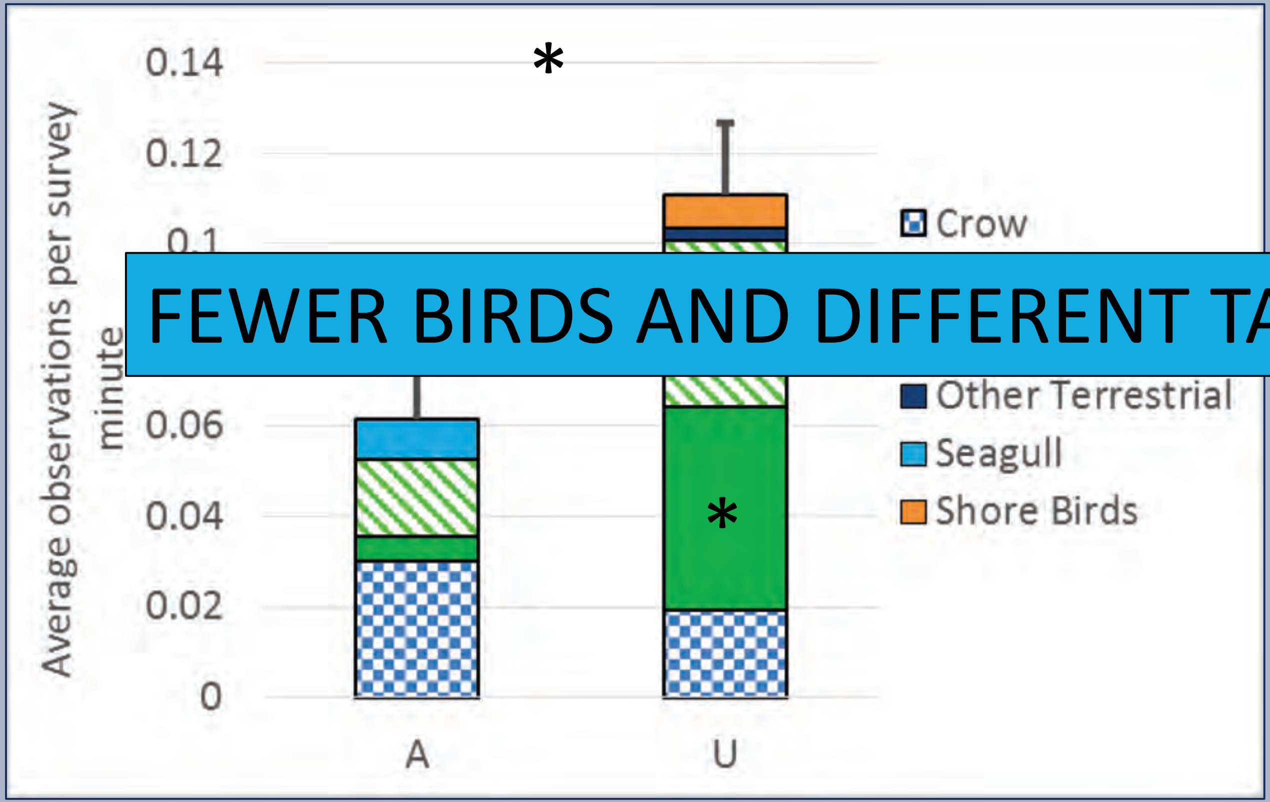
Wrack invertebrates



- 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

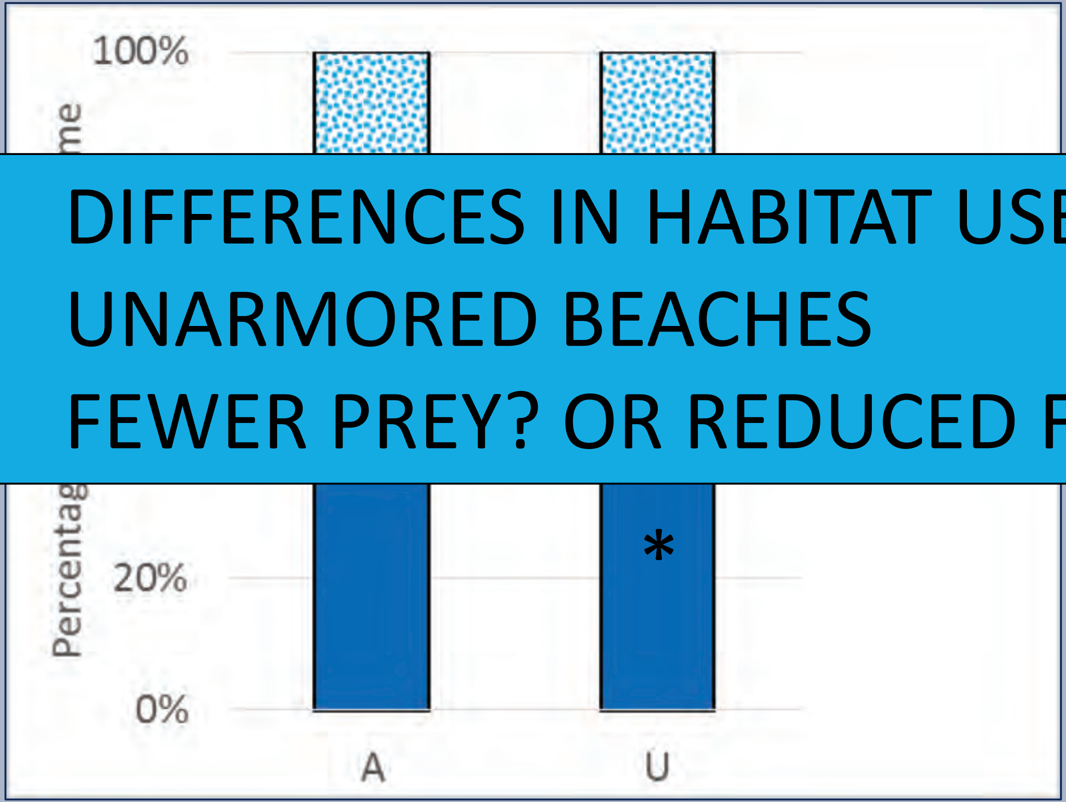


FEWER BIRDS AND DIFFERENT TAXA AT ARMORED BEACHES

- 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)

