The Differing Quality of Two Wetland Plant Communities and the Possible Impact on Threatened Rails

By

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Abstract:

This study observed differences in the quality of two marshes' plant communities at the Black Fork Wetlands Preserve to monitor potential changes in plant community structure due to invasive reed canary grass, *Phalaris arundinacea*. Two threatened bird species (*Rallus limicola* and *Porzana carolina* rails), preferring a blend of woody and emergent vegetation, have been repeatedly observed at a native plant marsh but only once at a *P. arundinacea*-dominated boardwalk marsh potentially due to differences in plant community structure. Species richness, evenness, and abundance was quantified at each site and biomass data collected for *Sparganium androcladum*, *Carex camosa*, *Typhus latifolia* along with *P. arundinacea.* Plant identifications were used to calculate the Floristic Quality Assessment Index and Simpson's Index as a measure of quality for each marsh. Aerial images were used to map the boardwalk site and measure percent cover of *P. arundinacea*. Percent cover was estimated to be 40%. The boardwalk marsh had less diversity than the rail marsh; approximately 90% of the vegetation sampled in the boardwalk marsh was *P. arundinacea* while *S. androcladum* at the rail marsh ranged from 20-70% across the areas of the transect. *P. arundinacea* had up to three times as much biomass as *S. androcladum,* indicating a denser community. The boardwalk marsh lacked woody vegetation within sampling plots while the rail marsh had both *Cornus stolonifera* and *Salix nigra.* Differences in the vegetation present and their differing distributions as a result of *P. arundinacea* growth may impact habitat suitability for fauna such as threatened rails.

Acknowledgements:

This study would not have been possible without the collaborative effort of many people; many thanks are given to Dr. Patricia Saunders and Prof. Merril Tawse for recruiting me into this project in Fall 2016. Much gratitude is also given to Dr. Dolly Crawford for sparking my interest in GIS research and for facilitating the incorporation of aerial imaging into the project. Appreciation is also given to Steve McKey for his invaluable assistance in verifying plant identifications, to John Simpson for a very informative lecture on wetland value and restoration, and to Dave Gentile from the Richland County Office for providing valuable historic photos of the Black Fork Wetlands Preserve.

This study was the first in Ashland University's Department of Biology and Toxicology to utilize UAV images for research purposes through cooperation with Ashland University's Department of Journalism and Digital Media. Special thanks are given to John Skrada for taking the time to gather the aerial footage of the boardwalk site, lighting the way for future work to be done with drone imaging in the Department of Biology and Toxicology.

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Introduction

Wetland conservation is an ongoing effort throughout Ohio and other states that have historically had large portions of wetland habitat. Some work has been done to mitigate damage to wetlands in order to preserve their current surface area and integrity with mixed success (Fennessy 1997). Wetlands also play a role in protecting other ecosystems and are of great use to humans, albeit in indirect ways. They can act as a buffer for flood waters, thus protecting rural and suburban areas from being directly exposed (Watson et al. 2016); they can also act as filters for agricultural waste, mitigating the harm it may otherwise cause (Coveney et al. 2002; Pappalardo et al. 2016). Wetlands are populated by a variety of wetland-specific organisms, including species of turtles, small mammals, and small birds, which begin to suffer under conditions of wetland loss (Gibbs 1993). One goal of wetland preservation is to protect those species that rely on these habitats.

A stable ecosystem is one which the structure and functions of an ecosystem are able to endure over time; if a stable ecosystem is faced with stress or disturbance, it should be able to recover in such a way that previous function and structure are restored (Loreau & Mazancourt 2013). Ecosystem stability has been closely linked with biodiversity; a highly diverse system is home to complex interactions between species that keep the system balanced and therefore sustainable (Campbell, Murphy & Romanuk 2011; Loreau & Mazancourt 2013). Invasions by non-native plants are one of the greatest threats to biodiversity through the displacement of native species, resulting in monotypic strands that erase the original habitat and causing unsustainable resource usage (Lavergne and Molofsky 2004; Loreau & Mazancourt 2013; Vitousek et al. 1996). This is an example of ecosystem collapse, wherein a system loses its structure and is unable to maintain its typical functions. An invasive such as reed canary grass unbalances the plant community by reducing the diversity of native species (Schooler, et al 2006; Lavergne and Molofsky 2004), making it unstable and at risk of collapse.

Biological invasions are a widespread issue impacting ecosystems across the world (Vitousek et al. 2006). Invasive plant species are becoming increasingly problematic to threatened wetlands. Invasions can reduce native plant diversity, potentially impacting ecosystem function as they form large homogenous patches (Schooler et al. 2006; Lavergne and Molofsky, 2004). Reed canary grass (*Phlaris arundinacea*) is a perennial originally native to parts of Eurasia and some parts of North America. Introduced to the United States around 1850, it was sown to help with soil stabilization as well as purification by taking up contaminants (Lavergne and Molofsky 2004). Reed canary grass is a ruderal, generalist species that is highly invasive to wetland communities due to its preference for a wide range of moist habitats and its various means of reproduction; it is problematic due to its ability to limit surface water movement, restricting flow throughout the wetland and thus affecting the hydrology of the wetland itself (Lavergne and Molofsky, 2004). These physical changes, in addition to the impediment of the growth of natural species, means that reed canary grass as an invasive can negatively impact the wetland structure. To wetland-specific animals, these changes could then impact their ability to survive. As a prevalent concern to modern environments (Weilhoefer et al. 2017), it is important to be aware of reed canary grass presence and to protect native wetlands from the damage it can cause, especially in regards to the animals that live in these habitats.

Reed canary grass has potential to be particularly harmful to the Virginia (*Rallus limicola*) and Sora (*Porzana carolina*) rails, both listed as species of concern in the state of Ohio. For these bird species, the plant community is a key factor in habitat selection. These wetland-specific rails have been associated with emergent vegetation which they use for foraging and breeding (Wilson, Jensen & Schultheis 2018). Sora rails seem to prefer habitats with tall *Polygonum* species while both rails prefer marshes with more woody flowering plants than sedges or grasses (Wilsoon, Jensen, & Schultheis 2018). Virginia rails often coexist with Sora but prefer marshes with small pools and mudflats for foraging (Wilson, Jensen & Schultheis 2018). The structure of the plant community is not only important as a factor in understanding how to best protect these threatened birds, but also because diverse native habitats are more stable than the monotypic spaces invasive plant species can form (Loreau & Mazancourt 2013; Schooler et al 2006).

The two marshes present a case of a native site known to be used by threatened Virginia and Sora rails versus an invaded site where rails are absent. This is ideal for examining what effects reed canary grass has on vegetative biodiversity through species abundance, distribution, and biomass which can then be connected to potential impacts on the rails. Examining these qualities makes it possible to understand not only what species are growing at each site but also how the plant communities themselves are shaped in regards to density and dominance of particular species or vegetation types. Forming a description of the current structure of the plant community of the two sites provides a baseline for monitoring future changes at both. If reed canary grass spreads throughout the Black Fork Wetlands from the boardwalk to the rail marsh, the changes in the rail marsh's plant community will be measurable. These changes could, in turn, impact the ability of the rails to survive at the marsh and the ability of the marsh itself to maintain its current structure and function (Campbell, Murphy, & Romanuk 2011; Loreau & Mazancourt 2013).

.Unmanned Aerial Vehicles (UAVs) are remotely controlled machines equipped with light sensors such as cameras to view sites from the air and may also be referred to as drones.

UAV or drone images can be used to identify plant species and communities via pixel coloration, allowing the image to be converted into vegetation data that can then be analyzed (Senthilnath, Kandukuri, Dokania and Ramesh 2017; Zhou, Yanming and Benqing, 2017). This offers a new perspective on vegetative sampling by allowing the presence or absence of a given species to be noted on a far greater scale than what would be practical through manual sampling. Some features, such as isolated vegetation patches, may be worth noting as present even though they are easily missed by transect sampling. However, commonly available satellite images from tools such as Google Earth are too low of resolution to provide a detailed view of smaller sites. Drone images provide an intermediate by providing a full view of the area of interest in a much clearer resolution, making it possible to see broad but detailed view of the study site. When used in conjunction with a representative transect, manually collected data could be applied to a drone image to classify vegetation types and quantify features such as percent cover of a given species across a broader range than through manual sampling alone.

In order to better understand the effects that reed canary grass can have on plant community structure, the objectives of the study were to describe the structure of the plant communities and assess the overall quality of two marshes at the Black Fork Wetlands Preserve. This project focused on studying the diversity and abundance of plant species at a native rail marsh and a nearby marsh which is heavily infested with invasive reed canary grass. It was expected that the rail marsh would have greater species richness and evenness with species of higher quality than at the boardwalk marsh, which was expected to be a low-quality site and consist almost entirely of reed canary grass. Because the invasive reed canary grass seemed highly abundant at the boardwalk site, it was expected that biomass samples of reed canary grass would be greater than for other major species like burr reed, narrowleaf cattail, or *Carex.*

Evaluating vegetative structure at a marsh the rails are known to inhabit may provide information on what traits they value in a habitat while also providing insight as to why they are found at the rail marsh but not at the boardwalk site. The two sites can be compared by not only evaluating the structure of their plant communities but by determining whether they both have communities known to be valued by rails. Overall, the wetland habitat qualities found may be used to offer context for further work done at the Black Fork Wetlands.

Methods:

Site Description:

This study focuses on two marshes of the Black Fork Wetlands Preserve in eastern Richland County, Ohio. For the duration of this study, we informally named these sites the rail marsh and the boardwalk marsh. The Black Fork Wetlands are fed by a series of streams that flow into or flow from and then into the Black Fork of the Mohican River, coming together at Charles Mill Lake. Both study sites have open water in their basin centers, with measured pond area being bigger for the boardwalk marsh than for that of the rail marsh. The surrounding land is for agricultural and residential use with undeveloped areas under dense tree cover. The sites were chosen due to location, previous rail observations, and apparent differences in the vegetation present. Previous work had been done tracking Virginia and Sora rails at the rail marsh which established that the site is used for foraging and nesting (Tawse, unpublished data). The rail marsh was also isolated from roads, reducing concerns about potential interference. The boardwalk marsh is located immediately next to a road but also is visibly covered with a large amount of reed canary grass which made it a location of interest for comparison with the uninvaded rail marsh.

Figure 1: Overview of the boardwalk marsh at 40°48’39.51” N 82°24’52.87” W. Image taken 7/11/2018. Red line represents the approximate size and location of the 50m boardwalk transect.

Figure 2: Overview of the rail marsh, center, at 40°48’15.52” N 82°24’53.82” W. Image taken 7/11/2018. Red line represents the approximate size and location of the 50m rail marsh transect.

The rail marsh – being in a less accessible location and with no observed *P. arundinacea* population, it appeared to be a suitable example of an undisturbed native marsh. Additionally, being centered on a pond, the marsh was fairly compact in a way that allowed for sampling within a short time frame. The boardwalk marsh is in many ways the opposite – characterized by large open swaths of reed *P. arundinacea,* the location spans a much greater area than the rail marsh. The overall area of each marsh was found using image analysis tools in Google Earth Pro version 7.3.2.5776, encompassing the area of open marsh as bordered by trees and water.

Feature	Rail Marsh	Boardwalk Marsh
Marsh Area (m^2)	9,050	77,121
Pond Area (m^2)	1,706	8,243

Table 1: The area of the rail and boardwalk sites along with the area of their ponds.

We focused on a portion of the marsh where the distance between the tree line and the water was narrower, compressing the bands of vegetation into a more easily managed area. The boardwalk area is characterized by large open spaces dominated by reed canary grass with noticeable *T. latifolia* presence. This marsh also has large *Polygonum* plants along with rice cutgrass. The rail marsh is characterized by a large *S. androcladum* community along with *Carex camosa*. Generally, the rail marsh is much muddier than at the boardwalk because the *P. arundinacea* forms a thick mat over the ground.

