USING AVIFAUNA TO ASSESS THE FUNCTIONAL SUCCESS OF THE RESTORED BEAVER CREEK WETLANDS NEAR CAVE RUN LAKE, MENIFEE COUNTY, KY

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by

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Accepted by the faculty of the College of Science and Technology,
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Master of Science in Biology degree.

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ABSTRACT

Wetlands are being constructed as a mitigation requirement to replace natural wetland functions lost due to human activities. Few long-term (>5 y) follow-up studies have been conducted on constructed wetlands to determine if they function like the natural systems they were designed to replace. Birds can provide a good indication of functional success, as they are present at multiple trophic levels. The presence of obligate wetland species should suggest that wetland functions are meeting these organism's life requirements. We surveyed avifauna bimonthly from June 2013 – May 2014 in 14 constructed wetlands in the Beaver Creek Wetland Complex, and at a nearby oxbow wetland (the reference site). Compared to the reference site, individual constructed wetlands had lower species richness and abundance, and approximately 70%-80% of the diversity (H' and D) observed in the reference site. Constructed wetland avian community overlap was approximately 70% - 75% similar to the reference wetland. Seasonally, avian metrics were most similar between constructed and reference sites in the spring and breeding season, and most different in the fall and winter. Diversity indexes declined sharply in the constructed wetlands in the fall and winter, while reference wetland diversity remained stable throughout the year. Water chemistry results suggest substrate developments may take decades more to accumulate the organic material and benthic flora similar to natural riparian wetlands. Our results suggest that 30 years post-restoration, the Beaver Creek Wetlands are not fully functional as natural wetlands systems; however they support diverse bird and wetland bird communities.

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CHAPTER 1

Introduction

Wetlands are one of the most important ecosystem types in the world, and provide high biological diversity and valuable ecosystem services (Mitsch and Gosselink, 2007). The United States has lost over 53% of its 89.4 million hectares of pre-European settlement wetlands (Dahl, 2011). Kentucky has posted a loss of nearly 90% (Bishel-Machung et al., 1996; Dahl, 2011). Policy changes, such as the Clean Water Act of 1972 have resulted in restoration of wetland area through implementation of protective actions based upon guidelines in the statute and resulting court decisions. To meet national goals, constructed wetlands are often built as mitigation for projects that destroy or alter existing wetlands (NAS, 2001).

Determining the success of a wetland mitigation project is often a neglected part of the process. For example, in most cases, post-restoration monitoring is only required annually for a maximum of five years (USEPA, 2008). In 2004, national goals of "no net loss" policies were changed to net gain goals (Dahl, 2011). In the most recent US Fish and Wildlife Service report on wetland status and trends in the United States, Dahl (2011) determined during this time in the United States there has been an overall increase in the total amount of freshwater wetlands; however a disproportional amount of this gain came from revised definitions for "freshwater ponds" classifying them as "restored wetlands." Despite this, total *vegetated* freshwater wetland area has declined. From 2004-2009, wetlands continued to decline across all categories.

Assessment of Wetland Restoration: Structure v. Function

Over the past two decades, a plethora of post-monitoring research suggests that constructed or restored wetland ecosystems do not usually function similarly to undisturbed natural systems (Bedford, 1996; Hilderbrand et al., 2005; Hoeltje and Cole, 2009; Maron et al., 2010; Minkin and Ladd, 2003; Race and Fonseca, 1996; Reiss et al. 2009; Suding et al., 2004; Woodcock et al, 2011; Zedler and Calloway, 1999). Often, wetlands are constructed to achieve compliance success rather than functional success (Kentula 2000). Kentula (2000) defined compliance success as when a project meets the terms of an agreement; usually based upon floristic criteria. Functional success occurs when a project restores the ecological functions of a system, and if the system is biologically viable and independently sustainable.

In practice, it is often assumed that constructed wetlands function like naturally occurring systems despite much evidence suggesting the opposite is true. Lehtinen and Galatowitsch (2001) found that constructed wetlands in Minnesota did not support as complex of amphibian communities as natural systems. Balcombe et al. (2005) found that avian and amphibian communities in West Virginia constructed wetlands outperformed natural systems in terms of diversity, but did not function like natural systems and did not display natural habitat cover.

In their review of wetland restoration, Mitsch and Gosselink (2007) pointed out that one of the most important aspects of any wetland restoration is hydrology. Mitigation projects that fail to achieve compliance or functional success most often fail to establish natural hydrologic patterns. Generally, if hydroperiods similar to natural wetlands can be produced, the resulting flora and fauna communities, and chemical conditions will be similar to natural systems

(Gosselink and Turner, 1978; Mitsch and Gosselink, 2007). Wetlands that have a greater range of water levels and conditions will typically show greater biological diversity (Cronk and Fennessy, 2001). Steven and Gramling (2012) found that Wetland Reserve Program projects that failed to meet function or wildlife community goals often were the result of hydrologic goals not being met.

Specific goals are important for any mitigation or restoration effort of wetlands (Mitsch and Gosselink, 2007). Since hydrology drives wetland ecosystem function, it is imperative that constructed and restored wetland assessment methods take into account proper hydroperiod restoration. Many restoration efforts have specific goals that may conflict with successful hydrologic restoration. For examples, many projects are built primarily for flood control, or as water supplies, and not as replacements for natural systems. Replacing destroyed wetlands with ponds or low-quality wetlands results in a net loss of wetland ecosystem function despite the net gain in habitat acreage (Dahl, 2011). It is also desirable that the hydrologic functions be self-sustaining (Mitsch and Wilson, 1996), rather than dependent upon human management. For example, Kaminski, et al. (2006) found that constructed wetlands in New York were dependent on active hydrologic management to maintain natural function.

Restoration goals often include a target floral or fauna diversity, to serve as habitat for specific flora or fauna, or to provide certain ecosystem services such as flood control or water quality control (Zedler, 2000). To assess these goals, attributes of wetlands that may be investigated are biotic communities or hydrologic characteristics (Kentula, 2000). While many assessments utilize vegetation, amphibians have been used as a zoological biotic indicator of wetland status (Balcombe et al., 2005; Lehtinen and Galatowitsch, 2001). Wetland hydrology and geochemical attributes have also been used to compare constructed and natural wetlands (Gingerich and Anderson, 2011; Hoover, 2009). Rapid wetland assessment methods have been developed based upon comparisons to reference sites using hydrogeomorphic features (Brinson, 1993), and floristic composition (Fennessey et al., 2004).

Mitigation projects were historically evaluated only on the site being restored and did little if anything to evaluate how the wetland interacts with the surrounding landscape (Kentula, 2000). Wetlands are ecotones, or areas where two different biomes are interacting, and therefore their natural function is closely connected to their interactions with the surrounding landscape (Mitsch and Gosselink, 2007). Natural function with the landscape would constitute energy flow and nutrient cycling with surrounding landscapes, providing normal ecosystem services (Costanza et al., 1997).

Landscape placement and topography can affect wetland attributes as well. Landscape influences hydrology and soil types, and generally lower relief areas are more prone to inundation (Kentula, 2000). Large amounts of microtopographic relief change within constructed systems promote microhabitat heterogeneity and biological diversity, which often promotes the preservation of hydrology and increased biodiversity (Zedler, 2000). Reeder and Caudill (2000) found that human landscape disturbances were a contributing factor to reduced Canada Geese (*Branta canadensis*) reproductive success in small constructed wetlands in Eastern Kentucky.

The regional landscapes for this study, Central Appalachia and the Cumberland Plateau, are characterized by high relief, steep slopes, and narrow valleys (Jones, 2005). With many well-drained upland soils resulting from high relief, wetlands are restricted largely to narrow riparian features and many headwater streams (Jones, 2005). Similar riparian wetlands in steep landscapes have been shown to remove sediment and nutrients from ground and surface waters flowing into waterways, and are frequently located in headwater regions (Whigham, 1999). They also provide a source of water in droughts, and offer important landscape-level biodiversity functions (Whigham, 1999).

Birds as Indicators of Wetland Restoration Success

The most common method used to evaluate functional success is vegetation surveys (Balcombe et al., 2005; Fennessy et al. 2004). Other methods used less commonly include benthic traits, fauna, and hydrologic analysis (Gingerich and Anderson, 2011; Snell-Rood and Cristol, 2003; Zedler, 2000). Wildlife models of functional evaluation have historically been rare due to a lack of satisfactory methods to determine success (Mitsch and Grosselink, 2007). The use of wetland vegetation as an evaluation method is logical, as it is the only biotic factor evaluated during wetland delineation (Mitsch and Grosselink, 2007) and vegetation is easier to approach and survey.

While the more common vegetation surveys are useful for managers, they only offer detailed insight to the lower trophic levels of the ecosystem. Avian communities have been shown to correlate with wetland vegetative communities (Bulluck and Rowe, 2006) and established rapid assessment methods (Stapanian et al., 2004). Wildlife such as avian communities provide additional information on wetland function because birds utilize a variety of habitats, feed at a variety of trophic levels, and many avian taxa are dependent upon specific wetlands for survival or reproduction (Balcombe et al., 2005; Kenawell, 2002). Birds as a group do not require many expensive resources to survey, and generally present a simpler identification processes than other taxonomic groups (Balcombe et al., 2005). There are a vast number of amateur bird watchers across the country, many of which possess considerable field observation skills, while other taxonomic groups do not garner such a following. This would make “citizen scientists” efforts to evaluate constructed wetland success easier (Dickinson, 2012; USFWS, 2011).

Avifauna community development has been used to assess wetland restoration in other regions. Snell-Rood and Cristol (2003) found that avian communities in restored Virginia bottomland hardwood forests were developmentally behind natural systems. In New York marshes, Brown and Smith (1998) found little difference in abundance and richness values between constructed and naturally occurring wetlands, but did find significant differences in similarity values for restored and natural communities. There was a statistical difference in the distribution of nearly 40% of the species they observed (Brown and Smith, 2001). Avian communities in Florida storm water retention wetlands supported more birds than did natural marshes, but had major differences in community assemblages (Beck et al. 2013). Davis et al. (2009) compared habitat implications in floodplain systems and found that Wood Ducks (*Aix sponosa*) in Mississippi and Alabama showed higher duckling mortality in systems with more open water and less vegetative cover. Constructed systems do not immediately show complex habitat cover, and may require years of time to develop different habitat types (Mitsch and Wilson, 1996).

In the Pacific Northwest, Evans-Peters and Dugger (2012) found that waterbird food (macroinvertebrates and vegetation) in constructed wetlands occurred in similar densities to natural systems, but was heavily dependent upon active hydrologic and vegetation management to maintain such levels. Beck et al. (2013) found that constructed storm water wetlands in Florida did not maintain a natural hydrology and did not support similar communities to natural systems and were subject to unnatural levels of nutrient loading. Hapner et al. (2011) found that recently constructed wetlands underwent significant community composition changes in their first 15 years. Part of these changes included a substantial shift from wetland obligate guilds to facultative old field guilds; however, overall bird use increased fourfold during this time. Meiklejohn and Hughes (1999) found that restored riparian wetlands in southern New England showed similar avian diversity and richness, but had different avian species compositions.

Study Goals and Objectives

In eastern Kentucky, a large wetland complex of constructed riparian wetlands along Beaver Creek in Meniffee County has been studied for over 20 years to determine trajectory towards functional success (Haight, 1996; Haight and Reeder, 1997; Kenawell, 2002; Kenawell and Reeder, 2002; Reeder, 2011). The goal of this study is to compare these restored wetlands to a reference site to determine if these wetlands are still on a trajectory towards functional similarity to natural systems. Our objectives include: 1) characterize the current as-built wetland vegetation structure and hydrology; 2) evaluate water quality to determine if the constructed wetlands have similar geochemical functions to the reference site; 3) seasonal identification and enumeration of avifauna; 4) determine if obligate wetland bird species are utilizing the wetlands; 5) compare bird community richness, diversity, and abundance, and community overlap to reference conditions; 6) compare avifauna richness, diversity, abundance, and community overlap seasonally to determine if there are periods of increased or impaired function throughout the year; and 7) compare current conditions to previous study conditions.

CHAPTER 2

Materials and Methods

Study Site Description

The study area was the Beaver Creek Wetlands constructed by the United States Forest Service in Daniel Boone National Forest, Morehead Ranger District within Menifee Co. Kentucky (Fig 2.1). This area is located at the edge of the Cumberland Plateau within the Eastern Coal Fields region of Kentucky. Luken and Bezold (2000) characterized the regional habitat, noting the geology is dominated by Pennsylvanian and Mississippian aged sandstone, shale, and siltstone as geologic parent materials for soils with an average annual rainfall of 116.6 cm. This series of wetlands was built through the Wild Wings Project to enhance waterfowl populations in the eastern Kentucky region. This project is a combined effort by the US Forest Service, Ducks Unlimited, US Natural Resource Conservation Service, Kentucky Department of Fish and Wildlife Resources, US Army Corps of Engineers, and other stakeholder groups.