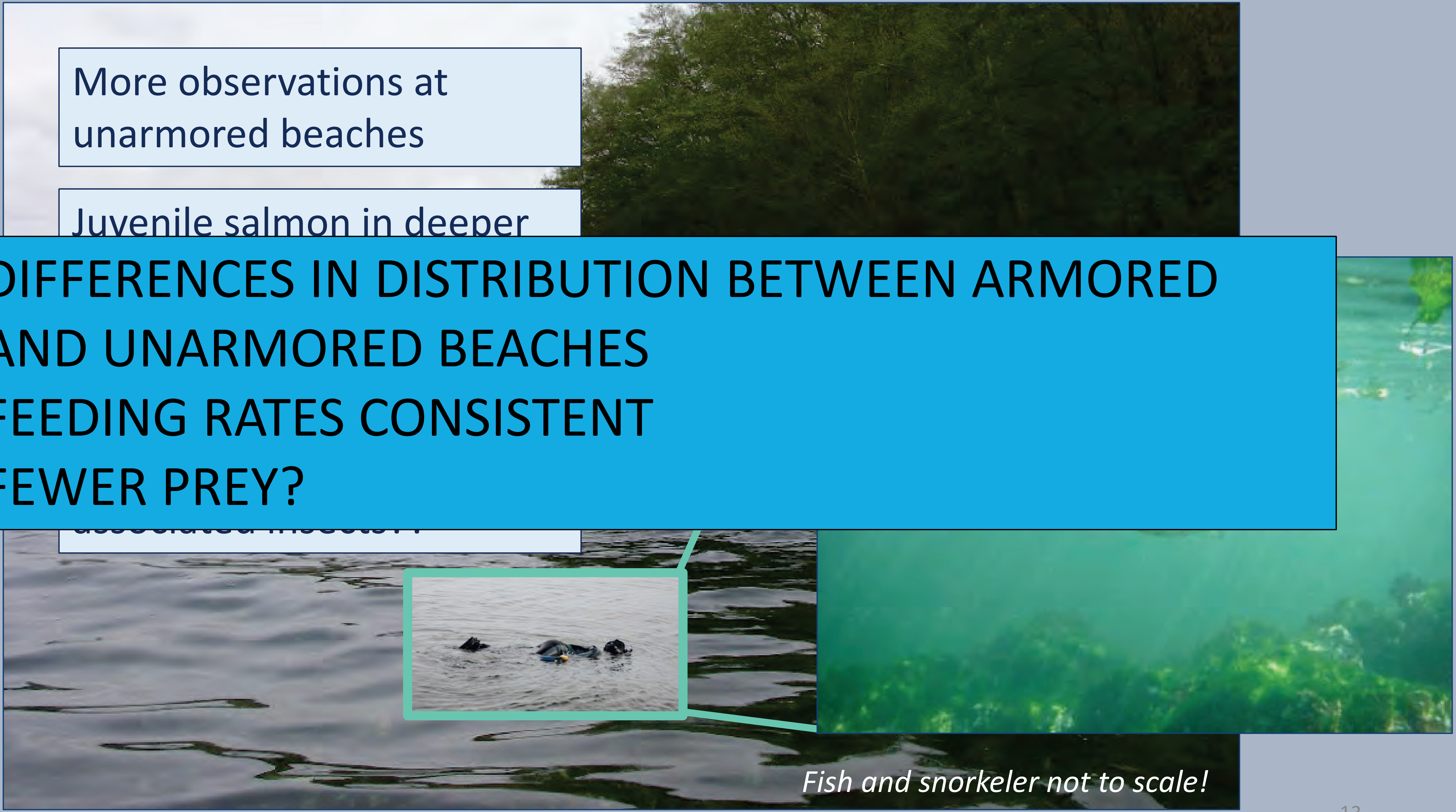


- DIFFERENCES IN HABITAT USE BETWEEN ARMORED AND UNARMORED BEACHES
- FEWER PREY? OR REDUCED FORAGING OPPORTUNITY?

