What can the soundscape of ephemeral wetlands tell us about the drivers of songbird and anuran community composition and diversity?

Ansley Williamson

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Abstract

Wetlands provide essential ecosystem services and natural habitats for many organisms, however, ephemeral wetlands are often overlooked by policy and management schemes because it is unclear if these partially wet areas are ecologically unique and important. The purpose of our study is to characterize the soundscape of ephemeral wetlands so that a clearer understanding of their optimal management and monitoring can be developed. We will compare community diversity and composition of songbirds and anurans (frogs and toads) in three ways: 1) in wet vs. dry sites, 2) in natural vs. developed areas, and 3) using human vs. automated detection. The soundscape will be characterized using acoustic recorders and artificial intelligence algorithms to identify species occurrences in the recordings. Our study will provide ecological information on the diversity of songbirds and anurans that are supported by ephemeral wetlands across a disturbance gradient to inform best management and monitoring practices.

Statement of Interest

The sounds ringing from the woods have lured me in since I was a child. My mother, an educator and bird lover, instilled a respect for nature within me. I often watched her question neighborhood children for breaking tree branches. “Oh no, can’t you hear the tree crying?” She would ask them. Their facial expressions surprised and slightly horrified; this left a lasting impression on me. We went on nature walks instead of watching TV, where I would listen intently for the red-winged black birds that my mom adores. Our camping trips taught me to respect our land and the environment that provides life to an abundance of species. My mom has been a key contributor to the love and compassion I have developed for birds and their environment.

My father, a retired naval officer, guaranteed me a life of relocation. Always near the water, I was fortunate enough to observe a vast diversity of flora and fauna. The older I got, the more I began to recognize different shorebirds and practices being employed on beaches and in wetlands to sustain their environment. My constant relocation fostered a unique perspective of the intrinsic value each of us holds of nature. This value is what drives my desire to study birds, conservation ecology, and biodiversity.

To pursue my goal, I obtained my Bachelor of Science Degree in Natural Resources & Environmental Management from the University of Hawai‘i. There, I learned methods in conservation planning, avian field surveys, invasive species management, stream and wetland restoration, policy application, and more. During my senior year, I produced my capstone project, Predation Control on the O'ahu 'Elepaio of Wailupe Valley. In collaboration with Pacific Rim Conservation, I developed a conservation plan for the critically endangered, native flycatcher. In my research, I completed stakeholder and environmental-benefit cost analyses, field surveys, recorded data, and implemented anti-rodent measures and protective exclosures throughout the valley. I particularly enjoyed working in the field and observing the ‘Elepaio; I loved collaborating with peers to dissect and determine the appropriate conservation plan for the species. This project awarded me the valuable experience of working with a non-profit to employ social and natural science applications.

To further my knowledge of birds, I have been eagerly participating in community bird walks where local bird-fanatics share their knowledge of bird songs, breeding behaviors, and distribution. Additionally, I have been volunteering with the *Audubon South Carolina* as a Shorebird Steward to communicate important conservation tactics to the public while simultaneously sharpening my bird identification skills. I’ve also been learning about our local water quality by volunteering for *Charleston Waterkeeper*, a local non-profit dedicated to reporting water quality across the Charleston area. These experiences have driven me to immerse myself in the interdisciplinary world of environmental conservation and better understand the importance of natural and social science applications.

Since beginning my graduate career at the College of Charleston, I’ve been eagerly learning all that I can in the EVSS program. Throughout my career, I aspire to apply my

knowledge of conservation to articulate important conservation issues to the public, restore ecological communities, and apply critical thinking methods to manage biodiversity. Through the completion of this research project I will gain valuable experience in acoustic ecology, ecological applications, natural science methods, and publication writing. This project will bring me closer to my goal of working to restore ecological communities and apply conservation tactics in a unique way. Through employing acoustic techniques I will participate in an area of research that is new to me. The completion of this project will make me competitive in the conservation job market and help me achieve my goal of working as an ecologist for the *National Audubon Society* or the *Department of Natural Resources*.

Through my career and volunteer experience, I've learned that community involvement and publicly available scientific dissemination is a critical component of environmental conservation. Through collaboration with different non-government organizations, government agencies, and private landowners, this project has a diverse set of stakeholders that will benefit from our results. This project will provide me with experience conducting scientific research and communicating that research to our stakeholders to inform their management practices.

We hope to target our research for publication in *Wetlands, Conservation Biology*, or the *Journal of Applied Ecology*. Additionally, we aim to produce a white paper to be distributed by *Audubon South Carolina*. The publishing of this research is aimed to inform the scientific literature through journal publication, as well as the white literature to inform conservation efforts employed by many private landowners and non-government organizations that execute the majority of bird conservation across all spatial scales.

