STATEMENT OF WORK

EVALUATING THE ABILITY OF GREAT LAKES COASTAL WETLANDS TO BUFFER WATERFOWL-DERIVED NUTRIENT INPUTS

Introduction

The primary goal of wetland management and restoration is typically to either increase biodiversity or enhance nutrient (nitrogen and phosphorus) retention, but not both in conjunction (1). Current restoration efforts in northern Ohio are shifting towards those that favor nutrient retention with the goal of decreasing nutrient pollution loads to Lake Erie (2). However, with the focus on nutrient retention, waterfowl habitat and management can be overlooked. These two services (waterfowl habitat conservation and nutrient retention) are sometimes viewed as opposing management objectives due to previous studies suggesting that waterfowl bring large loads of nutrients via excretion (3). However, this assumption is dependent on geographic region, wetland area across the landscape, wetland habitat structure, and other nutrient inputs. **We propose to investigate the amount of nutrients that waterfowl in NW Ohio contribute via guano excretion and how these wetlands buffer these nutrient additions.**

Wetlands in NW Ohio drain watersheds that are dominated by agricultural land use (4). This leads to nutrient run-off from fertilized fields passing through the watershed, and into Lake Erie, which experiences annual harmful algal blooms (5, 6). In NW Ohio, coastal wetlands have been, and are currently, being restored within the Lake Erie watershed to reduce the amount of nutrient loading to the lake. Wetlands are referred to as the “kidneys” of the landscape because they are hotspots of microbial nutrient removal processes like denitrification (removing nitrate from water by converting it to nitrogen gas) and abiotic processes like long-term phosphorus burial (7, 8). Within wetlands and other aquatic systems, animals can also alter nutrient recycling and transfers, though these contributions are considered less in nutrient management. Fish exert top-down control on algae, changing nutrient uptake and availability (9), invertebrates burrow in sediments and alter microbial nutrient removal process rates (10), and emerging insect larvae provide large nutrient subsidies to terrestrial systems (11). Waterfowl can also play a large role in transporting nutrients to and from wetlands, as well as altering the form in which nutrients are stored through feeding and excretion (12, 13). Therefore, waterfowl nutrient transport and recycling must be understood to fully account for nutrient inputs and recycling in wetlands, especially wetlands with goals of nutrient retention.

Coastal wetlands provide great stopover points for waterfowl, as they offer sheltered resting areas where food is plentiful. Waterfowl embark upon long distance migrations during which they stop frequently at multiple locations between extended periods of flight to forage. It is common for large populations of waterfowl (numbering in the tens of thousands) to congregate at stopover points, which results in the translocation of nutrients across ecosystem boundaries (3). Nutrients ingested at previous stopover points are excreted along the route and at the next stopover point. Bird guano is rich in nitrogen (N) and phosphorus (P) and can act like a fertilizer that stimulates the growth of algae, submerged vegetation, and other primary producers in aquatic systems. The limited amount of work done on how waterfowl transport nutrients between wetlands and recycle nutrients within wetlands has only been studied in arid areas containing single wetlands that experience extremely high waterfowl densities (3). In these densely visited stopover points, where wetlands are few and are very separated across the landscape, waterfowl can contribute large loads of nutrients, with waterfowl excretion accounting for up to 40% of the

N and 75% of the P inputs into the system (3, 14). While nutrient inputs are beneficial in nutrient-limited systems where the primary production is constrained by the supply of nutrients, nutrient inputs are detrimental in eutrophic systems since they can worsen harmful algal blooms. A large body of research has demonstrated that seabirds can transport a large amount of nutrients from the open ocean to otherwise nutrient-limited nesting and roosting islands through foraging excursions (15, 16). However, less attention has been paid to how birds supply nutrients to freshwater lakes and wetlands, especially in the western basin of Lake Erie. **There have been few studies considering how waterfowl contribute nutrients in flyways in the Great Lakes region where there is relatively higher wetland area and lower waterfowl densities.**

We aim to uncover the contribution of waterfowl on the nutrient budget of coastal wetlands in northwest Ohio, within the Mississippi flyway. This work will help uncover how waterfowl translocate nutrients across ecosystem boundaries. **A better understanding of nutrient input from waterfowl excretion will help inform decisions for wetland restoration and management (i.e., water level and vegetation management) that prioritize both waterfowl biodiversity and nutrient removal**. Studies have begun to suggest that increasing wetland restoration projects will help geographically disperse waterfowl (3) and that wetlands can effectively be managed for both nutrient removal and bird habitat (1, 14). Increased understanding of animal contributions to nutrient budgets in wetlands will provide us with more information for management decisions in ongoing restoration projects. Additionally, this paired management strategy is essential for not only reducing nutrients to downstream waters, but also for conserving and restoring additional habitat for migratory waterfowl.