Plant Abundance and Distribution:

Transects act as a defined sampling area, with data collected within one extrapolated to look at the site as a whole. Transects were established at both the pond and boardwalk marshes. The transects used in this study followed the guidelines of the Ohio Environmental Protection Agency (EPA) as outlined in the Integrated Wetland Assessment Program (Mack 2007), adjusted to suit the size of the areas sampled. A “standard” plot is listed as being 20 meters wide and 50 meters long, oriented to best capture the communities present at the marsh in question; this was modified to 10x50 meters. At the boardwalk marsh in particular, the transect was established in such a way as to emphasize the prevalence of reed canary grass while also allowing for investigation of the bands of vegetation observed closer to the water. Both transects were divided into five 10x10m^2 sections. Each 10x10m^2 square was be identified by a number, starting with 1 for the square by the tree line and 5 for the square in the open water of the marshes' ponds.

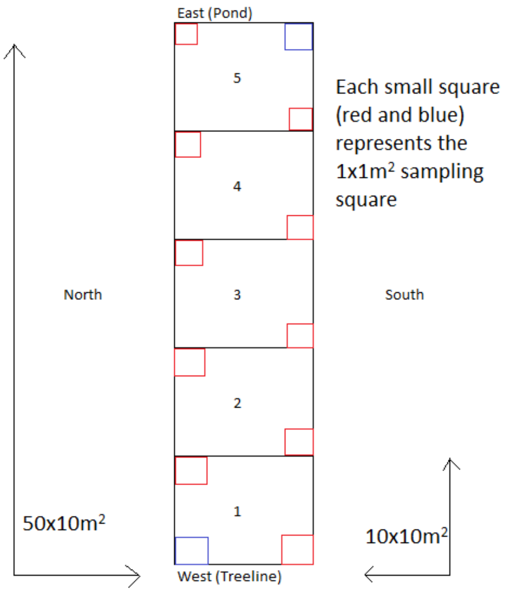
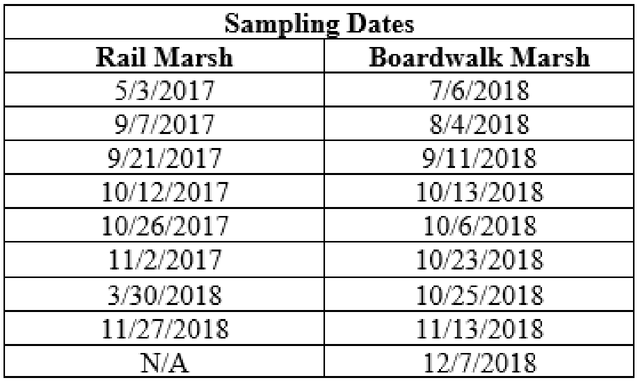


Figure 3: Structure of the transect design used at each site, 10 meters wide and 50 meters long divided into five 10x10 meters squared sections.

The rail marsh areas were sub-sampled using a 1x1m^2 sampling square, sampling the northeast and Southwest corners along with the Southeast corner of Square 1 and the Northwest corner of Square 5. The transect at the boardwalk focused on sampling the southern line of the transect (Southwest corner of Square 1 to Southeast corner of Square 5). For *S. nigra,* all individuals within each area were counted while for *C. stolonifera* all corners, along with the center of each western and eastern line, were sampled. Having the transects stretch from the tree line to the open water allowed them to better represent the several communities that may be present in the marshes. All plant species within the 1x1m^2 were identified and counted, making it possible to measure the abundance of each species in each square. These data are then compiled to assess distribution of species across the transect, demonstrating the fluctuations within the plant community throughout the site.

At the boardwalk marsh a similar method was used with some modification. In squares that were overwhelmingly reed canary grass dominated, the 1x1m^2 was used to identify and count non-reed canary species. Once this was done, a smaller 0.5x0.5m^2 was used to sample the densely-growing reed canary grass. This made it possible to account for other species within the sampling area without the difficulty of counting a massive amount of reed canary plants. Despite being abundant at both sites, only two individuals of *T. latifolia* fell within the initial sampling done at the boardwalk site while cattail at the rail marsh had not been collected for biomass, as sampling occurred before it was determined that cattail should be collected. To mediate this, cattail was collected separately at each site from other species collected.

For both marshes, sampling took place over the course of several months. While guidelines suggest that the best sampling window is from mid-June to late August, sampling in the project included spring, summer, and fall dates.



Sampling Dates	
Rail Marsh	**Boardwalk Marsh**
5/3/2017	7/6/2018
9/7/2017	8/4/2018
9/21/2017	9/11/2018
10/12/2017	10/13/2018
10/26/2017	10/6/2018
11/2/2017	10/23/2018
3/30/2018	10/25/2018
11/27/2018	11/13/2018
N/A	12/7/2018

Table 2: A list of sampling dates for both sites.

The transect at the rail marsh was established in spring 2017 and sampling was able to begin immediately in the fall. At the boardwalk marsh, August and September of 2018 were used to establish the transect which delayed collection. Although sampling was targeted in such a way that areas expected to have fragile species were sampled before those where the vegetation would maintain integrity later into the year, the wide sampling window and timeframe difference between the two sites means that some specimens may have been overlooked.

Floral Quality Assessment Index and Simpson's Index:

The sampling process required that the plant species in the transect and in the larger area of each marsh be identified, something which was possible with the help of various taxonomic keys. As much of the vegetation consisted of flowering plants, *Newcomb's Wildflower Guide* by Lawrence Newcomb was the main source used in identification; Lucy Braun's *Monocotyledoneae* and Edward Voss' *Michigan Flora* were also used, and all plant identifications were checked in the United States Department of Agriculture's Plant Database. Additionally, plant identifications were verified by a local naturalist familiar with Ohio flora.

Knowing the identity of species made it easier to categorize the species found through features such as genus and also allowed use of the Floristic Quality Assessment Index (FQAI) and Simpson's Index (Andreas et al. 2004). For example, *S. androcladum* was of interest not only due to its major presence at the rail marsh but also because of its status as a high-quality species as listed in the FQAI while *P. arundinacea*, as an invasive, has a ranking of 0 (Andreas et al. 2004). The generalized metric of using the quality rankings of all species present is fit for comparing the rail and boardwalk marshes due to apparent differences in native species presence. Previously completed work in Ohio sets a precedent for using the FQAI to compare wetland sites, particularly in assessing the quality of restored marshes (Fennessy 1997). Having the information needed to apply this metric to both marshes provides the most room for comparison and could provide insight on the influence of different species on perceived wetland quality according to current standards. Additionally, knowing the species present at both marshes and their corresponding rankings makes it possible to compare whether species with high rankings prefer one marsh over the other. A marsh with multiple high ranking species can be said to be of higher quality than another because of how these rankings are assigned. In the FQAI, rankings are given based on the selectivity of each species, examining factors such as wetland specificity and toleration to disturbance; a plant that might be found in a wide variety of environments is given a low ranking, while a plant that would rarely be found outside of wetland conditions is considered more selective and therefore is assigned a higher rank (Andreas et al. 2004). Unlike other indexes, such as Simpson's Index or the Shannon-Weiner Index, the opportunistic species of a highly disturbed community are weighted differently from the highly specific species of a native community making it a more effective tool for evaluating biodiversity.

The standard FQAI equation was used to calculate wetland quality:

$$I = \Sigma(CC_i/\sqrt{N_{native}})$$

where I is the FQAI score, CC_i is the coefficient of conservation (equivalent to the species ranking in the FQAI) of a plant species, and N_{native} is the number of native species sampled (Andreas et al. 2004).

For the rail marsh, N=8. An example calculation using *S. androcladum,* with a FQAI ranking – or coefficient of conservation value – of 7, is as follows:

$$I = (7/\sqrt{8})$$

The standard FQAI provides a weighted method of assessing the selectivity of species present at a site and thereby assessing biodiversity (Andreas et al. 2004) but does not account for the proportion of species present at a site.

For this reason, Simpson's Index was also used to evaluate site quality, particularly given observational differences in percent cover of common species at each location. While the rail marsh seemed to have a mix of species present – though some, like *Sparganium androcladum* were more noticeable – the boardwalk marsh appeared to largely consist of open spaces of *Phalaris arundinacea*. Because of this, it was decided that the proportion of species at each site, referred to as species evenness, should also be taken into account which is possible through Simpson's Index. This metric uses the abundance of species sampled to determine the likelihood that any two randomly selected individuals will be of the same species (Andreas et al. 2007). The weighting is not adjusted for species selectivity like in the FQAI and species evenness is given priority. Other work has shown that relying on Simpson's Index alone may be unsuitable for assessing habitat quality due to its focus on evenness rather than looking at the types of plants living within a community (Santini et al. 2017).

A modified version of Simpson's Index was utilized (Andreas et al. 2004):

$$1 - D = 1 - \Sigma(p_i)^2$$

In this equation, p_i is the proportion of a given species sampled at a site. In the original Simpson's Index equation, D is the Simpson's index value; the modified equation places the outcomes on a scale of limited range for easier comparisons between sites. With 1 being the highest possible score, meaning high biodiversity, and 0 having the lowest biodiversity, it is possible to use plant abundance to measure biodiversity through species evenness at the rail and boardwalk marshes. Using a combination of both the FQAI and Simpson's Index makes it possible to see both the selectivity of species present and how they are distributed across each site to gain a comprehensive view of the quality of each marsh.

Biomass of Major Species:

An additional means for evaluating plant community structure is by measuring average individual plant biomass of dominant species. As a metric sometimes used to look at resource availability or carbon storage in an ecosystem, biomass provides another perspective on the physical composition of a community (Owens, Rogers, Woodroffe 2018). Biomass provides an additional layer of insight – if few individuals are present but those individuals are larger than in denser squares, then those individuals may still make up a large piece of that part of the plant community despite being fewer in number. At the rail marsh, the biomass of two highly prevalent species (*Sparganium androcladum* and *Carex camosa*) was collected for each sampled square. Because of this, the biomass of similarly prevalent reed canary grass and cattail was collected from the boardwalk marsh. To determine biomass, all counted individuals of the species within the 1x1m^2 sampling square were clipped at the base and then dried in a drying oven; after drying, the samples were weighed to find the mass of each sample, giving the total mass of that species per m^2 at its site of origin.

Aerial Imaging of Plant Community Structure:

Additionally, as part of the study, an unmanned aerial vehicle (UAV), aka drone, was used to gather visual data on the distribution and patchiness of plant species present in the survey area. In this study, a DJI Spark drone was used equipped with a 1/2.3 inch complementary metal-oxide semiconductor (CMOS) sensor to capture video at a resolution of 1080 pixels. The drone was flown at heights of approximately 5 and 27.5 meters over the survey area of the boardwalk marsh to capture images of the transect and its surroundings. Aerial data was collected before sampling so that the represented site would be one undisturbed by manual sampling which involved vegetation removal for biomass measurements. The footage was converted into still images and specific pictures chosen to represent the site. After going through both the 5 and 27.5 meter image sets, images from 27.5 meters were chosen for building the survey site. For the purpose of building the digital model, images close to parallel with the ground, as opposed to being taken at an angle, were favored.

