Beach grass invasions, climate change, and flooding risk in coastal dune systems

Sally Hacker
Peter Ruggiero
Oregon State University

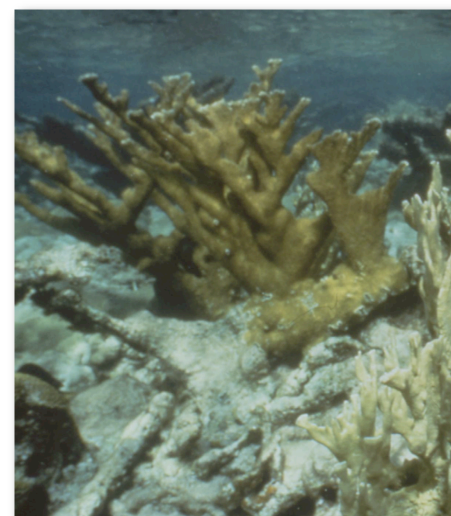
Eric Seabloom
University of Minnesota

Coastal Interface Habitats:

Provide critical ecosystem services for humans (Barbier, Hacker, et al. 2011, *Ecological Monographs*)

Structure	→	Functions	→	Services
Species diversity		Productivity		Fisheries management, raw materials
Species composition				CO_2 sequestration
Species abundance		Nutrient cycling		Water purification
		Wave dissipation		Coastal protection



Coasts have disproportionally high human population densities

2011: **Roughly half of all humans live on the coast, which makes up 4% of Earth's total area.**

2025: **Predicted to be 70%.**

Coasts have high human impact, often creating trade-offs in services:

For example, aquaculture and coastal protection

Coasts are on the frontlines of climate change:

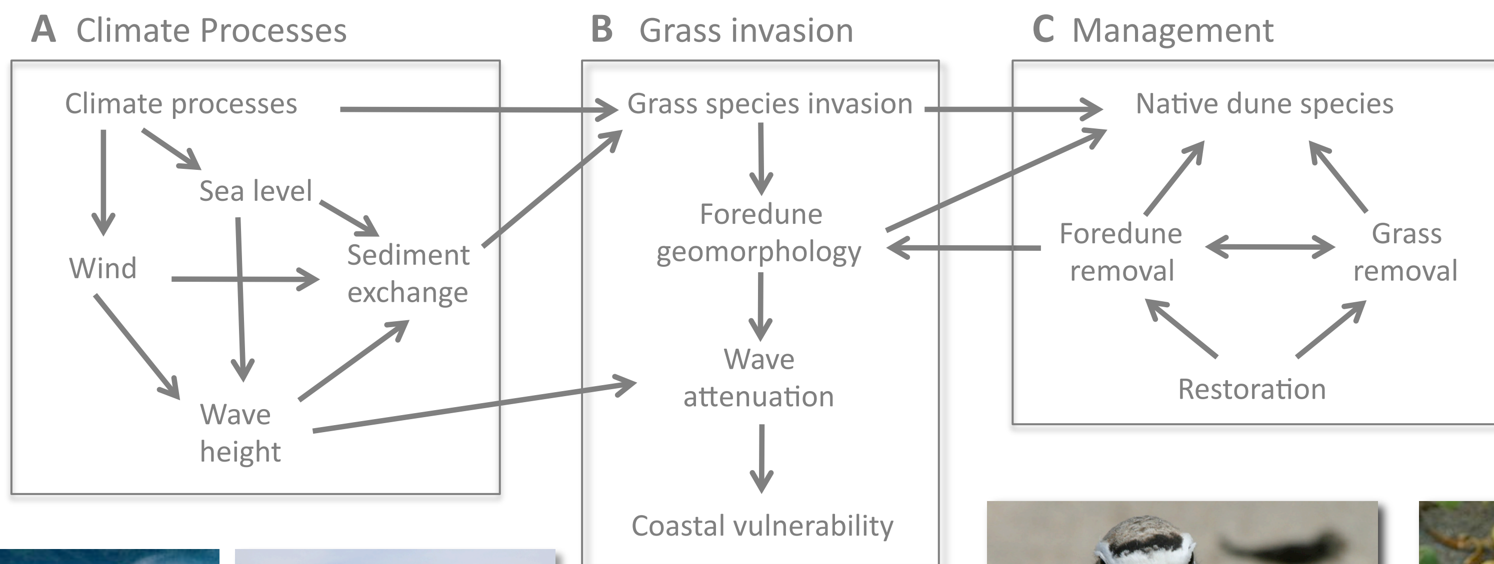
Extreme storms and wave events
Sea level rise

High population numbers, their impact, and climate change intersect on coasts to influence ecosystem services

Beach grass invasions on the Pacific Northwest coast

In this system,

climate processes, grass invasion, and management are tightly coupled to potentially create variable coastal vulnerability



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2. Determine the implications of beach grass invaders and climate change on coastal flooding risk,
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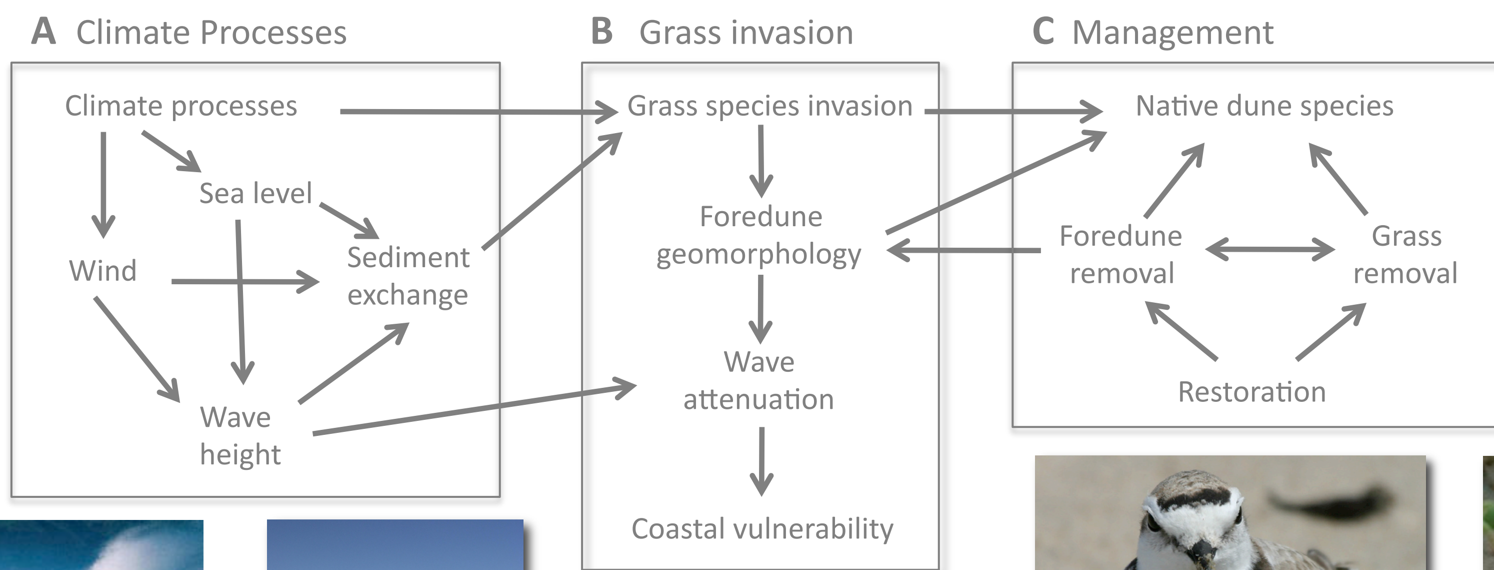