As the first woman in my family to graduate with a STEM degree, I am passionate and enthusiastic about continuing my research in this field. This project aims to positively impact songbird and anuran conservation by informing more effective management strategies to conserve these wetlands. We seek to spread awareness about the importance of ephemeral wetlands and the species that depend on this habitat.

Project Proposal

Introduction

Songbird and anuran populations across the world have been in a steady decline for decades due to habitat loss and fragmentation. Globally, wetland decline caused by land use change is a leading cause of biodiversity loss (Convention on Wetlands, 2021). Since 1970, 81% of inland wetland species populations and 36% of coastal and marine species have declined, and 25% of wetland species are at risk of extinction globally (Convention on Wetlands, 2021).

In coastal South Carolina, wildlife biodiversity has been impacted by development, deforestation, habitat fragmentation, pollution, and climate change impacts (Mantyka-Pringle et al., 2015). Our wetlands are facing the threat of deteriorating health because of disturbance

including development as well as consistent human presence. Between 1996 and 2010 the Southeast had the fastest rate of change in developed land of any coastal region in the country, and experienced development at a pace of 1 football field every 13 minutes (NOAA, 2010). This development increases impervious land cover such as roads, sidewalks, and roofs. These impervious surfaces redirect stormwater to stormwater management ponds and prevent the natural pooling that sustains wetlands (Beckingham et al., 2019). This disturbance has caused a loss of ephemeral wetlands across our region.

Stormwater management ponds were introduced to the area at an alarming rate to alleviate flooding issues associated with urban development. In the greater Charleston area, 108 ponds per year were created, on average, between 1994 and 2013 (Cotti-Rausch et al., 2018). It is unclear how stormwater detention and retention ponds are ecologically impacting our region. Studies show that stormwater retention ponds are causing pollution, eutrophication, and cascading ecological problems (Beckingham et al., 2019; Lewitus et al., 2008). Some of these stormwater retention ponds act as seasonally flooded, ephemeral wetlands. By characterizing the soundscape of urban ephemeral ponds, we aim to better understand the songbirds and anurans that depend on these sites.

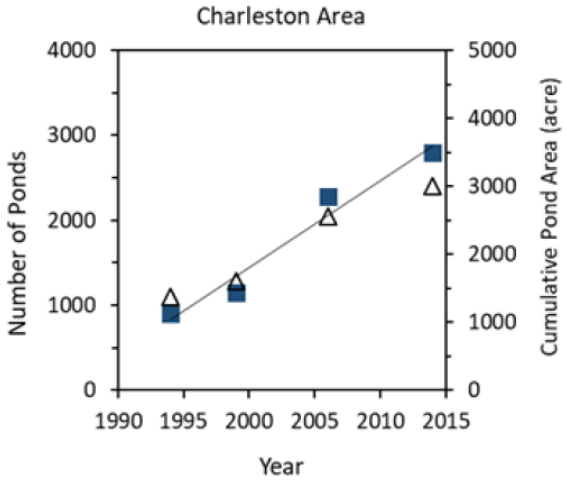

Figure 1. Change over time in pond number (squares) and cumulative surface area (triangles) of development-related ponds for the greater Charleston area (Cotti-Rausch et al., 2018).

Ephemeral wetlands are small pockets of habitat that are seasonally flooded and isolated from other water sources such as streams or rivers surrounded by upland habitat (Snodgrass et al., 2000). They are transitional ecosystems, where the habitat is only wet for part of the year and have the potential to support a unique diversity of inhabitants. Bennett and Nelson (1991) estimated that only 10% of the original distribution of ephemeral wetlands remain in the South Carolina Bay ecotone. Therefore, ephemeral wetlands are disappearing across the state and there is a critical need for research on the types of diversity they support to inform management decisions. In urban landscapes, small ephemeral wetlands are often referred to as storm retention

ponds which play a critical role in mitigating flood risk. Management around urban wetlands does not typically consider wild animal habitat, and therefore we expect these systems are ecological depauperate compared to sites in wildlands but few studies have examined this.

Although monitoring wetland biodiversity is of critical importance, it is also very expensive and time consuming to carry out. Therefore there is a need to develop sensor arrays that can be rapidly distributed to carry out rapid and accurate biodiversity assessments. One such non-destructive approach is to use automated recording devices to characterize the biotic and abiotic sound or soundscape in a habitat (Bradfer-Lawrence et al., 2020; Lin et al., 2017). Recent developments using machine learning and artificial intelligence algorithms (Kahl et al., 2021; Lapp et al., 2021) have now made it theoretically possible to characterize soundscapes without human supervision which could lower the cost of monitoring significantly. One question this study seeks to determine is whether automated recording systems have the same efficacy as these traditional methods that rely on human identification. Our results will be useful to conservation researchers and land managers alike.