Secondary consumers: juvenile salmon

More observations at unarmored beaches

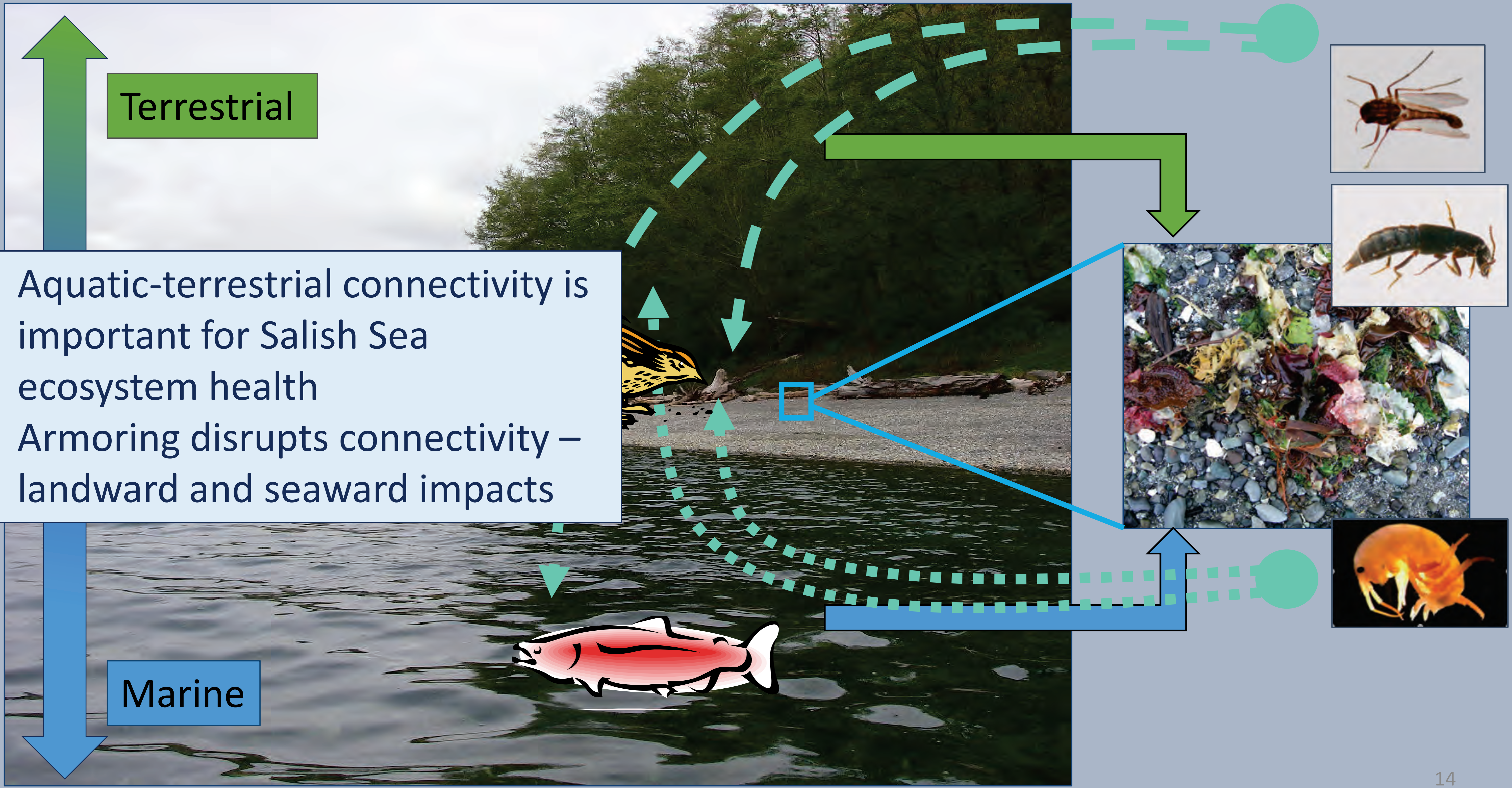
Juvenile salmon in deeper



- 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!

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

Sea Grant

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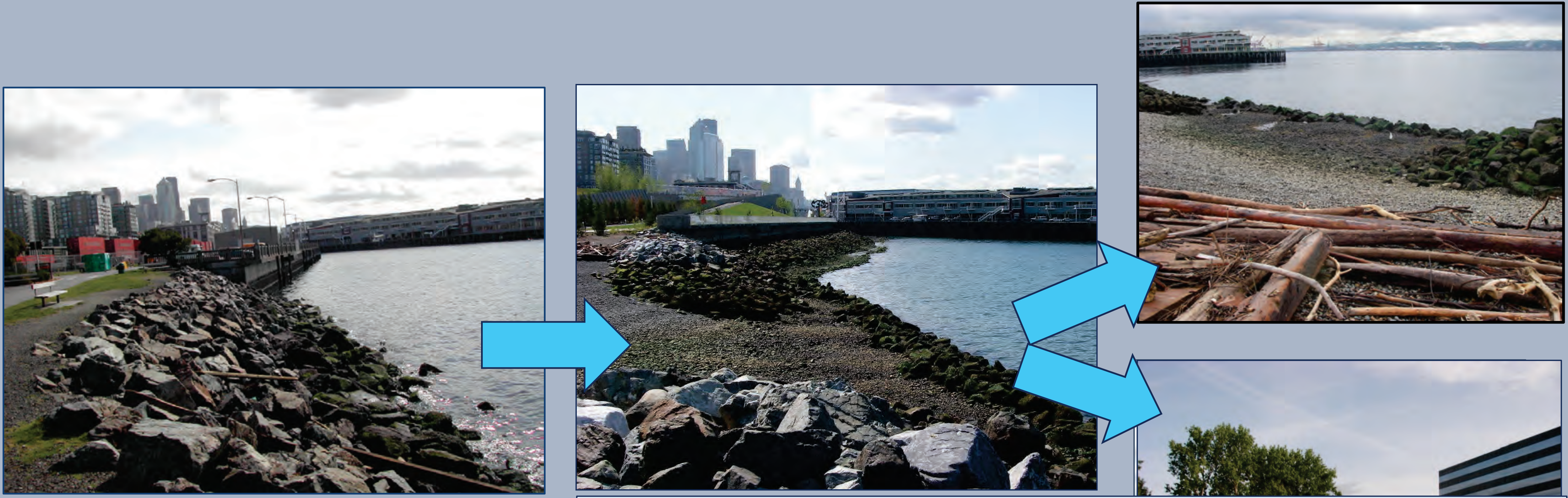
Restoration and conservation considerations

- Aquatic-terrestrial
- Physical-biological

- Restoring connectivity can restore ecological functions
- Can be stable/self-maintaining over time

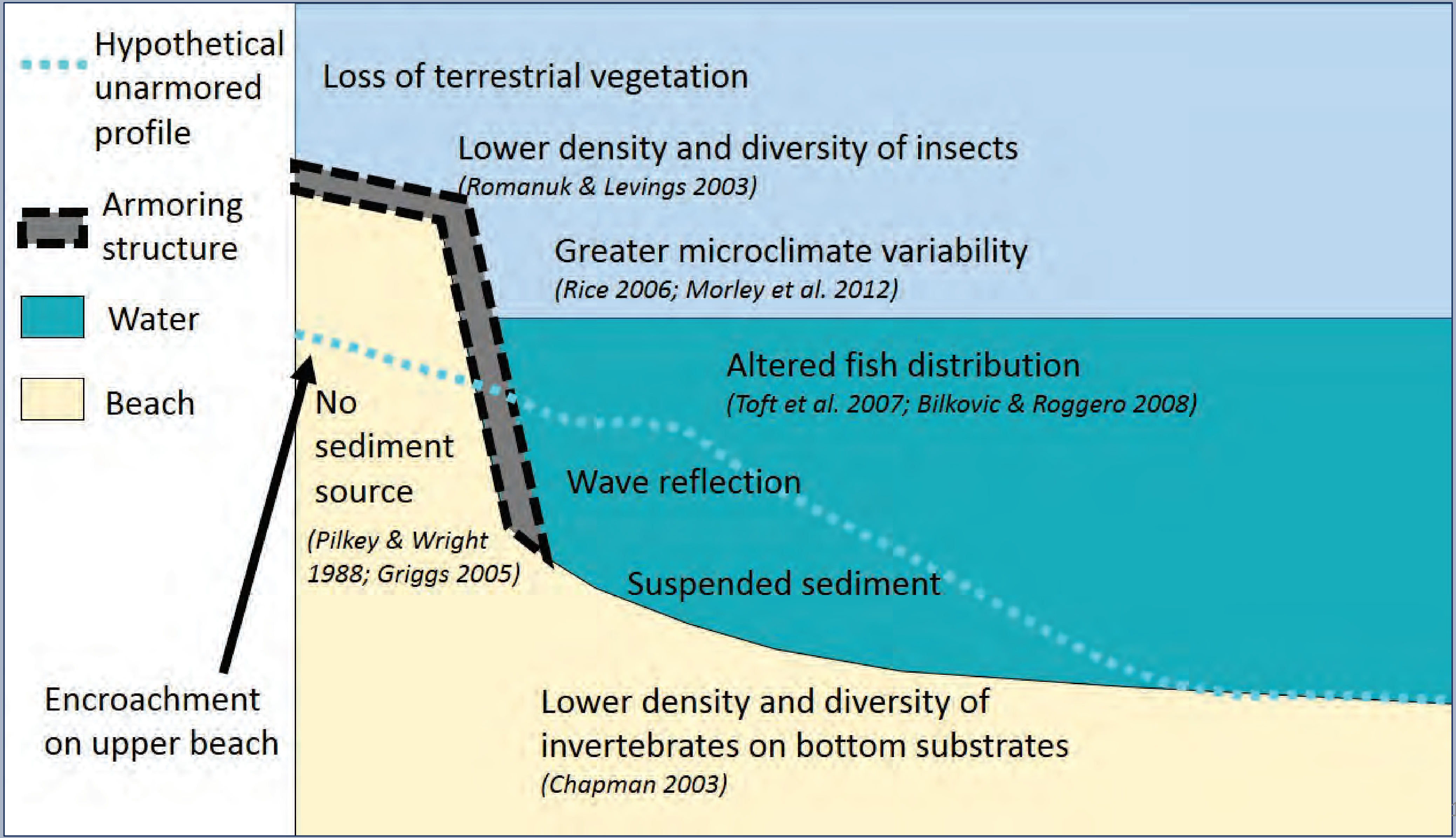
Restoration and conservation considerations