This complex consists of over 50 constructed ponds and wetlands ranging from 30+ years old to less than 10 years old (Beibighauser, pers. com.; Fig.2.1). This wetland complex has been the subject of scientific research for nearly twenty-years (Haight, 1996; Haight and Reeder, 1997; Kenawell, 2002; Kenawell and Reeder, 2002; Reeder 2011; Reeder and Caudill, 2000). Modifications were made to some wetlands in the last decade to reduce maintenance activity, enhance waterfowl habitat based on more recent literature, and to promote more natural function (Beibighauser pers. com., 2013).

All wetlands surveyed as part of this study were at least 15 years old. The wetlands are located along the lower portion of Beaver Creek and are influenced hydraulically by the US

Army Corps of Engineers artificial control of the Licking River through Cave Run Lake and Dam. Wetland vegetation is the result of 25+ years of natural recruitment, without intentional plantings (Beibighauser pers. com., 2013). Water control devices were installed in several basins. However, the devices were not utilized in any of the wetlands analyzed during this study. Steep, wooded slopes surround the complex and 22 ha of planted wildlife food (wheat, grass, clover, corn) are present in surrounding areas of the floodplain.

The reference wetland is located at Minor Clark Fish Hatchery near Farmers KY in Rowan County just below Cave Run Dam. This 1.8 ha wetland is located in a broader floodplain with some bottomland forest nearby. This system has been determined to have been a wetland for at least 300 years (Haight, 1996). Some reference wetlands that had been used in previous studies were unavailable for this study as they have since been destroyed by fill activities.

Table 2.1 Basic characteristics of the Rowan County Reference Wetland and Beaver Creek Wetland Complex (KY) during 2013-14 study

	Total Area (ha)	Age (years)	Average Depth (cm)	Dominant Habitat
Reference	4	300+	68	Open Water
Wetland 1	1.61	25	88	Submergent Vegetation
Wetland 7	0.6	22	37	Open Water
Wetland 11	2.03	24	76	Submergent Vegetation
Wetland 14	0.61	22	42	Emergent Herbaceous Vegetation
Wetland 16	0.13	21	29	Emergent Herbaceous Vegetation
Wetland 17	1.86	25	74	Emergent Herbaceous Vegetation
Wetland 20	0.35	19	31	Open Water
Wetland 25	0.63	21	32	Open Water
Wetland 33	0.08	18	< 1	Emergent Herbaceous Vegetation
Wetland 34	0.39	18	8	Emergent Herbaceous Vegetation
Wetland 35	0.33	16	47	Emergent Herbaceous Vegetation
Wetland 36	0.65	16	49	Emergent Herbaceous Vegetation
Wetland 38	0.74	15	42	Open Water
Wetland 40	0.09	15	36	Submergent Vegetation

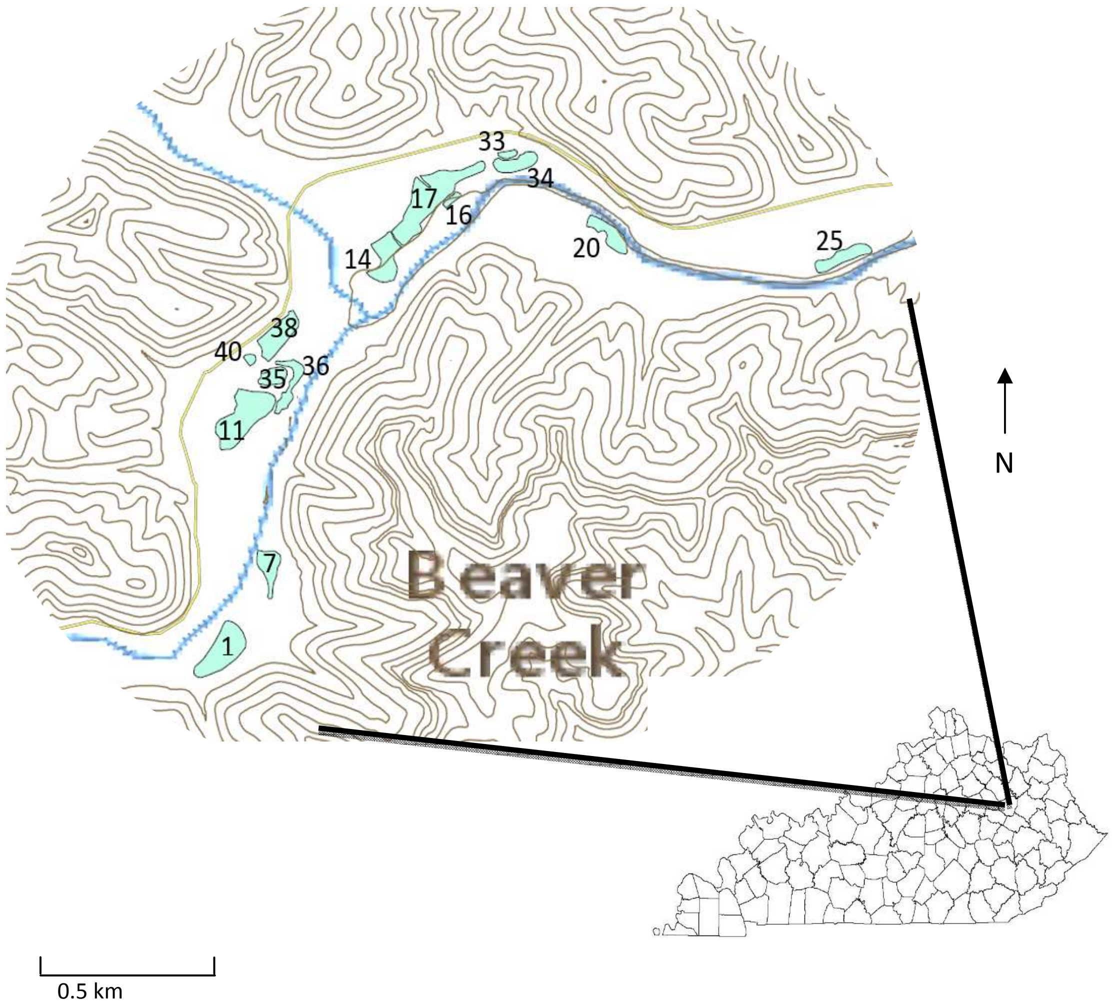

Fig 2.1. Location of the Beaver Creek Wetlands complex in Menifee County, Kentucky

Vegetation (Habitat) Surveys

Wetland plants were surveyed using 0.25 m^2 quadrats placed along a transect in 5 m intervals. (Brower et al. 1998; Canfield, 1941). Three to four transects were made for each wetland depending on size. Transect lengths were dependent on the size and shape of the wetland, but crossed the entire length of the wetland. Plants were evaluated for cover types: open water, submergent, emergent, shrub, or tree cover (Kenawell, 2002). Hydrologic conditions were noted by habitat type (open water, submerged vascular vegetation, emergent vascular vegetation, upland trees, and upland shrubs).

Water Chemistry Measurements

Once monthly, temperature, dissolved oxygen (DO), conductivity, and pH were measured with a YSI 556 handheld probe. Probes were calibrated daily, and checked for drift at the end of the day. Grab samples of standing water were collected from each wetland with an acid-washed 500 ml Nalgene bottle. Water samples were collected from a random point within 10 m of the survey point, and were stored at 4˚C until water analyses were completed. Soluble Reactive Phosphate (SRP) was measured using the ascorbic acid method (Murphy and Riley, 1962). Nitrate was determined with a variation of the sulfanilamide method following cadmium reduction (Henriksen and Selmer-Olsen 1970). Ammonia was determined using the Nesslerization technique (Jenkins, 1968). Sulfate concentrations were measured using the turbidimetric method for sulfate determination (Tabatabai, 1974). Iron concentrations were determined using the 1,10-Phenanthroline Method (Harvey et al., 1955)

Avifauna Identification, Categorization, and Enumeration

Avifauna were observed twice monthly from June 2013 to May 2014 at the Beaver Creek Wetlands in Menifee Co. Kentucky and the Reference wetland in Rowan County. Observations were generally made between 6:00 am and 11:30 am when most species of birds are at peak activity (Smith and Twedt, 1999). Wetland survey order was rotated to avoid bias of observation time, and all wetlands were approached from consistent routes and observation points, following the guidelines of Brown and Smith (1998). Avifauna surveys utilized 10 minute unlimited radius point counts and birds were only counted if they were within the wetland basin, flying over near canopy height or lower, or on the edge of the surrounding canopy to each wetland (Brown and Smith, 1998; Grover and Baldassarre, 1995; Kenawell, 2002). Birds that flushed upon approach were counted. Birds were identified by sight or sound, and confirmed with a field guide (Dunn and Alderfer, 2011; Peterson et al., 2010; Sibley, 2003) as needed. Other references were available for consultation if needed (Ehrlich et al., 1988; Kaufman, 2011; Palmer-Ball Jr., 2003). Zeiss 8x30 binoculars or Pentax 8x36 binoculars were used to aid visual identifications. Attempts were made to photograph rare species or new county records observed during this project. Photos are available at: “www.flickr.com/photos/bdwulker/sets/72157648705305900”. Observations were conducted in all weather conditions except thunderstorms or severe winds. Obligate species status was determined by consulting published literature and previous studies on this site, along with general knowledge of life histories by the investigators.

Data Analysis

Habitat types were compared between sites, and to the reference site, by similarities and differences in cover percentages. Water quality measurements were compared between wetlands and the reference site to assess potential biogeochemical functions.

Avifauna species richness (total number of species) and abundance (total number of individuals) were calculated for each wetland or complex and were used to compare total and obligate avian wetland usage. Wetland obligate species we categorized as avian species that are dependent on wetland areas for any portion of their life cycle. Wetland obligate species status was determined through consultation of past literature (Brown and Smith, 1998; Grover and Baldassarre, 1995), life history accounts (Ehrlich et. al. 1988; Palmer-Ball Jr., 2003; Sibley et al., 2009), and personal experience.

Shannon and Simpson dominance indices were calculated to determine bird community diversity (Simpson 1949; Shannon 1948). Higher species diversity results in more complex food webs and communities through resource availability, and is indicative of increased wetland function. Community overlap was also calculated between the constructed locations and the natural reference site using Horn's Index (R_o) (Horn, 1966 as described in Brower et al., 1998). While diversity indices may reflect wetland function (Zedler, 2000), community overlap reflects how similar those functions may be between two sites. Horn's index of community overlap was selected as it is relatively free of habitat size bias (Brower et al., 1998).

Avifauna diversity and similarity were compared throughout the course of the study as well as seasonally. Seasonal periods were assessed to determine if there are periods of time throughout the year where natural function is severely impeded. Seasonal period definitions were based upon definitions used by the Cornell Lab of Ornithology and project eBird: Breeding season (Jun-Jul), Fall migration (Aug-Nov) Winter (Dec-Feb) Spring migration (Mar-May) (Sullivan et al., 2009).

CHAPTER 3

Results

Wetland Habitat Characterization and Hydrology

Most wetlands were dominated by either open water, or emergent herbaceous vegetation. All wetlands contained both emergent herbaceous vegetation and tree cover. All wetlands, except for wetland 33, contained open water and submergent vegetation. The reference wetland was dominated by open water (58% cover) with emergent herbaceous vegetation (29% cover) and minimal amounts of submergent vegetations (7%) and tree cover (6%). The average for the Beaver Creek wetlands showed emergent herbaceous vegetation (35%) as the most prevalent cover type, followed by submerged vegetation (25%), with open water and tree cover at 20% (Figs. 3.2 and 3.3).

Wetlands with the highest percentage of open water included the reference wetland (58%), wetland 38 (46%), and wetland 20 (42%). Wetland 1 (56%) and Wetland 40 (49%) had the highest percent coverage by submergent vegetation. The wetlands showing the most cover by emergent herbaceous vegetation were wetland 14 (74%), wetland 33 (59%), and wetland 34 (59%). Shrub cover was recorded on 8 out of 15 wetlands and was most prevelant on wetland 11 (29%) and wetland 38 (18%) Trees made up less than 10% of total cover on most wetlands. Wetland 33 had the most tree coverage (41%).

Coverage class was variable between wetlands (Table 3.1). The reference wetland was most extensively covered by open water (2.32 ha) and Emergent herbaceous vegetation (1.16 ha). Submergent vegetation (0.28 ha) and Trees (0.24 ha) were relatively scarce and shrubs were not observed. Emergent herbaceous vegetation was collectively the most extensive cover type in the Beaver Creek Wetlands (3.58 ha), submergent vegetation (2.48 ha) was the next most extensive cover type followed by open water (2.06 ha) while shrubs (1.15 ha), and tree cover (0.82 ha) were the least extensive. Wetlands with the most area of open water were the reference wetland (2.5 ha), wetland 1 (1.33 ha), and wetland 11 (0.87 ha). The reference wetland had the greatest area of emergent vegetation with 1.28 ha, wetland 17 (0.99 ha) and wetland 11 (0.45 ha) were the next highest. Wetlands 11 (0.59 ha) and 17 (0.22 ha) had the most shrub cover. Wetlands 11 and 17 also had the highest tree coverage (0.10 ha and 0.13 ha respectively).