Successful conservation of songbirds and anurans depend on updated local data on the characteristics and changes in local populations. Without this data, many conservation tactics are unsuccessful. This study seeks to close the research gap by determining the composition and diversity of songbirds and anurans across a disturbance gradient of ephemeral wetlands. Specifically, I will address the following inter-related questions (Figure 2):

Q_1: Are ephemeral wetland soundscapes different from paired upland dry sites?

Q_2: Are ephemeral wetland soundscapes different in urban areas compared to natural areas?

Q_3: Are automated methods redundant or complementary to human detection methods?

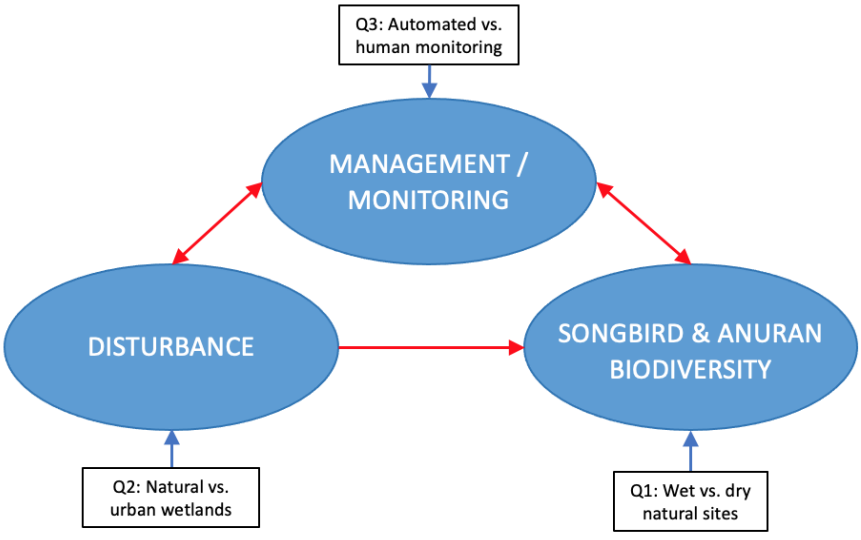

Figure 2. Path diagram indicating the conceptual linkages between disturbance, management/monitoring, and songbird and anuran biodiversity.

Methodologies

We will deploy Solo audio recording devices (Whytock 2018) to record songbird and anuran calls across several ephemeral wetland sites and upland dry sites. We will sample ephemeral wetlands at two natural areas: Stono Preserve and Halidon Hill Preserve (Figure 3 and 4). Human developed areas will be sampled in the greater Charleston metro area (Figure 5). We will compare the automated species detections to human guided detections to examine if these methods are complementary or redundant which will help to inform future monitoring schemes. This will allow us to analyze the diversity on a disturbance gradient, with wildlands, suburban, and urban lands having unique features and being utilized by their inhabitants in potentially unique ways.

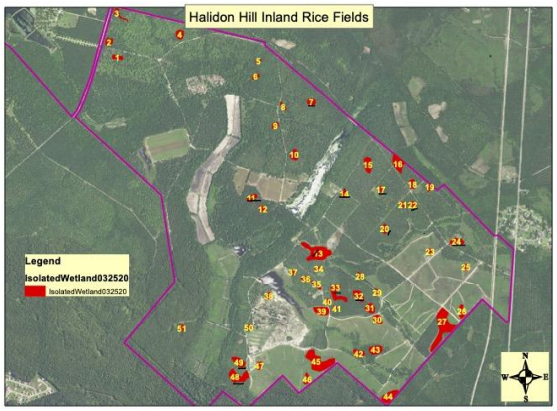

Figure 3. Halidon Hill Sampling Sites

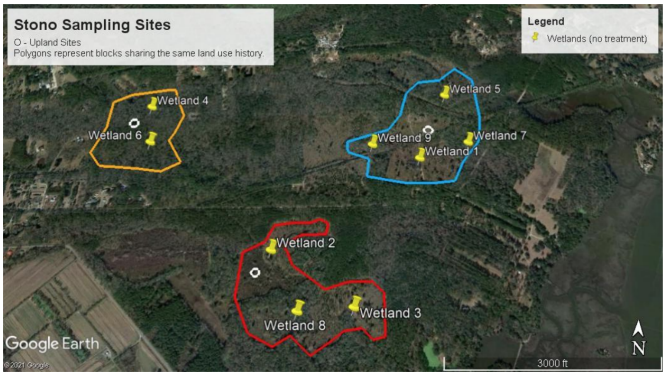

Figure 4. Stono Sampling Sites.

