MISG Final Narrative Report

Section A. Summary

Title of Project: Tracking biodiversity, community assemblage, and gene flow among interdunal wetlands along the Eastern shore of Lake Michigan, R/CGLH-5

Completion Date: Jan. 31 2021

Principal Investigator: Tiffany Schriever, Assistant Professor, Western Michigan University, 1903 W. Michigan Ave. Kalamazoo MI 49008, 269-387-5627, tiffany.schriever@wmich.edu

Co-Principal Investigator(s): Devin Bloom, Associate Professor, Western Michigan University, 1903 W. Michigan Ave. Kalamazoo MI 49008, 269-387-5608, devin.bloom@wmich.edu

Abstract

Coastal wetlands provide essential ecosystem functions such as water quality, maintaining the health of the Great Lakes and offer critical habitat for aquatic biodiversity. A type of coastal wetland, interdunal wetlands, develop in wind-formed depressions within open dunes or between beach ridges along the coastlines of the Great Lakes. Despite the paramount importance of interdunal wetlands in the Great Lakes ecosystem, the ecology and hydrology of this habitat remains virtually unknown. We conducted an inventory of macroinvertebrates and herpetofauna in interdunal wetlands from five major dune areas along the eastern shore of Lake Michigan. We tested for patterns of species diversity and population genetic diversity along environmental and latitudinal gradients. At local scales (within a dune area) we found macroinvertebrate communities are diverse, open dune wetlands tended to have lower functional and taxonomic richness than forested wetlands, and there is moderate-high compositional dissimilarity dominated by turnover. At the regional scale (coastline), the pattern of species turnover is repeated and the southern region had higher species richness than the northern region. We found that *Anax junius*, the green darner dragonfly displays a significant isolation-by-distance relationship while *Notonecta undulata,* grousewinged backswimmer does not, and that both species display two genetic clusters, one in the north and one in the south, along the coastline with significant increases in genetic diversity with increasing latitude. To our knowledge, our project is the first to characterize aquatic community assemblages of interdunal wetlands in the Great Lakes and represents the first recognized pattern for aquatic organisms across dune succession gradient.

Keywords: wetland, invertebrates, amphibians, genetics, conservation

Executive Summary

We sampled a total of 38 interdunal wetlands represented by 259 macroinvertebrate samples within five sand dune areas: Indiana dunes National Park (IDNL), Warren Dunes State Park (WDSP), and Saugatuck Harbor Natural Area (SHNA) in the southern Lower Peninsula of Michigan, and Ludington State Park (LSP) and Sleeping Bear Dunes National Lakeshore (SBD) in the northern Lower Peninsula (Fig. 1). Species richness ranged from 58 to 83 species within a park and overall 110 different species were identified. We found macroinvertebrate communities are diverse, open dune wetlands tended to have lower functional and taxonomic

richness than forested wetlands, and wetlands vary greatly in composition over small and large spatial scales.

The green darner dragonfly, which is a strong flyer, displays a significant increase in genetic differentiation correlated with increasing geographic distance while the grousewinged backswimmer, an intermediate dispser, does not. Both species display two genetic clusters along the coastline with significant increases in genetic diversity with increasing latitude. A species thought to be continuously distributed along the coastline is actually two closely related *Caenis* mayfly species with a remarkably strong north-south species break along the coastline.

We found seven species of frogs, two snake species, two lizard species, and one species of turtle. Green frogs were the most frequently encountered species. We found higher herpetofauna species diversity in the southern sites than in the northern sites.

