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RESEARCH:

invasions and ecosystem services

In the U.S. Pacific Northwest (PNW), the introductions and subsequent invasions of two Ammophila beach grasses caused landscape-scale transformations of coastal dune shape. The grasses created large, continuous, and densely vegetated foredune ridges parallel to the shoreline, replacing the natural sand-shifting and sparsely vegetated environment. The invasions resulted in threatening the Western snowy plover, and declines in some native plants.

At the same time, the large foredunes created by Ammophila provide an important ecosystem service for humans - coastal protection from overtopping waves. My research investigates both the positive and negative effects of these invasions. I seek to understand the biological and physical mechanisms that influence invasion success, community composition, and dune shape, as well as the implications of removing the invaders. It is especially important to understand these mechanisms and implications in light of documented increases in wave heights, and predictions of sea level rise during climate change.

Coastal Dune Research

2.1.Biophysical feedbacks influence coastal dune shape

3.2.Species interactions, environmental gradients, and coexistence

3.3.Coastal protection: invasions, sea level rise, and storm surge

4.4.Coastal foredune evolution: evidence for biotic control

5.5. Non-target effects of invasive species management

Beach grass invasions in the U.S. Pacific Northwest

Along the PNW coast, my colleagues and I documented correlations between coastal foredune shape, dominant beach grass species, and sediment supply rate (Hacker et al.

2012). To uncover the mechanisms behind these patterns, we designed two experiments to characterize the biophysical feedback among beach grass species and sediment supply. The experiments were performed in a full-scale, moveable bed wind tunnel and mesocosms (Zarnetske 2011, Zarnetske et al. 2012).

We found a species-specific control on foredune shape that is driven by plant morphology and growth responses to sediment supply rate. We determined that the European Ammophila arenaria is the superior dune building species followed by the U.S. East Coast A. breviligulata species, and the native Elymus mollis grass (Zarnetske et al. 2012).

This research shows strong support for ecological controls on dune geomorphology and coastal protection from waves.

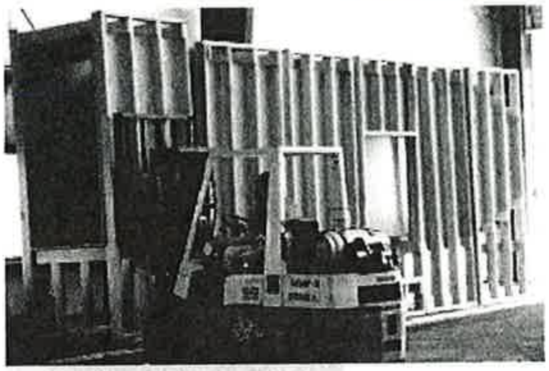
1. Biophysical feedbacks influence dune shape

2. Species interactions, environmental gradients, and coexistence

How do species interactions change along environmental gradients, and in turn, how does this influence invasion potential and species coexistence? To address these questions, I collaborated with ecologists and mathematicians to generate numerical models that examine the influence of beach grass species interactions and sediment supply gradients on PNW beach grass community composition over the long term. Our model shows that once introduced via natural or human means, *A. breviligulata* can invade and dominate coastal dunes across a range of sediment supply conditions along the PNW coast. Over the long term, coexistence among all three beach grass species was the most common outcome, largely a result of facilitation and indirect effects (Zarnetske et al. 2013).

Ammophila breviligulata is the inferior dune building species of the two dominant dune building species (Zarnetske et al. 2012). Thus, further invasions by *A. breviligulata* have the potential to reduce coastal protection. However, in southern regions of the PNW, where *A. arenaria* maintains taller dunes, and *A. breviligulata* is currently absent, our model predicts that the future invasions by *A. breviligulata* are more likely to result in co-dominance by both *Ammophila* species. This would potentially lessen a decline in dune height.

The invasion models provide key insights about potential future invasion scenarios. We combined these insights with future sea level and wave height projections to understand the influence of further *A. breviligulata* invasions, rising seas, and intensified storms on the risk to coastal dune inundation in the future. We found that although storm surge is the leading driving of wave overtopping, future *A. breviligulata* invasions could 1) triple the number of PNW areas vulnerable to wave overtopping, and 2) have 4 times more influence than sea level rise alone (Seabloom et al. 2013).



O.H. Hinsdale Wave Research Laboratory

Our experimental work shows that biological variables (plant morphology and growth form) as well as physical variables (sediment supply) influence dune shape. How do the relative contributions of biological vs. physical variables change over different time scales? This research focuses on a section of the PNW coast, the Columbia River Littoral Cell (CRLC), and combines high resolution data on vegetation community composition, sediment supply rates, and foredune shape along 100 km of coastline, over 21 years (Ruggiero et al. 2011, Zarnetske 2011, Zarnetske et al. in review).

3. Coastal protection: invasions, sea level rise, and storm surge

4. Coastal foredune evolution: evidence for biotic control

Ammophila invasions caused the federal listing of the Western snowy plover (Charadrius alexandrinus nivosus) which prefers bare ground habitat with sparse vegetation. We investigated how nearly 20 years of management targeted at the removal of Ammophila for plover recovery are impacting native plant species and dune morphology along 500 km of coastline in the PNW (Zarnetske et al. 2010). Despite increased plovers and decreased Ammophila in treated areas, plover habitat restoration has had the unintentional effect of reducing the richness and abundance of native dune plants. Frequent Ammophila removal has prevented the re-establishment of the natural disturbance regime and dune function. This research shows that a single-species approach to restoration and management can result in unintended negative effects. We suggest adopting a more synthetic community-wide management approach (Zarnetske et al. 2010).

5. Non-target effects of invasive species management

Links

relevant papers:

2013: *Journal of Ecology*, Indirect effects and facilitation among native and non-native species promote invasion success along an environmental stress gradient. ***Highly commended for Harper Prize*

2013: *Global Change Biology*, Invasive grasses, climate change, and exposure to storm-wave overtopping in coastal dune ecosystems.

2012: *Ecology*, Biophysical feedback mediates effects of invasive grasses on coastal dune shape.

2012: *Oikos*, Subtle differences in two non-native congeneric beach grasses significantly affect their colonization, spread, and impact

2011: PhD Dissertation: The influence of biophysical feedbacks and species interactions on grass invasions and coastal dune morphology in the Pacific Northwest, USA.

2010: *Ecosphere*: Non-target effects of invasive species management: beachgrass, birds, and bulldozers in coastal dunes

main collaborators: Sally Hacker (Oregon State University, OSU), Eric Seabloom (Univ. of Minnesota, UMN), Peter Ruggiero (OSU), Tarik Gouhier (OSU), Vrushali Bokil (OSU), Timothy Maddux (OSU), Jason Killian (OSU), Daniel Cox (OSU), Jeremy Mull (OSU), Aaron David (UMN)

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