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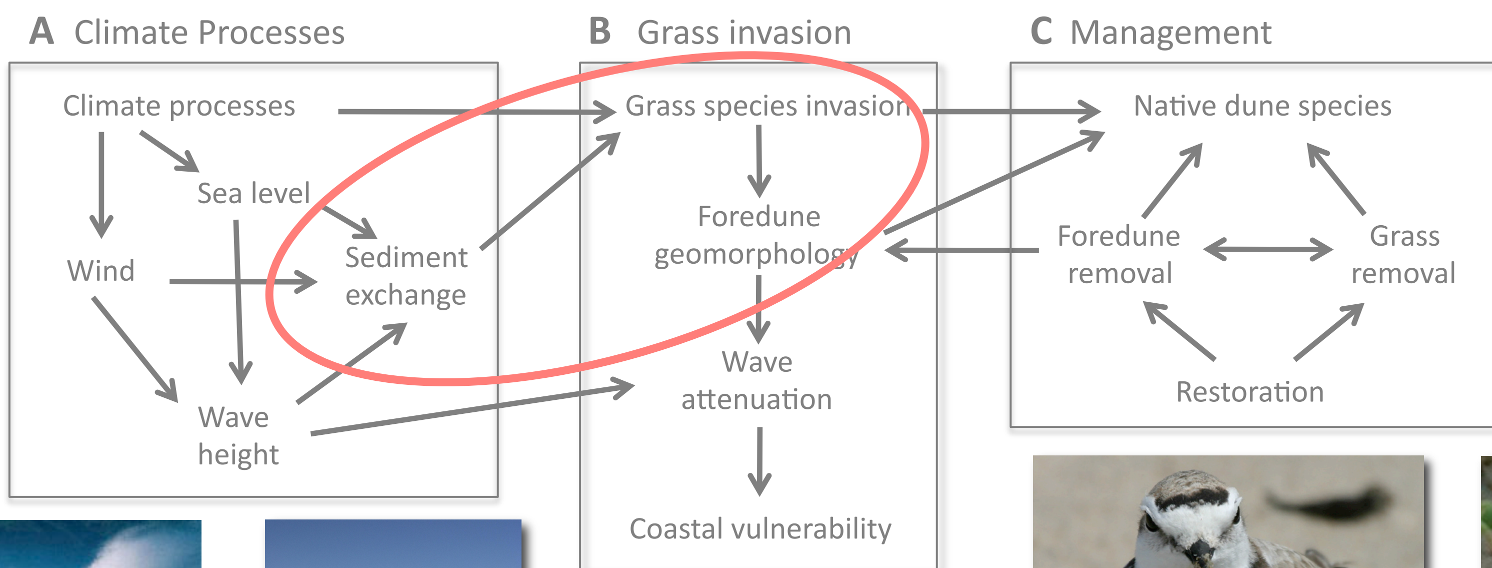


There are two basic factors driving this system:

Beach grass species

Sand supply

Beach grass species invasions


Native beach grass, *Elymus mollis*

Prior to 1900, Pacific beaches and dunes (Oregon 40%; Washington 45%) were sparsely vegetated, little grass, shifting sand

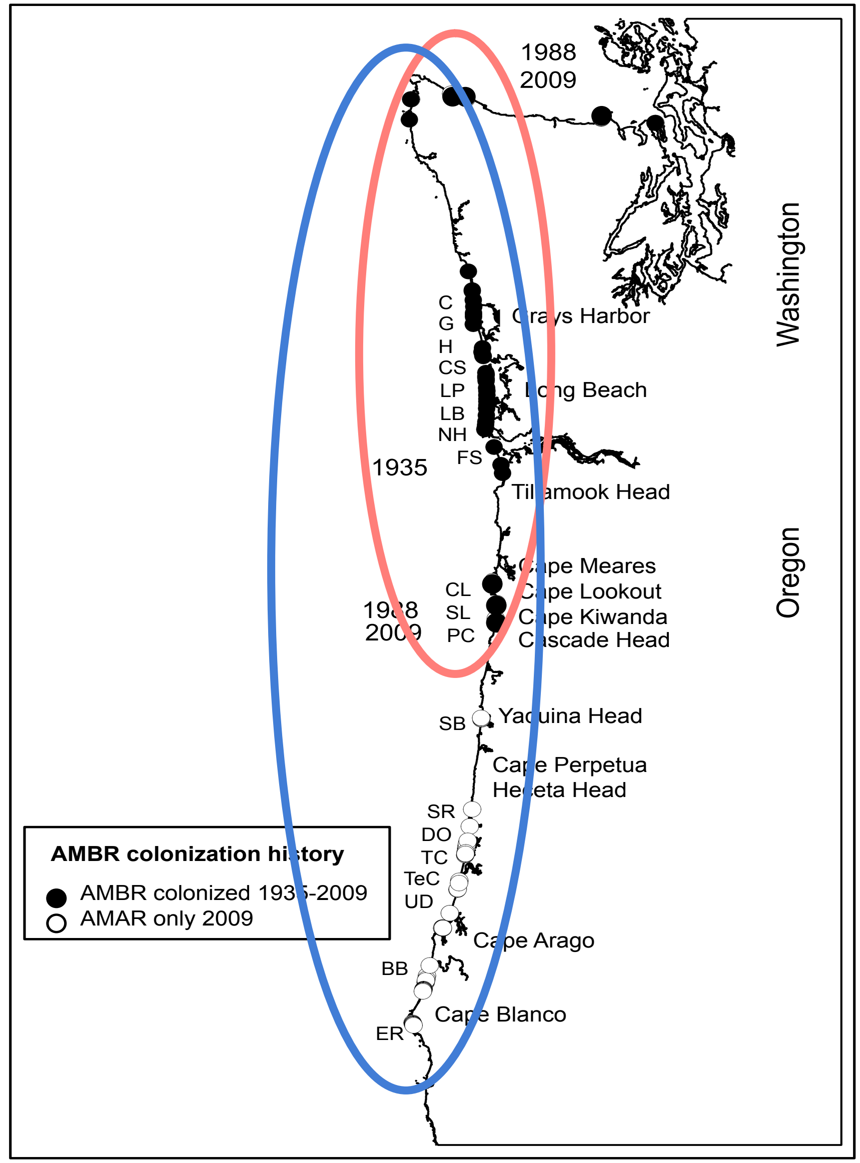
Beach grass species invasions

~1900-1950:

Widely introduced European beach grass, *Ammophila arenaria*

1935:

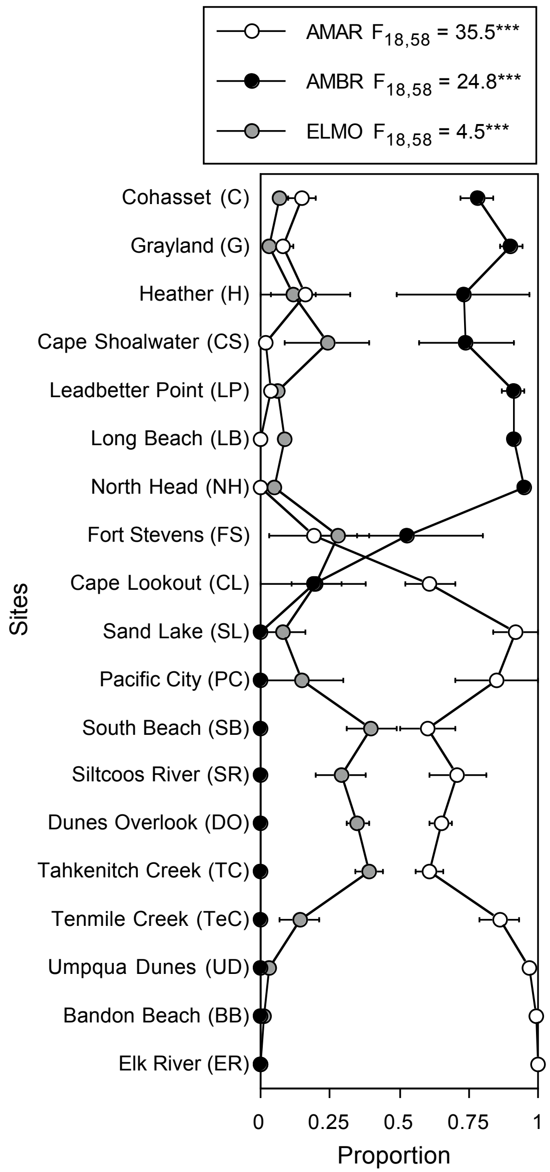
Locally introduced American beach grass, *Ammophila breviligulata*