Table 3.1. Percentage of habitat cover class for the Beaver Creek Wetlands and Rowan County Reference Wetland (Ref) during the 2013 growing season.

Wetland	Total Area (ha)	Open Water (%)	Submergent (%)	Emergent herb. (%)	Shrubs (%)	Trees (%)
Ref	4	58	7	29	0	6
1	1.61	27	56	14	0	3
7	0.6	36	17	35	7	5
11	2.03	8	35	23	29	5
14	0.61	12	5	73	0	10
16	0.13	7	17	58	0	18
17	1.86	16	12	53	12	7
20	0.35	42	18	30	4	6
25	0.63	39	30	27	0	4
33	0.08	0	0	59	0	41
34	0.39	3	6	59	20	12
35	0.33	20	13	48	9	10
36	0.65	7	15	44	7	28
38	0.74	46	5	21	18	10
40	0.09	10	49	28	0	13

Water Chemistry

Dissolved sulfate (SO_4) concentrations in the reference wetland waters were 3-times higher than those observed in any of the constructed systems (Table 3.2). The reference wetland Phosphate (SRP), Ammonia (NH_4), and Nitrate (NO_3) concentrations were comparable to the constructed wetland concentrations. Reference Iron (Fe) concentrations were much lower than most constructed wetlands (one fifteenth of the average), and reference SO_4 concentrations were 3-10 times higher than constructed concentrations. Overall, the wetlands had highly variable nutrient concentrations and seasonal nutrient variations whereas the references wetland had less variation in concentration. Wetlands 33 and 34 maintained a wet meadow status and did not contain enough surface water throughout the year for a reliable and valid comparison.

Table 3.2. Average nutrient concentrations ($\bar{x}$ ± standard deviation) for the Beaver Creek Wetlands and reference wetland from Jun 2013 to May 2014.

Wetland	SRP (μg/L)	NH_4 (μg/L)	Fe (μg/L)	SO_4 (mg/L)	NO_3 (μg/L)
Reference	58 ± 43	85 ± 34	13 ± 18	30.8 ± 5.8	47 ± 40
1	610 ± 455	509 ± 409	316 ± 416	3.62 ± 2.3	118 ± 155
7	25 ± 26	92 ± 66	140 ± 225	2.04 ± 1.4	77 ± 106
11	125 ± 224	315 ± 501	222 ± 165	4.12 ± 2.8	23 ± 18
14	35 ± 21	140 ± 90	363 ± 1064	1.62 ± 1.7	54 ± 67
16	29 ± 19	289 ± 467	363 ± 628	4.23 ± 3.9	96 ± 152
17	37 ± 31	162 ± 85	183 ± 355	6.51 ± 5.3	31 ± 24
20	33 ± 20	100 ± 72	276 ± 464	5.54 ± 4.9	75 ± 70
25	38 ± 31	75 ± 64	89 ± 70	7.16 ± 4.3	34 ± 21
33			Insufficient water levels		
34			Insufficient water levels		
35	76 + 55	113 ± 76	86 ± 28	9.58 ± 5.2	65 ± 57
36	217 ± 391	127 ± 115	218 ± 205	11.5 ± 11	47 ± 47
38	51 ± 44	90 ± 56	60 ± 35	2.57 ± 2.6	85 ± 102
40	66 ± 64	93 ± 59	141 ± 215	5.23 ± 3.1	53 ± 49

Comparisons of Avifauna Use and Community Diversity

During the course of this study, 5,972 birds were observed. Overall, we observed 121 species, of which 114 species were observed in the constructed Beaver Creek Wetlands. The Rowan County Reference wetland supported 84 species (Table 3.3). The percentage of species that were reliant upon wetland habitat for all or part of their life cycle (obligate species) was variable, but was about 43% in most of the Beaver Creek wetlands. This is similar to the percentage of obligate species observed at the reference site. Red-winged Blackbirds (*Agelaius phoeniceus*) were the most numerous species observed with 661 individuals tallied. Next most numerous species were Swamp Sparrow (*Melospiza georgiana*) with 490, Song Sparrow (*Melospiza melodia*) with 474, Canada Goose (*Branta Canadensis*) with 349, American Goldfinch (*Spinus tristis*) with 331, White-throated Sparrow (*Zonotrichia albicollis*) with 327, Wood Duck (*Aix sponsa*) with 297, and Carolina Chickadees (*Poecile carolinensis*) with 200 individuals tallied.

The reference wetland produced greater total species richness, abundance, and community diversity than any individual constructed wetland basins (Table 3.3). The Beaver Creek Wetlands did not outperform the Reference Wetland in any metrics. Within the Beaver Creek Wetland complex, the highest species richness was observed in the three largest wetlands: Wetland 1 (71), Wetland 11 (66), and Wetland 17 (65); while the lowest was observed in the smallest basin: Wetland 33 (29). Total abundance was highest in wetland 11 (665), and lowest in Wetland 40 (188)--one of the smallest wetlands.

Avifauna Shannon Diversity was highest in the reference wetland (1.25). The wetlands with Shannon Diversity most similar to the reference site were two of the largest wetlands (17 and 11), and one medium-sized wetland (20). The smallest wetlands (16 and 30) displayed the lowest Shannon diversity. The total Shannon Index for the Beaver Creek Wetland complex was 1.13 and the Simpson Index for the complex was 0.044. The average community overlap with the reference wetland was 73% (Fig 3.1), with the lowest being 64.5% (wetland 34) and the highest being 79.3% (Wetland 11). For the entire Beaver Creek Wetlands complex compared to the reference wetland, community overlap was 87.3%. The Beaver Creek wetlands are attracting obligate wetland birds in levels near that of the reference wetland; however, the highest value for almost every metric was seen in the reference wetland.

Table 3.3. Summary of avifauna observations at the Beaver Creek Wetlands and Rowan County Reference Wetland (Ref) from June 2013 to May 2014.

	Richness (S)	Abundance	Obligate Richness	Obligate Percent	Obligate Abundance	Shannon (H')	Simpson (D)
Ref	84	860	30	36%	375	1.254	0.031
1	71	579	15	21%	273	0.918	0.063
7	53	337	11	21%	89	0.957	0.041
11	66	665	22	33%	433	1.030	0.090
14	54	370	15	28%	172	0.933	0.075
16	42	242	13	31%	94	0.727	0.093
17	65	536	19	29%	236	1.037	0.045
20	56	323	14	25%	101	0.965	0.048
25	56	345	11	20%	118	0.858	0.058
33	29	222	6	21%	50	0.800	0.087
34	34	251	5	15%	96	0.857	0.072
35	56	422	16	29%	219	0.961	0.052
36	49	257	13	27%	104	0.913	0.064
38	58	560	16	28%	179	0.895	0.049
40	47	188	6	13%	53	0.983	0.053
BC Total	113	5156	31	27%	2217	1.128	0.044

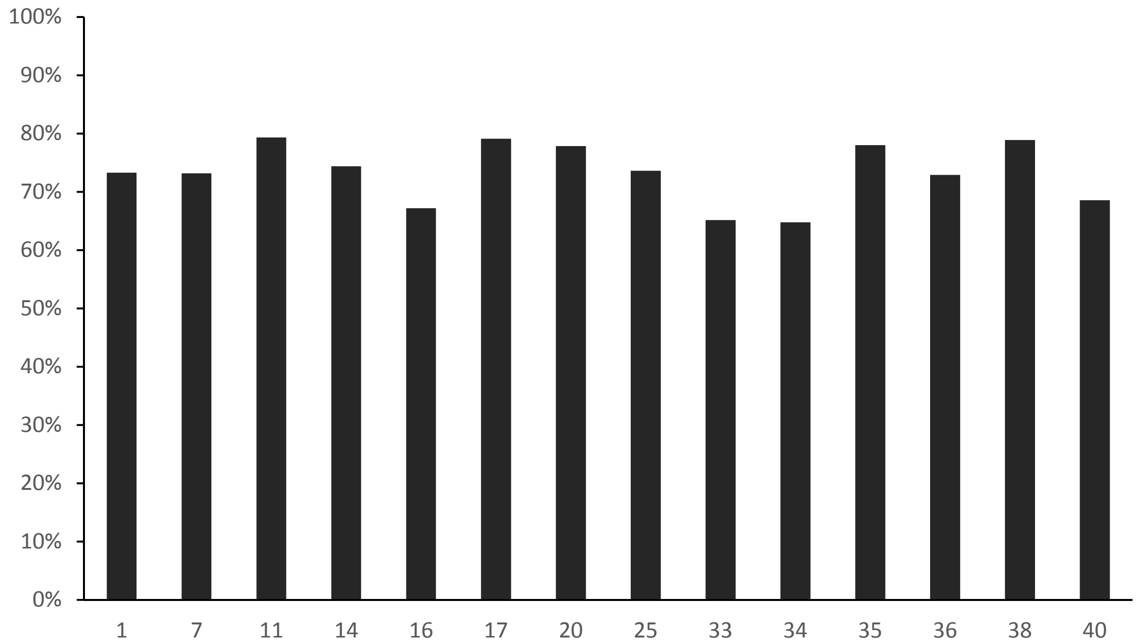

Fig 3.1. Avian community overlap percent (R_o) between individual Beaver Creek Wetlands and the Rowan County Reference Wetland from June 2013 to May 2014.

Seasonal Comparisons of Avifauna Use and Community Diversity

The highest richness was during the breeding season in the reference wetland, while spring migration was the period of highest (average) richness in the Beaver Creek wetlands (Table 3.4 - 3.7). All wetlands supported the fewest species and lowest abundance during the winter months. During any given season, the reference wetland always contained more species than any individual Beaver Creek Wetland. The Rowan County Reference wetland had higher obligate species richness than the Beaver Creek wetlands during all time periods analyzed. Total bird abundance for the Beaver Creek Wetland complex was highest in the fall, and lowest in the spring and winter.

Fall migration was the period of highest abundance in both the reference wetland and Beaver Creek wetland complex. The Rowan County Reference wetland contained greatest avian abundance of any individual basin in the breeding season, fall migration, and winter seasons, while Wetland 17 contained the highest abundance in the spring migration. The spring migration season was the time period with the highest obligate richness in both the Rowan County Reference (19) and Beaver Creek Wetlands ($\bar{x} = 10$).

Winter conditions resulted in the lowest obligate richness in all wetlands (Rowan County Reference = 12; Beaver Creek $\bar{x} = 3$.) Fall migration in the reference wetland had the highest obligate wetland species abundance while the Beaver Creek Wetland complex, had highest obligate species abundance was during the breeding season. For the total Beaver Creek Wetland complex, the spring migration period had the highest overall species richness and obligate bird richness, while the lowest diversity birds, obligate wetland species or not, occurred during winter season. Beaver Creek Wetland complex obligate richness values were comparable to the reference wetland in all seasons; while individual Beaver Creek Wetland obligate richness was lower than the reference wetland in all seasons (Fig 3.2).

Table 3.4. Avian community richness, abundance, diversity during the breeding season (Jun, Jul) for the Beaver Creek Wetlands and Rowan County Reference Wetland (Ref) in 2013.

	Richness (S)	Obligate Richness	Richness % Obligate	Abundance	Obligate Abundance	Shannon (H')	Simpson (D)
Ref	49	14	29	238	105	1.09	0.06
1	43	10	23	232	130	0.90	0.08
7	28	6	21	90	34	0.97	0.06
11	31	9	29	159	105	0.86	0.12
14	23	8	35	76	32	0.97	0.05
16	17	4	23	39	16	0.85	0.08
17	35	8	23	168	88	0.96	0.07
20	26	6	23	99	37	0.88	0.08
25	24	5	21	76	26	0.86	0.05
33	9	4	44	53	29	0.65	0.16
34	13	3	23	83	62	0.66	0.27
35	19	8	50	92	75	0.79	0.13
36	16	6	38	41	24	0.87	0.09
38	27	6	22	99	50	0.84	0.10
40	18	2	11	43	16	0.80	0.12
BC Total	72	15	21	1314	724	1.09	0.04

Table 3.5. Avian community richness, abundance, diversity during the fall migration season (Aug, Sept, Oct, Nov) for the Beaver Creek Wetlands and Rowan County Reference Wetland (Ref) in 2013.

	Richness (S)	Obligate Richness	Richness % Obligate	Abundance	Obligate Abundance	Shannon (H')	Simpson (D)
Ref	42	14	33	290	114	1.05	0.05
1	30	5	17	161	66	0.62	0.11
7	24	4	17	91	19	0.76	0.06
11	29	7	24	253	148	0.68	0.18
14	28	5	18	184	80	0.69	0.12
16	20	4	20	84	27	0.51	0.14
17	25	5	20	119	32	0.79	0.07
20	27	6	22	102	20	0.84	0.06
25	26	5	19	110	44	0.64	0.11
33	18	1	6	123	15	0.61	0.14
34	18	1	6	74	11	0.63	0.08
35	26	4	15	122	30	0.70	0.07
36	25	3	12	110	34	0.60	0.12
38	33	8	24	258	51	0.57	0.11
40	18	3	17	48	13	0.67	0.07
BC Total	66	13	20	1760	590	0.84	0.06

Table 3.6. Avian community richness, abundance, diversity during the winter season (Dec, Jan, Feb) for the Beaver Creek Wetlands and Rowan County Reference Wetland (Ref), 2013 - 2014.