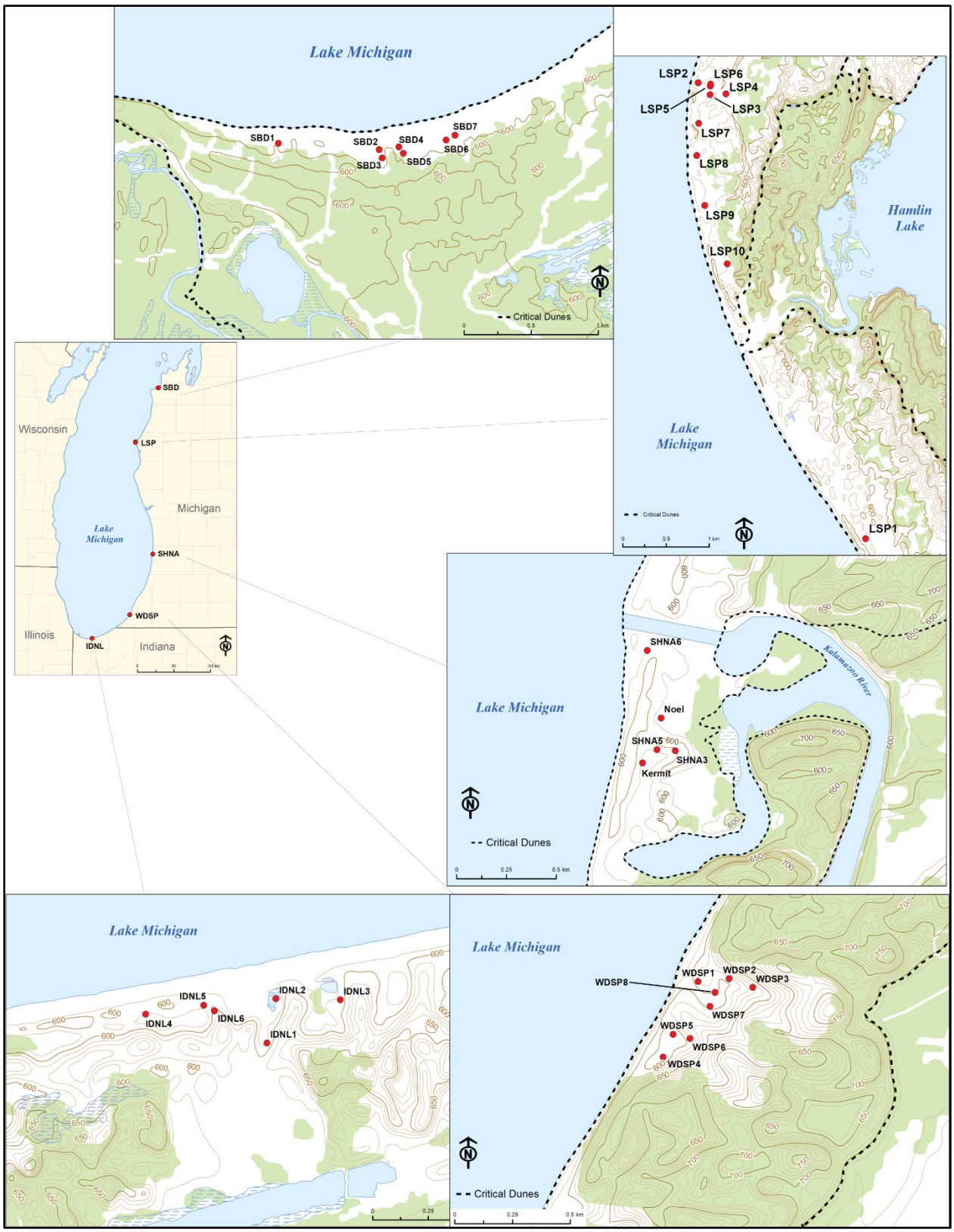

Figure 1 Interdunal wetlands sampled along Lake Michigan coastline.

Section B. Accomplishments

Introduction

Coastal wetlands hold great regional and global ecological significance because they are unique habitats that provide essential ecosystem functions (Sierszen et al. 2012) maintaining the health of the Great Lakes and offer critical habitat for aquatic biodiversity. Interdunal wetlands are a type of coastal wetland that forms in-between dunes along Lake Michigan's coastline. Despite the paramount importance of interdunal wetlands the ecology and hydrology of this habitat remains virtually unknown. To our knowledge, our project will be the first to characterize the community wide assemblages of interdunal wetlands in the Great Lakes and determine the processes regulating community assemblage patterns. **Our objectives were to:**

1. Characterize and inventory the spatiotemporal richness and community composition patterns of interdunal wetlands for amphibians, reptiles and aquatic macroinvertebrates along the Eastern shore of Lake Michigan. *We hypothesized that biodiversity and species composition will vary along the Lake Michigan coastline. We predicted increasing species richness, high species turnover and low species similarity along the coastline from north to south reflecting a regional temperature gradient and highly variable nature of these habitats. We hypothesized community structure will respond to spatially relevant factors. On a regional scale, we hypothesized variation in community composition between north and south ecoregions. On a local scale, we hypothesized that wetland hydroperiod and size will influence measures of species diversity and community structure.*
2. Assess functional trait structure in the invertebrate assemblages of interdunal wetlands along the Eastern shore of Lake Michigan. Interdunal wetlands are harsh environments (i.e., high

temperature, shallow, no canopy, variable hydroperiod) acting as 'habitat filters' that exert strong controls on the taxonomic and trait composition of communities. We expected interdunal wetlands to differ in community composition because of both regional and local factors. Communities that have different compositions of species are likely to have different trait diversity. Therefore, *we hypothesized functional trait diversity differs among wetlands due to a strong hydrologic filter. We predicted higher functional richness in more permanent wetlands, but unique trait combinations in temporary wetlands (e.g., adaptations to intermittency). We also predicted differences in trait structure and diversity between northern and southern sites due to environmental gradients along the coastline.*

3. Determine population structure and levels of gene flow among interdunal wetland populations.

We used population genetics to determine spatial connectivity among wetlands. We estimated levels of genetic diversity, structure and rates of gene flow within and among interdunal wetland sites. Dispersal abilities of the organisms determine distance decay relationships (Cañedo-Argüelles et al. 2015), so we estimated isolation by distance using taxa with different life-history strategies. Determining levels of gene flow among sites in a spatio-temporally dynamic system is both conceptually important and provides critical data for resource managers. Interdunal wetlands are locally abundant, but regionally (i.e. among sites) isolated, with large reaches of coastline lacking interdunal wetlands. *Because these habitats are unique and isolated systems, we hypothesized that invertebrate populations inhabiting interdunal wetland experience strong isolation by distance, with relatively low levels of gene flow among sites. We predicted limited gene flow among sites, but we expect variation in genetic structure due to differences in species dispersal ability.* Alternatively, the ephemeral nature of interdunal

wetlands may create an environmental filter that selects for taxa capable of dispersing among sites (Ribera 2008) and mitigating the effects of isolation by distance.

Project Narrative

Macroinvertebrate survey and community dynamics study: We sampled the aquatic macroinvertebrate community from six wetlands at Indiana dunes National Park (IDNL), eight wetlands at Warren Dunes State Park (WDSP), and five wetlands at Saugatuck Harbor Natural Area (SHNA) in the southern lower peninsula of Michigan, and ten wetlands at Ludington State Park (LSP) and seven wetlands at Sleeping Bear Dunes National Lakeshore (SBD) in the northern lower peninsula (Figure 1) monthly from April through October 2018. This field intensive study identify species distributions, illustrated the wetlands in the southern parks had high species diversity.

The indicator species analysis revealed several species that were uniquely associated with either a particular park or ecoregion. For example, five taxa of varying functional roles (*Dixella*, meniscus midge, *Erythemis* pondhawk dragonfly, *Hydrocanthus* burrowing water beetle, *Oxyethira* caddisfly, and *Desmopachria* predaceous diving beetle) were unique to SHNA and one taxa was unique to IDNL (Lymnaeidae Snail). Wetland area ranged from approximately 46 to 5,539 m^2, but was not a significant predictor of α diversity. Despite a short latitudinal gradient, our results reveal that regional temperature and precipitation regimes underpinning a latitudinal gradient influences wetland macroinvertebrate species richness. Macroinvertebrate species richness increased with decreasing latitude (Figure 2), but showed no relationship with pond area. Pairwise comparisons of community abundance data determined interdunal wetlands are ~48% dissimilar and that beta diversity is driven mostly by balanced variation in

species abundances (turnover). From one wetland to the next you can find radically different communities. Interdunal wetland aquatic macroinvertebrate communities were moderately to highly dissimilar (i.e., high beta diversity), despite being located within a shared dune landscape. We found that balanced variation in abundance (replacement) contributed highly to beta diversity patterns, and both beta diversity and its replacement component were correlated with changing environmental (local and bioclimatic) conditions along the coastline (Figure 3).