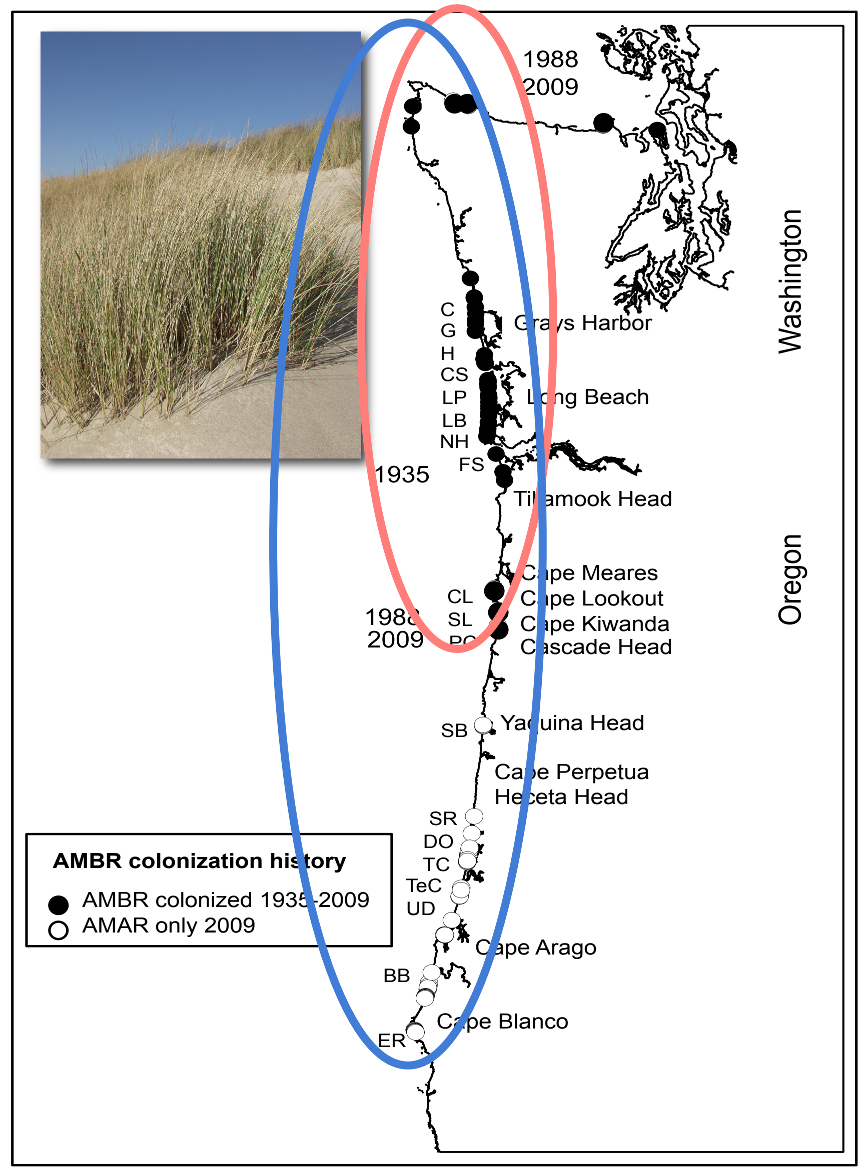


Hacker et al. 2011. *Oikos*.

Beach grass species invasions

Beach grass distribution





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There are two basic factors driving this system:

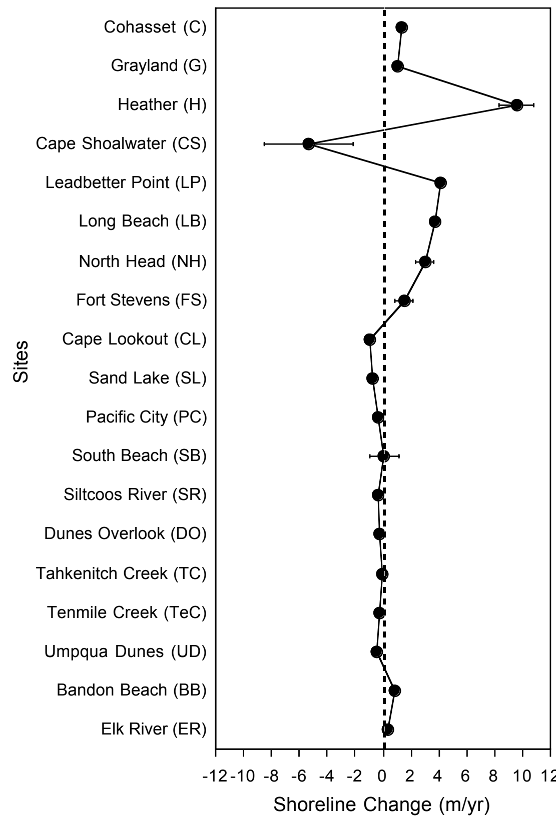
Beach grass species

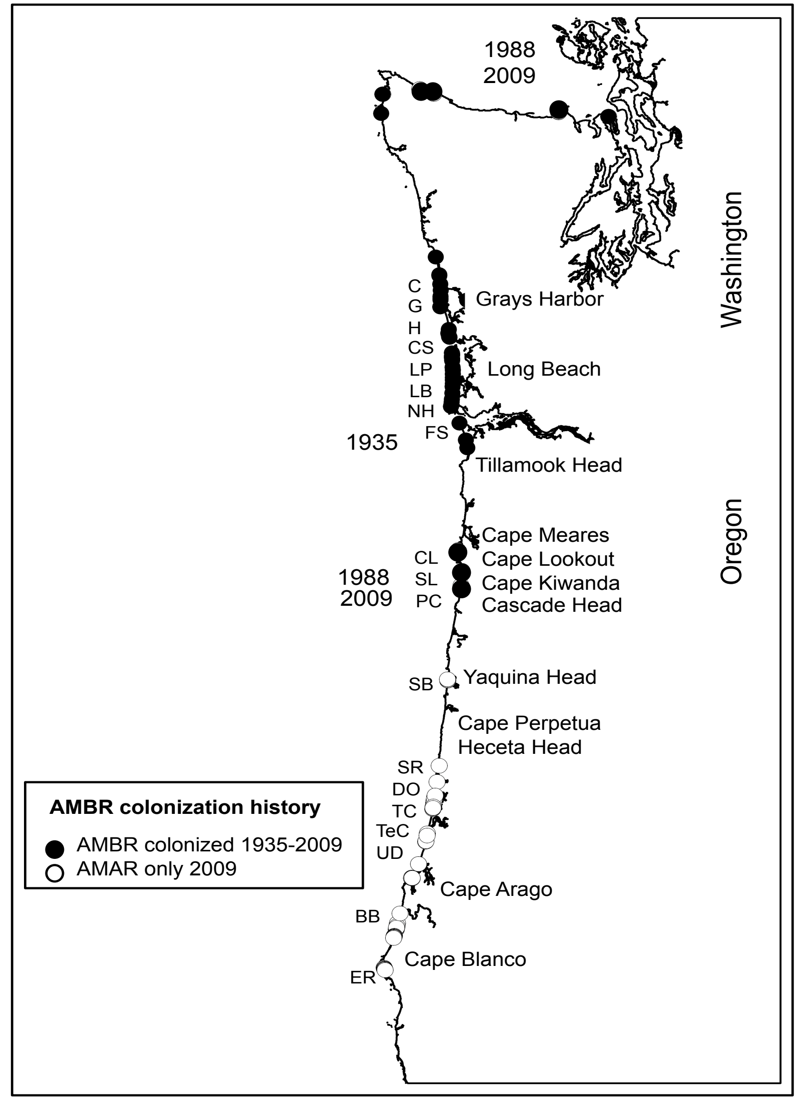
Sand supply

Sand is deposited or lost from beaches depending on offshore supply and wave environment