- Aquatic-terrestrial
- Physical-biological

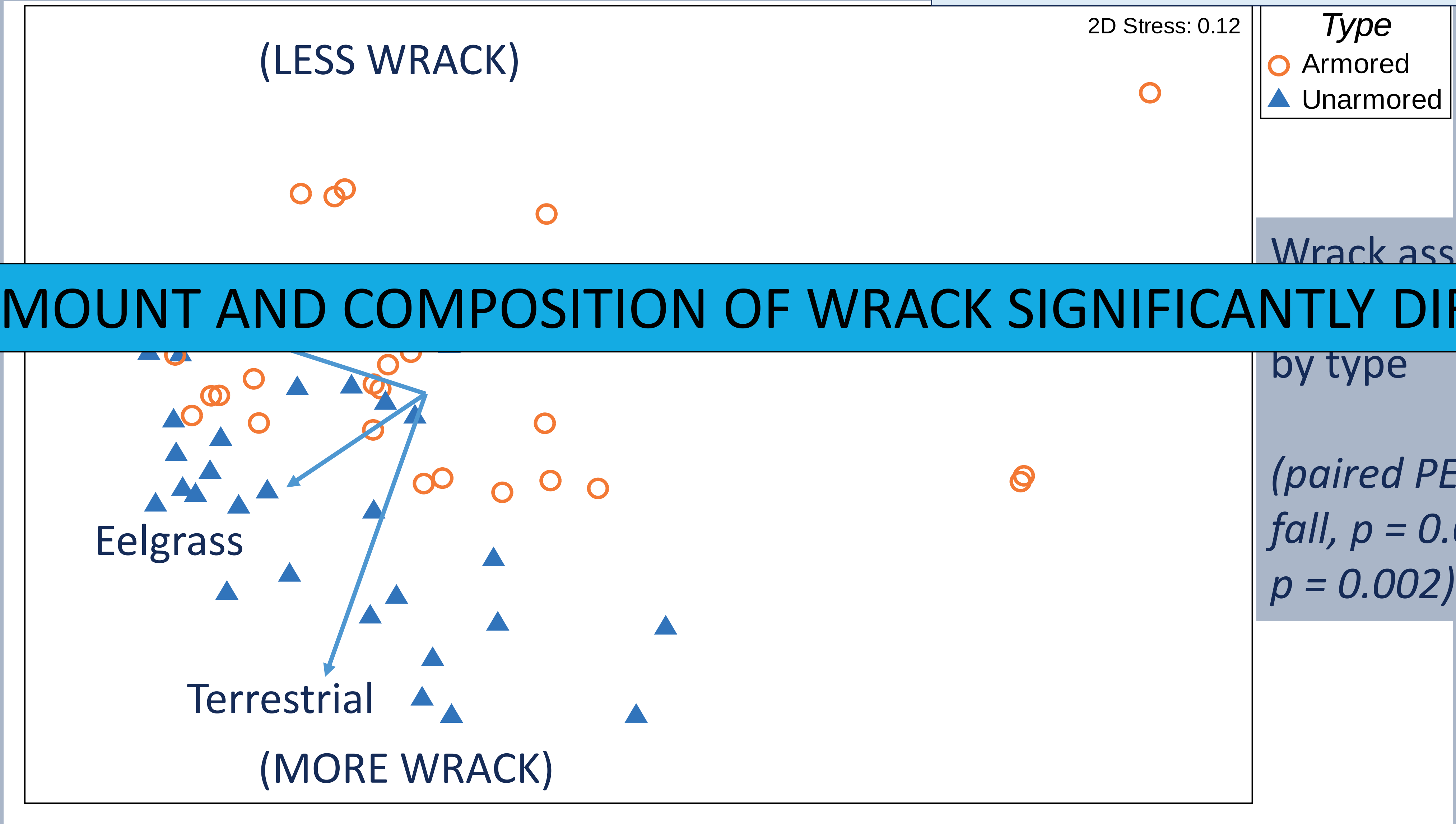
- Full restoration of aquatic-terrestrial connectivity sometimes not possible
- Connectivity can be restored for some components or processes within urban constraints

Shoreline armoring – previous research



Results: wrack "assemblage"