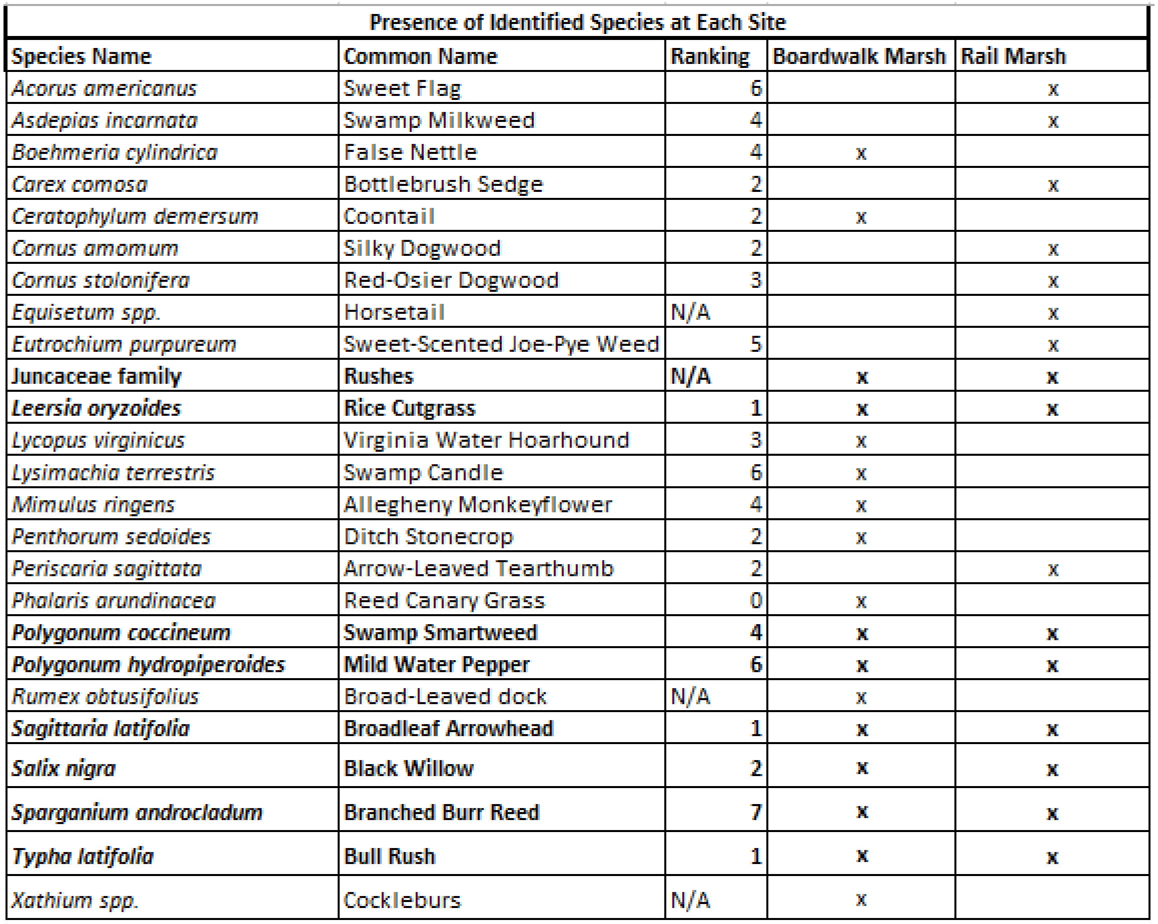
A digital representation of the boardwalk marsh was successfully constructed by georeferencing individual still frames collected from aerial drone footage and combining them into a mosaic of the boardwalk site. Top-down images were used to construct an accurate representation of the site, capturing the entirety of the transect along with the surrounding area. Area 1 by the tree line is partially obscured by the branches, as with a sampling height of 27.5 meters the drone was close to the uppermost branches of the trees. However, much of Area 1 is still visible and the entirety of Areas 2-5 is clear. Additionally, some of the area outside of the transect was also represented to provide a broader view of the transect's location. Having a mosaic image of the transect site made it possible to better see features noticed at ground level with a better resolution than with other tools, such as Google Earth Pro.

By using the manual sampling data to identify the vegetative composition of parts of the transect shown, a classification algorithm was trained to distinguish vegetation types and extrapolate beyond the sampling area to classify the entire represented site. Known features were assigned values, resulting in four categories: Reed canary grass, trees, other vegetation, and water. The percent cover of *P. arundinacea* as determined through digital analysis can be compared to manual sampling results to verify the accuracy of the digital sampling.

Results:

Identification and Species Richness:

At each site, various plant species were found both within and outside of the established transects (Table 2). Some species, such as *Carex comosa* and *Phalaris arundinacea* were unique to the rail and boardwalk marshes respectively; others, such as *Typha latifolia*, could be found at both locations. Initial observations found large quantities of *Sparganium androcladum* and *Carex comosa* at the rail marsh along with *P. arundinacea* and *T. latifolia* at the boardwalk marsh, with *T. latifolia* and *S. androcladum* being present at both sites.



Presence of Identified Species at Each Site

Species Name	**Common Name**	**Ranking**	**Boardwalk Marsh**	**Rail Marsh**
Acorus americanus	Sweet Flag	6		x
Asdepias incarnata	Swamp Milkweed	4		x
Boehmeria cylindrica	False Nettle	4	x	
Carex comosa	Bottlebrush Sedge	2		x
Ceratophylum demersum	Coontail	2	x	
Cornus amomum	Silky Dogwood	2		x
Cornus stolonifera	Red-Osier Dogwood	3		x
Equisetum spp.	Horsetail	N/A		x
Eutrochium purpureum	Sweet-Scented Joe-Pye Weed	5		x
Juncaceae family	**Rushes**	**N/A**	**x**	**x**
Leersia oryzoides	**Rice Cutgrass**	**1**	**x**	**x**
Lycopus virginicus	Virginia Water Hoarhound	3	x	
Lysimachia terrestris	Swamp Candle	6	x	
Mimulus ringens	Allegheny Monkeyflower	4	x	
Penthorum sedoides	Ditch Stonecrop	2	x	
Periscaria sagittata	Arrow-Leaved Tearthumb	2		x
Phalaris arundinacea	Reed Canary Grass	0	x	
Polygonum coccineum	**Swamp Smartweed**	**4**	**x**	**x**
Polygonum hydropiperoides	**Mild Water Pepper**	**6**	**x**	**x**
Rumex obtusifolius	Broad-Leaved dock	N/A	x	
Sagittaria latifolia	**Broadleaf Arrowhead**	**1**	**x**	**x**
Salix nigra	**Black Willow**	**2**	**x**	**x**
Sparganium androcladum	**Branched Burr Reed**	**7**	**x**	**x**
Typha latifolia	**Bull Rush**	**1**	**x**	**x**
Xathium spp.	Cockleburs	N/A	x	

Table 3: A list of the species found at each site and their qualities as designated in the Ohio Vascular Plant Database (Andreas et al. 2004). As an introduced rather than native or invasive plant, *Rumex obtusifolius* is not given a ranking. Plants not identified to the species level have been listed to their closest level of classification.

In total, the boardwalk had 17 different plants while the rail marsh had 16; 8 plants were found at both sites.

Biodiversity:

Differences in vegetation were clear between the two sites. The boardwalk marsh had a higher number of species, but the range of these species were very limited. The rail marsh demonstrated greater evenness, and while *S. androcladum* was a common feature along the transect other species were also present in relatively high abundances (Figure 4). This is in contrast to the boardwalk marsh, where *P. arundinacea* dominates in each location it grows in including most of the sampled transect (Figure 5) with the exception of Area 5.

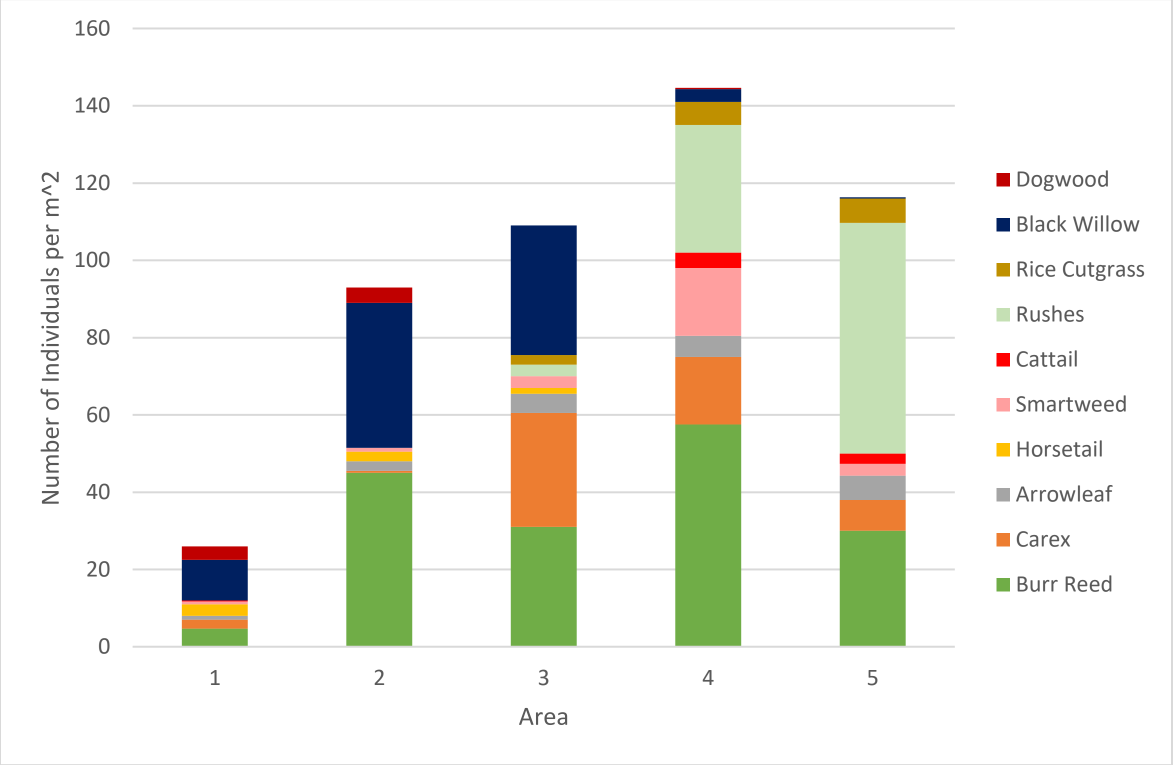


Figure 4: The average abundance of species across the rail marsh transect. Because two sampling lines were done at the rail marsh, the average of samples of a species was used for each area.

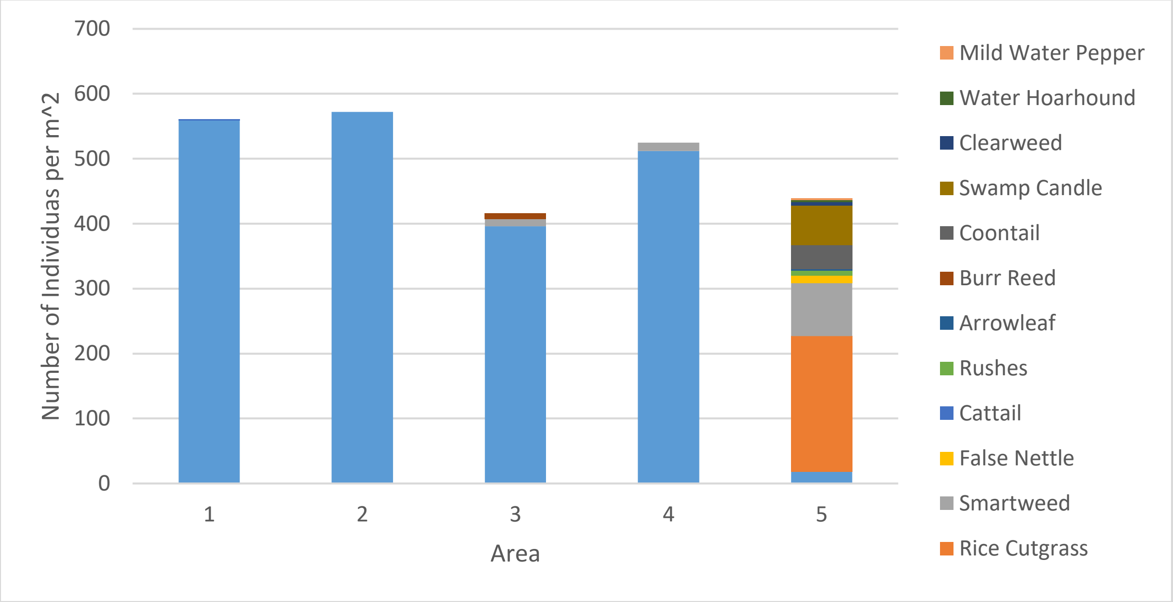


Figure 5: Abundance of species across the boardwalk marsh transect. Note that Areas 1-4 are almost entirely *Phalaris arundinacea.*

Every area of the rail marsh had more species per m^2 than corresponding locations of the boardwalk marsh with the exception of Area 5, which had 8 species at the rail marsh and 9 at the boardwalk site. However, despite having more species present, the total number of individuals counted across species per m^2 was lower than abundance values of *P. arundinacea* at the boardwalk marsh. While *S. androcladum* and *C. camosa* dominated the rail marsh, their abundance was far lower than that of *P. arundinacea.* Overall, the number of species observed increased along the length of the rail marsh transect before dropping in Area 5 by the water. At the boardwalk marsh, however, each area is entirely (or nearly so) *P. arundinacea* except for Area 5, where it is seemingly replaced with *Leersia oryzoides.* It was found that *S. androcladum* on average made up between 20-70% of the plants counted at the rail marsh while *P. arundinacea* consisted of 95-100% of plants counted in all but Area 5 of the boardwalk marsh.