	Richness (S)	Obligate Richness	Richness % Obligate	Abundance	Obligate Abundance	Shannon (H')	Simpson (D)
Ref	35	12	34	192	89	1.11	0.05
1	20	3	15	117	46	0.67	0.11
7	19	2	11	111	19	0.57	0.09
11	17	7	41	76	49	0.78	0.20
14	13	3	23	42	21	0.67	0.16
16	10	2	20	47	17	0.40	0.17
17	19	3	16	125	25	0.62	0.11
20	15	6	40	71	26	0.44	0.15
25	14	3	21	102	26	0.49	0.14
33	9	1	11	31	3	0.44	0.15
34	15	2	13	59	12	0.50	0.10
35	14	3	21	83	32	0.40	0.15
36	13	3	23	50	18	0.52	0.12
38	21	4	19	108	24	0.70	0.08
40	11	2	18	36	9	0.63	0.10
BC Total	40	8	20	1047	327	0.67	0.09

Table 3.7. Avian community richness, abundance, diversity during the spring migration season (Mar, Apr, May) for the Beaver Creek Wetlands and Rowan County Reference Wetland (Ref) in 2014.

	Richness (S)	Obligate Richness	Richness % Obligate	Abundance	Obligate Abundance	Shannon (H')	Simpson (D)
Ref	41	19	46	140	67	1.08	0.04
1	30	9	30	69	31	0.70	0.05
7	21	7	33	45	17	0.73	0.06
11	39	16	41	177	131	0.85	0.11
14	27	12	44	68	39	0.63	0.09
16	25	11	44	72	34	0.58	0.11
17	32	17	53	124	91	0.76	0.09
20	30	10	33	51	18	0.91	0.02
25	28	8	29	57	22	0.80	0.04
33	11	3	27	15	3	0.66	0.05
34	18	4	22	35	11	0.82	0.06
35	35	13	37	125	82	0.94	0.10
36	28	9	32	56	28	0.80	0.07
38	31	11	35	95	54	0.91	0.05
40	29	6	21	61	15	0.94	0.05
BC Total	92	25	27	1027	573	1.12	0.06

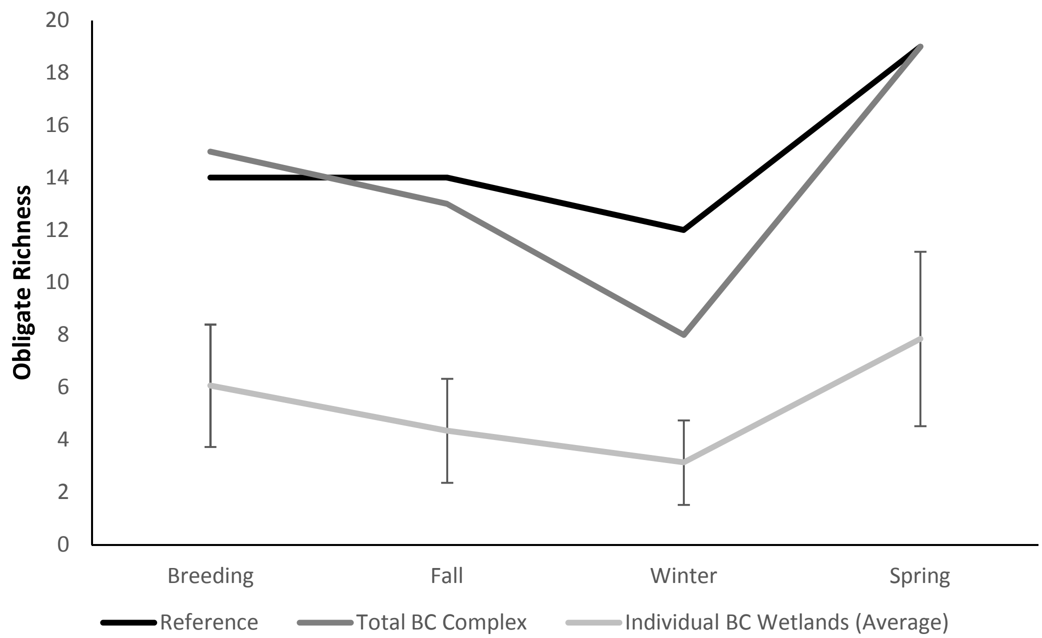

Fig 3.2. Seasonal change in obligate wetland species richness for the Rowan County Reference Wetland, Beaver Creek Wetland Complex total, and average individual Beaver Creek Wetlands from Jun 2013 to May 2014

Shannon diversity was highest in all seasons in the reference wetland. The reference wetland demonstrated very little relative change in community diversity throughout the year; while all constructed wetlands showed a relatively large amount of change in overall diversity throughout the year (Table 3.8, Fig. 3.3 - 3.5). The reference wetland had the lowest Simpson Index values (likelihood that two randomly selected individuals are from the same species) during the fall migration and winter season; however wetlands 7, (0.06) 14 (0.05) and 25 (0.05) had values similar or lower to the reference wetland (0.06) during the breeding season. During spring migration Wetlands 20 (0.02) and 25 (0.04) Simpson Diversity scored better or similar to the reference wetland (0.04). As seen with the Shannon Index assessment of community diversity, the reference wetland recorded the lowest change in Simpson Index value over the year (Table 3.9). Shannon and Simpson Diversity for the whole complex was in general greater than individual wetlands. For the total Beaver Creek Wetland complex, change in Shannon Diversity (0.38) over the year was much higher than the reverence wetland (0.06) while change in Simpson Diversity (0.03) was slightly higher than the reference wetland (0.02).

Table 3.8. Seasonal change in avian Shannon Index (H') value for the Beaver Creek Wetlands and Rowan County Reference Wetland (Ref) from Jun 2013 to May 2014

	Breeding Shannon	Fall Shannon	Winter Shannon	Spring Shannon	Δ Shannon
Ref	1.09	1.05	1.11	1.08	0.06
1	0.90	0.62	0.67	0.82	0.28
7	0.97	0.76	0.57	0.85	0.40
11	0.86	0.68	0.78	0.95	0.27
14	0.97	0.70	0.67	0.76	0.30
16	0.85	0.51	0.40	0.67	0.45
17	0.96	0.79	0.62	0.87	0.34
20	0.88	0.84	0.44	1.01	0.57
25	0.86	0.64	0.49	0.93	0.44
33	0.65	0.61	0.44	0.70	0.26
34	0.66	0.63	0.50	0.86	0.36
35	0.79	0.70	0.40	1.01	0.61
36	0.87	0.61	0.52	0.93	0.41
38	0.84	0.57	0.71	0.96	0.39
40	0.80	0.67	0.63	1.01	0.38
BC Total	1.09	0.84	0.74	1.12	0.38

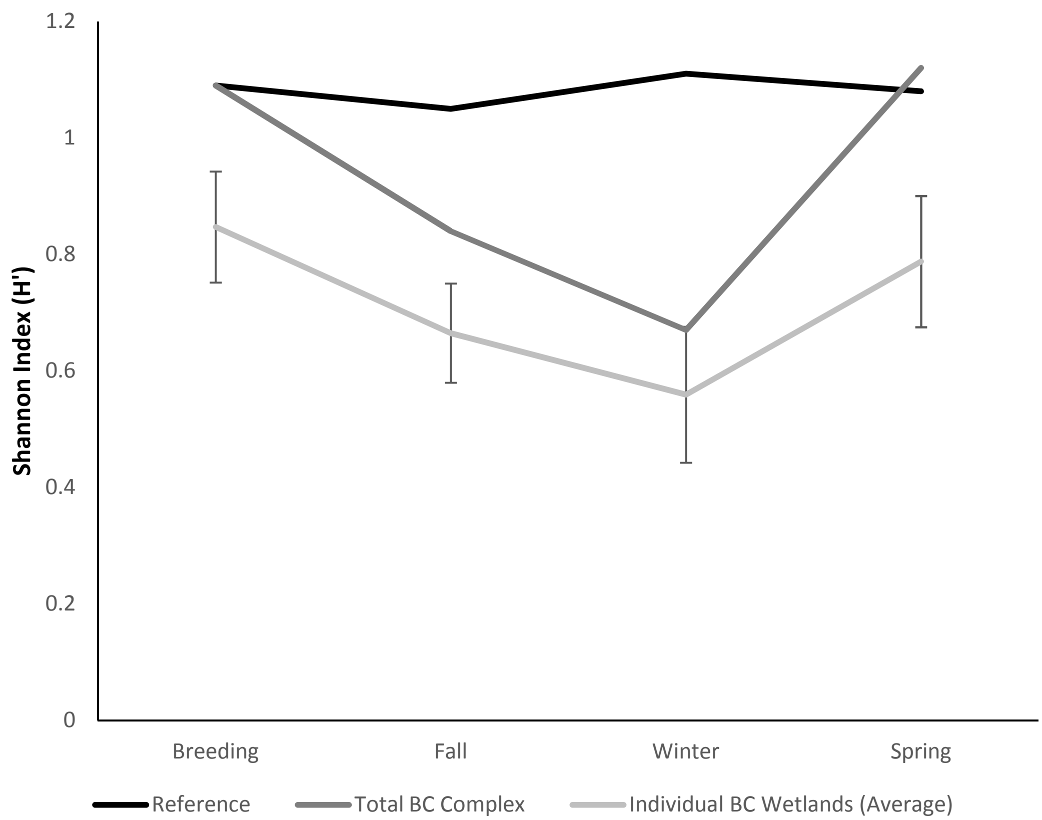

Fig 3.3. Seasonal change in avian Shannon Diversity (H') for the Rowan County Reference Wetland, Beaver Creek Wetland total complex, and average individual Beaver Creek Wetlands from Jun 2013 to May 2014

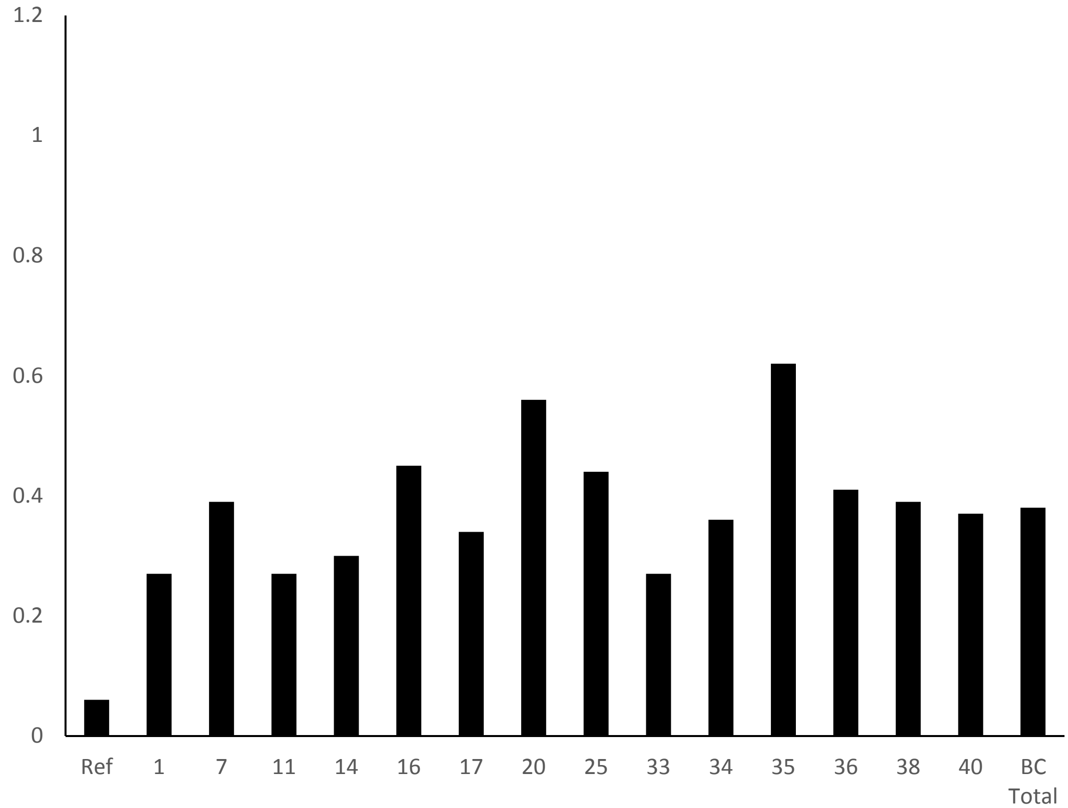

Fig 3.4. Difference in maximum and minimum seasonal avian Shannon index (H’) values for the Beaver Creek Wetlands and the Rowan County Reference Wetland (Ref) from Jun 2013 to May 2014

