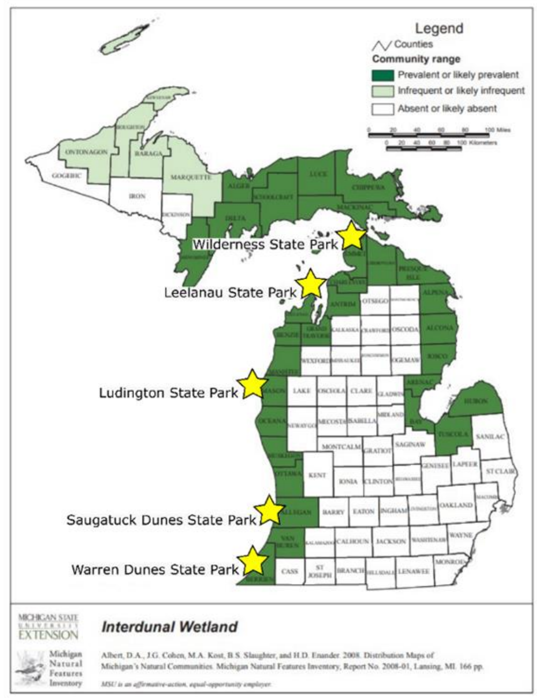
Title: Connecting interdunal wetlands and foredune plant communities along a climatic gradient

Statement of Work

Interdunal wetland ecosystems develop in low-elevation depressions that occur between dune ridges of coastal areas (Kost et al., 2007). These low-lying areas may intercept the ground water level and become saturated either ephemerally or year-round. Interdunal wetlands are abundant along all Great Lakes, including the coastline of Lake Michigan (Figure 1). These habitats are home to a variety of threatened and endangered species such as the Yellow Pitcher Plant, Butterwort, Piping Plover, Blanchard's Cricket Frog, and Spotted Turtle (Kost et al., 2007). In addition to their importance for biodiversity, wetland areas of dune systems and their vegetation may play an important role in primary succession and initial soil development in coastal dune ecosystems (Grootjans, 1998; Jones et al., 2008). Interdunal wetlands along the Great Lakes are imperiled due to heavy anthropogenic activity, including development and off-road vehicle use. Furthermore, changing climate including the effects of increasing temperature, summer drought, and greater variability in lake levels may pose a significant threat to wetlands by changing patterns of wetland saturation (DeVries-Zimmerman et al., 2021). Understanding the drivers of interdunal wetland creation and maintenance is critical for informing management and conservation strategies for these ecosystems across the Great Lakes.

Figure 1. Distribution map of interdunal wetland habitat (reproduced from Albert et al., 2008) with stars indicating proposed research locations.



Both sediment and groundwater processes are important for interdunal wetland creation and maintenance along the Great Lakes. While connections between hydrology and interdunal communities have been characterized (e.g. DeVries-Zimmerman et al., 2021), the relationships between sediment dynamics and interdunal wetlands have yet to be fully examined despite their potentially critical role in interdunal wetland creation and maintenance (Kost et al., 2007). Sand movement on dunes may cause complete or partial burial of wetland areas (Kost et al., 2007), while storm activity may initiate wetland development by forming blowouts—low-lying depressions in dune fields–which then fill with water and become new wetlands (Hesp, 2002). Such sediment disturbance may alter wetland plant community composition and structure based on plant species burial tolerance, as has been shown in associated sand dune ecosystems (Kost et al., 2007; Forey et al., 2008). Understanding the complex relationships between these processes and interdunal wetland dynamics is important for appropriate management and conservation of these highly dynamic systems.

Foredune plant communities may play an important role in interdunal wetland dynamics by affecting the stability of dune sediments. Aboveground community characteristics of dune vegetation such as total vegetative cover, plant height, and stem density are known to intercept and trap moving sediments while belowground features of dune vegetation, such as root biomass and root architecture, may increase sediment stability (Feagin et al., 2015; De Battisti and Griffin, 2019). Dune vegetation is known to stabilize dune fields (Hesp, 2002; Feagin et al., 2015), and many species, including *Ammophila breviligulata*—the dominant dune grass of the proposed study region—are used in restoration efforts to stabilize sediments and initiate dune development. Changes in the foredune plant community trait and species composition, for example due to climate change, may therefore have cascading effects on interdunal wetlands by changing the frequency and degree of sedimentation and blowout formation (Hesp, 2002; Feagin et al., 2015; De Battisti and Griffin, 2019).

Hypotheses and Aims

The overall goal of this study is to examine whether dune and interdunal wetland plant communities are related by characterizing the plant community traits and species composition of these two ecosystems across a climatic gradient.

Three major questions will be addressed with this study: **1) Do foredune and interdunal plant communities and associated plant functional traits change along a climatic gradient? 2) Do dune plant functional traits influence interdunal wetland sediment stabilization? 3) Will changes in wetland sedimentation affect wetland species survival?**