Amount of algae, eelgrass, and terrestrial wrack



Wrack assemblage

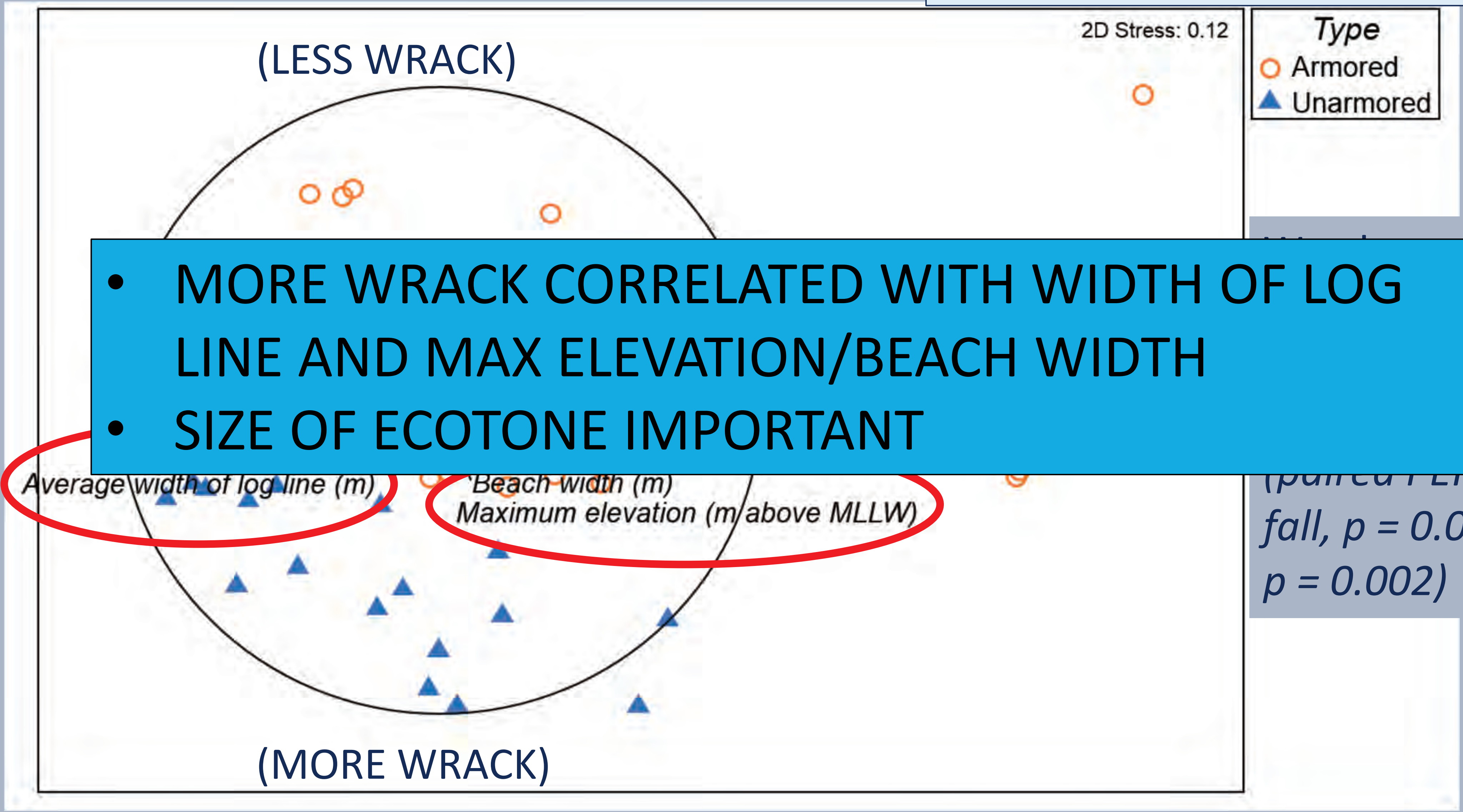
AMOUNT AND COMPOSITION OF WRACK SIGNIFICANTLY DIFFERENT

by type

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

Results: wrack "assemblage"

Amount of algae, eelgrass, and terrestrial wrack



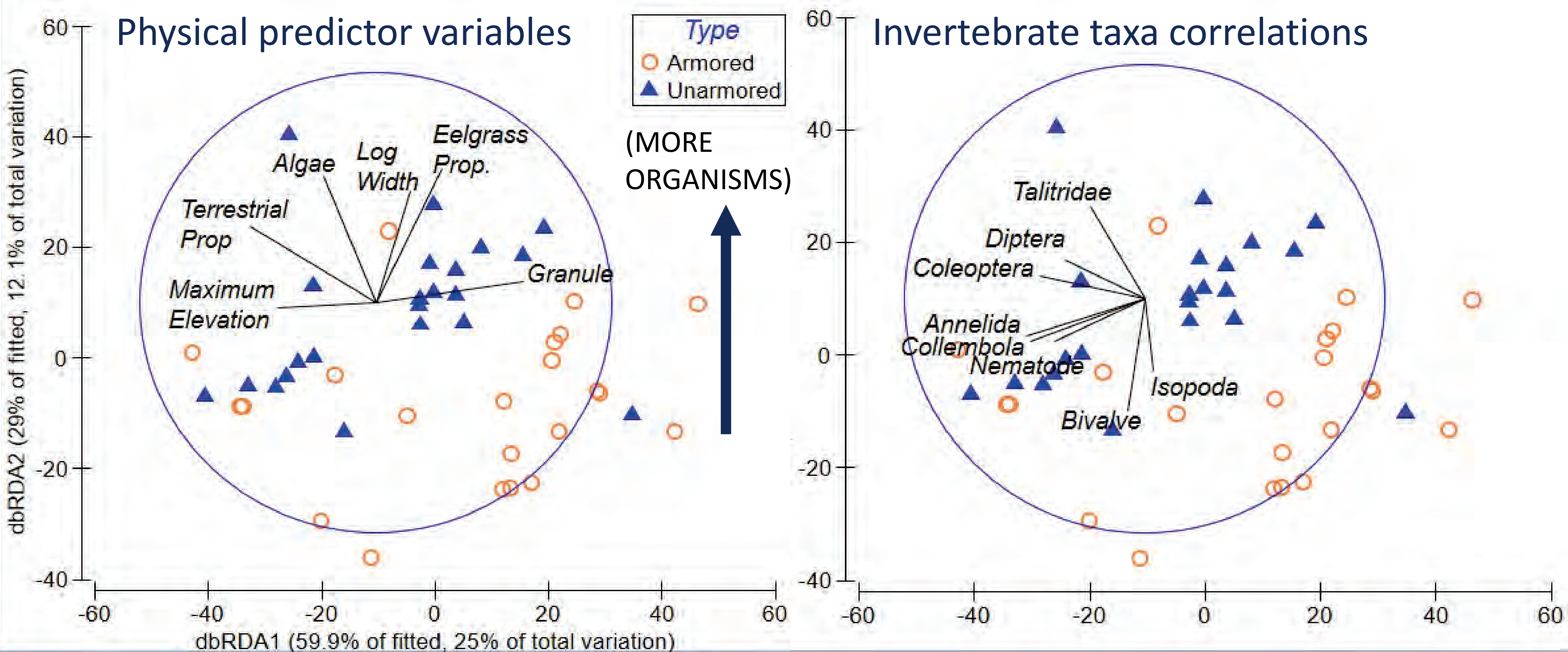
- MORE WRACK CORRELATED WITH WIDTH OF LOG LINE AND MAX ELEVATION/BEACH WIDTH
- SIZE OF ECOTONE IMPORTANT

…blage …ifferent

…ANOVA, *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)