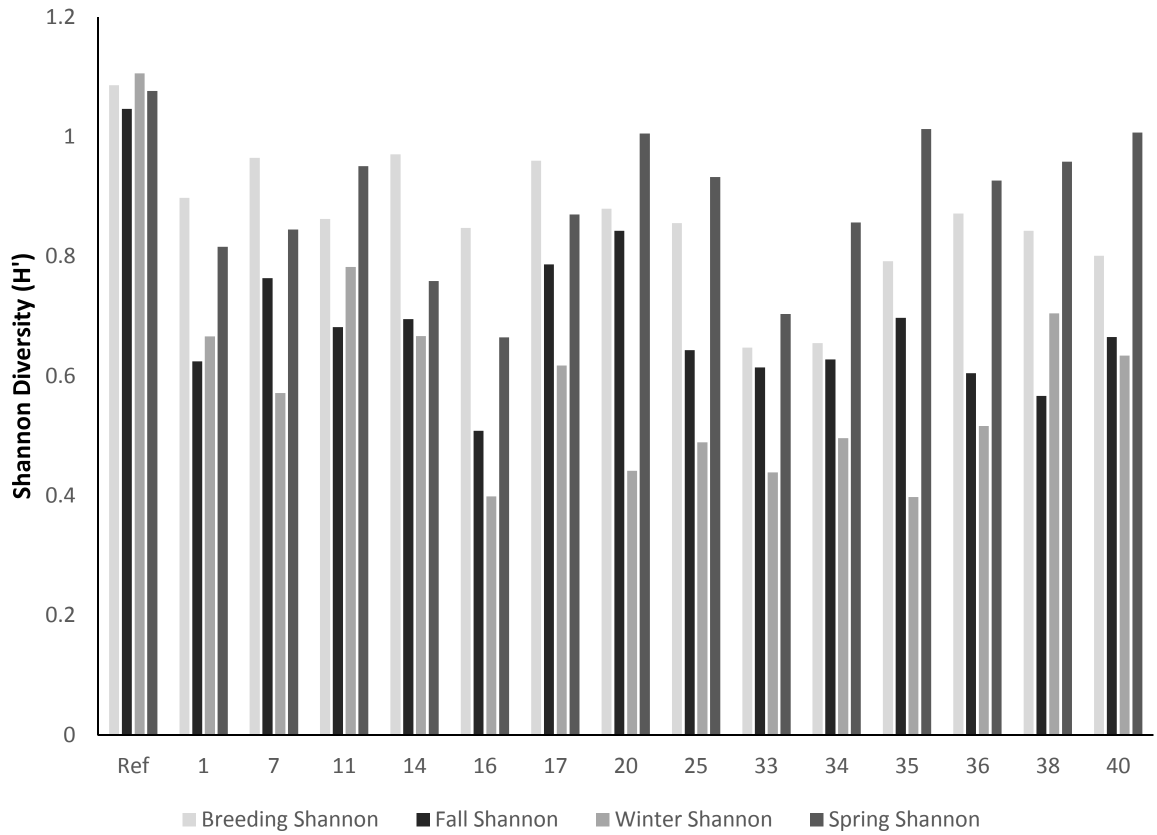

Fig 3.5. Avian Shannon Index (H') values by season for the Beaver Creek Wetlands and Rowan County Reference Wetland (Ref)

Table 3.9. Seasonal change in Simpson Index value for the Beaver Creek Wetlands and the Rowan County Reference Wetland (Ref) from Jun 2013 – May 2014

Wetland	Breeding Simpson	Fall Simpson	Winter Simpson	Spring Simpson	Δ Simpson
Ref	0.06	0.05	0.05	0.04	0.02
1	0.08	0.11	0.12	0.05	0.07
7	0.06	0.06	0.09	0.06	0.03
11	0.12	0.18	0.20	0.11	0.09
14	0.05	0.12	0.17	0.09	0.12
16	0.08	0.14	0.17	0.11	0.09
17	0.07	0.07	0.11	0.09	0.04
20	0.08	0.06	0.15	0.02	0.13
25	0.05	0.11	0.14	0.04	0.10
33	0.16	0.14	0.15	0.05	0.11
34	0.27	0.08	0.10	0.06	0.21
35	0.13	0.08	0.15	0.10	0.07
36	0.09	0.12	0.12	0.07	0.05
38	0.10	0.11	0.08	0.05	0.06
40	0.12	0.07	0.11	0.05	0.07
BC Total	0.06	0.06	0.09	0.06	0.03

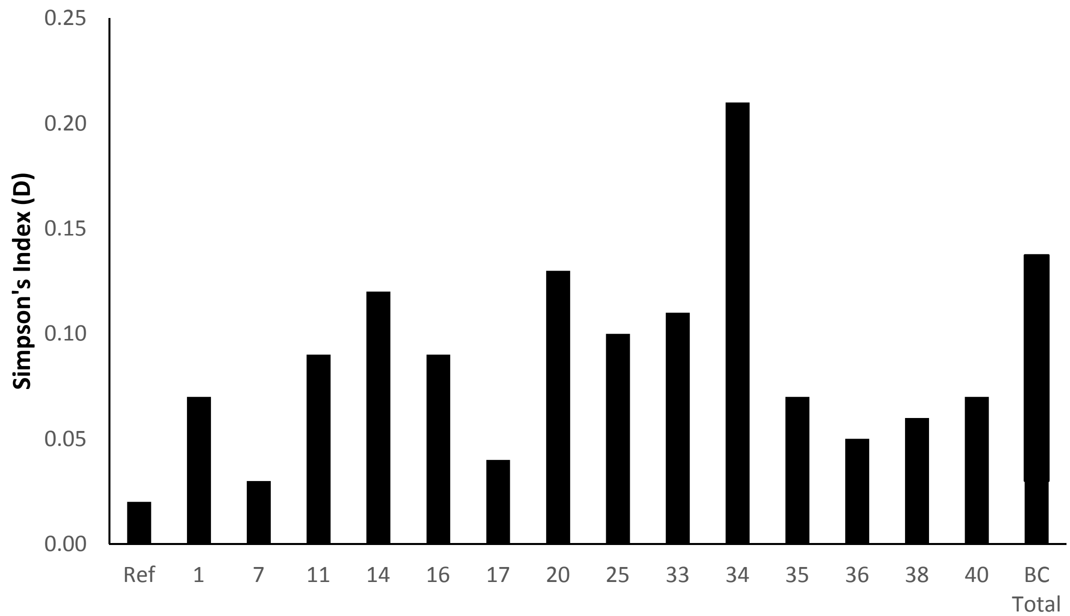

Fig 3.6. Difference in maximum and minimum seasonal Simpson Index (D) values for the Beaver Creek Wetlands and Reference Wetland.

Community overlap was lower in the fall, winter, and spring seasons than when calculated for the entire year (Table 3.10). For the breeding season, results included wetlands with noticeably lower overlap values, but also several wetlands with similar or slightly higher overlap values. The average annual community overlap value (R_o) was 73%. Of all seasons, the breeding season R_o (68%) averaged highest. The fall migration R_o (57%), and winter season R_o (57%) were the intermediate in terms of average community overlap; while the spring migration R_o (51%) was the period that averaged lowest community overlap with the reference wetland. For individual wetlands, the breeding season generally showed the highest R_o. The season with the lowest R_o value varied dependent on wetland. Few constructed wetlands had a seasonal overlap value higher than their respective yearly overlap values.

Table 3.10. Seasonal and annual Percent Overlap Values (R_o) for avian communities in the Beaver Creek Wetlands

Wetland	Year	Breeding	Fall	Winter	Spring
1	0.73	0.64	0.52	0.63	0.53
7	0.73	0.75	0.52	0.54	0.41
11	0.79	0.70	0.67	0.62	0.53
14	0.74	0.64	0.58	0.65	0.53
16	0.67	0.64	0.54	0.5	0.47
17	0.79	0.71	0.59	0.64	0.53
20	0.78	0.77	0.60	0.58	0.47
25	0.74	0.79	0.63	0.43	0.54
33	0.65	0.58	0.42	0.58	0.45
34	0.65	0.46	0.51	0.58	0.55
35	0.78	0.59	0.68	0.60	0.53
36	0.73	0.67	0.52	0.54	0.57
38	0.79	0.81	0.67	0.64	0.56
40	0.69	0.71	0.49	0.49	0.49
Total	0.87	0.85	0.76	0.67	0.75

CHAPTER 4

Discussion

Since Kenawell's (2002) study, the United States Forest Service made modifications to several wetlands in an attempt to incorporate the suggestions from that study. These changes included merging wetlands 24 and 25 and grading and "shallowing out" wetlands 7, 17, 20, 33, 34, and 38. These changes resulted in an overall reduction in depth, but more microtopographic variance of the wetland substrates. Since the previous study, beaver activity has nearly doubled the former size of wetland 36.

Wetland Habitat and Water Chemistry

Kenawell (2002) found the Beaver Creek wetlands tended to be dominated by submergent vegetation and open water. Emergent herbaceous vegetation covered relatively little area, and never covered more than 50% of any single wetland. In 2014, emergent herbaceous vegetation is seen as a much more dominant cover type, while submergent vegetation and open water have decreased. Trees and shrubs, while still minor components of the habitat cover of many wetlands have increased in prevalence since 2002. Odland and del Moral (2002) found plant communities remained dynamic more than 13 years after a permanent drawdown of a lake and wetland habitat. Given the relatively similar age of the Beaver Creek Wetlands and the changes in cover-type proportions since 2002, it is likely that floral communities are still developing. Wetland cover-type succession tends to progress from open water and unvegetated states, to submergent and emergent herbaceous dominated states, to eventually being dominated by woody vegetation (Golet et al., 1993; Mitsch and Gosselink, 2007). The Beaver Creek Wetlands reduction in open water and increase in emergent herbaceous vegetation suggests it is following a similar trajectory. The Beaver Creek Wetlands trends in changing habitat cover follow expected trends from temperate North American wetlands (Golet et al., 1993; Mitsch and Gosselink, 2007). This suggests that hydrologic patterns in Beaver Creek Wetlands are similar to natural patterns, allowing for natural habitat succession to occur. While the Beaver Creek Wetlands, as a whole, are likely exhibiting some natural function in hydrology, several individual wetlands are likely not. Wetlands 33 and 34 went through several month periods where there was not sufficient water to take a full sample in accordance with chemistry sampling procedures, though wet soils were persistent in wetland 34. Habitat cover types were also measured in different proportions from other wetlands. This indicates a hydrologic failure, and obvious differences in wetland function from the reference wetland. Hydrologic failure is the most common problem with wetland restoration (Mitsch and Gosselink, 2007). All other wetlands maintained surface water across the entire basin throughout the year.

The Beaver Creek Wetland water nutrient concentrations displayed significant seasonal variance—especially compared to the reference wetland. This variation in the Beaver Creek wetlands may be due to poor hydroperiod restoration. Hydrologic events, such as a heavy rain after a prolonged dry period, or the backing up of Beaver Creek due to US Army Corps of Engineer activity at Cave Run Dam for reservoir regulation, seem to have a more pronounced effect on surface inundation.

The difference in water chemistry provides some indications about the progress in both hydrologic and biogeochemical restoration. The data indicate that substrate processes have not yet been fully restored in the constructed wetlands. Because the watershed is mostly forested with low human population size or impact, regional surface waters are generally mostly infertile (Davis and Reeder, 2001). In the reference site, dissolved nitrogen and phosphorus are generally lower than most of the Beaver Creek wetland surface waters. The stability of nutrients in the reference wetland suggest greater stability of nutrient processing indicative of mature systems (Odum, 1969). The Beaver Creek wetland surface water nutrient fluctuations are indicative of a younger, less developed ecosystem.

Lack of ecosystem maturity can also be observed by analyzing the redox and sulfate cycles indicated by the sulfate and iron concentrations in surface waters. Sulfate was consistently found in nearly an order of magnitude higher concentrations in the reference wetland, and dissolved iron concentrations were usually an order of magnitude lower. These elements are in high concentrations in the regional bedrock, and are important indicators of sediment redox conditions and microbial community activity. Redox conditions indicative of functioning wetlands are dependent upon proper soil particle size and organic matter accumulation. The reference wetland has greater accumulations of organic material in its substrate.

Sulfate is one of the later compounds to be reduced by microbes as wetland soils become increasing anoxic, preceded by oxygen, nitrate, manganese, and iron (Reddy and D'Angelo, 1994). Microbial redox reactions of sulfur are the main source of sulfates found in wetland surface water (Jørgensen, 1988). Sulfate concentrations and sulfate reduction by sulfate reducing bacteria have been shown to be most influenced by total organic matter accumulation in wetland substrate (Brener, 1984; Westrich and Brener, 1984). The Beaver Creek Wetlands do not show obvious signs of significant organic matter accumulation or reduced soils based on observations made while taking water samples, so it is likely that lack of organic matter and soil development is responsible for the differences seen in nutrient concentrations.