In terms of functional trait composition we found interdunal wetlands within more vegetated or forested conditions had higher functional richness than interdunal wetlands in open dune fields. This relationship was also related to distance from Lake Michigan, whereas the farther the wetland was from lake, the higher the functional richness (Figure 4). Higher functional richness is attributed to more niches in forested wetlands. At Ludington State Park, we found a moderate correlation between terrestrial vegetation and invertebrate bray-curtis dissimilarity matrix ($r = 0.5188$, $r = 0.0039$) in interdunal wetlands, indicating as sites become more dissimilar in terms of terrestrial vegetation, they also become more dissimilar in terms of aquatic invertebrate community composition. Open dune interdunal wetlands have unique invertebrate communities and stark differences in the functional community structure compared to nearby forested interdunal wetlands. These differences can be attributed to more vegetation and leaf litter dependent feeding guilds in forested wetlands compared to higher proportion of collector-gatherers (algae eaters) and predators in open interdunal wetlands.

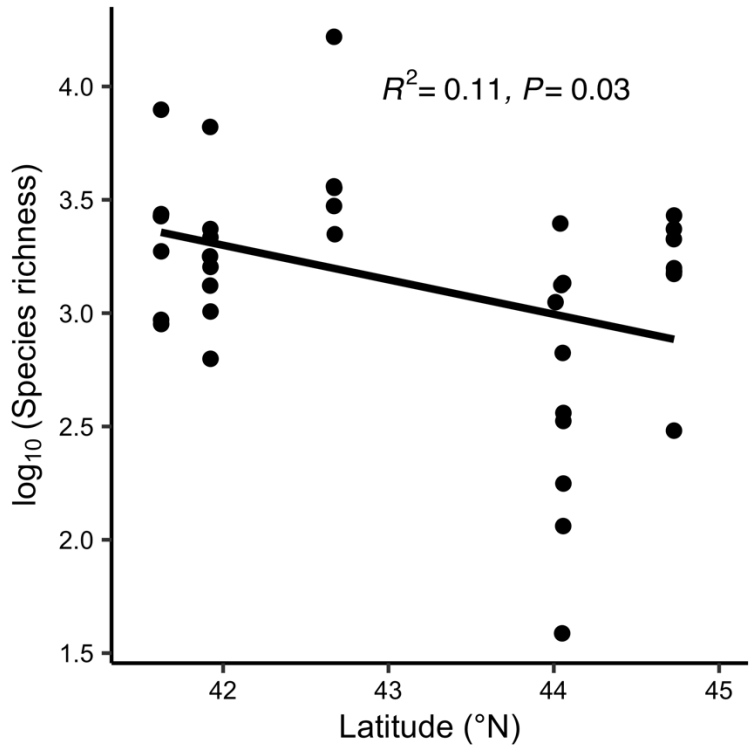

Figure 2 Relationship between macroinvertebrate species richness and latitude of wetland.

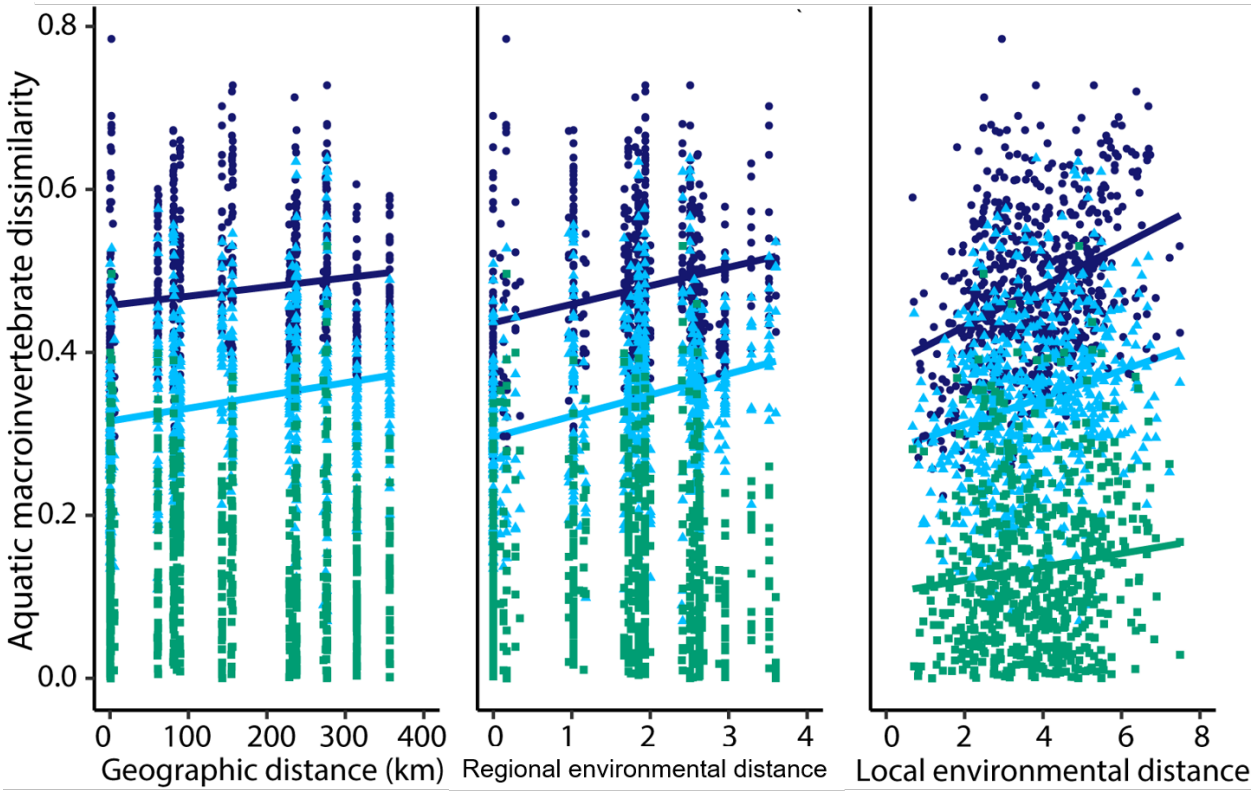

Figure 3 Aquatic macroinvertebrate community dissimilarity (dark blue circles) and its balanced variation in abundance (light blue triangles) and abundance gradient (green squares) components with geographic distance, regional environmental distance (bioclimatic) and local environmental distance. Lines are significant Mantel correlation tests.