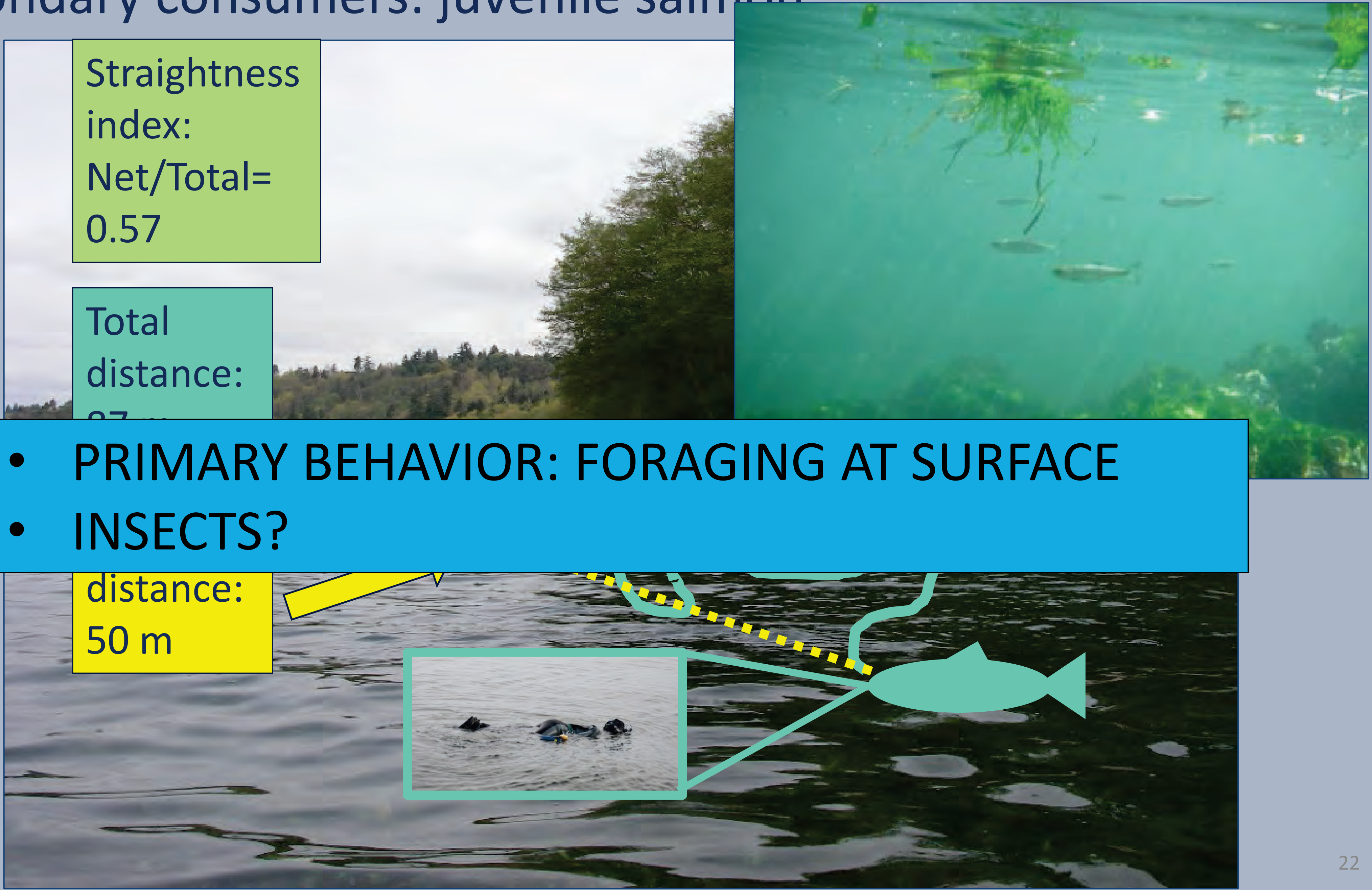
Secondary consumers: juvenile salmon

Straightness index: Net/Total= 0.57

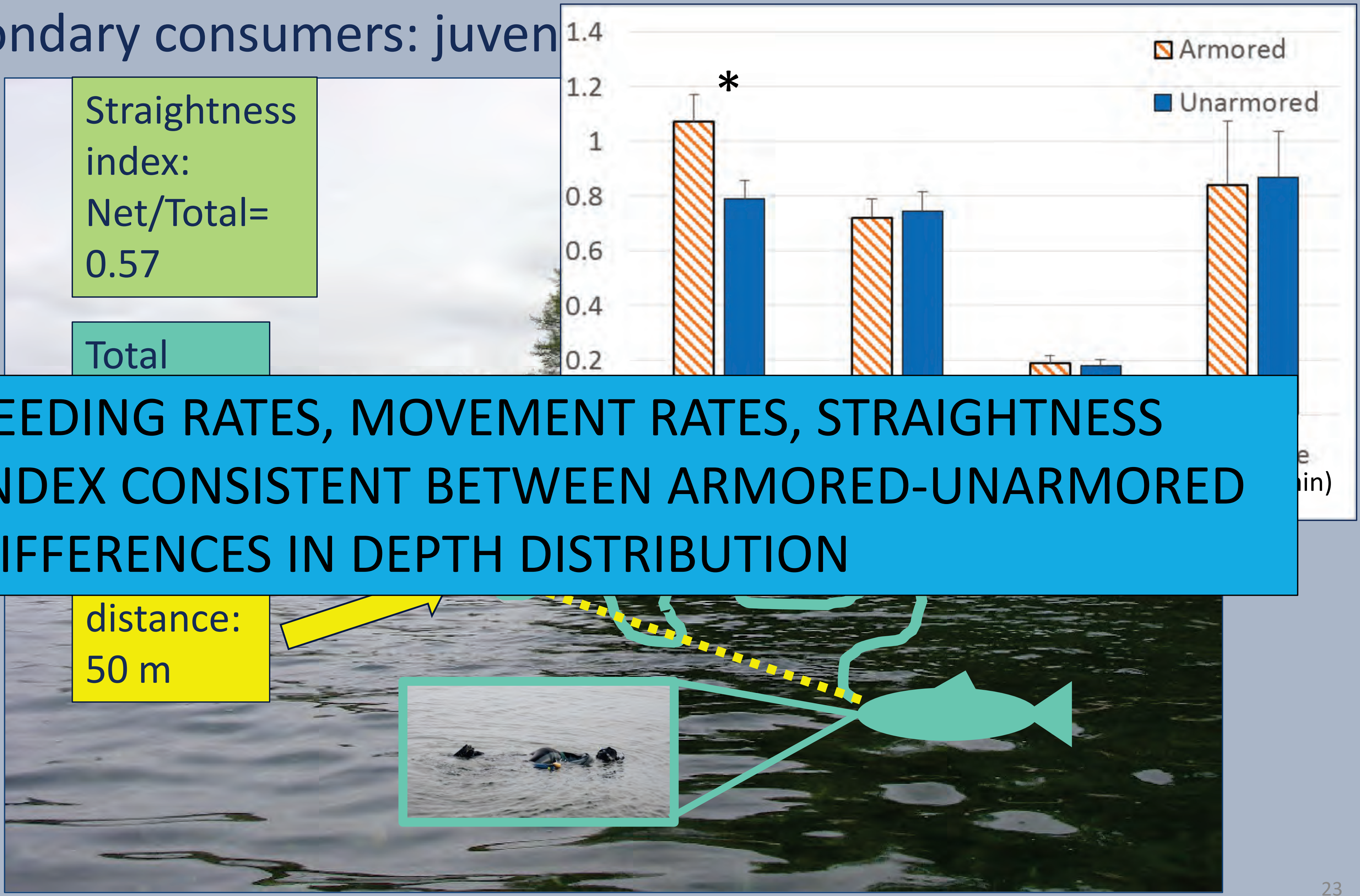
Total distance:

- PRIMARY BEHAVIOR: FORAGING AT SURFACE
- INSECTS?

distance: 50 m

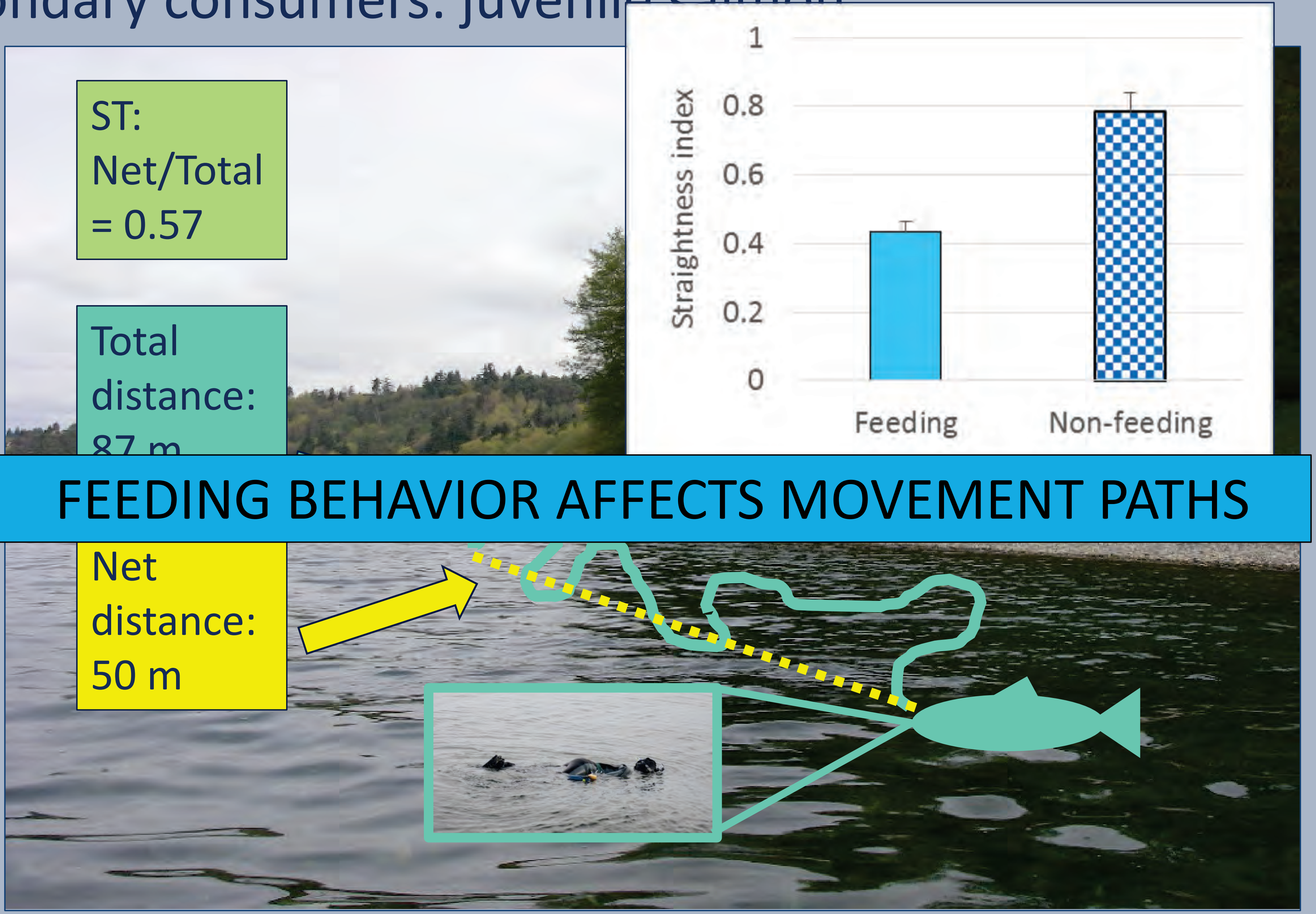


Secondary consumers: juven

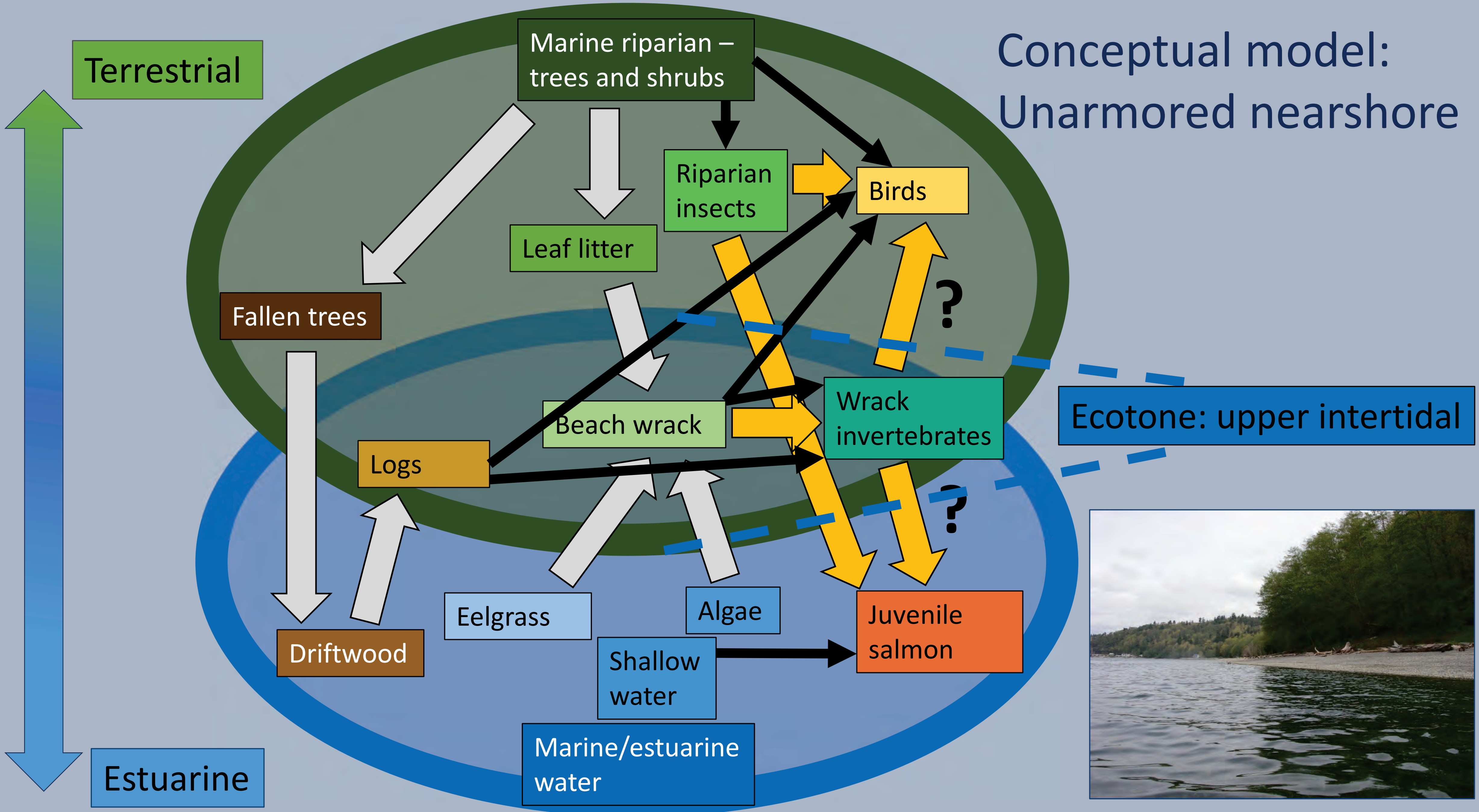


- FEEDING RATES, MOVEMENT RATES, STRAIGHTNESS INDEX CONSISTENT BETWEEN ARMORED-UNARMORED