Part of the issues with inadequate soil development issues may result from construction methods that are often unavoidable when restoring wetlands. Beibighauser (2011) notes that heavy equipment is often required to achieve hydrologic goals. This activity can lead to unintentional or intentional soil compaction of constructed wetlands. While it is unknown how significant of an effect this may have on the Beaver Creek Wetlands, it has been noted (Unger and Casper, 1994) that human knowledge of the negative effects of soil compaction on vegetation growth spans millennia. Moreno-Mateos et al. (2012) conducted a review of several hundred studies world-wide, and found that constructed wetland organic matter accumulation regularly lagged behind levels found in reference wetlands at 20 years of age. In addition to this finding, at 50-100 years of age constructed wetlands had still not achieved levels of biogeochemical cycling found in corresponding reference wetlands. Even after more than 50 years, it was still uncertain if these differences were a result of slow recovery, or the wetlands being on trajectory to an alternative state.

The Beaver Creek Wetlands are approximately 20-30 years of age. This would affect food availability and diversity in the wetlands, and possibly explain the greater avian diversity in this wetland. Gosselink and Turner (1978) found that nutrient concentrations can affect wetland species assemblages, and can also be influenced by hydrology. Substrate core data has shown the reference wetland has been a wetland for 300+ years (Haight, 1996) and, has had greater opportunity to accumulate organic matter than constructed wetlands that are nearing 30 years of age.

Indications of Functional Success Based Upon Avifauna

The reference wetland had higher bird richness, abundance, and diversity than any of the constructed Beaver Creek Wetlands. While the differences in richness and abundance may be in part explained by wetland size differences, the diversity differences cannot. Kenawell (2002) found that size was the most important factor in determining richness and abundance of avifauna, but not for species diversity. Snell-Rood and Cristol (2003) found that size was also a factor effecting richness and abundance in bottomland forests in Virginia, however size (3-8 ha) had little effect on diversity. Constructed and natural wetlands in New York also had richness and abundance linked to wetland size, but diversity was largely unaffected by wetland size (0.25-1.75 ha) (Brown and Smith, 1998). This study largely supported these findings as the highest richness and abundances were seen in constructed wetlands. Wetland size was less predictive of Shannon or Simpson diversity indexes, as higher metric values were observed in several small wetlands (< 1 ha) than larger wetlands (> 1 ha). In the previous study, Kenawell stated wetland 17 appeared to be the most successful constructed wetland in terms of use by avifauna. The reference wetland Shannon index of 1.254 was higher than the constructed average of 0.917 and the top constructed value of 1.037 from wetland 17. From a diversity standpoint, this claim is supported by this study.

Forty-three percent of all birds observed in the Beaver Creek Wetlands were considered obligate wetland species. The majority of these birds were Red-winged Blackbirds, Swamp Sparrows, Canada Geese, and Wood Ducks. This is a slight increase from the previous study on the same wetlands (Kenawell 2002) where 38% of all individuals recorded were from wetland obligate species, most of which being Red-winged Blackbirds, Wood Ducks, and Green Herons. In this study, Green Herons were rare occurrences in the Beaver Creek Wetlands. This is most likely due to the elimination of many former fishing areas for herons by successional growth surrounding the wetlands over the last 10-12 years. The original functional assessment of the Beaver Creek Wetlands (Haight, 1996) found 55% of the surveyed avian community to be obligate wetland species. It should be noted however, that this study surveyed different wetland basins than this study and Kenawell's 2002 study. Haight (1996) only surveyed five wetland basins, and no wetland had more than 25 total species observed making that dataset much more limited than this and Kenawell's assessments.

Differences can be seen in non-obligate species that occur in the wetlands. Blue Jays are an upland woodland species (Ehrlich et al., 1988) that was infrequently recorded in the reference wetland, which is located in a relatively low lying floodplain. Blue Jays were more frequently encountered in the Beaver Creek Wetland complex, which are surrounded by upland forest. This is likely reflective of differences in landscape placement of wetlands, which has been shown to have implications on wetland function (Whited et al., 2000) and communities (McCall, 1999).

Despite the lower diversity values and obligate species richness seen in the individual Beaver Creek Wetlands, the total Beaver Creek Wetland Complex had similar diversity values and obligate richness to the reference wetland. This finding suggests it is possible that the entire complex supports avian communities as diverse or nearly as diverse as the reference wetland, and may function like natural wetlands as a whole unit. It is important to note however, that this data is the result of 13 more point counts per sampling period, and the Beaver Creek Wetland complex a is 2.5 times larger area than the Reference wetland. The sampling issues could be resolved by conducting more point counts on the reference wetland, and fewer points in the Beaver Creek Wetland complex, or by expanding the study area to outside the immediate Cave Run Lake area to find additional natural wetlands for additional reference sites. The difference in total area needed to achieve similar avian communities may support current mitigation practices of restoring more area than was destroyed to achieve wetland functions. Birds noticeably absent from the Beaver Creek Wetlands generally required larger areas of water such as Bald Eagles (*Haliaeetus leucocephalus*), Osprey (*Pandion haliaetus*), and members of the family Laridae. All of these taxa were observed in the reference wetland.

Community overlap (R_o) increased since the 2002 Kenawell study from an average overlap value of 63.5% to 73.3%. Most of this increase came from the lower end of performance in the previous study, as can be seen in the range of scores between the two studies. In 2002, individual R_o ranged from 47.9%-75.2%. In this study, the lowest score exceeded the average score for 2002, with a range of 64.8%-79.3%. All wetlands surveyed in 2002 increased in community overlap except for wetland 34, which was 9.4% lower in R_o. The difference in the 2002's highest scoring and lowest scoring wetlands also shows a strong trend. Previously poor scoring wetlands make up most of the community overlap gains. The top 3 scoring wetlands from 2002 (35, 34, and 38) average net change in R_o was 0.43% while the 3 lowest scores from 2002 (16, 14, and 25) increased by an average of 20.1% community overlap. This suggests that the Beaver Creek Wetlands may be reaching the maximum of their potential to support avian communities similar to those seen in natural wetlands, and the trajectories of many top preforming wetlands appear to be plateauing over time.

The entire Beaver Creek Wetland complex had higher community overlap as a whole unit than the 14 individual wetland basins did. This shows that the whole complex may support avian communities similar to the reference wetland, but over a greater area. This metric (R_o) is less influenced by varying sample sizes (and differences in number of samples), however additional reference wetlands and/or reference point counts would be needed to compensate for localized habitat differences at the different point count locations.

Many previous studies have shown that constructed or restored wetlands do not totally replace natural wetlands (Bedford 1996; Hilderbrand et al., 2005; Hoeltje and Cole, 2009; Maron et al., 2010; Minkin and Ladd, 2003; Race and Fonseca 1996; Reiss et al. 2009; Reeder, 2011; Sudding et al., 2004; Woodcock et al, 2011; Zedler and Calloway, 1999) and that restored wetlands are not likely to support avian communities similar to those of natural wetlands (Brown and Smith, 1998; Snell-Rood and Cristol, 2003). Our results mirror these findings, as diversity and community overlap indicated differences between the constructed and reference wetlands. There are several examples of constructed wetlands supporting similar avian richness values to those of reference wetlands. Brown and Smith (1998) and Balcombe et al. (2005) found constructed wetlands with similar or higher species richness values to those of reference wetlands. It is noted (Balcombe et al., 2005) that similar richness does not necessarily indicate similar wetland function. Balcombe et al. (2005) and Muir Hotaling et al. (2002) both observe that there is little evidence that constructed wetlands function as sinks or sources of populations of breeding wetland birds. Determining reproductive success of similar or dissimilar avian communities would add to the understanding of constructed wetland function.

Wetland Functional Success Based Upon Seasonal Avifauna Community Assessments

Wetland avifauna communities were also analyzed on a seasonal basis. Previous studies at this location have surveyed up to 9 months in order to assess avifauna communities, but do not show differences in temporal occurrences of birds (Haight, 1996; Kennawell, 2002). In the reference wetland, the greatest species richness was observed in the breeding season while during spring migration we noticed the greatest species richness in the constructed wetlands. Typically, birds are most dependent on their habitats in the breeding season, while migration habitats are used for less time as temporary stopovers. Reduced richness (and obligate richness) in the breeding season may be a reflection of less suitable habitat in the constructed wetlands.

The reference wetland had minimal change in seasonal diversity throughout the year with a change in Shannon index under 0.06. The reference wetland's change in seasonal Shannon diversity ranged anywhere from 0.26 to 0.61. In some cases, constructed wetland avian diversity was reduced by over 50% during one season versus another. In wetland 35, the winter Shannon diversity value was 0.40, more than 60% lower than its spring migration value of 1.01. Winter was typically the lowest diversity period in the constructed wetlands, but had the highest diversity in the reference wetland (by a narrow margin.) This diversity difference may be reflective of incomplete community assemblages during certain times of the year in the constructed basins.

Very few, if any studies have directly compared avian community composition between constructed and natural wetlands on a seasonal basis throughout a full year. Community overlap values were seasonally lower than the annual value, which previously had been the only value investigated. This suggests that while constructed wetlands may be supporting certain bird communities during the course of the year similar to the reference wetland, they are not supporting them at the same time as the reference wetland. Many bird species are migratory, and may function differently in different regions and ecosystems depending on the time of the year, hence a species occurrence during the wrong season may be a reflection of different wetland functions at that time of the year.

Timing of wetland usage is particularly important in groups such as birds, where many individuals travel great distances and exploit varying ecological niches at different times and in different habitats. In a survey of restored Pennsylvania riparian buffer areas, Argent and Zwier (2007) found that bird species uses of habitats and behavior varied in different seasons. One potential factor in modified uses of the same habitats by birds could be changing macroinvertebrate communities and food availability. In Florida wetlands, Cook et al. (2014) found crayfish movements that were tied to seasonal hydrology changes. In Great Lakes coastal wetlands Gathman and Burton (2011) found that macroinvertebrate abundance greatly increased while diversity decreased along different vegetative zones in periods of flooding. Vegetative zones stayed relatively unchanged through these periods.

In this study, most waterfowl found in the Beaver Creek Wetlands were observed during brief stopovers during the spring migration. Reference wetland waterfowl observations consisted of spring migrants as well as overwintering birds. The winter of 2013-2014 was one of the coldest in recent years, and the majority of the Beaver Creek Wetlands froze for a portion of the winter season, while the reference wetland maintained several open pockets. In temperate zone wetlands, size and water depth likely affected ice development, and therefore food availability during this time. Wading and diving birds also may have been affected by seasonal vegetation growth in foraging areas, or seasonal hydrology affecting available prey such as fish and amphibians. Brooks and Davis (1987) found that population densities of Belted Kingfishers, which have water depth requirements for feeding, were most dependent on total optimal foraging area. This same vegetation growth is likely responsible for the large Swamp Sparrow (*Melospiza georgiana*) numbers that were observed in the Beaver Creek Wetlands, as the majority of these birds were seen in dense herbaceous vegetation along wetland edges. Palmer-Ball (2003) notes that the largest concentrations of Swamp Sparrow and other sparrow species in Kentucky are in wet areas with very dense vegetative cover, such as wetland edges.

Overall, the Beaver Creek Wetlands are not fully functional as natural wetlands systems; however they support diverse bird and wetland bird communities. Over the past 30 years, the vegetation has increased in coverage, which resulted in greater avifauna abundance and community overlap (with the reference wetland) than observed in previous studies (Haight, 1996; Kennawell, 2002). Soil development, especially organic matter accumulation, may take decades more time to become similar to natural wetlands. The lack of organic matter in the sediment could explain the differences in water chemistry, and may result in lower benthic biomass for the wetland food chain.

Birds are excellent indicators of ecosystem functions, because of their complex life history requirements, and migratory patterns. We found avifauna seasonal patterns can help identify wetland design flaws and problems with ecosystem development. How a wetland failed to replicate natural seasonal patterns can provide essential insights to managers. This knowledge could guide future modifications to enable the replication of natural patterns.