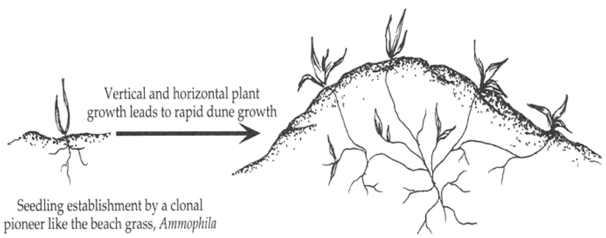
Sand Supply

Sand Supply Distribution– measured as shoreline change





Beach grass and sand interact to form foredunes



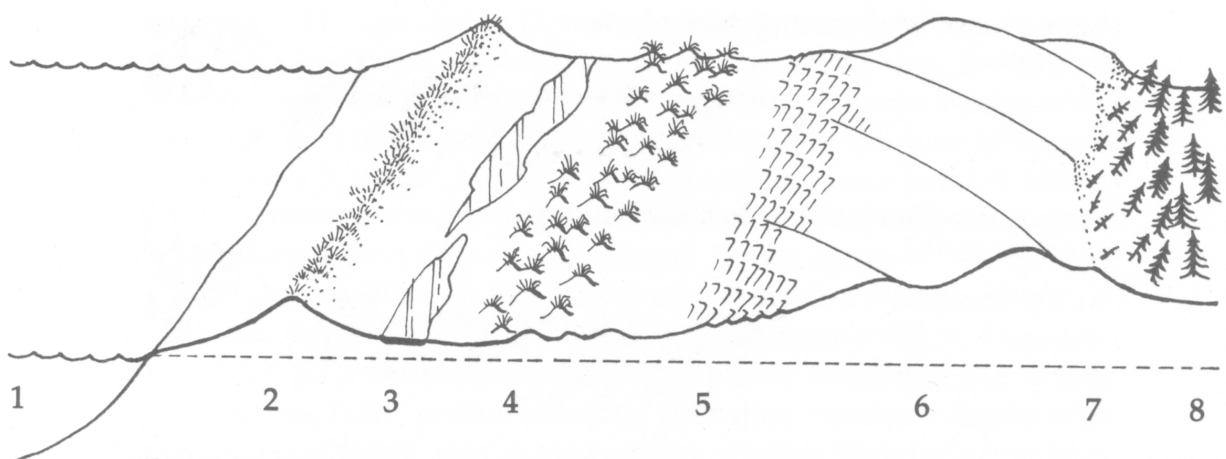
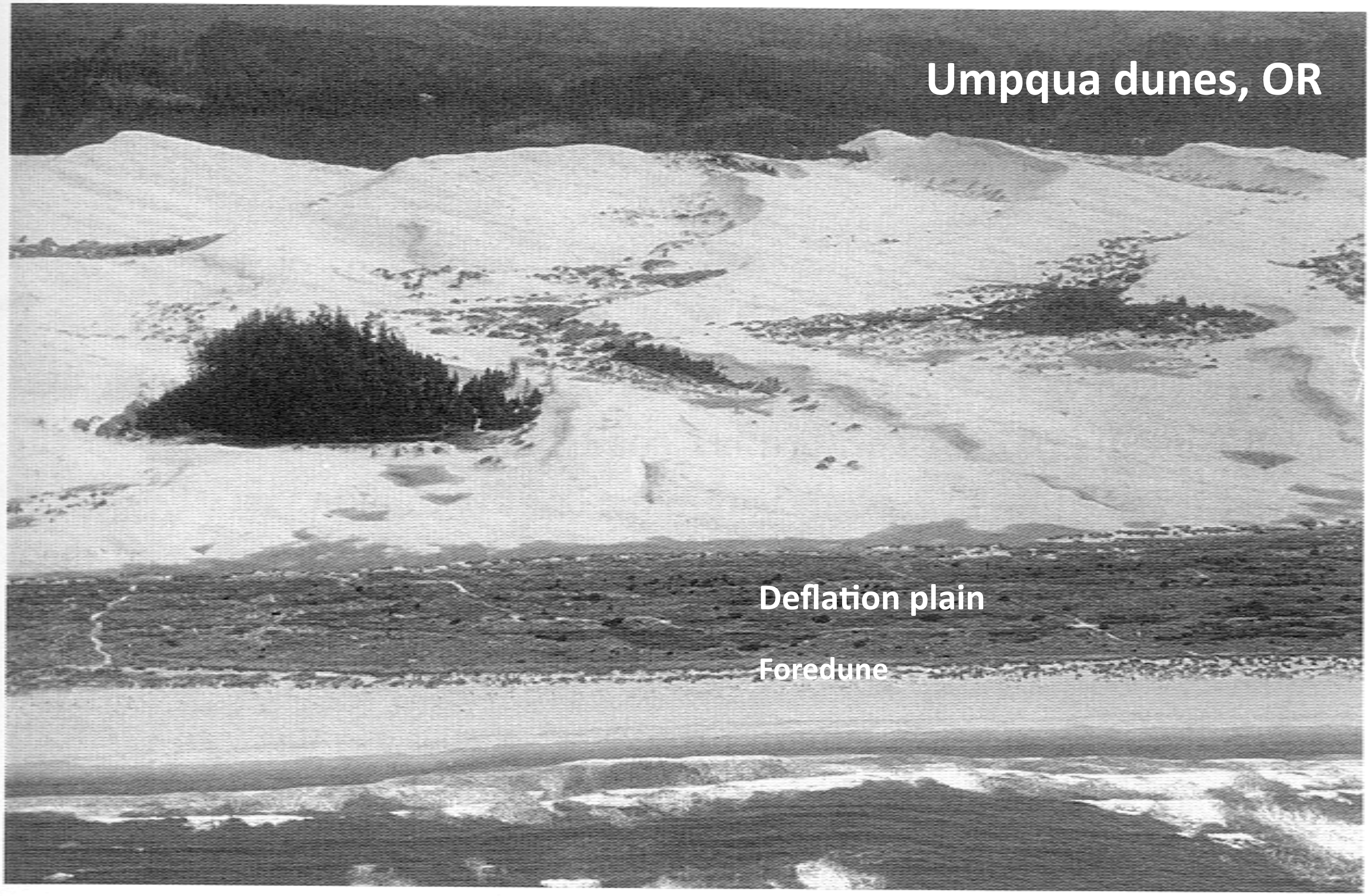


Figure 56. The Dune Landscape. **1** Ocean. **2** Foredune. **3** Deflation plain. **4** Beachgrass hummocks. **5** Transverse ridges. **6** Oblique dunes. **7** Retention ridge. **8** Forest. (Kellerman.)

(from Schultz 1990)

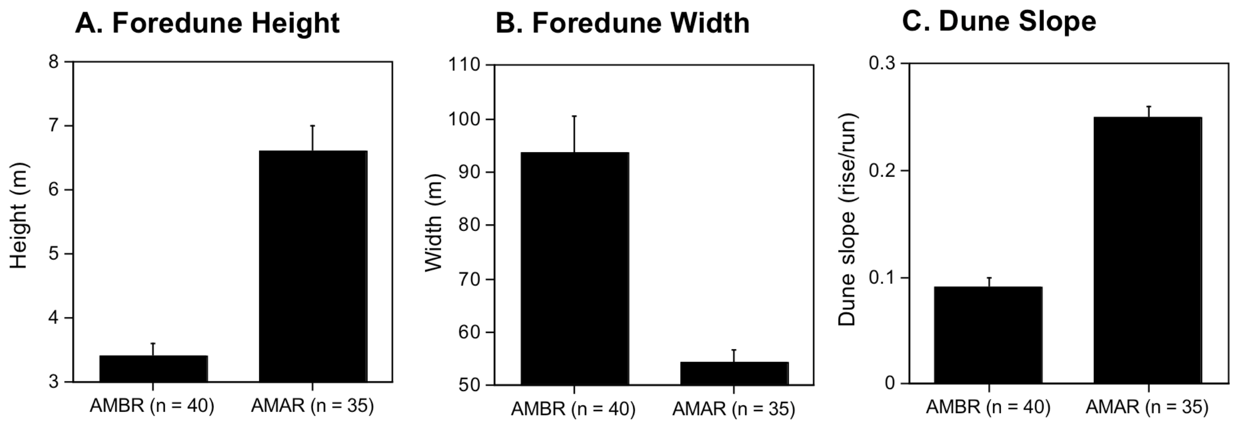


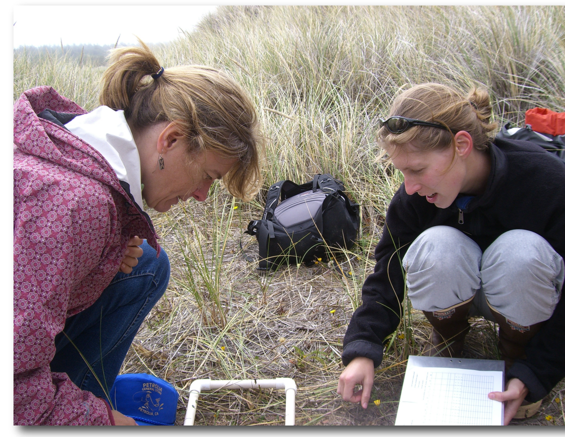
(from Komar 1997)