- DIFFERENCES IN DEPTH DISTRIBUTION

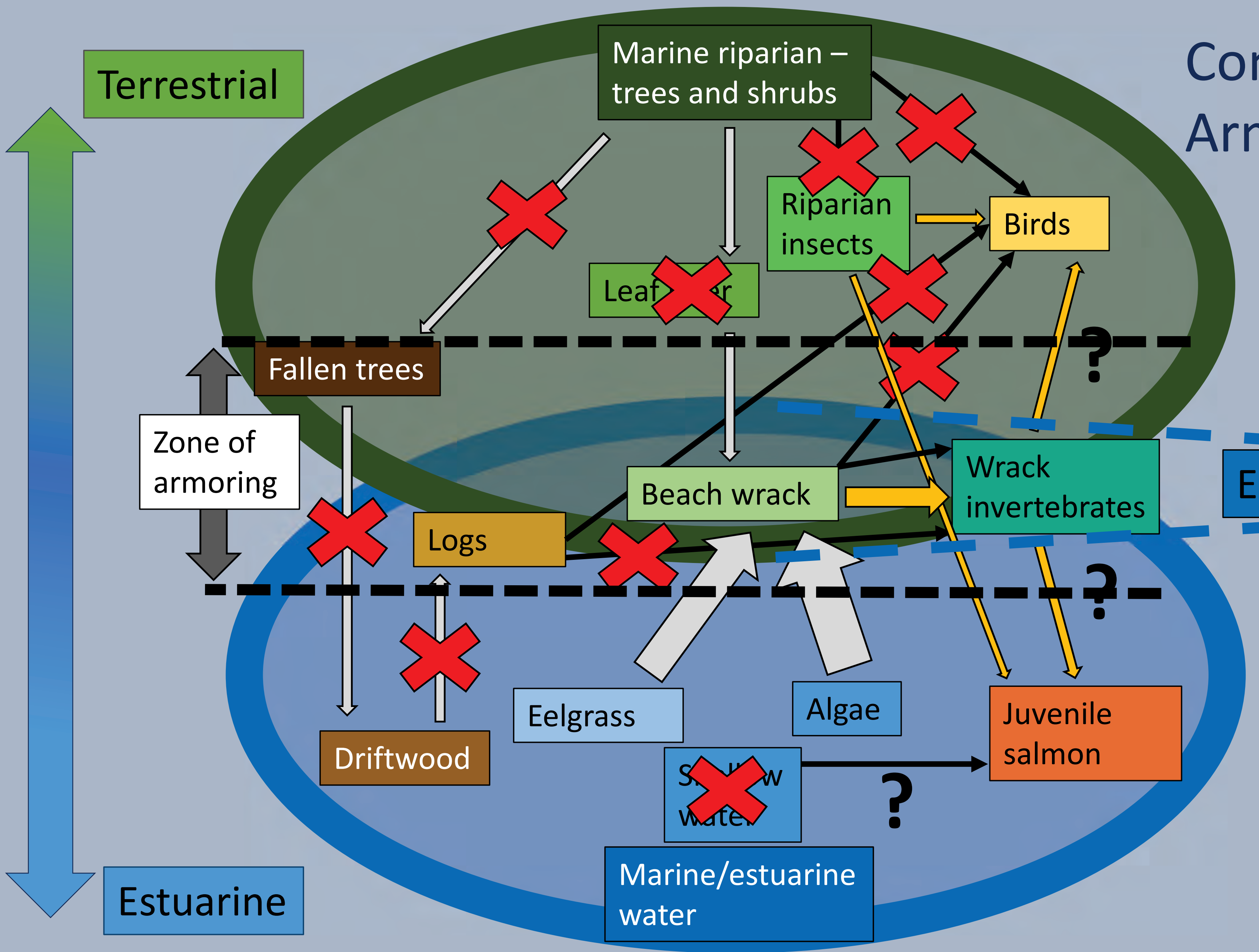
Secondary consumers: juvenile salmon



Conceptual model: Unarmored nearshore



Conceptual model: Armored nearshore



Conceptual model: Armored nearshore