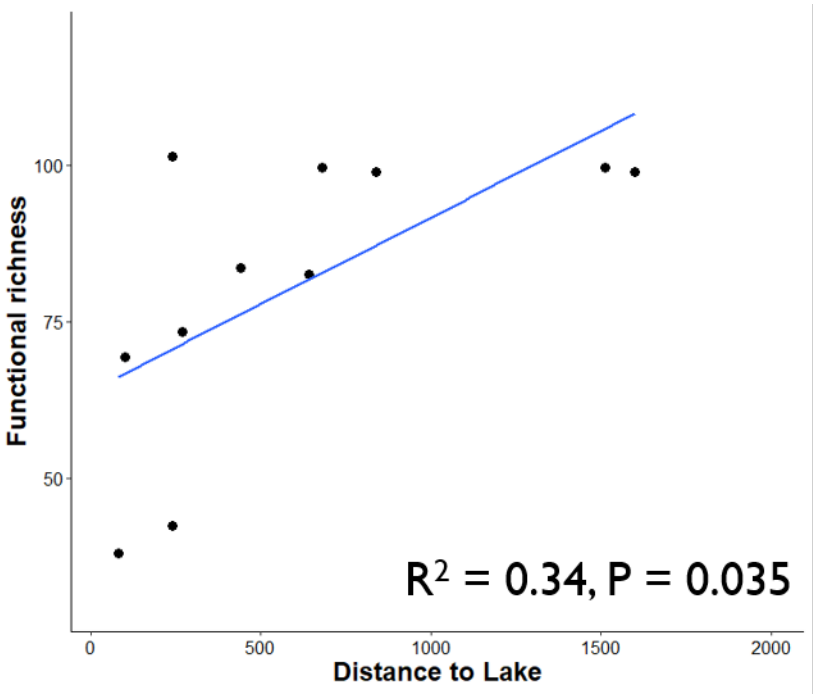

Figure 4 Wetland distance from lakeshore is positively related to the macroinvertebrate functional richness.

Insect population genetics study: In this study, we use restriction enzyme associated DNA sequencing (RADseq) to investigate population and landscape genetic structures of three aquatic insects, all of which were confirmed to species through mitochondrial DNA (COI) barcodes. We collected up to 10 aquatic insect larvae per dune area (sites same as macroinvertebrate study) for three species that differ in dispersal ability and life history strategies: *Anax junius* (high), *Notonecta undulata* (intermediate), and *Caenis amica* (low). The COI data revealed our *Caenis* samples included two closely related *Caenis* species with a remarkably strong north-south species break along the coastline (Figure 5). *Anax junius* illustrated an isolation-by-distance pattern using a Mantel test between pairwise f_{st} and geographic distance between focal sampling areas (Mantel R statistic= 0.49, p=0.009; Figure 6). This means as wetlands become farther apart, *A. junius* populations become more genetically

dissimilar. *Notonecta undulata* displays a non-significant, positive linear relationship between pairwise fst and geographic distance (Mantel R statistic=0.41, p=0.058). A linear regression analysis between observed heterozygosity and latitude for *A. junius* displayed a significant and strong correlation (p=0.01, R^2=0.91) where observed heterozygosity increases with increasing latitude. We think this could be due to more stable environmental conditions at lower latitude dune areas (individuals do not need to disperse as often in comparison to northern sites with less environmental stability), habitat range shifts northward in light of climate change, or because of postglacial colonization and successive population founder events moving from southern to northern sites, and these patterns of decreasing genetic diversity with decreasing latitude have been seen in organisms including bumble bees, birds, fish, and plants (Jackson et al. 2018, Hasselman et al. 2013, Hirao et al. 2017, Hindley et al. 2018). Overall, the patterns of Isolation-By-Distance and genetic structure (K=2) observed in both *A. junius* and *N. undulata* suggest that distance between viable dune wetland area is the most important factor shaping population structure within both insect species. It is possible that some of our sampled *A. junius* interdunal wetland populations may be residents rather than migratory leading to higher genetic divergence and differentiation among populations. Our results indicate that *N. undulata* interdunal wetland populations maintain high gene flow and weak signals of isolation by distance, indicating that *N. undulata* overcomes landscape resistance to gene flow.