Ecosystem consequences of foredunes

- Likely increases coastal protection from waves, wind, and possible tsunamis
- Increases sand stabilization for development behind the foredune
- Dynamic nature of shifting sand environment gone; decline in some now endangered species of native plants and animals

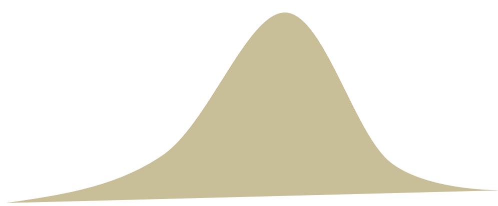
Two congeneric grasses associated with different foredune shapes





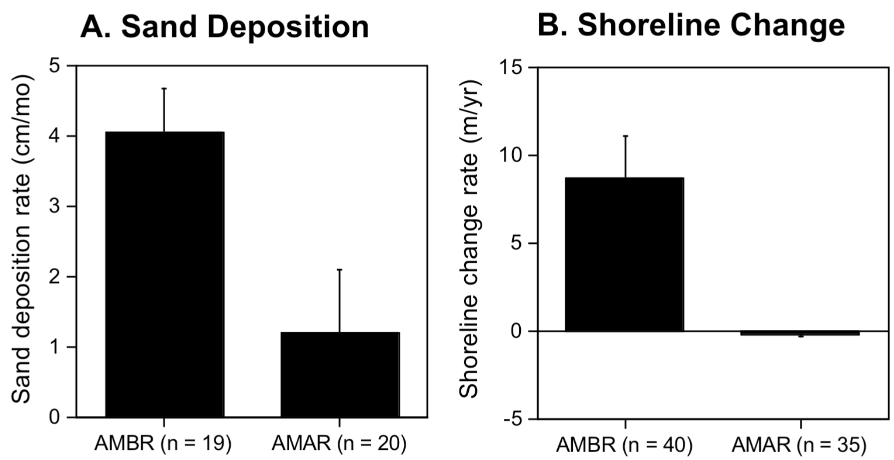
Ammophila breviligulata foredunes

Ammophila arenaria foredunes



Hacker et al. 2011. *Oikos*.

Pattern confounded with sand supply



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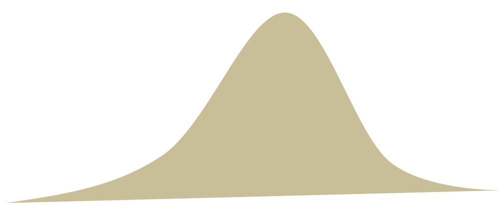

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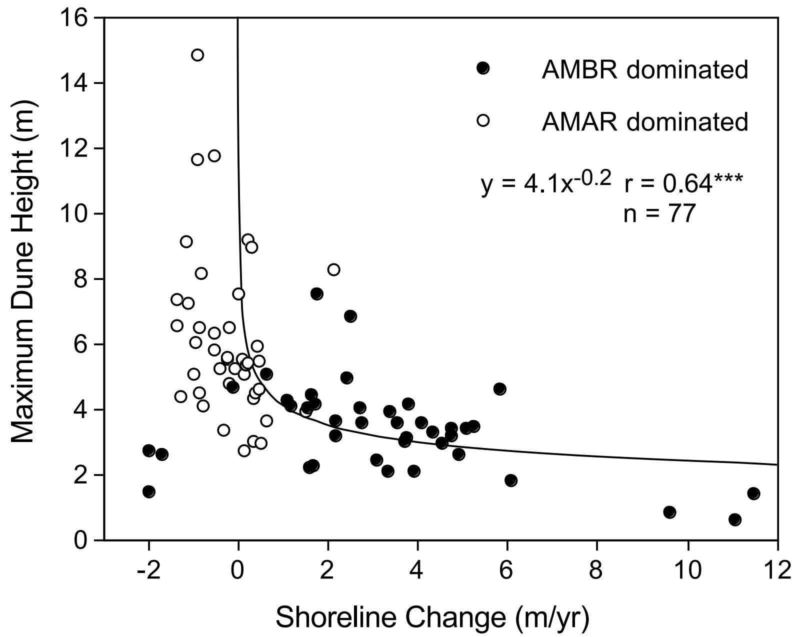
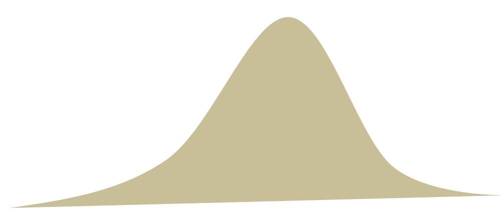
Sand supply (shoreline change) directly affects dune height



High sand supply, short and wide dunes

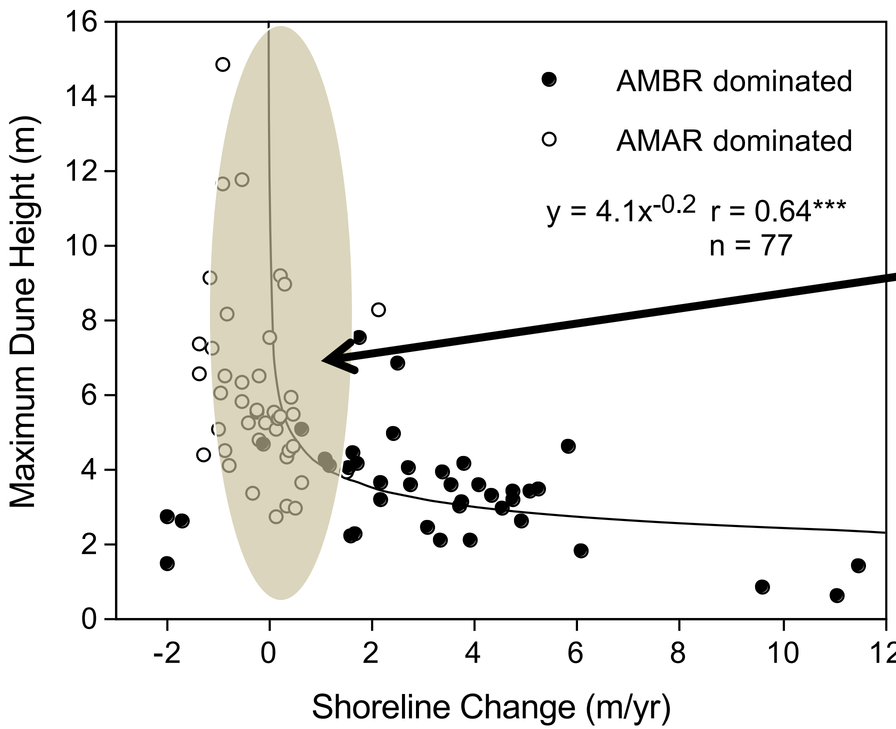
Low sand supply, tall and narrow dunes



Hacker et al. 2011. *Oikos.*

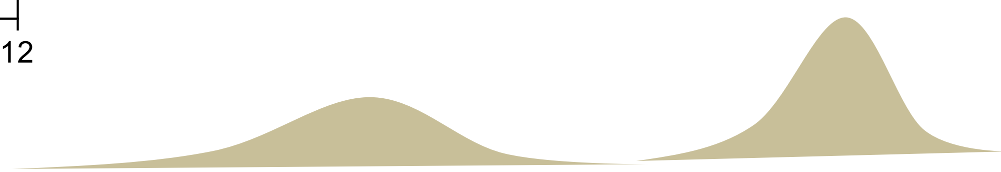
But do grasses (differentially) affect dune height? Yes