Urban Sampling Sites

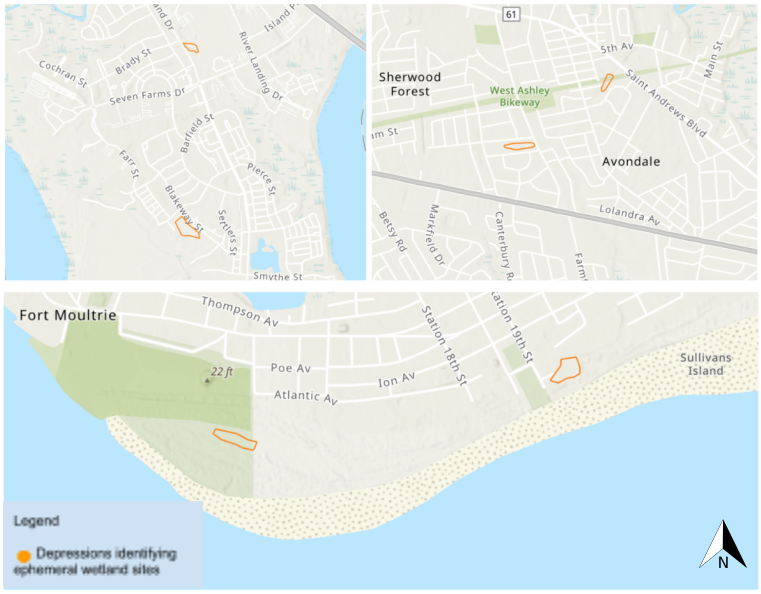

Figure 5. Urban Sampling Sites (Daniel Island, West Ashley, Sullivans Island).

We will determine levels of disturbance at each site by determining the amount of impervious land covered (curve number modeling) and ambient noise recorded. We will perform data analysis to create species distribution models (SDM) for detected species at all sites, which can be tested by future MS students or by local/state agencies. Linkages between disturbance and songbird and anuran biodiversity will allow us to report on these relationships, as depicted in Figure 2.

This study will utilize Solo System audio recording devices (Figure 6) (Whytock, 2018) and Cornell's Lab of Ornithology BirdNET Analyzer (Kahl et al., 2021) to identify bird species from their songs and calls. Additionally, we will utilize the repeat interval-based bioacoustic identification tool (RIBBIT) to automatically identify anuran calls (Lapp et al., 2021). Both BirdNET Analyzer and RIBBIT are open source tools that can be applied in various windows programs, Python, and R Studio.

Figure 6. Solo System Audio Recorder with all components and rain-proof box (Whytock, 2018).

To compare our data with human-identified point counts we will replicate similar methods to Jackson Barratt Heitmann's project. The soundscape will be characterized using acoustic recorders and human observations made at dawn and dusk. We will utilize point counts conducted in 10 minute intervals. We will deploy solo audio recorders from May 15-June 15, 2022 and May 15-June 15, 2023. Bird songs and calls will be notated auditorily through the BirdNET Analyzer program. We will notate the number of each species identified in each plot, to get abundance and species richness data. Human ID surveys were performed at each site twice during the summer of 2021 and will be during the summer of 2022. I compare this data to the automated species detections and assess whether these methods are beneficial to use simultaneously or redundant which will help to inform future monitoring schemes.

Timeline

2022	**Summer**	**Fall**	**Winter**
Objectives	- Collect data across all sampling sites - Begin processing data through programs - Write and defend thesis proposal	- Complete processing and correction of data - Write introduction and methods sections for thesis and publication	- Analyze data for trends in composition and diversity
2023	**Spring**	**Summer**	
Objectives	- Begin writing results and discussion sections of manuscript - Begin preparing manuscript for scientific publication	- Collect data across all sampling sites - Analyze data for trends in composition and diversity - Submit thesis for review - Schedule thesis defense - Defend thesis - Prepare manuscript for publication	

Conclusion

Ephemeral wetlands present a unique opportunity to support a wide diversity of inhabitants. These wetlands are understudied within our region and generally overlooked due to their small size. By studying which songbirds and anurans use these habitats we seek to spread awareness about their importance for these species and general ecological diversity. By testing the efficacy of the automated bird identification software we provide alternatives to researchers. This data will be useful to land owners, state agencies, and non-governmental agencies. We seek to deepen our understanding of how disturbance impacts the community composition and diversity of ephemeral wetlands so we can inform more effective management strategies to conserve these wetlands.