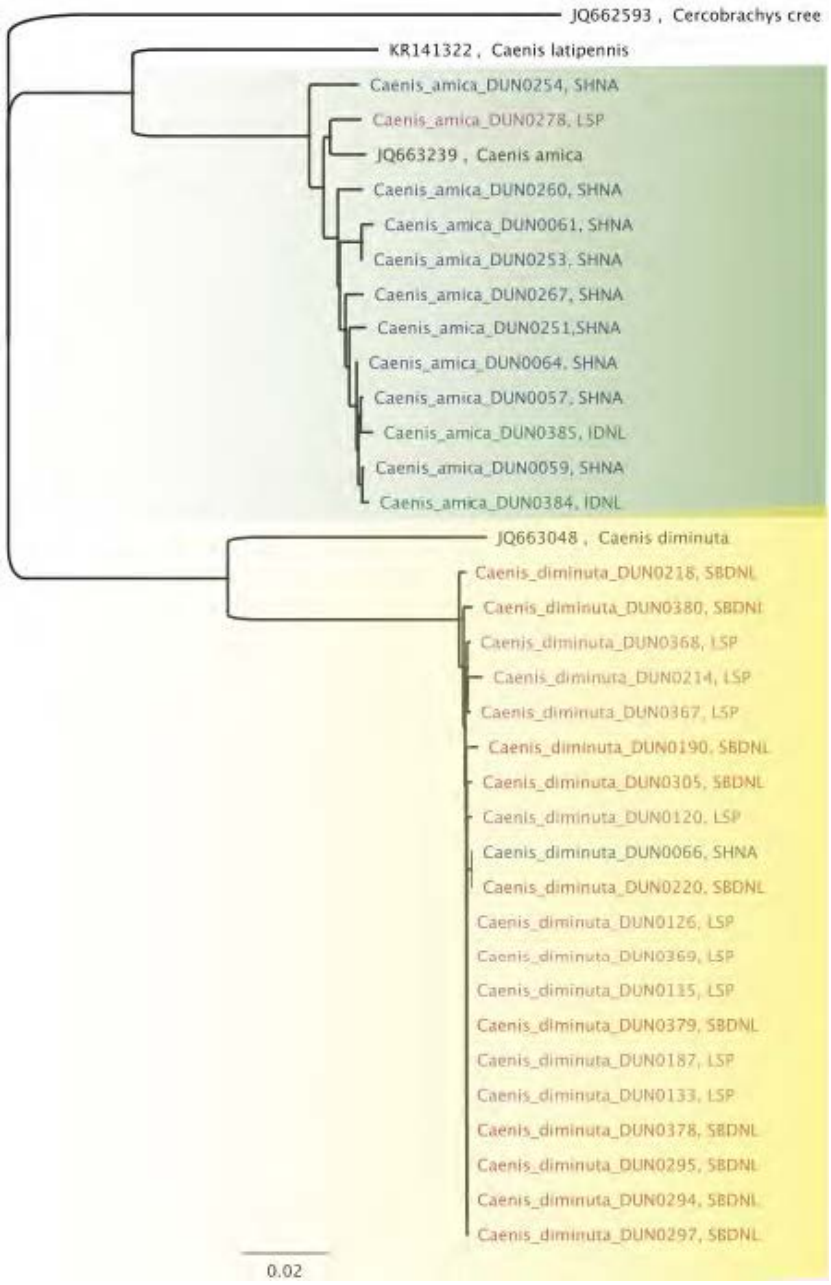

Figure 5 Neighbor-joining tree of all barcoded Caenis individuals. Individuals highlighted in green are Caenis amica and those highlighted in yellow are Caenis diminuta. Site names are at the end of the specimen name.

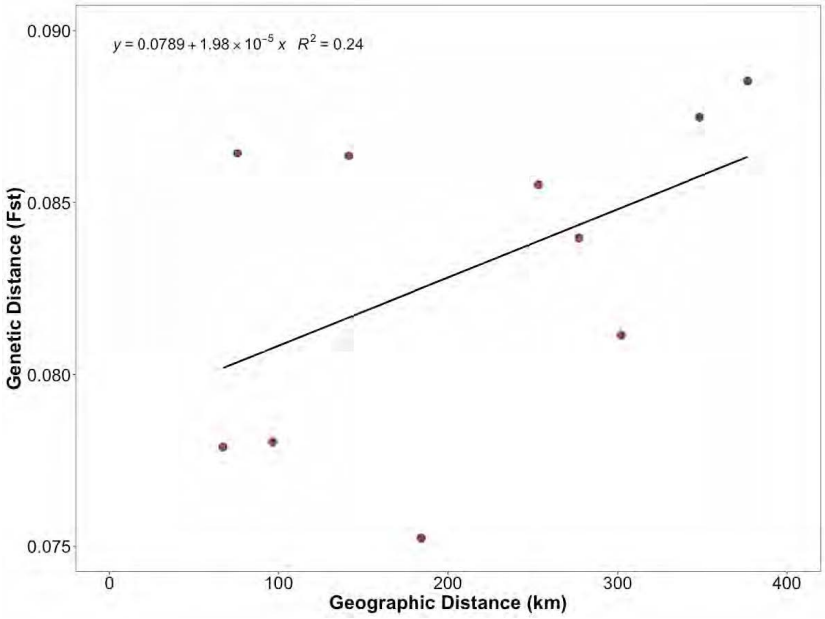

Figure 6 Pairwise genetic distance among A. junius populations (Fst) and geographic distance between wetlands (km).

Herpetofauna survey and community dynamics study: We performed 102 daytime herpetofauna visual encounter surveys recording a total of 306 individuals (Figure 7). In total we found six species of anurans (*Lithobates clamitans* (Green Frog), *Anaxyrus americanus* (American Toad), *Anaxyrus fowleri* (Fowler's Toad), *Hyla versicolor* (Gray Treefrog), *Pseudacris crucifer* (Spring Peeper) and *Pseudacris triseriata* (Chorus Frog)), two snake species (*Heterodon platirhinos* (Eastern Hognose Snake) and *Coluber constrictor foxii* (Blue racer)), and two squamates (*Aspidoscelis sexlineata* (Six-lined Racerunner) and an unidentified skink species). *P. crucifer* and *P. triseriata* were found only during acoustic surveys while all others were spotted in survey transects. In ponds without transects one additional species of frog (*L. castesbeiana* (American Bullfrog)) and one species of turtle (*Chrisemys picta* (Painted Turtle)) were found. Six lined racerunner and Fowlers toad were found only in Indiana. We found Green frogs most frequently during surveys with sightings occurring every month, but Gray Treefrogs were found

in the highest numbers (tadpoles included) less frequently. Herpetofauna (amphibians and reptiles) species diversity declined with increasing latitude. Beta diversity significantly increased with increasing latitude (proportional effective species turnover β), meaning the communities share fewer herpetofauna species the farther away they get from the southernmost site.

Figure 7 Photographs of amphibians and reptiles encountered in interdunal wetlands during this study. Picture a) Eastern Gray Treefrog, b) Green frog, c) hatchling Painted turtle, d) field site LSP2 in Ludington State Park, e) Gray Treefrog tadpole, f) Eastern Hognose Snake, g) Fowler's toad, h) American Bullfrog, and i) Spring Peeper.

Hydrology of interdunal wetlands: Doing this project led me to think about the hydrology of interdunal wetlands. It is assumed that interdunal wetlands are directly linked to Lake Michigan water levels via groundwater (Cole & Taylor, 1995; Albert, 2007), although they are higher in elevation and water doesn't typically flow up a gradient. The lake link has not been definitively confirmed. I conducted field studies in 2019 and 2020 to characterize water source of interdunal wetlands both spatially along Lake Michigan eastern shoreline and temporally

through seasonal variation. The stable isotope compositions (δ^{18}O and δ^{2}H) of water were used to determine the relative contributions of different water sources to the groundwater in interdunal wetlands in Michigan. We sampled porewater (shallow groundwater) from 24 wetlands in Warren Dunes State Park, Saugatuck Harbor Area, Ludington State Park, and Sleeping Bear Dunes National Lakeshore (6 in each park) in June, August, and October 2020, which resulted in the collection of 137 porewater samples from interdunal wetlands, 14 surface water samples from 6 sources (Lake Hamlin (at LSP), Lake Michigan, Platte River (at SBD), Kalamazoo River (at SHNA), Precipitation (in Kalamazoo), and 72 community invertebrate samples. The porewater samples were analyzed for stable isotopes of water (2H and 18O). The oxygen and hydrogen isotopic compositions of shallow ground waters from the interdunal wetlands and Lake Michigan lie on an evaporation line with a slope of ~5, with parks showing different slopes from the local meteroric water line suggesting evaporation (Figure 8). The isotopic composition of Lake Michigan was stable, whereas wetlands exhibited considerable spatial variability along the coastline and among wetlands (range ^{18}O -10.3‰, range ^{2}H 53.4‰). We did not see evidence of seasonal shifts in isotopic composition. Wetlands vary in main water source, with some are almost solely Lake Michigan, while others are a mix of local rivers and unknown water sources (Figure 9). Hydrologically more interesting than thought. This work matters because the definition of a Great Lakes coastal wetland is defined as an area of wetland directly influenced by the waters of one of the Great Lakes or its connecting channels. In addition, The Navigable Waters Protection Rule does not protect surface water features connected only via groundwater. We must know how to classify these waters to avoid harm and uphold protection.