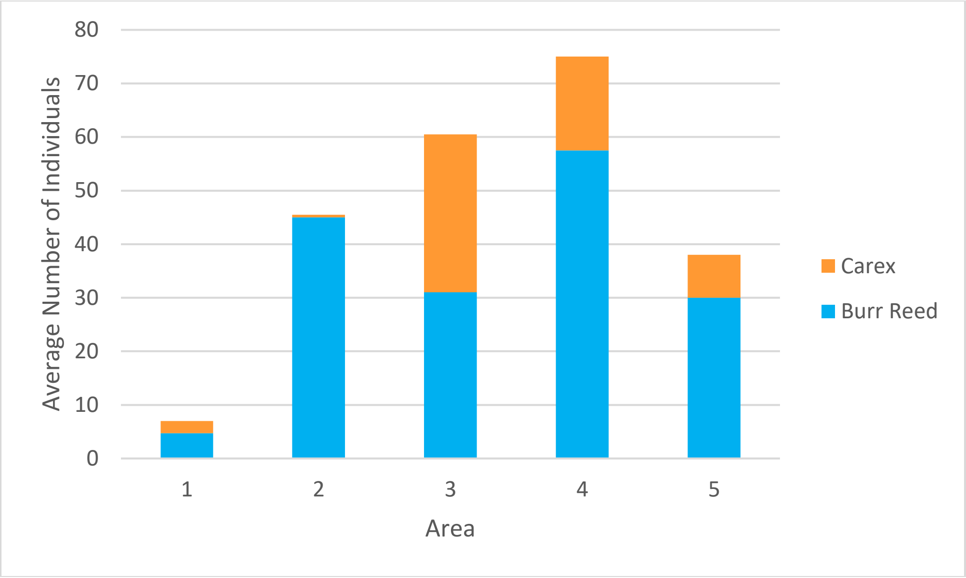


Figure 6: A comparison of the abundance of *Sparganium androcladum* and *Carex comosa* across the rail marsh.

Unlike *P. arundinacea,* which had a steady presence across the transect up until Area 5, *S. androcladum* in the rail marsh varied more in its abundance. At the rail marsh, *S. androcladum* had low presence in Area 1 by the tree line, and peaked in Area 4 – closer to the water, but not at the pond's shore. Towards the middle of the transect was also where *C. comosa* peaked, with its highest abundance being in Area 3. While *S. androcladum* was mixed with large numbers of *Carex comosa,* the boardwalk marsh transect did not show a similar balance between *P. arundinacea* and *Typha latifolia*. In contrast, the *P. arundinacea* of the boardwalk marsh was at its highest abundance in Areas 1 and 2 and only slightly dropped in Areas 3 and 4, with Area 4 having the lowest abundance. While *T. latifolia* was at the boardwalk marsh as shown in Figure 7, very little was captured in the initial boardwalk sampling and was vastly outnumbered by the amount of *P. arundinacea* present.

In the area where *P. arundinacea* was least abundant, the next most abundant plant was *L. oryzoides*, a native species of low quality. While *S. androcladum* abundance fluctuated along with *C. comosa* over the course of the rail marsh transect, *P. arundinacea* steadily increased along the length of the boardwalk marsh transect before suddenly dropping near the water, with only a small amount of *T. latifolia* recorded at the tree-line. While both *S. androcladum* and *P. arundinacea* are examples of species being widely present throughout a site, they distribute themselves very differently in their respective locations.

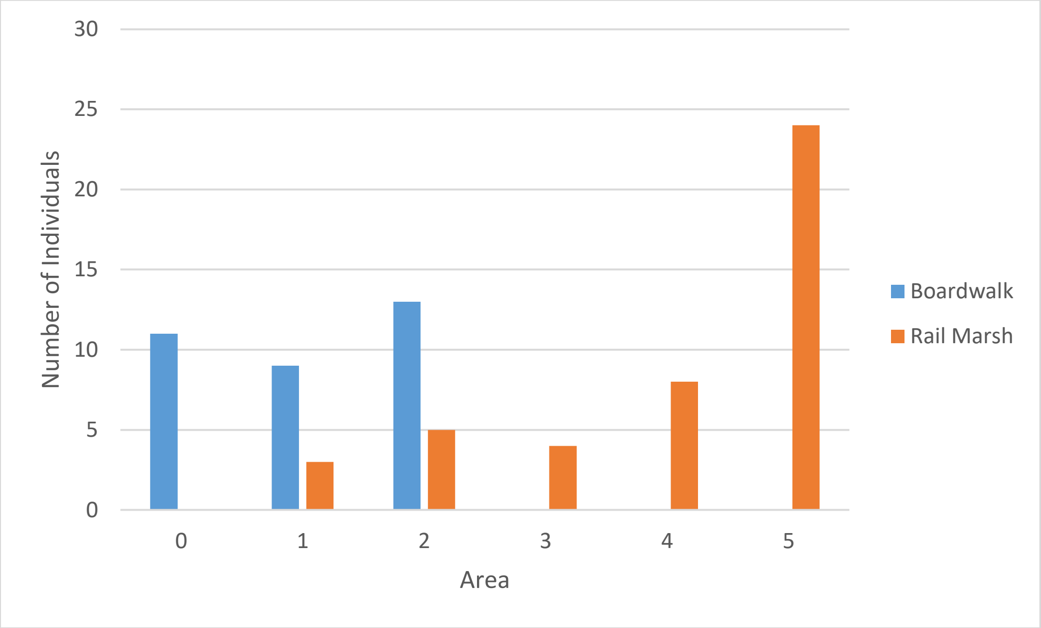


Figure 7: The abundance of cattail across the boardwalk and rail marshes. Area 0 refers to a sampling square beyond Area 1 towards the tree line at the boardwalk marsh to provide enough data for comparison, as *T. latifolia* was not present beyond Area 2. Rail marsh sampling used the established Areas 1-5 and an equivalent sample for Area 0 was not taken.

The two sites demonstrated opposing patterns in cattail distribution as shown by Figure 7. At the boardwalk marsh, *T. latifolia* was found at the marsh's edge near the tree line. Inwards from Area 2, cattail was not present as the site transitioned to open spaces of *P. arundinacea* and *Polygonum spp.* At the rail marsh, however, *T. latifolia* was concentrated at the marsh's edge by the water in Area 5. This abundance dropped in Area 4 then remained steady across the rest of the transect. Compared to values in Figures 6 and 7, if excluding Area 1 (where *S. androcladum, C. comosa,* and *T. latifolia* all have low abundance), *T. latifolia* abundance is greatest where *S.*

androcladum and *C. comosa* values are lowest. Count values at both sites for *T. latifolia* were overall lower than the abundances of *S. androcladum, C. comosa,* and *P. arundinacea*.

FQAI and Simpson's Index:

Adding the sums of each coefficient of conservation over the number of native plants for the rail marsh produces a FQAI score of 7.4. For the boardwalk marsh, a score of 11.2 was found, an unexpectedly higher result. The boardwalk marsh did have more species across its transect, with most of the biodiversity occurring in Area 5. Overall, while the boardwalk transect had more selective species, Figure 5 shows that most of these species are isolated and that the majority of the site remains invasive *P. arundinacea.* Additionally, the Simpson's Index score for each site was found. The rail marsh received a relatively high score of 0.71 while the boardwalk marsh only received a score of 0.31. This matches the results of Figures 4 and 5, which show a blend of species across the rail marsh transect but a heavily skewed distribution of species at the boardwalk marsh. Together, these values show that while most of the biodiversity at the boardwalk marsh was isolated in Area 5, some of the species in that area were unexpectedly selective; meanwhile, while the species at the rail marsh were less selective, they were more evenly distributed rather than any one species controlling the site.

Biomass:

Because initial observations found a high abundance of *P. arundinacea, T. latifolia, S. androcladum,* and *C. comosa* at the two sites, biomass was collected for these species. At the rail marsh, *S. androcladum* was more abundant than *C. comosa* both in regard to the number of individuals present (Figure 6) and also in its biomass (Figure8).

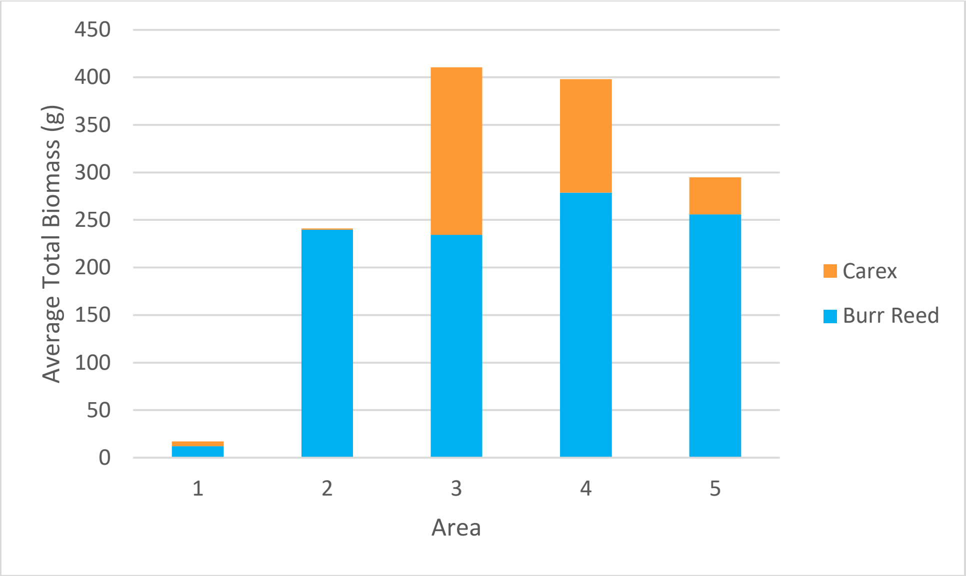


Figure 8: A comparison of the average total biomass of *Carex comosa* and *Sparganium andocladum* across the rail marsh. Averages were taken in the same way as for abundance to represent each area of the transect.

The biomass of *S. androcladum* showed less variation than did the number of individuals present in each area of the transect. Both abundance and biomass peaked in Area 4, but the biomass peak is less extreme. Contrarily, the biomass peaks for *C. comosa* more closely resemble its respective abundance peaks. Both *S. androcladum* and *C. comosa* see low abundance in Area 1 by the tree line; *S. androcladum* biomass remains steady along the course of the transect, while *C. comosa* biomass peaks in Area 3 and then drops as it approaches the water.

Initial observations were that the *P. arundinacea* covered massive stretches of the boardwalk marsh, with little space between individual plants. During sampling they were often tangled together and heavily overlapping with other individuals. Their relative abundance (Figure 5) is further highlighted by *P. arundinacea*’s biomass distribution along the boardwalk transect (Figure 9).