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APPENDIX A

Avian observations by year and season for study wetlands

Species	Reference Wetland	Wetland 1	Wetland 7	Wetland 11	Wetland 14	Wetland 16	Wetland 17	Wetland 20	Wetland 25	Wetland 33	Wetland 34	Wetland 35	Wetland 36	Wetland 38	Wetland 40
Acadian Flycatcher		1													
American Black Duck				3								2		3	
American Coot	1											1		1	
American Crow	27		2	11	7	1	8	13	5	3	6	3	5	1	3
American Goldfinch	37	20	14	28	41	4	41	25	11	37	23	9	12	20	9
American Redstart		2					1		1			1			1
American Robin	23		12	2		5	30	4		35	4			2	2
American Tree Sparrow									8						
American Woodcock	1			1											
Bald Eagle	1														
Baltimore Oriole		1		1			2	1	1						
Bank Swallow					2										
Barn Swallow	2	15	13	5	5	1	3	5				2			
Belted Kingfisher	10	3	3	3	1		6	6				2	2	2	
Black Vulture	2	2													1
Black-and-white Warbler		1				1		1				1			1
Black-billed Cuckoo		1													
Black-crowned Night-heron	2		1												
Blue Jay	5	20	23	19	6	5	10	6	6	4	7	13	7	15	11
Blue-gray Gnatchatcher	11		2	1				4	3		2	3	3	2	3
Blue-winged Teal	5	1		1	1		1	1	1			4		3	
Blue-winged Warbler							1	1	1		1			1	
Bonaparte's Gull	5														
Broad-winged Hawk				1											
Brown Creeper											1		1		
Brown Thrasher	3	2			1										1
Brown-headed Cowbird				1										2	2
Bufflehead	4			6		1	2		4			4	2		
Canada Goose	48	94	6	82	20	3	19	1	8		2	33	11	22	
Carolina Chickadee	36	20	11	9	7	2	10	13	18	7	14	12	11	20	10
Carolina Wren	9	16	7	7	4	10	11	10	5	7	8	5	10	7	10
Cedar Waxwing	40	4		20	1		1					6	2	53	
Chimney Swift				3								2			
Chipping Sparrow		3				1		1				1	1	1	
Cliff Swallow					4	3	17	1		12	40	1		4	
Common Grackle	16	3	4	4	2	4		2	3	1	3	1	1	6	

Common Yellowthroat	12	7	9	11	11	9	13	6	7	4	9	9	6	9	5
Double-crested Cormorant	3														
Downy Woodpecker	8	3	2	5			3	2	5	2	3	2	1	6	1
Eastern Bluebird	20	1	3	8	1		4	2	1	1	2	18	1	4	
Eastern Kingbird	5	3	1	4	2	1	5	1	3			3	2	7	1
Eastern Phoebe	8	1	2	1	1	2	6	1	3			2		3	3
Eastern Screech Owl	1		1												
Eastern Towhee		7	6	1	3	1			1	1		2	3	7	5
Eastern Wood-pewee	1	3	1	3			1						2		
European Starling	8	1		1	1		1								
Field Sparrow	3		8	2				3	21			1			2
Fox Sparrow		1													
Gadwall	1														
Golden Eagle					1										
Golden-crowned Kinglet	1	3			1	2	2	3	2			1	1	3	
Gray Catbird	3	2	5	2		1	2	1	1			1	1	1	1
Great Egret	2	1													
Great-blue Heron	21	2	1	6	5		2		1				2	2	
Greater Scaup	4														1
Green Heron	20		1	6	1									2	
Hairy Woodpecker	1	3		1			3		1	1				2	1
Hooded Merganser	20	5		8			4	10					2	7	
Hooded Warbler		1													
House Wren	1							1							
Indigo Bunting	11	2	5	1	15	6	12	10	10	8	4	3	1	5	2
Killdeer	1														
Lesser Scaup	5														
Louisiana Waterthrush		1							1		2				
Magnolia Warbler	1	1											1		
Mallard	34	3		8			4	4	1			17		4	
Marsh Wren					2	1									
Mourning Dove	3					2	1			1		1			
Northern Bobwhite	1		1					1				2			2
Northern Cardinal	13	10	10	5	1	2	5	1	2	7	1		4	11	3
Northern Flicker	4	1	7	9	6	3	8	4	3	2	1	6	4	7	4
Northern Mockingbird	3	1							1						
Northern Parula	3	1			1		3	2	1						
Northern Rough-winged Swallow	8	11	8	3	5	1	16	3	2				1		
Northern Waterthrush				1											
Orchard Oriole	1		1		5		3	3						3	1
Osprey	2														
Ovenbird		1	1												
Palm Warbler	10				2		3		1			2			

Pied-billed Grebe	9			1			2			1					
Pileated Woodpecker		5	3	2			1	1	2		3	1	3	3	
Prairie Warbler							1							1	
Prothonotary Warbler	1	1													
Purple Martin	1	8		35	1	1	1					4	4		
Red-bellied Woodpecker	1	2		4	4					1	2	1	5	3	1
Red-eyed Vireo	1	3	1	2	3	2	2	1	2	1	2	1	3	4	2
Red-headed Woodpecker													1	3	2
Red-shouldered hawk	6	8	6	9	6	8	10	7	4		4	8	6	6	7
Red-tailed Hawk				1	1			1						1	
Red-winged Blackbird	82	29	19	160	68	24	59	22	27	13	21	49	22	39	27
Ring-billed Gull	16														
Ring-necked Duck	6			10			1	3				31			
Rose-breasted Grosbeak		1					1		1						1
Ruby-throated Hummingbird	2		1					3	1						
Rusty Blackbird						2	11						1		
Scarlet Tanager		2		2	2		1								1
Sharp-shinned Hawk	1	1		1									1	1	1
Solitary Sandpiper				1										1	
Song Sparrow	34	36	31	21	34	53	45	34	31	24	24	28	25	36	18
Swamp Sparrow	18	18	27	37	42	39	40	26	53	18	24	43	46	41	18
Tennessee Warbler	2	2			1	1							1		
Tree Swallow	6	10	5	5	3		8		2		1	2		10	2
Tufted Titmouse	9	12	8	5	1	2	6	4	5		6	7		11	1
Turkey Vulture	14	16	3	11	4	2	7		1		1	1	1		
Warbling Vireo							1								
White-breasted Nuthatch	1	5	6	2	2		1	2	3	2	4	3	3	5	
White-crowned Sparrow			1		1		1		1						1
White-eyed Vireo	10	9	2	3	5	4	5	7	3	5	1	2	4	7	3
White-throated Sparrow	26	13	29	4	10	16	16	34	33	20	21	25	21	52	7
Wild Turkey	9							1							
Wilson's Snipe				1		1	1	2				1			
Winter Wren		5	2									2		1	1
Wood Duck	30	84	13	45	5	7	34	13	10			15	2	38	1
Wood Thrush			1												
Yellow Warbler	3	6	1	4	4	2	3	3	4	2		3	3	1	1
Yellow-bellied Sapsucker	1	5	2				2								2
Yellow-billed Cuckoo	5	3	2	1				1	3				1	1	3
Yellow-breasted Chat	2		2		4	4	7	2	4	1				3	
Yellow-rumped Warbler	29	6	1	3	2	2	3	1	5	1	3	18	3	44	
Yellow-throated Vireo		1							2						2
Yellow-throated Warbler	4	3		1	1		2	2	5		1	1	1		

Breeding Season Bird Observations:

Species	Reference Wetland	Wetland 1	Wetland 7	Wetland 11	Wetland 14	Wetland 16	Wetland 17	Wetland 20	Wetland 25	Wetland 33	Wetland 34	Wetland 35	Wetland 36	Wetland 38	Wetland 40
Acadian Flycatcher		1													
American Black Duck															
American Coot															
American Crow	2		1		1	1	2	4	3					1	3
American Goldfinch	17	6	8	10	6	1	19	16	6	11	7		4	5	2
American Redstart		1					1		1						
American Robin	9														2
American Tree Sparrow															
American Woodcock	1			1											
Bald Eagle															
Baltimore Oriole		1		1			2	1							
Bank Swallow					2										
Barn Swallow	2	15	13	2	4	1	3	4				2			
Belted Kingfisher	2	3	1	1			3					1	1	2	
Black Vulture		1													
Black-and-white Warbler		1						1				1			
Black-billed Cuckoo		1													
Black-crowned Night-heron															
Blue Jay	2	5						2						2	
Blue-gray Gnatchatcher	7							2	1		1	1			
Blue-winged Teal															
Blue-winged Warbler															
Bonaparte's Gull															
Broad-winged Hawk															
Brown Creeper															
Brown Thrasher	2	1													
Brown-headed Cowbird															
Bufflehead															
Canada Goose	2	48										19			
Carolina Chickadee	8	2	2					4	4	1				1	
Carolina Wren	3	1	1	2		1	1	2	3		1				
Cedar Waxwing	3	4		3								2	2		
Chimney Swift															
Chipping Sparrow		2													
Cliff Swallow					4	3	17	1		12	40				
Common Grackle	16	2	2	2		2								4	
Common Yellowthroat	8	6	5	6	6	3	9	4	5	3	8	4	5	4	2

Double-crested Cormorant															
Downy Woodpecker	1			1			1								
Eastern Bluebird	2		2				2	2			2				
Eastern Kingbird	2	2	1	3	2		3	1	3			1		4	1
Eastern Phoebe	5		1	1			2		1					2	2
Eastern Screech Owl															
Eastern Towhee						1									
Eastern Wood-pewee	1	3	1										1		
European Starling					1										
Field Sparrow															
Fox Sparrow															
Gadwall															
Golden Eagle															
Golden-crowned Kinglet															
Gray Catbird	2	2	3	2		1	2	1	1			1	1	1	1
Great Egret	1														
Great-blue Heron	2	1		2	3								2	1	
Greater Scaup															
Green Heron	9		1	4											
Hairy Woodpecker				1			1								
Hooded Merganser															
Hooded Warbler		1													
House Wren	1														
Indigo Bunting	2	1	3		8	3	8	5	6	6	3			5	2
Killdeer	1														
Lesser Scaup															
Louisiana Waterthrush															
Magnolia Warbler															
Mallard	4						2					17		4	
Marsh Wren															
Mourning Dove	1					2	1					1			
Northern Bobwhite	1														
Northern Cardinal		2	3	4	1		5		2		1		2	1	1
Northern Flicker	1		1	5	1			1	1			2		1	
Northern Mockingbird															
Northern Parula	3	1			1		1								
Northern Rough-winged Swallow	8	11	8		4		12	2	2						
Northern Waterthrush															
Orchard Oriole	1		1		5		1							1	1
Osprey															
Ovenbird		1													
Palm Warbler															
Pied-billed Grebe															
Pileated Woodpecker															
Prairie Warbler							1								

Prothonotary Warbler	1	1													
Purple Martin	1	7		35								4	4		
Red-bellied Woodpecker				1											1
Red-eyed Vireo	1	3	1	2	2	2	2		2		1	1	2	2	2
Red-headed Woodpecker														1	
Red-shouldered hawk	2			1			1	2					1	2	
Red-tailed Hawk															
Red-winged Blackbird	46	19	11	33	9	9	24	18	11	13	14	18	10	27	14
Ring-billed Gull															
Ring-necked Duck															
Rose-breasted Grosbeak															
Ruby-throated Hummingbird	1														
Rusty Blackbird															
Scarlet Tanager		1													
Sharp-shinned Hawk															
Solitary Sandpiper															
Song Sparrow	3	7	2	5	4	3	3	5	3	3	3	4	2	2	2
Swamp Sparrow															
Tennessee Warbler															
Tree Swallow	6	7		2	2		5		2					5	1
Tufted Titmouse							1	1						1	
Turkey Vulture		16	3	1											
Warbling Vireo							1								
White-breasted Nuthatch		1													
White-crowned Sparrow															
White-eyed Vireo	7	4	2	3	3	1	2	5	2	3	1		1	4	2
White-throated Sparrow															
Wild Turkey	9														
Wilson's Snipe															
Winter Wren															
Wood Duck	18	31	8	22	2		19	11	5			11		12	
Wood Thrush			1												
Yellow Warbler	2	3		1	2	1	2	1	3	1		1	2		
Yellow-bellied Sapsucker															
Yellow-billed Cuckoo	4	3	2	1				1	3				1	1	3
Yellow-breasted Chat	2		2		3	4	7	2	3					3	
Yellow-rumped Warbler															
Yellow-throated Vireo		1													1
Yellow-throated Warbler	3	2		1			2		3		1	1			

Fall Migration Bird Observations:

Species	Reference Wetland	Wetland 1	Wetland 7	Wetland 11	Wetland 14	Wetland 16	Wetland 17	Wetland 20	Wetland 25	Wetland 33	Wetland 34	Wetland 35	Wetland 36	Wetland 38	Wetland 40
Acadian Flycatcher															
American Black Duck															
American Coot														1	
American Crow	13		1	11	5		6	8	2	2	3	3	4		
American Goldfinch	9	5	6	15	32	3	15	9	5	21	10	7	8	2	2
American Redstart		1													
American Robin	2		10			2	5	4		35	4				
American Tree Sparrow															
American Woodcock															
Bald Eagle															
Baltimore Oriole															
Bank Swallow															
Barn Swallow															
Belted Kingfisher	4		2	2			3	3				1	1		
Black Vulture															
Black-and-white Warbler															
Black-billed Cuckoo															
Black-crowned Night-heron	2														
Blue Jay		8	9	5	4	3	7	2	4	4	4	8	3	6	2
Blue-gray Gnatchatcher															
Blue-winged Teal															
Blue-winged Warbler															
Bonaparte's Gull															
Broad-winged Hawk				1											
Brown Creeper													1		
Brown Thrasher															
Brown-headed Cowbird															
Bufflehead															
Canada Goose	13	7													
Carolina Chickadee	5	7	3	5	4	2			5	5	4	2	5	11	1
Carolina Wren	2	9	4	4	3	5	7	6	2	4	3	2	6	4	4
Cedar Waxwing	37			17	1		1					4		53	
Chimney Swift				1											
Chipping Sparrow															
Cliff Swallow															
Common Grackle															
Common Yellowthroat	4		2		3	4	3	1	1			1		1	2