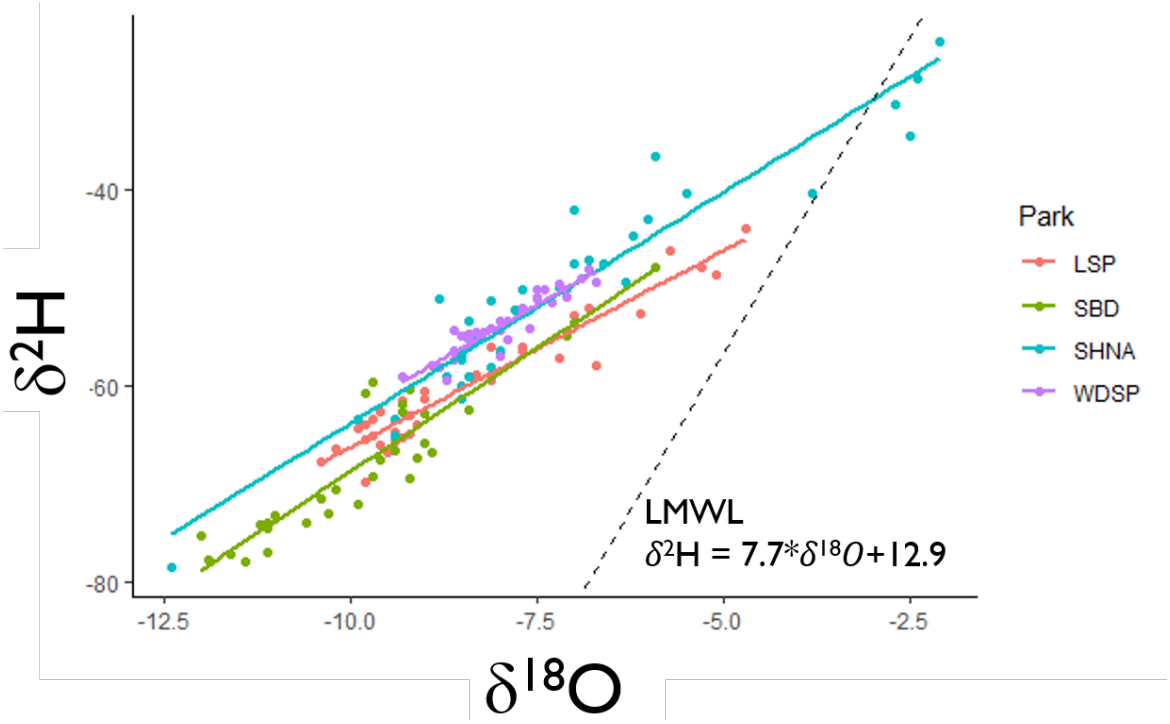

Figure 8 Relationship of d18O to d2H for each sampled park. The Kalamazoo Local Meteoric Water Line (LMWL) is also shown.

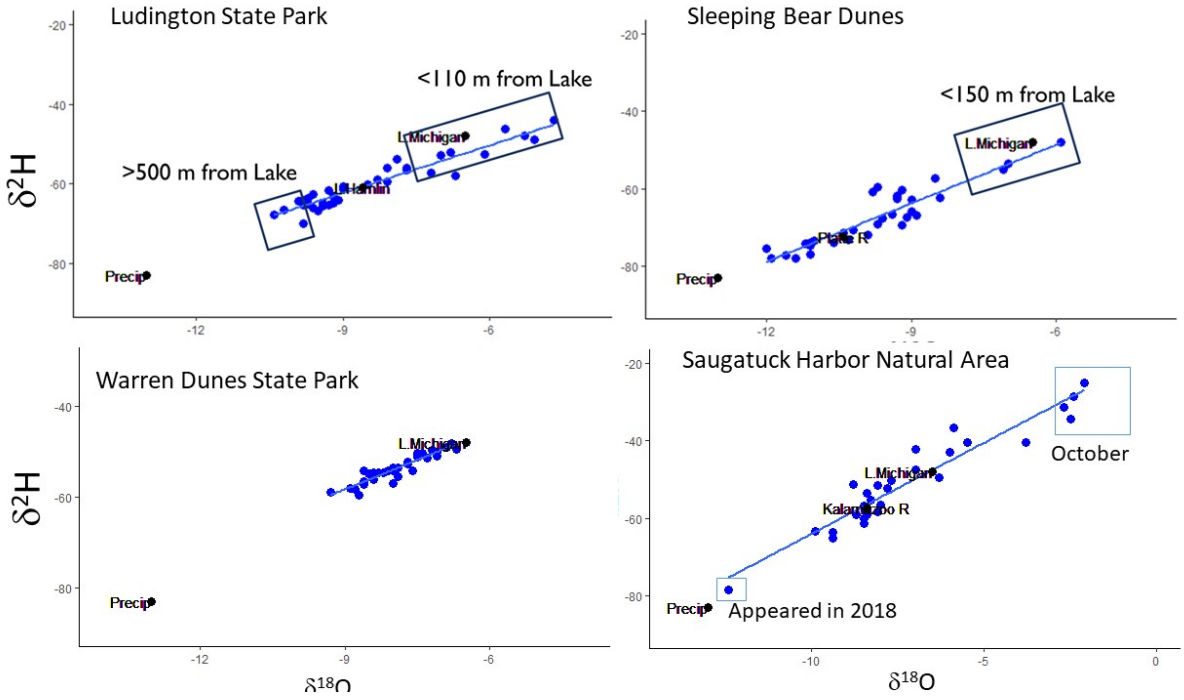

Figure 9 Hydrogen and Oxygen stable isotope composition of interdunal wetlands sampled in four parks in relation to water sources of Lake Michigan, Platte River, Lake Hamlin, Kalamazoo River, and Precipitation (Precip).