Ammophila arenaria builds taller dunes under similar sand supply



Same shoreline change ± 1m or less

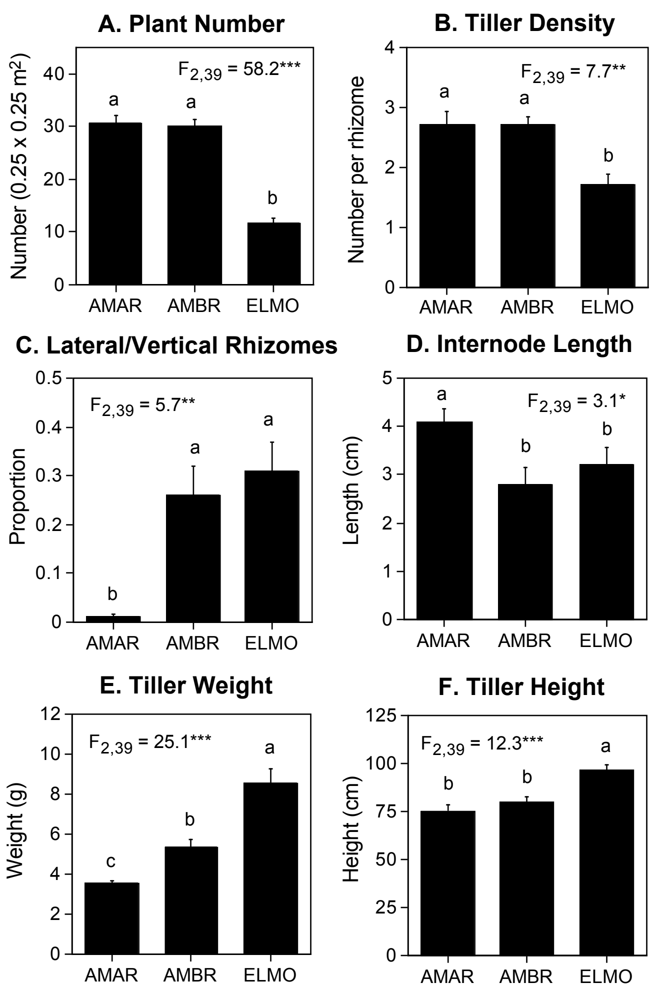
Variable	AMBR dominated Mean ± SE N = 13	AMAR dominated Mean ± SE N = 36	Stats (t)
Shoreline change rate (m/yr)	0.36 ± 0.49	-0.27 ± 0.11	1.9
Total beach grass cover (%)	29.2 ± 3.5	28.8 ± 1.5	0.1
Max. foredune height (m)*	3.8 ± 0.4	6.4 ± 0.4	3.6***
Max. foredune width (m)*	109.2 ± 13.5	53.5 ± 2.3	6.3***



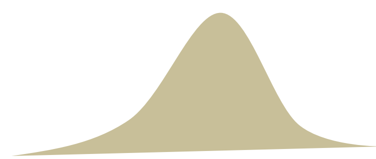
Hacker et al. 2011. *Oikos.*

Why are the foredune elevations different for the two congeners?

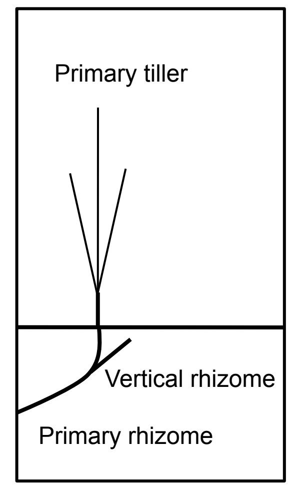
Differences in morphology and growth form



***Ammophila arenaria*:**
Thinner stems
More vertical rhizomes
Longer rhizome internodes

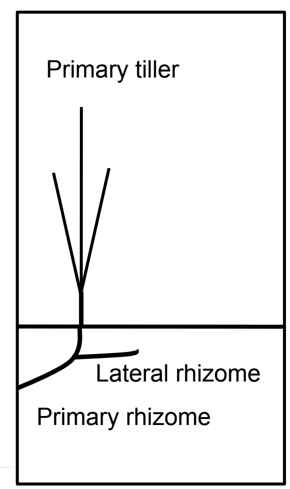


AMAR



***Ammophila breviligulata*:**
Thicker stems
More lateral rhizomes
shorter rhizome internodes

AMBR



Hacker et al. 2011. *Oikos.*

Sand Capture and Growth Response Experiments

(Phoebe Zarnetske, PhD work)

3 species: *A. arenaria*, *A. breviligulata*, *E. mollis*

3 sand supply regimes

Wind Tunnel

Hinsdale Wave Research Laboratory, OSU

Sand Bags

Hatfield Marine Science Center, OSU

Zarnetske, Hacker, et al. in review.

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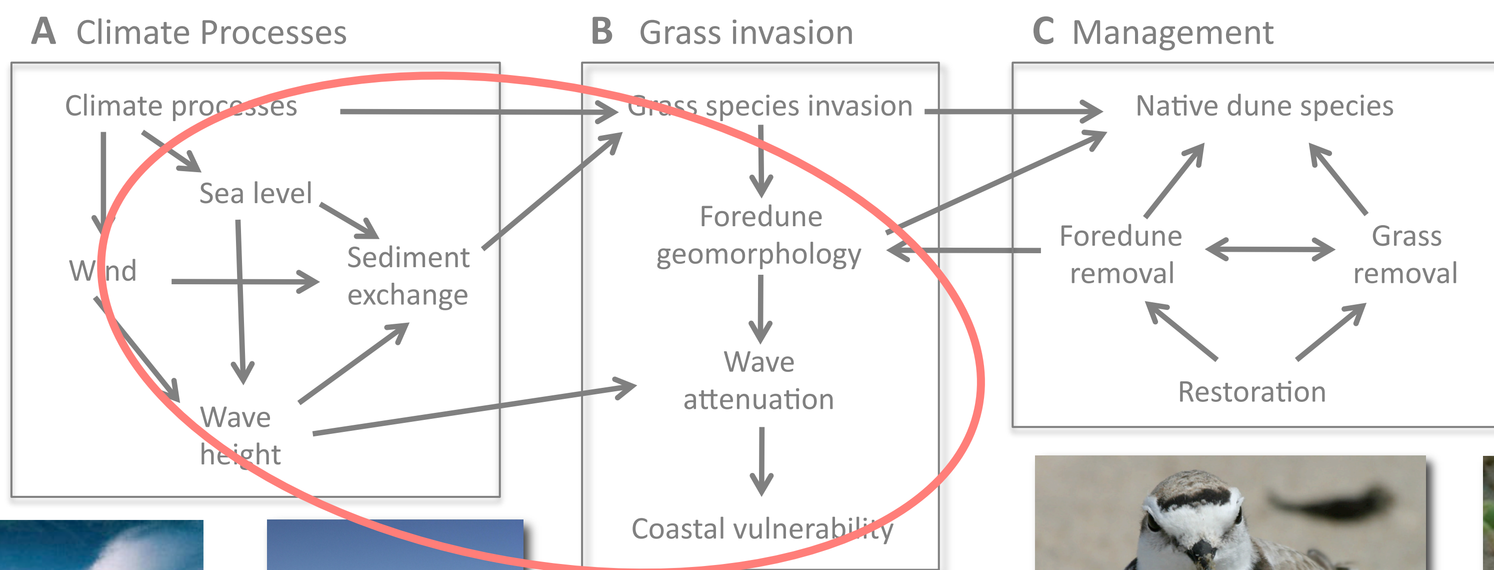