Objectives and Major Hypotheses

We have four major objectives including (1.) estimating the nutrient contributions by waterfowl in wetlands, (2.) comparing waterfowl-derived nutrient loading to watershed runoff nutrient loading, (3.) measuring how much of the nutrients from waterfowl guano will be retained by wetland sediment, and (4.) determining how waterfowl guano changes the algal community based on its N:P ratio. This will help inform wetland conservation and restoration decision-makers on how to restore and manage wetlands for multiple services, including biodiversity, habitat for waterfowl, and nutrient removal.

Methods: Observation and Experimental Design

This project will be completed at Old Woman Creek National Estuarine Research Reserve (OWC) located in northwest Ohio, along Lake Erie. This Great Lakes coastal wetland experiences high nutrient runoff from the landscape which is 70% agricultural land use (4). With substantial nutrient runoff, NW Ohio serves as a great location to uncover the nutrient input of waterfowl and how the amount of nutrients added from guano compare to that of landscape runoff. With additional wetlands within a short flying distance away, OWC provides a unique system where waterfowl densities are geographically spread out, which contrasts other studies that have only looked at high densities of waterfowl in single or few surrounding wetlands.

To investigate the amount of nutrients that waterfowl release into OWC, we will complete weekly waterfowl counts of the waterfowl located in the wetland, as well as behavioral observations of time spent foraging, from November 2022 to April 2023 when most waterfowl migrate through NW Ohio. We will both do manual point counts at predetermined locations from the shore in addition to counts over the whole wetlands (Figure 1) using drones at 60 meters high, which has been shown to be an effective method to non-intrusively count waterfowl (17).

Drone images will be stitched together and be used to identify and count the number of waterfowl using the wetland. To fill in waterfowl counts between the weekly observations, we will interpolate waterfowl counts between the two surrounding observation dates. We will use these data along with published waterfowl nutrient excretion rates (18, 19, 20) of the dominant waterfowl species residing in OWC to estimate the load of nutrients (g/day) that they are excreting and contributing to the coastal wetland. Once we calculate the total load of nutrients from waterfowl excretion, we will compare this to previously published external loading from the OWC watershed (11,594 kg Total P year $^{-1}$, 136,022 kg Total N year $^{-1}$, 1,067 kg PO_4^{3-} year $^{-1}$, and 97,782 kg NO_3 year $^{-1}$) (21, 22). We selected Old Woman Creek due to readily available data from the extensive watershed monitoring program with a large dataset of nutrient concentrations entering and leaving the wetland, and calculated nutrient loadings to Lake Erie.

Figure 1. Left: Locations accessible for waterfowl point counts. Right: Possible drone route for waterfowl counts, with points indicating where pictures will be taken.

We will also observe foraging activity at each point count location (as depicted in Figure 1) bimonthly for 6-hour periods to gather behavior data (including arrivals/departures) and to estimate the amount of time spent foraging. This data will allow us to better categorize the time use of waterfowl to understand how they are bringing nutrients in, recycling nutrients within, and transporting nutrients out of OWC. Thus, we will be able to not only measure and calculate the amount of nutrients they bring in and recycle within the system collectively, but also separate out how many nutrients released via excretion are subsidies from other ecosystems and how many are recycled within the system.

To understand how efficiently wetland sediments can take up nutrients released from waterfowl excretion, we will use fresh guano collected from waterfowl trapped during population monitoring in Winous Point Marsh (where managing agencies have ongoing waterfowl studies) which will be added to OWC sediment and surface water microcosms in a lab experiment. We will add a gradient of different guano mass (prepared in a slurry) to different microcosm treatments (Figure 2) and complete this experiment for each of the most numerically dominant species of waterfowl in our region. We will also have a control microcosm treatment with OWC sediment and surface water but without guano so that we can factor in ambient rates of nutrient removal occurring. We will complete this experiment in typical winter temperature incubated conditions as well as more moderate autumn/spring temperatures to get nutrient removal rates coincident with times of the year when waterfowl are present but microbial activity is lowest. We will sample water from each microcosm five times across 3 days, which will then be analyzed for a suite of nutrients (NO_3^-, NH_4^+, urea, and PO_4^{3-}). We will use these concentration measurements collected over time to calculate nutrient flux rates, which will show at what rate wetland sediments can remove these

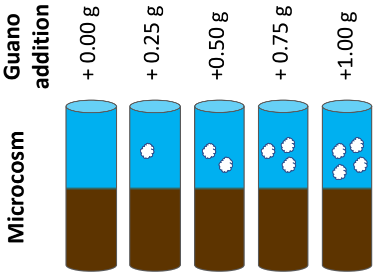

Figure 2. Proposed wetland-guano nutrient uptake experiment (each treatment replicated 4 times).

nutrients from the surface water.