Research/Management Implications

Communities structured by replacement (like ours) require the establishment of many protected areas in order to maintain regional (Socolar et al. 2016) diversity. In this system, the establishment of protected areas alone may not be enough to maintain aquatic macroinvertebrate γ diversity (Vanschoenwinkel et al. 2013). Protecting coastline connectivity may be important for aquatic macroinvertebrate persistence in interdunal wetlands that periodically, or unexpectedly, drop with precipitation regimes and lake levels. Our population genetic results indicate that all three species, *Anax junius*, *Notonecta undulata*, and *Caenis amica,* occupying the same naturally fragmented habitat are subject to resistance to gene flow despite dispersal ability.

Potential Applications, Benefits and Impacts

The culmination of this project has advanced the scientific discovery of a rare habitat, interdunal wetlands from multiple angles and opened up inquiry to new questions of the ecology and hydrology of interdunal wetlands. Resource managers may use our aquatic invertebrate and herpetofauna species lists and occupancy information for management decisions within their parks, for advertising, and for conservation of habitat and species.

Section C. Outputs

Media Coverage

Our coastal wetland research has garnered attention from news outlets as I was interviewed by Gordon Evans of WMUK radio. Article for the WMUK 102.1 radio interview “How The Climate and Human Activity Can Change Wetlands”. Kalamazoo, MI, 21 March 2019. https://www.wmuk.org/post/how-climate-and-human-activity-can-change-wetlands#stream/0

I was interviewed by Erin Flynn with the Office of Marketing and Strategic Communications at WMU about conducting research during Covid-19 pandemic. Wetland projects test waters to restart research at WMU. https://wmich.edu/news/2020/06/60039

Great Lakes Research and Education Center interviewed Dr. Schriever about our work on interdunal wetlands. May 16, 2019. Facebook post https://www.facebook.com/GreatLakesNPS/posts/646650045776028

Testing the Interdunal Waters in 2018 Arts and Sciences Magazine. https://www.wmich.edu/arts-sciences/schriever

Link to video highlighting research in Schriever lab with students in the WMU Biological Sciences Department. https://www.youtube.com/watch?v=bo78buxqbwo

Journal publications

Frazier, C.F. and T.A. Schriever. *In prep.* Succession acts as a driver of community composition, biodiversity, and short-term temporal patterns in Great Lakes interdunal wetlands. Target journal Wetlands

Nienhaus, H., S. W. Fitzpatrick, D.D. Bloom, and T.A. Schriever. *In prep.* Population genetics of aquatic insect species with differing dispersal ability from Lake Michigan's naturally fragmented interdunal wetlands. Target journal Ecography

Stewart, N., and T.A. Schriever. *In prep.* Local conditions drive balanced variation in abundance in interdunal wetland macroinvertebrate communities. Target journal Ecology

Frazier, C., H. Nienhaus, R. Everts, D.D. Bloom, and T.A. Schriever. *In prep.* Aquatic Lepidoptera diversity in interdunal wetlands. Target journal The Great Lakes Entomologist

Presentations

Invited seminars

1. Schriever, T. Feb. 15, 2021. Ecohydrology of Interdunal Wetlands along the Eastern Coastline of Lake Michigan. Geological and Environmental Sciences seminar series, WMU. 60 Attendees
2. Schriever, T. Feb. 7, 2020. The importance of coastal wetlands in generating unique biodiversity and conservation opportunities. Conservation Ecology Seminar Series, School for Environment and Sustainability, University of Michigan. 60 Attendees
3. Schriever, T. Mar. 26, 2019. Shoring up the Great Lakes coastline: the importance of coastal wetlands in generating unique biodiversity, recreational experiences, and conservation opportunities. WMU Discovery Symposium during Spring Convocation. 35 Attendees
4. Schriever, T. Nov. 16, 2018. Hydrologic variation and freshwater dynamics from species to ecosystems. Michigan State University. Kellogg Biological Station seminar series.

Conference presentations

1. Frazier, C.F. and T.A. Schriever. 2019. Patterns of functional community structure in Great Lakes interdunal wetlands. International Association for Great Lakes Research (IAGLR), Brockport, New York, USA. 700 attendees
2. Nienhaus, H., D.D. Bloom, T.A. Schriever. 2019. Population and Landscape Genetics of Insect Species from Interdunal Wetlands along Lake Michigan's Shoreline. IAGLR, Brockport, New York, USA. 700 attendees

3. Stewart, N., T.A. Schriever. 2019. Spatiotemporal patterns of aquatic macroinvertebrate community assemblages in interdunal wetlands. IAGLR, Brockport, New York, USA. 700 attendees
4. Frazier, C.F. and T.A. Schriever. 2018. Examining the relationship between macroinvertebrate community structure and habitat conditions in Great Lakes interdunal wetlands. Midwest Ecology and Evolution Conference, Hickory Corners, Michigan, USA. 185 attendees
5. Schriever, T.A. and D. Volz. 2018. Dragonfly and damselfly (Odonata) biodiversity in interdunal wetlands at Saugatuck Harbor Natural Area. Society for Freshwater Science (SFS), Detroit, Michigan, USA.
6. Frazier, C.F. and T.A. Schriever. 2018. Examining the relationship between macroinvertebrate community structure and habitat conditions in Great Lakes interdunal wetlands. SFS, Detroit, Michigan, USA

Outreach

Jeffers Elementary outreach for 72 2nd grade students on April 23, 2020 on aquatic diversity in interdunal wetlands and the work of an aquatic ecologist.

Portage Northern Middle School STEM Event, November 2018. 117 attendees

Undergraduate/Graduate student names and degrees supported by this grant

Nicole Stewart, MS Biological Sciences 2020
Halle Nienhaus, MS Biological Sciences 2020
Andrew Hopkins, MS Biological Sciences 2019
Christopher Frazier, MS Biological Sciences 2019

Theses or dissertations related to the research project

Gilbert, Claire, "Analysis of Interdunal Wetlands and Ecosystem Dynamics using UAS and OBIA in Ludington State Park, Michigan" (2020). *Master's Theses*. 5173. https://scholarworks.wmich.edu/masters_theses/5173. I sat on Claire Gilbert's graduate committee for her master's degree from WMU geography department. While her thesis focused on Geospatial methods, she did help us out by adding calculations of vegetation from drone photography. She used satellite and Lydar data to quantify dune vegetation around our study wetlands in Ludington State Park. We will use this data (currently used in Maddie Holms thesis and Chris Frazier's ms we are preparing) to quantitatively access whether vegetative type and structure surrounding each sampled wetland influences invertebrate and amphibian community structure. Below is the URL to get access to the associated tables for each feature class and individual characteristics of dune vegetation and wetlands. The kml files can be directed imported into Google earth. Just keep in mind that the application has limited pooling capabilities with large datasets and may take a very long time to load. Here is the website URL https://gis.cc.wmich.edu/ludington/