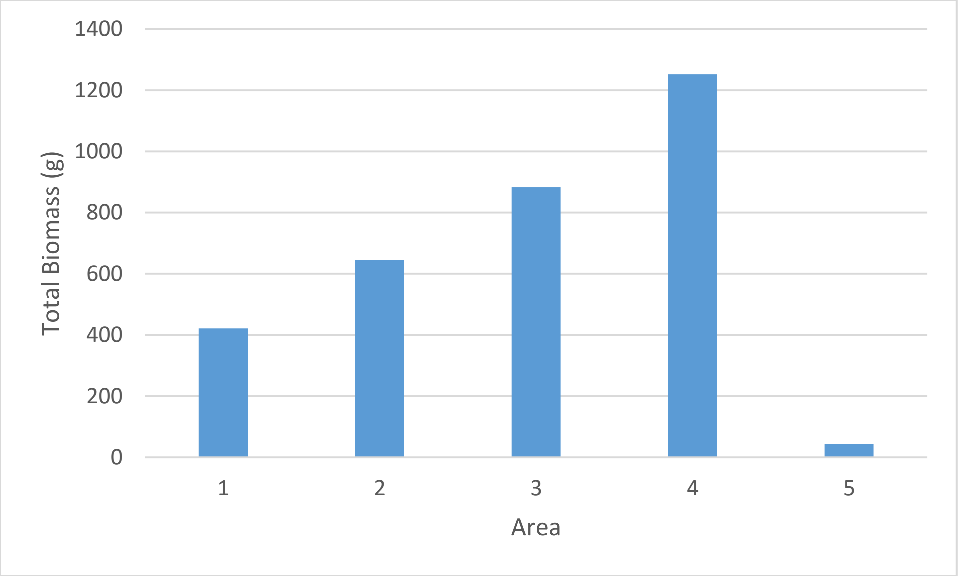


Figure 9: Distribution of the total biomass of *Phalaris arundinacea* across the boardwalk transect. Note that, unlike the relatively level measures of abundance, the biomass increases as the transect approaches the water before abruptly dropping in Area 5.

Unlike *S. androcladum* which maintained relatively steady biomass across the rail marsh transect, or *C. comosa* which had biomass values that roughly correlated with its abundance, *P. arundinacea*’s biomass steadily increases down the elevation gradient of the transect. It peaked in Area 4 before abruptly dropping in Area 5, where barely any reed canary grass was present. However, the individuals counted in Area 1 were generally much smaller and appeared to be much younger than those observed further along the transect. In areas 3 and 4, the individuals counted were larger and thicker, with some extending into the long flags that hold *P. arundinacea*’s seeds. In addition to having a unique biomass distribution, *P. arundinacea* also differs from *S. androcladum* and *C. comosa* in regard to the relationship between biomass and the number of individuals collected.

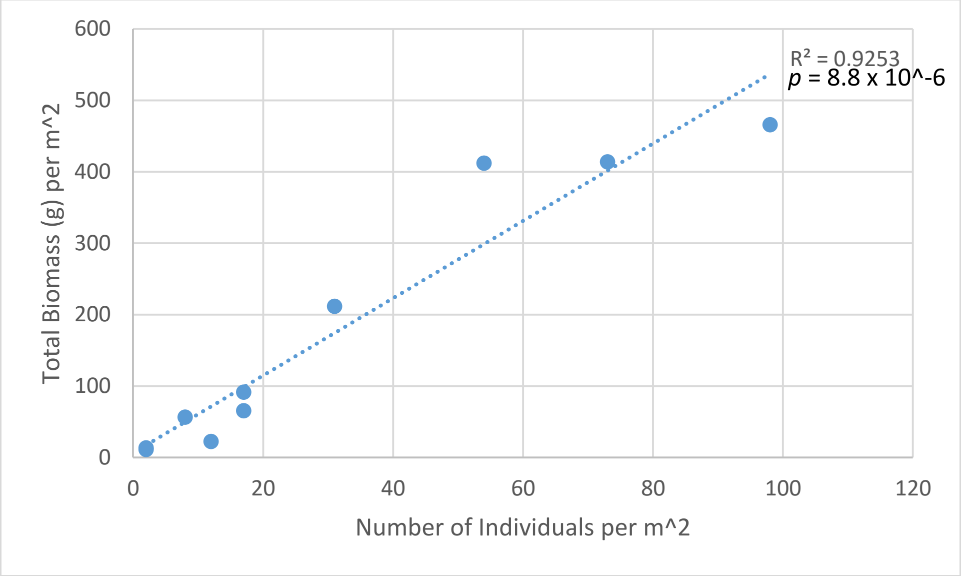


Figure 10: The relationship between the biomass of a given sample and the number of individuals within that sample for *Sparganium androcladum.*

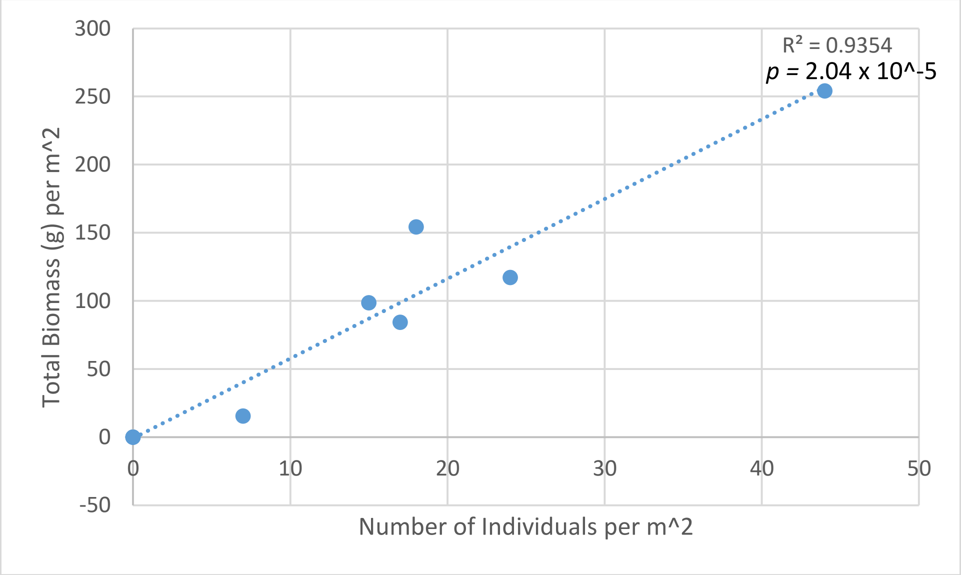


Figure 11: The relationship between the biomass of a given sample and the number of individuals within that sample for *Carex comosa*.

When examining the relationship between biomass and abundance for both *S. androcladum* and *C. comosa* at the rail marsh, they showed positive linear relationships with R^2 values greater than 9 and *p*-values less than 0.05; with more individuals present, biomass was greater (Figures 10, 11). However, *P. arundinacea* did not show a similar trend (Figure 12).

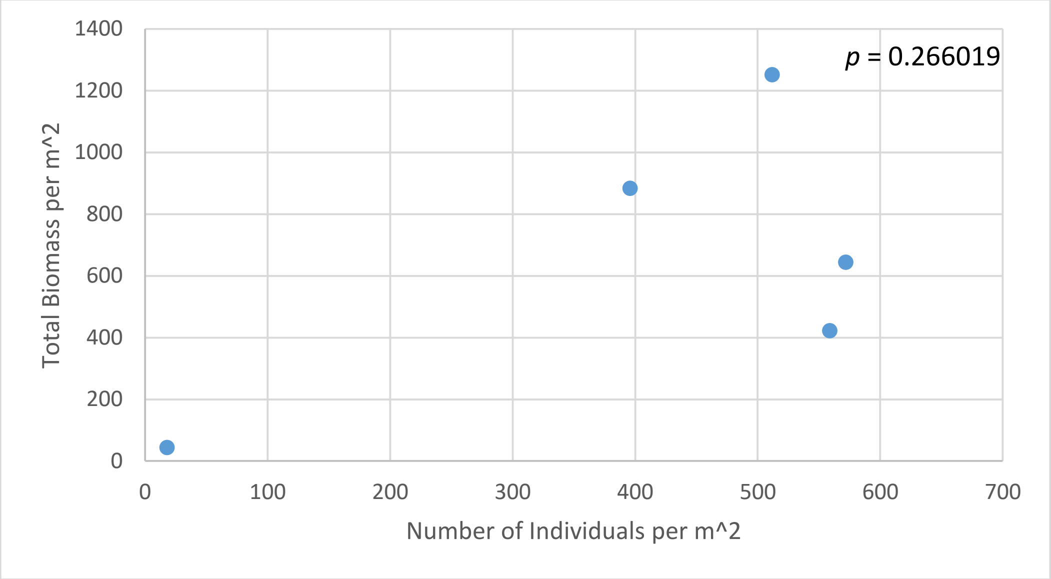


Figure 12: The relationship between the biomass of a given sample and the number of individuals within that sample for *Phalaris arundinacea* at the boardwalk site.

Unlike for *S. androcladum* and *C. comosa,* the relationship between biomass and the number of individuals was not linear for *P. arundinacea*. Instead, total biomass fluctuated with no correlation to the number of plants collected.

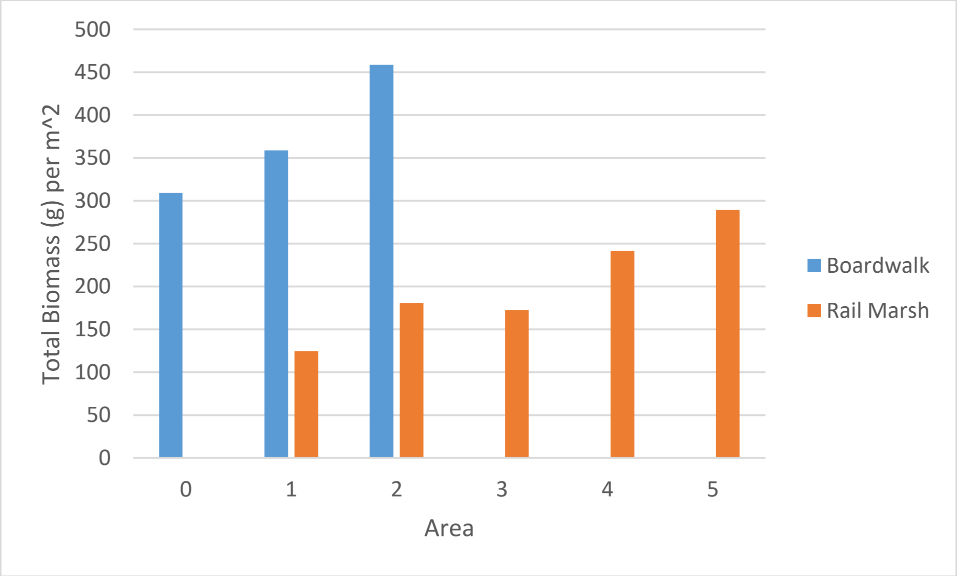
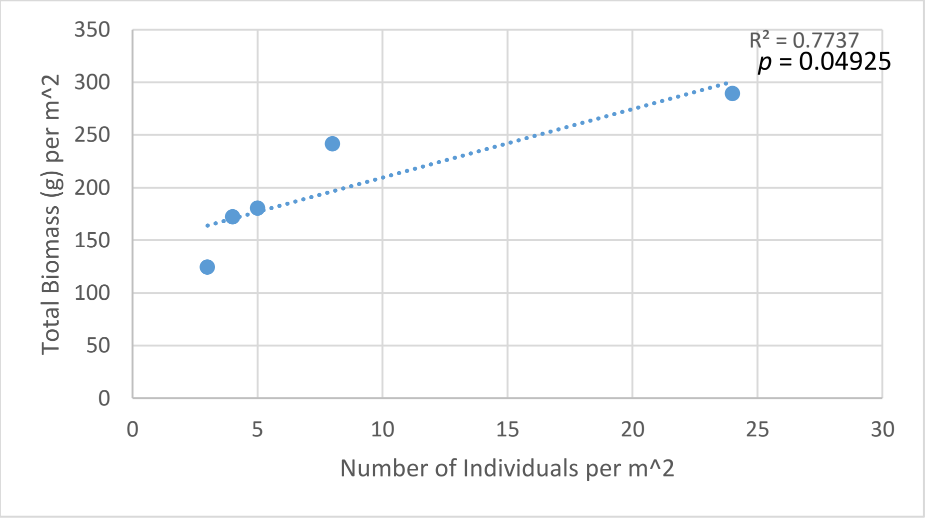