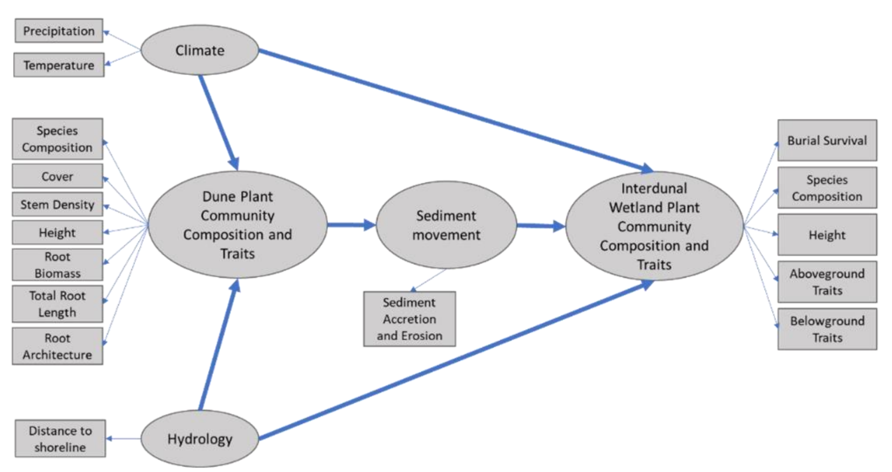
Previous work by the Emery lab has shown that the foredune species *A. breviligulata* decreased in tiller size along a latitudinal gradient, a trait associated with increased foredune stability (Emery and Rudgers, 2014). While it is unknown whether other traits will show similar variation, this latitudinal gradient presents an opportunity to examine the relationships between multiple plant traits and dune-interdunal wetland plant communities *in situ* by establishing sites along a known gradient of trait expression. I hypothesize that, in the northernmost part of the study area characterized by cooler, drier growing seasons, foredune plant communities will have traits that confer less stability to sediments, which will increase the likelihood of sediment disturbance to interdunal wetland areas. Wetland communities in these locations will be composed of faster growing, burial tolerant or disturbance-avoiding species. Conversely, the southern interdunal wetlands will have less sediment disturbance and be composed of a greater proportion of slow growing, burial intolerant species. In this way, both plant trait and species composition of interdunal wetlands will reflect foredune plant trait and species composition.

Methods

To address questions 1 and 2, Sites along a climatic gradient will be established in Wilderness State Park, Leelanau State Park, Ludington State Park, Saugatuck Dunes State Park, and Warren Dunes State Park (Fig. 1). Three interdunal wetlands will be identified in each site and three transects each will be established from the foredune across the interdunal wetland areas perpendicular to the shoreline. Quadrats 1 m x 1 m will be placed every 5 m along each transect and species composition, cover, stem density, and height will be recorded for each species per plot. 2 cm x 15 cm soil cores will be collected from the center of each plot to examine community-level root traits. Soil samples will be returned to the lab and root biomass, total root length, and root architecture quantified using the WinRhizo software, already available in the Emery lab. Sediment accretion and erosion will be examined by placing erosion pins in quadrats along each transect and measuring the height of the sediment during the summer and fall, which corresponds to seasonal changes in vegetation structure (Levin et al., 2008). Climate information for the previous year and the two years of this research project will be collected from proximate metrological stations at each site. Because of its importance in determining wetland hydrology—another important factor structuring interdunal wetlands—distance of the wetland edge from the shoreline will also be measured.

Plant community composition and trait data of dunes and associated wetlands will be compared in the R statistical package using principal components analyses (PCA) and non-metric multidimensional scaling (NMDS) to understand the relationships of traits and species composition with sediment stability. Structural equation models of species and trait responses with climatic and hydrology variables will also be created to understand the importance of foredune plant community characteristics and climate to interdunal wetland plant communities and traits (Figure 2).

Figure 2. Hypothesized causal relationships between environmental variables (climate and hydrology), dune plant community characteristics, sediment movement, and interdunal wetland plant communities.



To address question 3, A manipulative sand burial experiment will be conducted on two dominant species of interdunal wetland plants—*Juncus balticus* (Baltic rush) and *Cladium mariscoides* (twig-rush)—which are known to be burial tolerant (Kost et al., 2007). Two additional dominant wetland species will be selected based on surveys of each interdunal wetland area and included in burial experiments. Forty plants per species will be either collected from the field or ordered from native plant nurseries depending on availability. Individuals will be placed in PVC collars filled with sand, watered twice per week as needed, and allowed to acclimate in a growth chamber for two weeks (Brown and Zinnert, 2018). Growth chamber conditions will be set at a 16-hour light cycle and ~600 μmol/m^2/s light availability representing mean values for Michigan in June (Emery and Rudgers, 2013). The temperature will be set at 25° C/11° C which representing average high and low temperatures for Michigan in June. Plant height prior to burial will be collected and then one-time burial treatments will be applied to represent sedimentation due to storm disturbance. Burial depths based on annual accretion rates for Michigan sand dunes will be 0 (control), 5 (low burial), 15 (medium burial), and 30 (high burial) cm with 10 replicates per species per treatment (Van Dijk, 2004). Plant height above the sediment will be measured once per week for 8 weeks. Whole plants will then be removed from collars and above and belowground traits will be evaluated for each species. These traits will be used to assess resource allocation and growth responses of plants to burial. Plant survival will also be recorded.

How this work benefits coastal wetlands

This study would be one of, if not, the first to examine the relationships between Great Lakes foredune and interdunal wetland plant communities in the context of sediment dynamics. Data generated by this study may inform landscape-level conservation efforts of sand dune ecosystems that incorporates interrelationships between proximate plant communities. This work may also provide insights into other conservation issues, such as the spread of invasive species and their potential impacts on interdunal wetlands.

How funds would be used

Funding would be used to support field and laboratory research efforts. Most funds will be used to cover travel costs associated with field survey work in Michigan.

Plans for sharing research results with larger audiences

Existing connections with Sleeping Bear Dunes National Park, The Nature Conservancy, and Great Lakes Research and Education Center provide opportunities to discuss the importance of conserving interdunal wetland habitat and present data from this project. Findings would also be shared at scientific meetings (e.g. Ecological Society of America Annual Meeting) and through publication in relevant journals.

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