Global warming may be causing increased storm activity, wave heights, sea level, and ocean upwelling

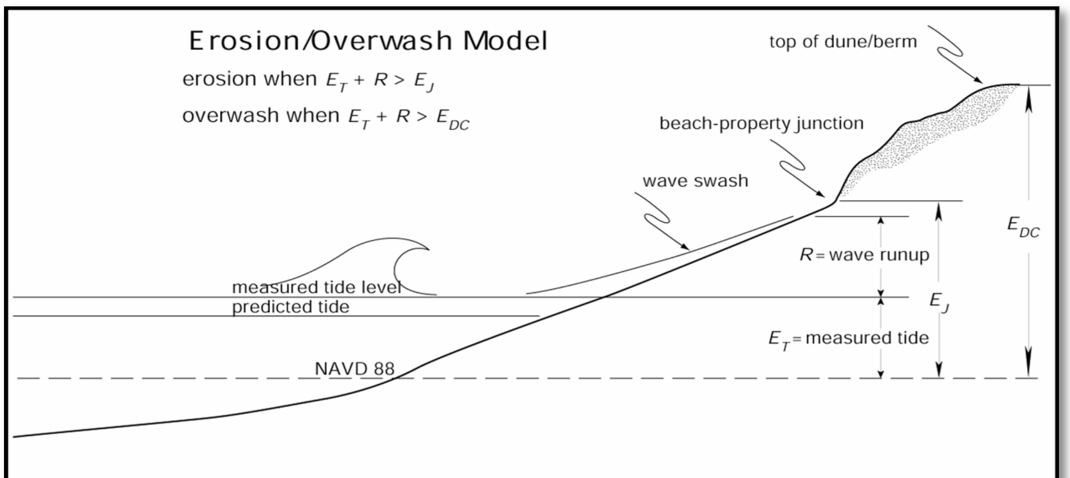
Co-PI, Peter Ruggiero, has shown that wave heights have increased 30% in the last 15 years (Ruggiero et al. 2010).

In 1995, average large wave height = 10 m
Now, average large wave height = 14 m

Model the relative contribution of the two beach grasses and climate change to coastal flooding risk

- Use lidar data to determine dune morphometrics every 50 m along the OR and WA coast (Mull 2011)
- Determine realistic climate change scenarios for wave heights and sea level in the future
- Plug into beach geomorphic model

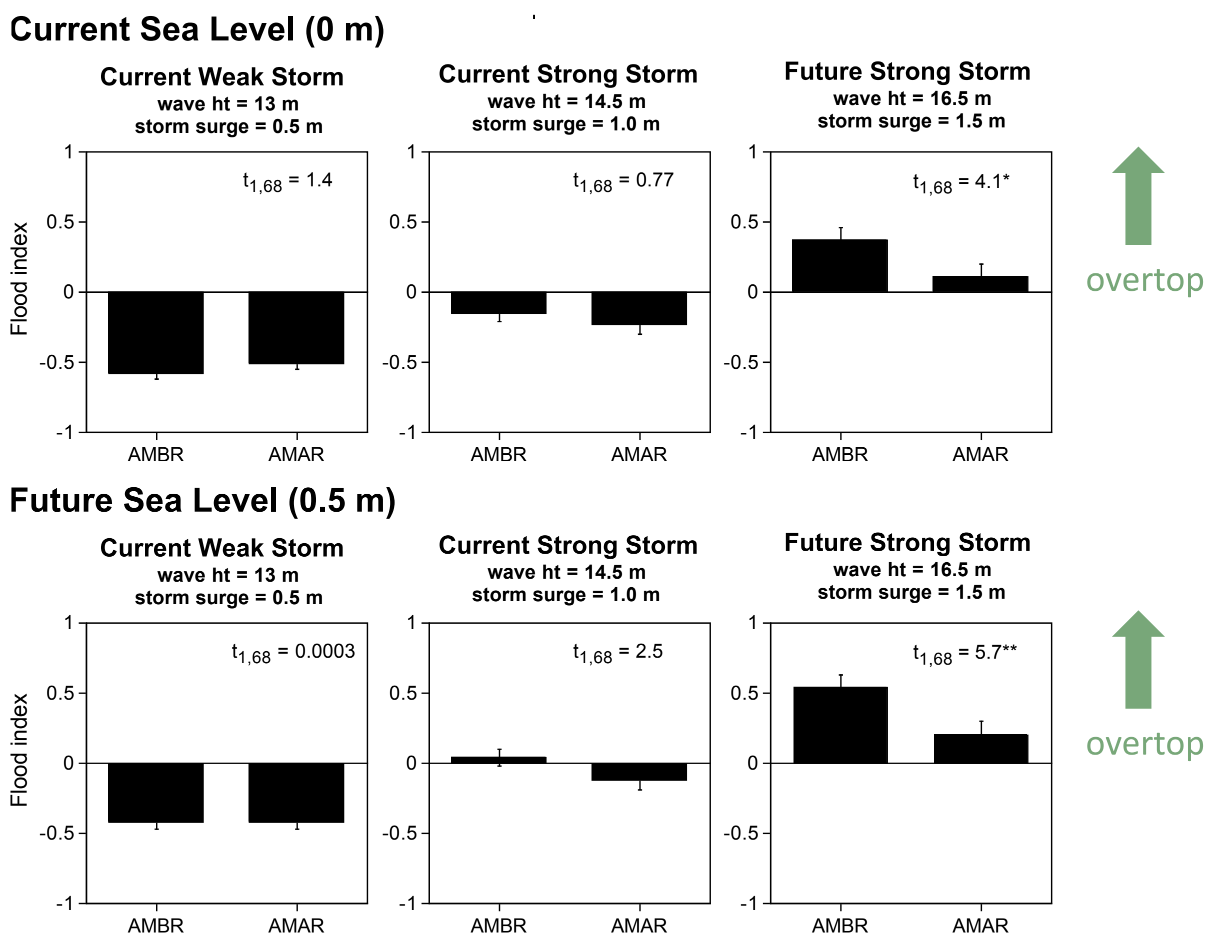
$$TWL = Z_T + 1.1\left(0.35\tan\beta(H_0L_0)^{1/2} + \frac{\left[H_0L_0(0.563\tan\beta^2 + 0.004)\right]^{1/2}}{2}\right)$$

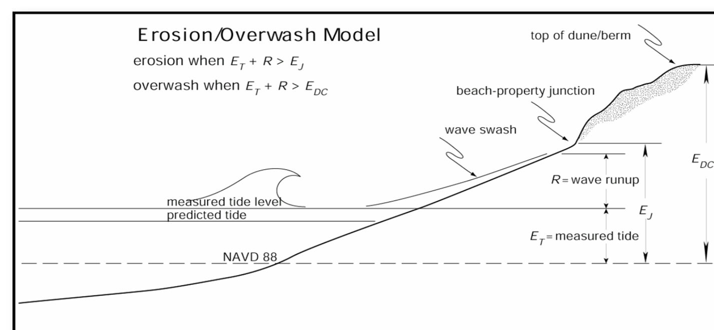


Calculate flooding index = (TWL – dune face height)

Seabloom, Ruggiero, Hacker et al. in review.

Model the relative contribution of the two beach grasses and climate change to coastal flooding risk



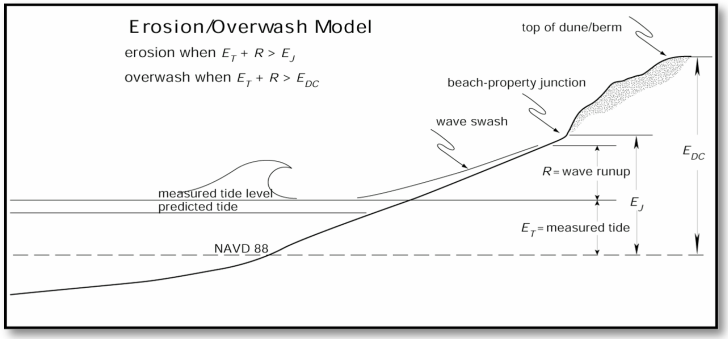


Seabloom, Ruggiero, Hacker et al. in review.