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Faculty letter

I enthusiastically support Ansley Williamson's proposed research project. Ansley has proven herself to be an emerging leader and scholar in the EVSS master's program during the short time she has been on campus. Ansley has a successful first year in the EVSS program, and although she currently lacks funding Ansley has already begun collecting audio recordings at the wetlands my research group has been working on (Figure 2, 3). The chief strengths of the proposed work are that:

1. *It will fill an important knowledge gap.* It is well understood that wetlands are extremely important but small ephemeral wetlands are almost completely ignored in protection schemes and management plans. In the coastal plain, ephemeral wetlands are numerous and blanket the landscape. It is largely unknown if management and policy should be targeting these fragile and unique habitats.
2. *There is a clear experimental component to the proposed work.* Ansley will collect one year of data this spring and summer. In the fall of 2022, tree thinning treatments will be implemented at Halidon Hill. In the spring and summer of 2023, Ansley will be able to collect post treatment response data. Additionally, some wetlands receive prescribed fire annually at Halidon Hill while the wetlands at Stono preserve have received fire treatment at varying intervals in the past. Therefore, there are clear treatments and controls to compare in a data analysis.
3. *We have a strong interdisciplinary team*. Ansley has assembled a strong interdisciplinary group of academics, practitioners, and primary land owners that will ensure strong relevance and transferability of his results into management and conservation decisions. The team includes Lisa Lord of the Longleaf Alliance, an NGO focused on land management of privately held lands, Dr. Stacey Lance, a principal investigator at the Savannah River Lab focused on frog and salamander communities, Dr. Travis Folk of Folk land management, and members of the Coen family who own and help to manage the Halidon Hill property. Dr. Lance is collecting data on frogs and salamanders at the same Halidon hill sites so Ansley has also set herself up to participate in a timely comparative study between how these groups respond to disturbances. Another student in my lab Jackson Barratt Heitmann will also collaborate with Ansley and they have already demonstrated they are a good team.
4. *Ansley is an exceptional and emerging scientist*. She developed this project and wrote this proposal herself. I have collaborated closely with her as the project developed but she has taken ownership of this project. Ansley has also proven to have excellent field knowledge of birds, and I consider her to already be a talented writer and a clear thinker.

The primary broader impacts of the proposed work will be:

1. To provide actionable information to our specific partners and to the broader scientific and land management community on how to best consider the conservation benefit and changes in ephemeral wetland communities.
2. To train Ansley Williamson as a scientist and communicator. Ansley plans to pursue his PhD after completing his master's degree. The proposed work will position Ansley very well to enter a PhD program in ecology and evolutionary biology.
3. Ansley will integrate her work into the outreach my group is leading at the Stono Preserve student garden. As a member of the garden team, Ansley is helping with outreach to the broader community including K-12. Ansley plans to develop K-12 focused activities that highlight the importance of ephemeral wetlands and ecological research such as guided bird walks and ephemeral wetland vegetation identification activities.
4. Ansley will also help to mentor an undergraduate researcher that I will recruit from my biology 211 course. Ansley and I will work with the undergraduate student(s) to procure funding for a summer research project from the SSM summer research funding. Ansley and I will then both work to help mentor and develop the undergraduate student's project which will be designed to be integrated with the work proposed here.

The funding listed below would cover items Ansley needs to record the soundscape with previously purchased equipment but requires additional accessories, in addition to mileage reimbursement (Table 1). I am not requesting any funding for myself as part of this proposal. Ansley will receive my full attention as she works on this project. She is one of two graduate students in my lab currently and they are both working together on different components of this larger project.

In closing, I give the proposed work and Ansley my full endorsement. I am excited about the project and I'm excited about working with Ansley and our collaborators. I think that a lot of interesting science and management guidelines will be developed as a result of this project.

Best,
Dan McGlinn, PhD
Associate Professor
Department of Biology, College of Charleston

Table 1. Budget

Item List	Cost
Mileage Reimbursement for 2023 field season Trip (6) to Stono ($0.585/mile x 27 mi) = $94.77 Trip (6) to Halidon Hill ($0.585/mile x 22 mi) = $77.22 Trip (6) to Urban Sites ($0.585/mile x 18 mi) = $63.18	$235.17

Ratchet Straps (4 pack for $25 x 4 = $100)	$100
Additional Solo Audio Equipment ($200 x 2 needed = $400)	$400
Lithium Cell CR1220 3V Battery (12 pack for $6 x 3 = $18)	$18
Conference Registration (Average cost)	$500
Total Cost	$1,253.17