Holm, Madison, "Odonate Species Richness and Canopy Gradient in Ludington State Park" (2020). *Honors Theses*. 3370. https://scholarworks.wmich.edu/honors_theses/3370

Somers, Emma, "Scope: A Senior Exhibition" (2020). *Honors Theses*. 3325. https://scholarworks.wmich.edu/honors_theses/3325 Emma's Art Honors thesis included several paintings of insects collected during our Sea Grant project field work. Emma Somers was an undergraduate field and lab assistant who painted a toad bug collected a Warren dunes State Park. Her painting was selected to be in the student showcase April 4 – 21, 2019 in Western Michigan University's Richmond Center for Visual Arts. https://twitter.com/bloomchovies/status/1116503277624090624

Volz, Devon, "Biodiversity of Larval and Adult Dragonflies and Damselflies (Odonata) of Interdunal Wetlands at Saugatuck Harbor Natural Area" (2017). *Honors Theses*. 2924. https://scholarworks.wmich.edu/honors_theses/2924

Volunteers

2019 – 2020. 7 undergrad volunteers. 588 hours
2020 – 2021. 8 undergrad volunteers. 288 hours

Related Projects

The hydrology of Great Lakes interdunal wetlands and the effects on their macroinvertebrate assemblages, WMU Faculty Research and Creative Activities Award (FRACAA), $9,938. 7/1/2019 - 12/30/2020

Awards and Honors

Student awards

Halle Nienhaus. 2021. Graduate Student Teaching Effectiveness Award (MS level). Department of Biological Sciences, WMU

Nicole Stewart. 2021. Charles River Research Life Science Award for Excellence in Graduate Research, WMU

Madison Holm. 2020. WMU Lee honors College Research or Creative Scholarship Award

Frazier, Christopher. 2019. IAGLR Science Communication Scholar. Presentation title, Patterns of functional community structure in Great Lakes interdunal wetlands

Halle Nienhaus. 2019. General Endowment Award. Society for Freshwater Science. Title of project, Population and landscape genetics of three insect species from interdunal wetlands along the Eastern shore of Lake Michigan

Halle Nienhaus. 2019. International Association for Great Lakes Research Science Communication Scholar. Title of presentation, Population and landscape genetics of aquatic insect species from interdunal wetlands along Lake Michigan's shoreline

Halle Nienhaus. 2019. ConGen Workshop 2019 Travel Scholarship. University of Montana-Flathead Biostation. Title of project: Population genetics of aquatic insects from Lake Michigan's interdunal wetlands

Halle Nienhaus. 2019. Best Abstract Award. Poster title, Population and landscape genetics of aquatic insect species from interdunal wetlands along Lake Michigan's shoreline. Bell's Brewery Sci Mix Recycled Poster Session

Nicole Stewart. 2019. Student Research Grant. Research title, Disentangling the drivers of food chain length in interdunal wetlands; the productivity, ecosystem size, and productive space hypotheses. Society of Wetland Scientists International chapter and SWS North Central Chapter

Nicole Stewart. 2019. International Association for Great Lakes Research Science Communication Scholar

Andrew Hopkins. 2018. Student Research Grant. Research title, Measuring Disturbance and Community Assembly of Amphibians and Reptiles in Interdunal Wetlands. Society of Wetland Scientists, North Central Chapter

Section D. Data Management Plan Form: Completion Phase

See attached pdf of MI Sea Grant Data Management Completion phase.

Section E. References

Albert, D. A., 2007. Natural community abstract for interdunal wetland. Michigan Natural Features Inventory, Lansing, MI.

Cañedo-Argüelles, M., K. S. Boersma, M. T. Bogan, J. D. Olden, I. Phillipsen, T. A. Schriever, and D. A. Lytle. 2015. Dispersal strength determines meta-community structure in a dendritic riverine network. Journal of Biogeography 42:778–790.

Cole, K. L., & R. S. Taylor, 1995. Past and current trends of change in a dune prairie/oak savanna reconstructed through a multiple-scale history. Journal of Vegetation Science 6: 399–410.

Hasselman, D. J., D. Ricard, and P. Bentzen. 2013. Genetic diversity and differentiation in a wide ranging anadromous fish, American shad (*Alosa sapidissima*), is correlated with latitude. Molecular Ecology 22:1558–1573.

Hindley, J. A., B. A. Graham, P. C. Pulgarin-R, and T. M. Burg. 2018. The influence of latitude, geographic distance, and habitat discontinuities on genetic variation in a high latitude montane species. Scientific Reports 8:1–11.

Hirao, A. S., M. Watanabe, S. Tsuyuzaki, A. Shimono, X. Li, T. Masuzawa, and N. Wada. 2017. Genetic diversity within populations of an arctic–alpine species declines with decreasing latitude across the Northern Hemisphere. Journal of Biogeography 44:2740–2751

Jackson, J. M., M. L. Pimsler, K. J. Oyen, J. B. Koch-Uhuad, J. D. Herndon, J. P. Strange, M. E. Dillon, and J. D. Lozier. 2018. Distance, elevation and environment as drivers of diversity and divergence in bumble bees across latitude and altitude. Molecular Ecology 27:2926–2942.

Ribera, I. 2008. Habitat constraints and the generation of diversity in freshwater macroinvertebrates. Aquatic Insects: Challenges to Populations. J. Lancaster & R.A. Briers Eds. Pg 289-311.

Sierszen, M. E., J. A. Morrice, A. S. Trebitz, and J. C. Hoffman. 2012. A review of selected ecosystem services provided by coastal wetlands of the Laurentian Great Lakes. Aquatic Ecosystem Health & Management 15:92–106.

Socolar, J. B., J. J. Gilroy, W. E. Kunin, D. P. Edwards. 2016. How should beta-diversity inform biodiversity conservation? Trends in Ecology and Evolution 31:67–80.

Vanschoenwinkel, B., F. Buschke, and L. Brendonck. 2013. Disturbance regime alters the impact of dispersal on alpha and beta diversity in a natural metacommunity. Ecology 94:2547–2557.