Our models show that the dominance of *A. breviligulata* (and the predicted subsequent lowering of dune heights):

1. Tripled the number of areas at risk of flooding from overtopping

2. Posed a fourfold larger flooding risk than sea-level rise



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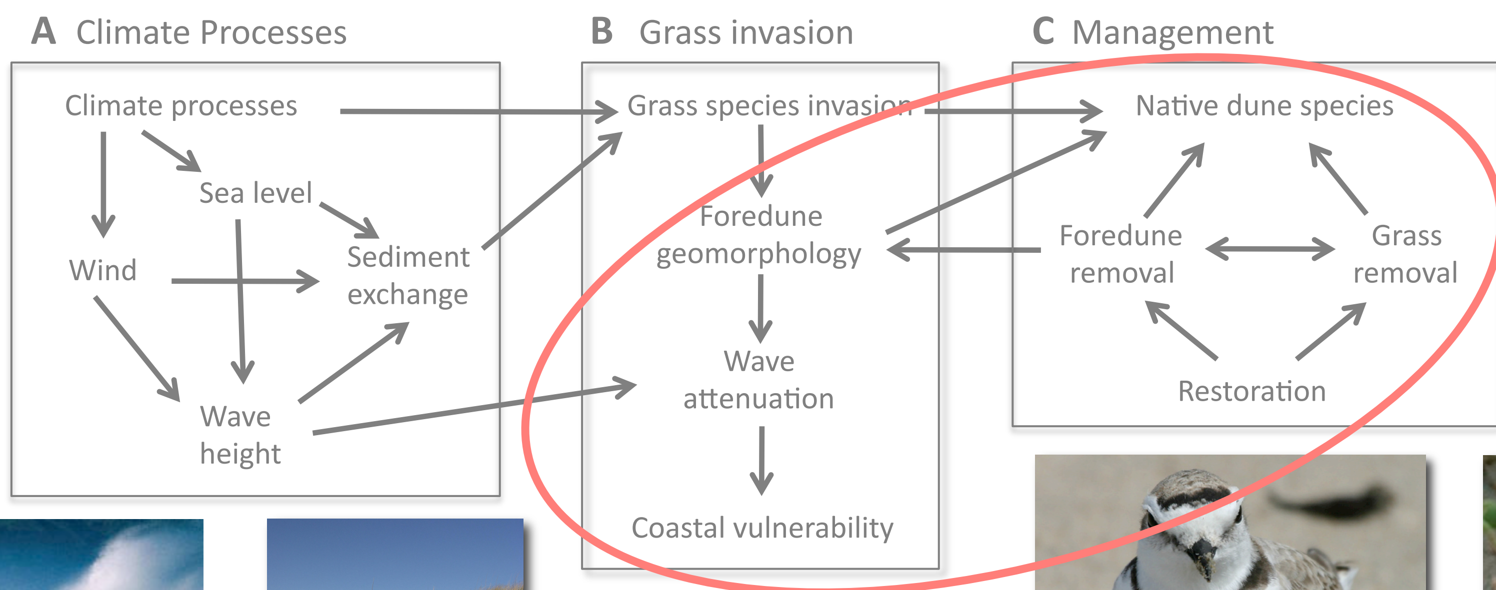
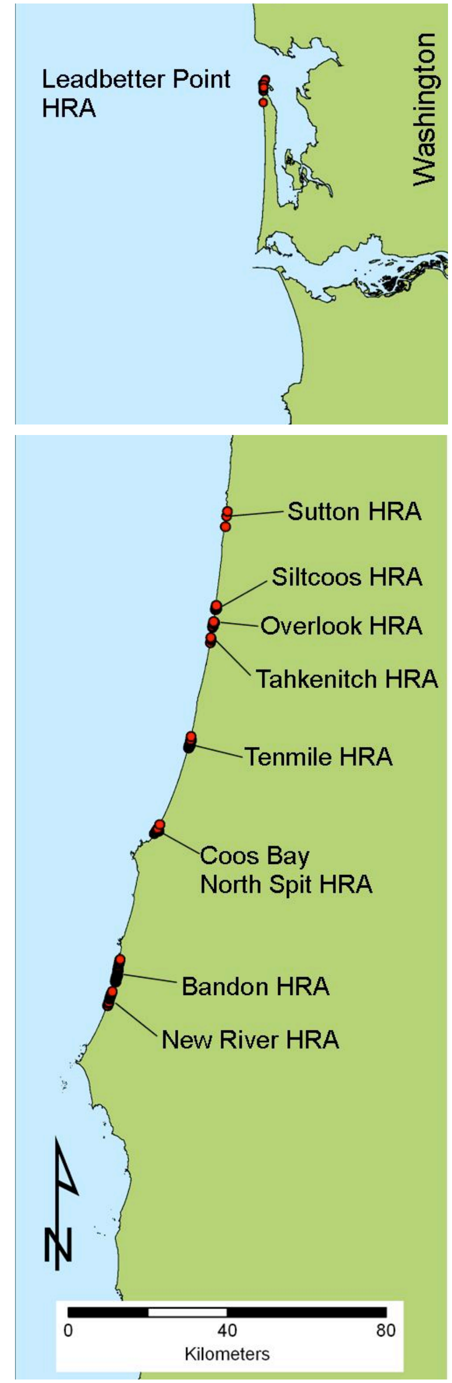


Tradeoffs between native ecosystem restoration and coastal flooding risk



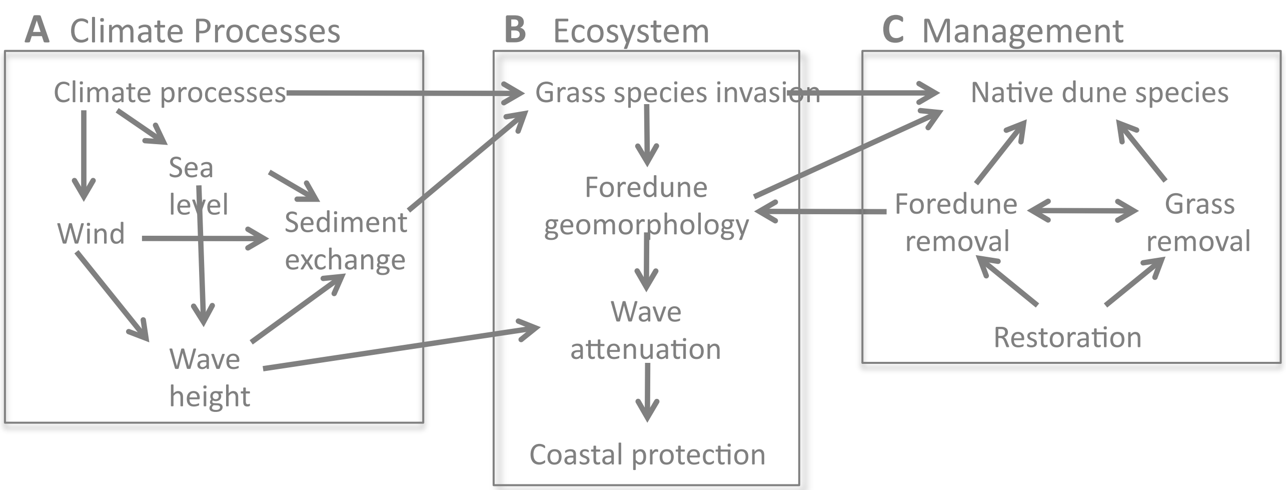
Zarnetske, Seabloom, & Hacker. 2010. *Ecosphere*.

In summary,

1. Invasive congeneric beach grasses have different effects on structure, function, and ultimately coastal vulnerability provided by dunes.
   If AMBR moves south, coastal flooding will increase

2. Climate change will exacerbate flooding risk (esp. wave ht) but is likely to be secondary to the effects of invasion in lowering dune heights.

4. There is likely a tradeoff between coastal ecosystem restoration and coastal vulnerability



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