We will also look at how nutrient addition from waterfowl can change algal community composition. In this experiment, we will add the guano-water slurry from several waterfowl species to clear bottles with OWC surface water and incubate these bottles under lighted conditions. After approximately four days, we will collect samples to measure algal biomass and community composition, as well as measure concentrations of the same nutrients as the previous experiment (NO_3^-, NH_4^+, urea, and PO_4^{3-}), and total N and total P to determine biological and chemical changes induced by guano. The relative supply of N and P can be important for determining whether different algal groups will dominate (e.g., harmful cyanobacteria). This experiment will allow us to see if guano, which can be relatively low in P (23), promotes P limitation, favoring a more diverse, natural assemblage of algae, or enhances N limitation, which could favor an algal community dominated by toxin-producing cyanobacteria that are present under high N conditions.

Timetable

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Waterfowl counts			🟧	🟧	🟧	🟧	🟧	🟧				
Uptake (+ guano) experiments	🟧	🟧										
Excretion calculations									🟧	🟧		
Nutrient sample analysis				🟧	🟧	🟧						
Presentations of research										🟧	🟧	🟧
Manuscript preparation										🟧	🟧	🟧

PORTIONS OF THIS WORK ALREADY COMPLETED

No portion of this work has been completed thus far.

BENEFITS OF THIS STUDY TO COASTAL WETLANDS

Coastal wetlands of the Great Lakes can play incredibly important roles in improving water quality by removing nutrients from water before it enters the Great Lakes. However, we do not fully understand the pools and in the nutrient budget nor the mechanisms responsible for nutrient removal in these coastal wetlands. Additionally, these coastal wetlands provide critical habitat to many species, including waterfowl. Waterfowl and other wetlands birds can bring in nutrients from other systems, unlock nutrients stored in wetland vegetation and invertebrates, and remove nutrients from wetlands as they leave. However, we do not know how these movements and use of wetlands affect nutrient budgets in wetland systems. Even further, we do not know how the amount of nutrients supplied by bird guano compares both to the amount of nutrients contributed to these coastal wetlands from external loading and to the nutrient removal rates of the wetland. This work will give us insight into how birds play a role in removing/supplying nutrients in coastal wetlands, and therefore will better inform wetland managers on how to manage and properly restore Great Lakes coastal wetlands in ways that facilitate both habitat for waterfowl and other birds, as well as nutrient removal processes.

HOW FUNDS WILL BE USED

I will use these funds to pay for supplies and travel to and from my field site. Funds will be used to pay for the drone (DJI Phantom) and SD cards for the population surveys, image stitching software (PIX4D) for analyzing the drone photos, a pair of binoculars for an undergraduate research assistant to help with the behavior observations, consumables and chemicals for the two experiments proposed and associate water chemistry analyses, and lastly to cover costs for traveling up to the field site weekly over 5 months. If any additional funds remain, they will be used for conference registration and/or publication fees.

PLANS FOR SHARING RESEARCH

I plan to share my research with three different groups of researchers, citizen stakeholders, and resource managers. First, I plan on sharing my results with members involved with the H2Ohio program in Ohio which focuses on wetland restoration and monitoring across Ohio. This group includes members of the Ohio Department of Natural Resources, consulting firms (e.g., LimnoTech), and academics from a variety of institutions. These researchers have expressed interest in knowing how wetland birds can affect wetland nutrient budgets, and one of my committee members is leading the monitoring component of this program, giving me a great opportunity to share this research with this mixed group of government, academic, and consulting stakeholders. Second, I plan to share my research with is the Friends of Old Woman Creek. This is a group of citizen scientists and stakeholders invested in the research and conservation of Old Woman Creek National Estuarine Research Reserve. They hold an annual research meeting, where I will share my findings with both these citizen scientists and the scientists and managers that work at the Old Woman Creek National Estuarine Research Reserve. Third, I plan on sharing my research at 1-2 national conferences that have a mix of academic and government/management attendees, such as the Society of Wetland Scientists, Society for Freshwater Science, and Coastal and Estuarine Research Federation conferences. For even broader dissemination of this work, I will publish a manuscript in a peer-reviewed journal.

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