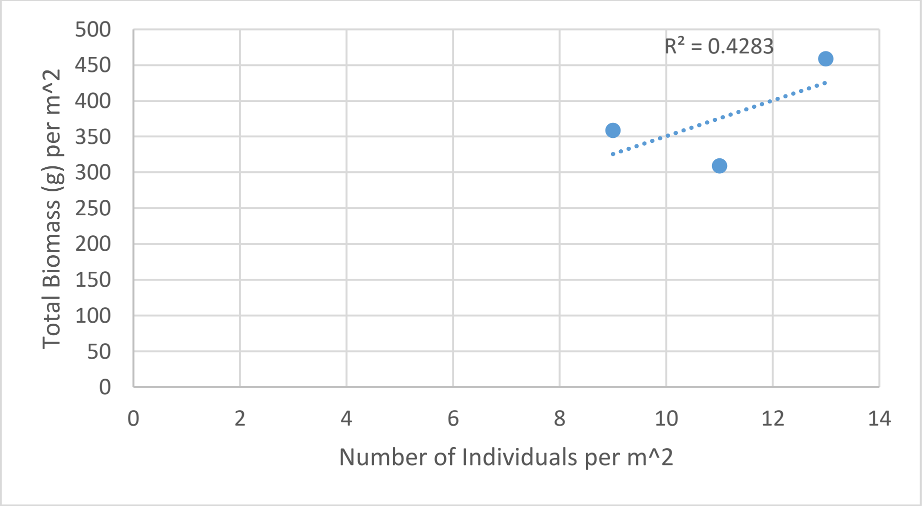
Figure 13: The distribution of the total biomass of *T. latifolia* across the boardwalk and rail transects. As with the abundance data, Area 0 sampling was only done at the boardwalk marsh.

T. latifolia biomass at the boardwalk differed from its fluctuation in abundance shown by Figure 7, as Figure 13 shows biomass steadily rising in the areas in which it is present. However, the rising biomass along its area of occupation is similar to the biomass trend demonstrated by *P. arundinacea* in Figure 9 (although *P. arundinacea's* biomass values are much higher). Meanwhile, *T. latifolia* at the rail marsh followed a similar trend to its abundance shown in Figure 7, showing the same distribution pattern in both values.

While the trend was weaker, *T. latifolia* at the rail marsh also demonstrated a linear relationship between biomass and the number of individuals collected, but only at the rail marsh.



A



B

Figures 14 A and B: The relationship between biomass of a given sample of *T. latifolia* and the number of individuals in that sample; Figure A represents *T. latifolia* at the rail marsh while figure B represents *T. latifolia* at the boardwalk marsh.

The linearity of biomass to the number of individuals collected was stronger at the rail marsh than at the boardwalk marsh. Additionally, while fewer individuals were found at the boardwalk marsh, total *T. latifolia* biomass values were greater than those of the rail marsh.

Finally, the average biomass of individuals from each sample was looked at to see how individual plant size shifts with density across the two marshes.

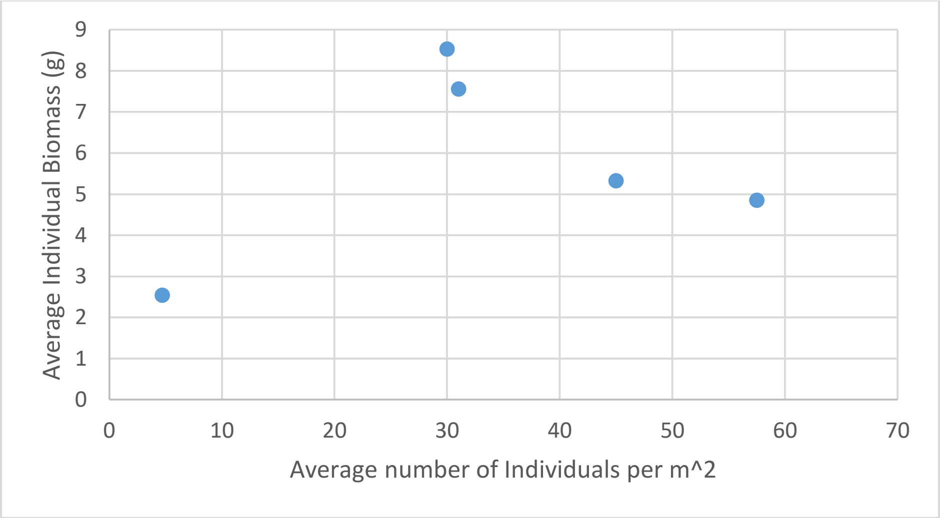


Figure 15: The average individual biomass values as calculated for *S. androcladum* at the rail marsh.

Rather than a linear relationship, individual biomass for *S. androcladum* at the rail site appeared to follow an arc, hitting a peak individual mass at approximately 8.5 grams per individual at densities of 30 individuals per m^2; after this point, individual biomass drops and appears to plateau at approximately 5 grams per individual.

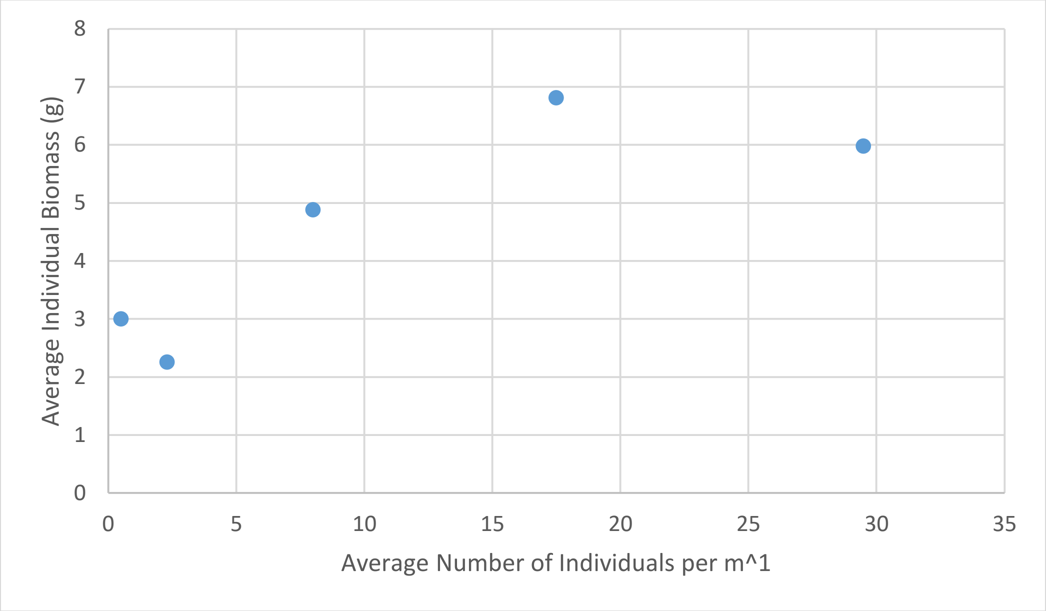


Figure 16: The average individual biomass values as calculated for *C. comosa* at the rail marsh.

C. comosa followed a similar arc-shaped trend, with individual biomass peaking at 6.8 grams per individual at approximately 17 individuals per m^2. However, the drop following the peak is less extreme than as seen in *S. androcladum*.

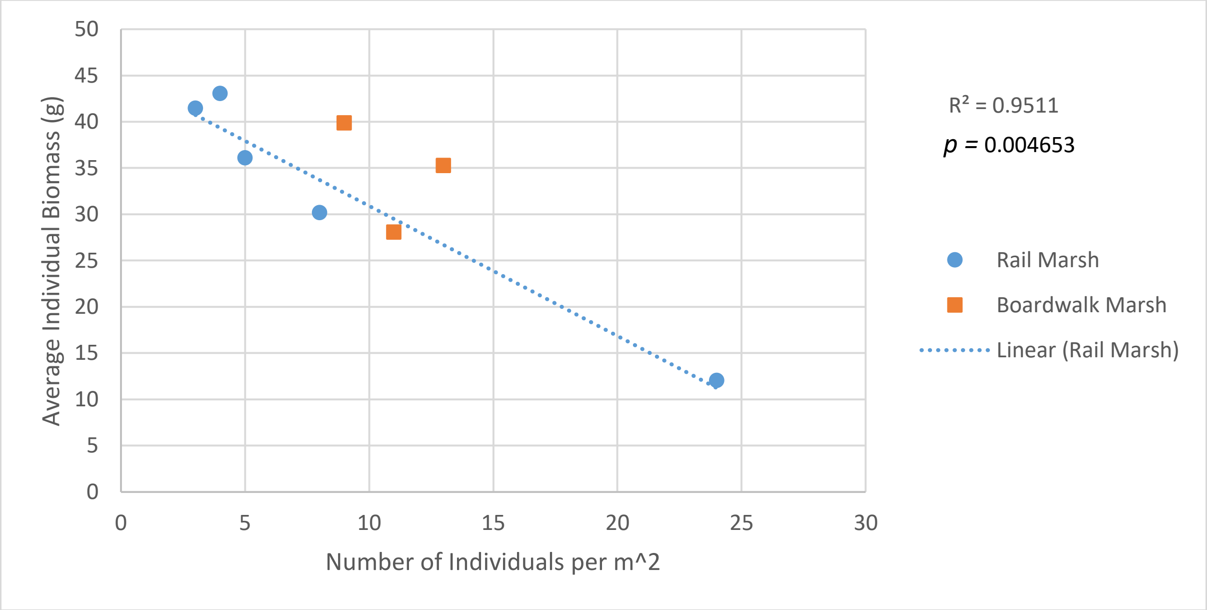


Figure 17: The average individual biomass as calculated for *T. latifolia* at the rail and boardwalk marshes.

At the rail site, *T, latifolia* does follow a linear trend – it hit a peak individual biomass of 43 grams per individual relatively early at 4 individuals per m^2 and then declined as the number of individuals rose. The decline is drawn out more than in the other species, showing a general decline in individual biomass as the density of individuals increases. At the boardwalk site, *T. latifolia* appears to drop in individual biomass before increasing again, but this could be due to variation within the small sample size; further sampling of boardwalk *T. latifolia* could clarify whether a trend is present.

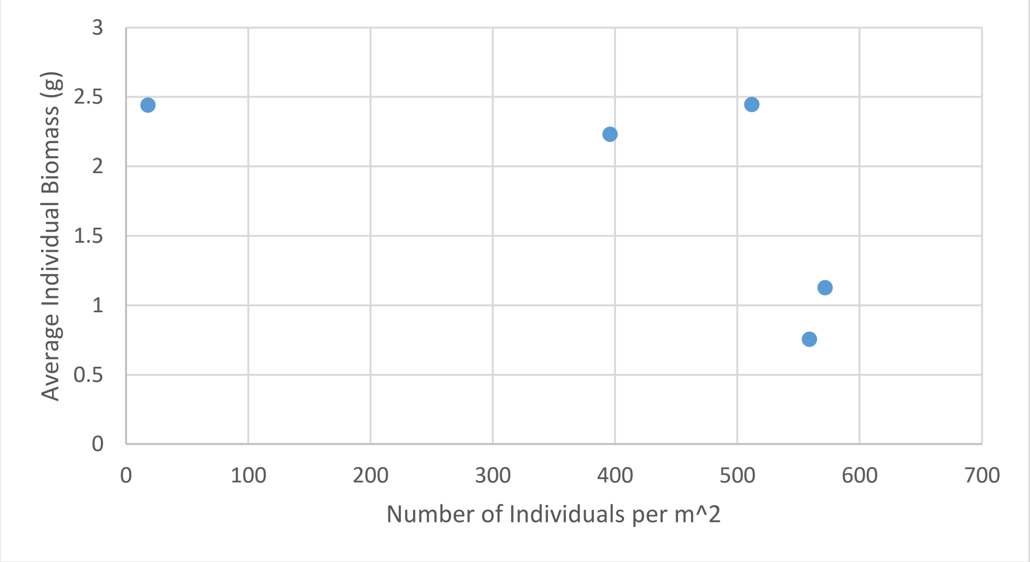


Figure 18: The average individual biomass as calculated for *P. arundinacea* at the boardwalk marsh.

P. arundinacea does not show a similar trend to the other species in individual biomass (Figure 18); rather than forming an arc or showing a general decline in biomass as density increases, *P. arundinacea* biomass per individual remained fairly steady even as density increased until hitting a threshold of approximately 550 individuals per m^2.

Aerial Images:

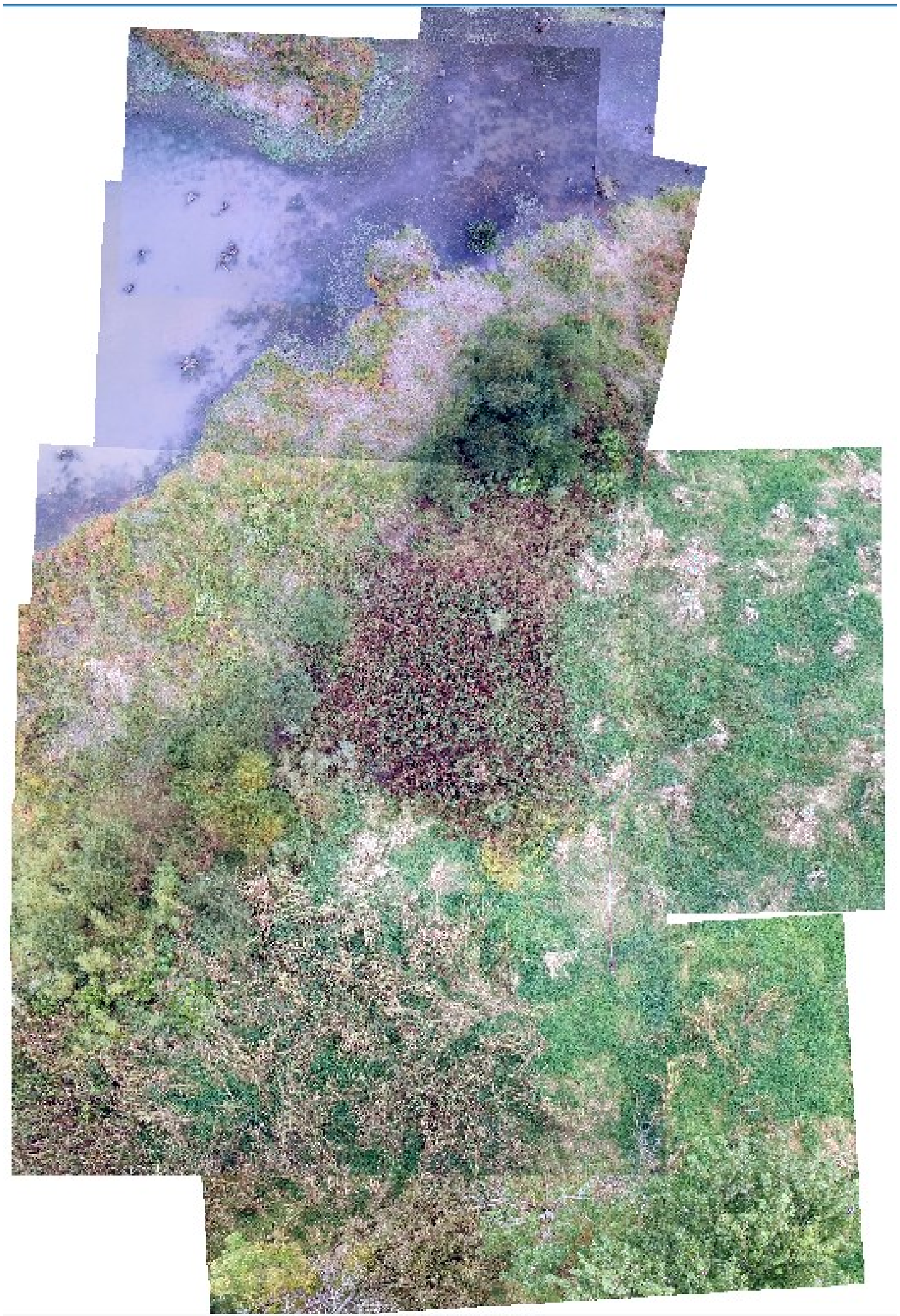


Figure 19: The composite image of the transect and its surrounding area – notice the patch of *S. nigra* in the middle of Area 4, a patch of *P. coccinium* in Area 3, and a patch of *T. latifolia* interspersed with *P. arundinacea* in Area 2. The easternmost edge of Area 1 is partially obscured by trees outside of the transect.

The image shows distinct bands of vegetation consistent with the manual sampling data shown by Figure 5. The manual sampling data found an abrupt jump from a *P. arundinacea*-based community to one dominated by *L. oryzoides* as the transect transitions from Area 4 to Area 5. This is represented in the image by the distinct band at the water's edge, showing the jump from *P. arundinacea* to *L. oryzoides.* However, the image shows other features that were not captured in the manual sampling. While no woody species were observed in Figure 5, the drone image shows a distinct clump of *S. nigra* in the middle of Area 4; also shown is a patch of *P. coccinium* in the middle of Area 3 and a patch of *T. latifolia* in Area 2, with *P. arundinacea* filling the spaces between individuals. These patches all lay within the middle of the transect, and as such are poorly represented by the manual sampling shown in Figure 5. However, the drone image shows that these isolated patches do exist, providing further context outside of what manual sampling alone could represent (Figure 19).

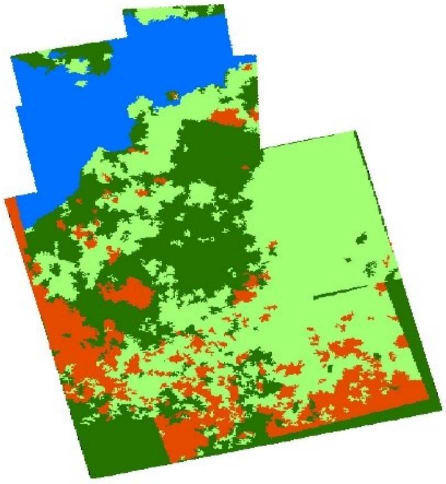


Figure 19: The mosaic of the drone site after classification. Light green represents reed canary grass, dark green represents other vegetation, orange represents trees, and blue represents water.

Through classification of the drone image, it was possible to evaluate percent-cover of different vegetation types.

Class Name	Number of red pixels of this class type	Number of green pixels of this class type	Number of blue pixels of this class type	Sum of pixels/area (m^2)	% area of mosaic this veg type occupies (m^2)
Water	0	112	255	367/234.88	27.01
Other Vegetation	38	115	0	153/97.92	11.26
Reed canary grass	163	255	115	533/341.12	39.22
Trees	230	76	0	306/195.84	22.52
Totals	431	558	370	1359/869.76	100.00

Table 3: The results of performing a supervised classification operation on the drone image.

In the classification process, it was found that almost 40% of the drone image was *P. arundinacea.* Additionally, the algorithm classified 20% of the image as trees while only 11% of cover was classified as other vegetation; water was listed as covering almost one-third of the image.

Discussion:

Overall, differences in the communities of the boardwalk and rail sites were clear. While the rail marsh had a blend of various species across its transect, the boardwalk site was dominated by *P. arundinacea* both in regards to abundance and biomass. This overall greater density and the reduced biodiversity that accompanies it shows how great an effect *P. arundinacea* can have in shaping its surroundings.

Biodiversity and Plant Abundance:

Others studies have found that *P. arundinacea* can reduce the abundance of native plants, with native plant abundance and species diversity being reduced in the presence of *P. arundinacea* (Schooler et al. 2006; Lavergne and Molofsky 2004). The rail marsh was found to have a greater variety of species in each area along the transect compared to the boardwalk marsh, as shown by Figures 4 and 5. The relative abundance of different species in a given area was more even at the rail marsh than at the boardwalk marsh. Nearly all sampling done at the boardwalk marsh yielded predominantly *P. arundinacea* indicating that even with further sampling, the transect is primarily composed of the invasive. Where *P. arundinacea* was the main species present, there were few to no other species present and any natives found in those areas were low in abundance. In Area 5, on the shore by the open water, where *P. arundinacea* was almost absent, both diversity and the abundance of species present increased. This information, along with the presence of relatively selective *L. terrestris* and other native species in the absence of *P. arundinacea*, indicates that the invasive may be outcompeting native species at the boardwalk site. These results would support past studies finding that *P. arundinacea* harms the biodiversity of native plant species, and present a current example of the risk of *P. arundinacea* to preserving native habitats (Schooler et al. 2006; Lavergne and Molofsky 2004; Vitousek et al. 2006). If it were to spread to other sites at the Black Fork Wetlands Preserve, such as the rail marsh, it is likely that much of the current native vegetation would be pushed out and lost.

Another notable difference between the two sites is the lack of woody vegetation at the boardwalk marsh. At the boardwalk site, woody species were sparse with the most notable example being a clump of *S. nigra* in the middle of Area 4. However, the rail marsh had woody

S. nigra and *C. stolonifera* across its length mixed with herbaceous vegetation such as *S. androcladum* and *C. comosa.* Areas 2 and 3 in particular had the most even mix of herbaceous and woody vegetation. This could be related to the overall reduced biodiversity at the boardwalk site due to *P. arundinacea* as shown by other studies (Schooler et al. 2006; Lavergne and Molofsky 2004; Vitousek et al. 2006). The boardwalk site was historically forested and cleared sometime after the year 2000; introduction of *P. arundinacea* afterwards may have prevented repopulation by species like *S. nigra* in addition to interfering with native emergent vegetation. One potential area of future work would be to explore the effect that *P. arundinacea* may have on the growth of woody species – while many studies focus on the invasive's effect on emergent vegetation, little work has been done exploring a connection between *P. arundinacea* and species like *S. nigra* and *C. stolonifera*. It may be that *P. arundinacea* blocks new sapling growth in a manner similar to how it blocks growth of emergent vegetation through its dense coverage of invaded habitats.

One problem encountered was that 3 samples could not be identified to a species level, 2 of which were sampled in the transects themselves: *Equisetum* spp. and rushes from the Juncaceae family. This was especially problematic with rushes, where individuals could be identified as a rush but lacked any fruiting parts to use for further investigation. It was estimated that at least two species of rush may be present due to size differences, but with no identifying features available this could not be confirmed. Rushes typically bloom in the summer from May to July, with some species blooming until August. It is likely that the sampling window played a role in missing the identifiable features – sampling for identification purposes was started in early July, but transect sampling was completed largely in late August and early September, which is after most vegetative surveys end (Mack 2007). This means that for many species the prime sampling window may have been missed both at the rail and boardwalk sites. However, the late sampling time was mitigated to as great an extent as possible by collecting some identification data in the summer and prioritizing locations near the water with more fragile species like *S. latifolia.* Given that many species were present in both the summer and the fall – with many persisting and remaining identifiable even through October - and that multiple features including flowers, seeds, and leaf shape were used to identify species, it is reasonable to say that the transects represent the major species present at each site despite this setback.

FQAI and Simpson's Index:

Both the FQAI and Simpson's Index were used to assess wetland quality at the rail and boardwalk marshes. It was expected that the rail marsh would have a higher FQAI and a higher Simpson's index score because it lacked the invasive *P. arundinacea*; however, the FQAI score indicated that the rail marsh was of lower quality than the boardwalk marsh while the Simpson's Index score at the rail marsh was higher than at the boardwalk as expected. Combined, these two metrics show that species at the rail marsh are less selective but have a more balanced distribution while the boardwalk marsh has some higher ranked species despite *P. arundinacea* dominating much of the site.

Previous work with the FQAI has focused on measuring the effectiveness of wetland restoration and has found that native wetlands tend to achieve higher scores; it is reasonable to think that this would hold true when comparing a native marsh to one that has been invaded (Fennessy 1997). In this regard, the lower FQAI score at the rail marsh is particularly surprising. However, it is worth noting that compared to other sites examined, the FQAI scores at both the rail marsh and boardwalk site are quite low (Andreas et al. 2004). It is possible that this is in part due to the project's small size and, as a result, limited sampling effort; for the purposes of this study, it is still valuable to compare the FQAI values of the two sites in relation to eachother.

The difference in species evenness between the two sites was part of why they were chosen for comparison. Initial observations noted a variety of plant species present and in variable quantities at the rail marsh, while the boardwalk presents as a monotypic habitat of *P. arundinacea* with few other species of note, such as *T. latifolia* and *Polygonum coccineum.* The FQAI focuses on the selectivity of species observed at the site while Simpson's Index prioritizes species evenness and biodiversity, regardless of species selectivity (Andreas et al. 2004). The boardwalk marsh had some selective species present such as *Lysimachia terrestris* but the FQAI did not account for their low abundance in comparison to species such as *P. arundinacea* and *L. oryzoides.* Similarly, the rail marsh had species ranging from low to high quality but in abundances that were move even, with no one species taking over the transect at the same level as was seen at the boardwalk marsh. The FQAI index results indicate that, despite the overwhelming amount of *P. arundinacea* present, the boardwalk marsh does have the potential to be a high quality site due to the presence of selective species like *Lysimachia terrestris* and *Polygonum hydropiperoides*. If *P. arundinacea* were removed, the site could potentially become occupied by these higher-quality species; additionally, the small amount of *S. androcladum* found indicates that the site could develop an emergent community more similar to that of the rail marsh. Future projects could test potential reclamation by removing patches of *P. arundinacea* and observing whether native species take its place.

Biomass:

In general, it was expected that the trend between the number of individuals collected and biomass would be linear with more individuals resulting in a higher recorded mass. A linear trend was noticed in the relationship between biomass and the number of individuals collected for *S. androcladum, T. latifolia,* and *C. comosa* which was expected. Surprisingly, *P. arundinacea* did not follow this trend and instead seemed to have little correlation between biomass and the number of individuals collected, indicating that the total biomass of a sample was not dependent on the abundance of *P. arundinacea* at the sampling site. It is suspected that the vegetative growth of *P. arundinacea* is responsible for the lack of an observable trend.

Vegetative growth of *P. arundinacea* was widely present at the boardwalk marsh; it can grow from a seed into a new plant, but may also reproduce by budding with thick rhizomes that stretch underground (Lavergne et al. 2004). These budding individuals were observed to be thicker, more rigid, and longer than other individuals that were not part of a budding system. *P. arundinacea* also produces tall flags for its seeds, with flagged individuals also being larger and more rigid in structure. A given location can have a mixture of individuals in these different forms, meaning that biomass sees a greater fluctuation on an individual-by-individual basis. As such, when talking about the density of reed canary grass at a site both abundance and biomass should be considered, as the two factors do not seem to correlate as they do for other plant species.

This seemed to be supported by Figures 15 through 17, which show trends in individual biomass – other species, such as *S. androcladum, C. comosa,* and *T. latifolia* at the rail marsh show similar patterns in growth. For these species, individual biomass would increase until hitting a peak and then dropping. *P. arundinacea*, however, maintained a relatively steady individual biomass until suddenly dropping. It is worth noting that the lowest point in Figure 18 is the biomass of individuals from Area 1, while the second-lowest point is the biomass of individuals from Area 2. Both of these areas had individual count values similar to those of

Areas 3 and 4 despite having overall lower biomass values. Area 1 was predominantly young plants while Area 2 had a mix of younger and older plants; further out in the transect, older plants expressing vegetative growth were much more common. Because the first two areas had lower biomass values overall despite having similar abundance values, it seems likely that age of the plants may play a role.

Both the abundance and biomass of *P. arundinacea* are likely to contribute to its ability to form monotypic stands and block out native plant life – little room is left for anything else to grow, and as a species that can reproduce through budding, both above and underground spaces become tangled through the crossing stems and roots (Lavergne et al. 2004). Many studies on *P. arundinacea* have focused on percent cover, with which the high levels of *P. arundinacea* at the boardwalk site are consistent (Schooler et al. 2006; Weilhoefer et al. 2017). With almost 3 times as many individuals of *P. arundinacea* per m^2 at the boardwalk marsh than individuals of all species at the rail marsh, biomass of *P. arundinacea* alone at the boardwalk site was almost double that of *S. androcladum, C. comosa,* and *T. latifolia* combined at the rail site, emphasizing the density of *P. arundinacea* growth and its ability to block out other species.

Aerial Imaging:

It was possible to form a composite image of the transect site in addition to some of the surrounding area with limitation. While it was possible to represent the transect using detailed digital images, footage of the transect was captured unevenly, with the northern side having more photos parallel to the ground while footage from the southern side tended to be at a more oblique angle. Additionally, the northern side was overall filmed more than the southern side; though the transect was successfully constructed, the ability to represent areas outside of the transect was limited. It is recommended that future studies ensure that the camera remains as parallel to the ground as possible when collecting footage and that, if the sampling procedure remains undefined, the entire area be equally covered to ensure easier digitization of the study site.

Other studies on using a drone for vegetative classification have focused on the presence of a specific species or multiple but distinct species rather than looking at mixed community features (Sandino et al. 2018; Zhou et al. 2018). In some ways this study was similar in regards to focusing on the presence of *P. arundinacea* at the boardwalk site, but there was a greater focus on the overall structure of the vegetative community with an interest in seeing how the species present are distributed and how such distribution may relate to potential for usage of the site by Virginia and Sora rails. Other studies have also used RGB (red, green, and blue) spectrum data to classify vegetation (Sandino et al. 2018; Senthilnath et al. 2017; Zhou et al. 2018).

The classification results attained somewhat accurately represent the site, but with some error. Some areas known to be other vegetation, such as *Polygonum*, were misclassified as trees while parts known to be predominantly *Leersia oryzoides* were identified as *P. arundinacea.* However, many areas were successfully categorized successfully with *P. arundinacea* classification appearing, despite some error, similar to what is seen in the initial drone image. A supervised classification was used, meaning that pixels of known species were chosen and the RGB values fed into the algorithm. By continuing to train the algorithm by feeding in more values to aid it in the process of categorizing pixels by vegetation type, the system can become more accurate and thus better represent the site. Overall, these results show that supervised classification is a viable means of representing areas of interest and could be used to extrapolate outside of the initial transect; however, because the supervision requires a knowledge of the plant life present at the site, it seems prudent for manual sampling data to continue to support the processing of aerial images rather than drone photography acting as a replacement.

Regardless, this method of sampling a larger representative area for the boardwalk marsh resulted in being able to see the entirety of the boardwalk site at once, with a clearer and broader view than that offered by on-the-ground observation or tools previously used, such as Google Earth. Being able to see the entirety of the transect in this way was useful because it provides a visual display of the zones observed through manual sampling while also making it possible to evaluate certain vegetation that was not represented through sampling, providing further context to data previously collected. A primary example of this is through the representation of the patches of *Salix nigra, Polygonum coccinium*, and *Typha latifolia* in the middle of the boardwalk transect in Areas 4, 3, and 2 respectively. While these species had some limited representation in the manual sampling along the southern line of the transect as shown by Figure 5, the digital imaging provides a better view of their presence at the marsh. These patches are isolated, surrounded by a *Leersia oryzoides*-dominated community to the north and *Phalaris arundinacea* to the south. This demonstrates that while these species do exist at the boardwalk site, their distribution is far from even – rather, it is patchy and isolated.

Other studies have found that Virginia and Sora rails prefer a mix of woody and emergent vegetation, and the drone images provide further context to how this relates to the boardwalk marsh (Wilson et al. 2018). While no woody species were sampled within the boardwalk transect, the drone images show that woody *Salix nigra* is present at the site but sparse rather than forming the emergent-woody blend seen at the rail site. The observed correlation between a woody-emergent mix and habitat usage by Virginia and Sora rails indicates that the limited presence of woody species at the boardwalk site could be one reason why rails are not observed there. Overall, use of the drone images contributed to understanding the results of the manual sampling within the context of the site as a whole, and provided information that was not represented within the manual sampling alone. In turn, this allows for a better analysis of potential suitability of the boardwalk site for Virginia and Sora rails.

Impact on the Rails:

Other studies have shed some light on both Virginia and Sora rail habitat preferences in regards to the vegetative structure of the marshes they nest and forage in. Ongoing projects tracking rails at the Black Fork Wetlands have primarily observed their presence at a non-invaded marsh with only one rail being observed at the reed canary grass marsh (Tawse, personal observation). Generally, Virginia and Sora rails prefer emergent vegetation for foraging and nesting mixed with woodier species, with lower preference for grass or sedge-based communities; Virginia rails also utilize small mud patches for foraging (Wilson et al. 2018). This is consistent with observations of rails at the Black Fork Wetlands, with repeated observations of Virginia and Sora rails at the rail marsh, which has the patches of woody vegetation distributed throughout it. This is in contrast to the boardwalk site where woody vegetation was sparse, existing in the form of a clump of *Salix nigra* in the middle of square 5 and scattered shrubs as shown by the compiled drone images. Interestingly, although Sora rails also are noted to use habitats with tall *Polygonum* spp. like the *Polygonum coccineum* patch at the boardwalk, the necessity of woody species for rail usage still leaves the boardwalk site currently unsuitable (Wilson et al. 2018). Images taken of rail nests indicate that *S. androcladum* is being used for nesting material by Virginia rails at the rail marsh (Tawse, personal observation). Whether this is because of its abundance at the rail marsh or because of a preference for *S. androcladum* is unclear, but seems to support a disinterest in grasses and sedges; *Carex comosa* and *Leersia oryzoides* are both present at the rail marsh, but do not appear to be utilized for nesting material.

At present, the boardwalk marsh does not have the qualities associated with rail use that we found at the rail marsh.

P. arundinacea is known to outcompete other native species as it homogenizes the spaces it invades. Some emergent species were still found – of particular note, a small amount of *S. androcladum* at Area 3, along with *T. latifolia* near the tree line of the transect. The boardwalk marsh shares other species with the rail marsh, such as *L. oryzoides* and *P. coccineum*, and has other emergent species including *L. terrestris, P. hydropiperoides*, and *P. pumila*. It is possible that, without the presence of invasive *P. arundinacea*, the plant community of the boardwalk marsh would consist of emergent vegetation at least partially similar to that of the rail marsh and some of which have been observed to be used by the rails, such as *S. androcladum*. Because rails prefer emergent vegetation over grasses and sedges, this could make it more appealing to the Virginia and Sora rails of the Black Fork Wetlands; however, the boardwalk had very little woody vegetation. For the boardwalk site to become appealing to the rails, woody species like *S. nigra* would need to expand in addition to the reclamation by native herbaceous vegetation like *S. androcladum* in the event of *P. arundinacea* removal. However, as recently as the early 1990s the site had been forested, and current traces of woody species like *S. nigra* imply that a resurgence in woody vegetation along with native emergent species could be possible. If this were to happen, the boardwalk site may become more suitable for nesting and foraging for Virginia and Sora rails and expand their territory at the Black Fork Wetlands Preserve.

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Biography:

Emily Nicholls was born in Newport News, Virginia on November 16, 1996. She moved to Palau, Italy and later Fallon, Nevada before coming to Ohio and graduating from Mount Vernon High School in 2015. At Ashland University, Emily is majoring in Biology with a minor in Spanish. She works as a writing assistant, Spanish and biology tutor, and S-STEM peer mentor. She has been on the Dean's list 5 semesters and was awarded a scholarship from the Ohio EPA's Environmental Fund. Upon graduation, Emily plans to begin studying for a Ph.D. in Environmental and Occupational Health at the University of Pittsburgh.