Double-crested Cormorant	3														
Downy Woodpecker	1	2	2	2				1	2	1	2		1	2	
Eastern Bluebird	14			4					1			13	1	4	
Eastern Kingbird	2														
Eastern Phoebe	3	1	1		1	1	4	1	2			2		1	1
Eastern Screech Owl															
Eastern Towhee		1	2		1					1		1	2	1	
Eastern Wood-pewee							1								
European Starling		1		1											
Field Sparrow	3			2				3	5						
Fox Sparrow		1													
Gadwall															
Golden Eagle															
Golden-crowned Kinglet					1	1	1		2			1		1	
Gray Catbird	1														
Great Egret															
Great-blue Heron	9	1			1									1	
Greater Scaup															
Green Heron	11			1										1	
Hairy Woodpecker		3					1							2	1
Hooded Merganser	2			4				5						2	
Hooded Warbler															
House Wren															
Indigo Bunting	7	1	1	1	7	2	4	5	1				1		
Killdeer															
Lesser Scaup															
Louisiana Waterthrush															
Magnolia Warbler	1	1											1		
Mallard	14	3						2	1						
Marsh Wren					2	1									
Mourning Dove															
Northern Bobwhite															
Northern Cardinal	4	7	3					1		4			1	5	
Northern Flicker			3	1	4	1	5	2	1	2	1	4	2	3	2
Northern Mockingbird	2														
Northern Parula															
Northern Rough-winged Swallow															
Northern Waterthrush															
Orchard Oriole								1							
Osprey	1														
Ovenbird															
Palm Warbler	10				2		3		1			1			
Pied-billed Grebe	9			1											
Pileated Woodpecker		4	1	1			1	1	1		3	1	3	2	
Prairie Warbler														1	

Prothonotary Warbler															
Purple Martin															
Red-bellied Woodpecker		1		2	3					1	1	1	3	2	
Red-eyed Vireo					1					1				1	
Red-headed Woodpecker													1	2	2
Red-shouldered hawk	2		1	2		2		2			2	1		1	4
Red-tailed Hawk								1							
Red-winged Blackbird	22			99	38	1	3		8			9		1	2
Ring-billed Gull															
Ring-necked Duck															
Rose-breasted Grosbeak		1							1						1
Ruby-throated Hummingbird	1		1					3	1						
Rusty Blackbird															
Scarlet Tanager					1										
Sharp-shinned Hawk															
Solitary Sandpiper															
Song Sparrow	12	17	10	13	18	22	12	14	13	11	6	11	13	16	6
Swamp Sparrow	12	9	12	27	36	21	20	7	32	15	11	19	32	25	9
Tennessee Warbler	2	2			1								1		
Tree Swallow															
Tufted Titmouse	3	3	2	2	1	1	1		3		2	2		8	
Turkey Vulture	3			8	4	1	6				1				
Warbling Vireo															
White-breasted Nuthatch		2	2		2			1	1	2	3	1	1	2	
White-crowned Sparrow					1										1
White-eyed Vireo	1	3				2	2	2		2		2	2	2	1
White-throated Sparrow	13	9	8	4	6	7	4	14	8	11	13	7	14	33	6
Wild Turkey															
Wilson's Snipe															
Winter Wren												2			
Wood Duck	8	46	3	13			3	2	2				1	19	
Wood Thrush															
Yellow Warbler															
Yellow-bellied Sapsucker	1	2	2												
Yellow-billed Cuckoo	1														
Yellow-breasted Chat															
Yellow-rumped Warbler	21	3		3	1	2	1	1	5	1	1	16	2	42	
Yellow-throated Vireo															1
Yellow-throated Warbler															

Winter Season Bird Observations:

Species	Reference Wetland	Wetland 1	Wetland 7	Wetland 11	Wetland 14	Wetland 16	Wetland 17	Wetland 20	Wetland 25	Wetland 33	Wetland 34	Wetland 35	Wetland 36	Wetland 38	Wetland 40
Acadian Flycatcher															
American Black Duck				3										3	
American Coot															
American Crow	9				1										
American Goldfinch	8	9		3	2		7			3	6	2		11	2
American Redstart															
American Robin	9		2			3	25								
American Tree Sparrow									8						
American Woodcock															
Bald Eagle															
Baltimore Oriole															
Bank Swallow															
Barn Swallow															
Belted Kingfisher	3							1							
Black Vulture															
Black-and-white Warbler															
Black-billed Cuckoo															
Black-crowned Night-heron															
Blue Jay	3	7	12	11	2	2	3	1	2		2	4	4	7	4
Blue-gray Gnatchatcher															
Blue-winged Teal															
Blue-winged Warbler															
Bonaparte's Gull															
Broad-winged Hawk															
Brown Creeper											1				
Brown Thrasher															
Brown-headed Cowbird															
Bufflehead	4														
Canada Goose	22	34	4	32	16		6	1	3			9		8	
Carolina Chickadee	11	8	6	4	3		10	7	5		7	6	4	6	4
Carolina Wren	4	5	2	1	1	3	3	1		3	3	2	4	1	4
Cedar Waxwing															
Chimney Swift															
Chipping Sparrow															
Cliff Swallow															
Common Grackle															
Common Yellowthroat															

Double-crested Cormorant															
Downy Woodpecker	5	1		1			2	1	3	1	1	1		4	
Eastern Bluebird	1	1	1									1			
Eastern Kingbird															
Eastern Phoebe															
Eastern Screech Owl															
Eastern Towhee		6	4	1	2				1					6	3
Eastern Wood-pewee															
European Starling	8														
Field Sparrow			8						15						
Fox Sparrow															
Gadwall															
Golden Eagle															
Golden-crowned Kinglet	1	1				1	1	3					1	2	
Gray Catbird															
Great Egret															
Great-blue Heron	5			1											
Greater Scaup	3														
Green Heron															
Hairy Woodpecker	1						1		1	1					
Hooded Merganser	10	5		4				3					2	2	
Hooded Warbler															
House Wren															
Indigo Bunting															
Killdeer															
Lesser Scaup	3														
Louisiana Waterthrush															
Magnolia Warbler															
Mallard	14			4				2							
Marsh Wren															
Mourning Dove	1									1					
Northern Bobwhite															
Northern Cardinal	5		4			2				3				3	2
Northern Flicker	2		3	1	1	1	3	1	1				2	3	1
Northern Mockingbird	1														
Northern Parula															
Northern Rough-winged Swallow															
Northern Waterthrush															
Orchard Oriole															
Osprey															
Ovenbird															
Palm Warbler															
Pied-billed Grebe															
Pileated Woodpecker		1	1	1											
Prairie Warbler															

Prothonotary Warbler															
Purple Martin															
Red-bellied Woodpecker	1	1			1						1		1	1	
Red-eyed Vireo															
Red-headed Woodpecker															
Red-shouldered hawk	2		1				3				2				
Red-tailed Hawk														1	
Red-winged Blackbird				2	3	2	3	1	2		1	1	3		1
Ring-billed Gull	16														
Ring-necked Duck	3														
Rose-breasted Grosbeak															
Ruby-throated Hummingbird															
Rusty Blackbird															
Scarlet Tanager															
Sharp-shinned Hawk	1														
Solitary Sandpiper															
Song Sparrow	11	7	15	2	4	9	22	11	13	7	11	11	8	14	6
Swamp Sparrow	4	7	15	3	2	15	16	18	21	3	11	22	13	11	8
Tennessee Warbler															
Tree Swallow															
Tufted Titmouse	1	9	6	2			4	3	2		4	3		2	
Turkey Vulture															
Warbling Vireo															
White-breasted Nuthatch	1	2	3				1				1	1	1	1	
White-crowned Sparrow															
White-eyed Vireo															
White-throated Sparrow	10	4	21		4	9	12	17	25	9	7	18	6	19	
Wild Turkey															
Wilson's Snipe															
Winter Wren		5	2											1	1
Wood Duck	2														
Wood Thrush															
Yellow Warbler															
Yellow-bellied Sapsucker		2					1								
Yellow-billed Cuckoo															
Yellow-breasted Chat															
Yellow-rumped Warbler	7	2	1				2				1	2	1	2	
Yellow-throated Vireo															
Yellow-throated Warbler															

Spring Migration Bird Observations:

Species	Reference Wetland	Wetland 1	Wetland 7	Wetland 11	Wetland 14	Wetland 16	Wetland 17	Wetland 20	Wetland 25	Wetland 33	Wetland 34	Wetland 35	Wetland 36	Wetland 38	Wetland 40
Acadian Flycatcher															
American Black Duck												2			
American Coot	1											1			
American Crow	3							1		1	3		1		
American Goldfinch	3				1					2				2	3
American Redstart												1			1
American Robin	3			2										2	
American Tree Sparrow															
American Woodcock															
Bald Eagle	1														
Baltimore Oriole									1						
Bank Swallow															
Barn Swallow				3	1			1							
Belted Kingfisher	1				1			2							
Black Vulture	2	1													1
Black-and-white Warbler						1									1
Black-billed Cuckoo															
Black-crowned Night-heron			1												
Blue Jay			2	3				1			1	1			5
Blue-gray Gnatchatcher	4		2	1				2	2		1	2	3	2	3
Blue-winged Teal	5	1		1	1		1	1	1			4		3	
Blue-winged Warbler							1	1	1		1			1	
Bonaparte's Gull	5														
Broad-winged Hawk															
Brown Creeper															
Brown Thrasher	1	1			1										1
Brown-headed Cowbird				1										2	2
Bufflehead				6		1	2		4			4	2		
Canada Goose	11	5	2	50	4	3	13		5		2	5	11	14	
Carolina Chickadee	12	3						2	4	1	3	4	2	2	5
Carolina Wren		1				1		1			1	1		2	2
Cedar Waxwing															
Chimney Swift				2								2			
Chipping Sparrow		1				1		1				1	1	1	
Cliff Swallow												1		4	
Common Grackle		1	2	2	2	2		2	3	1	3	1	1	2	
Common Yellowthroat		1	2	5	2	2	1	1	1	1	1	4	1	4	1

Double-crested Cormorant															
Downy Woodpecker	1			1								1			1
Eastern Bluebird	3			4	1		2			1		4			
Eastern Kingbird	1	1		1		1	2					2	2	3	
Eastern Phoebe						1									
Eastern Screech Owl	1		1												
Eastern Towhee												1	1		2
Eastern Wood-pewee				3									1		
European Starling							1								
Field Sparrow									1			1			2
Fox Sparrow															
Gadwall	1														
Golden Eagle					1										
Golden-crowned Kinglet		2													
Gray Catbird			2												
Great Egret	1	1													
Great-blue Heron	5		1	3	1		2		1						
Greater Scaup	1														1
Green Heron				1	1									1	
Hairy Woodpecker															
Hooded Merganser	8						4	2						3	
Hooded Warbler															
House Wren								1							
Indigo Bunting	2		1			1			3	2	1	3			
Killdeer															
Lesser Scaup	2														
Louisiana Waterthrush		1							1		2				
Magnolia Warbler															
Mallard	2			4			2								
Marsh Wren															
Mourning Dove	1														
Northern Bobwhite			1					1				2			2
Northern Cardinal	4	1		1									1	2	
Northern Flicker	1	1		2		1									1
Northern Mockingbird		1							1						
Northern Parula							2	2	1						
Northern Rough-winged Swallow				3	1	1	4	1					1		
Northern Waterthrush				1											
Orchard Oriole							2	2						2	
Osprey	1														
Ovenbird			1												
Palm Warbler												1			
Pied-billed Grebe							2			1					
Pileated Woodpecker			1						1					1	
Prairie Warbler															

Prothonotary Warbler															
Purple Martin		1			1	1	1								
Red-bellied Woodpecker				1									1		
Red-eyed Vireo								1			1		1	1	
Red-headed Woodpecker															
Red-shouldered hawk		8	4	6	6	6	6	3	4			7	5	3	3
Red-tailed Hawk				1	1										
Red-winged Blackbird	14	10	8	25	18	12	29	3	6		6	21	9	11	10
Ring-billed Gull															
Ring-necked Duck	3			10			1	3				31			
Rose-breasted Grosbeak							1								
Ruby-throated Hummingbird															
Rusty Blackbird						2	11						1		
Scarlet Tanager		1		2	1		1								1
Sharp-shinned Hawk		1		1									1	1	1
Solitary Sandpiper				1										1	
Song Sparrow	8	5	4	1	8	19	8	4	2	3	4	2	2	4	4
Swamp Sparrow	2	2		7	4	3	4	1			2	2	1	5	1
Tennessee Warbler						1									
Tree Swallow		3	5	3	1		3				1	2		5	1
Tufted Titmouse	5			1		1						2			1
Turkey Vulture	11			2		1	1		1			1	1		
Warbling Vireo															
White-breasted Nuthatch			1	2				1	2			1	1	2	
White-crowned Sparrow			1				1		1						
White-eyed Vireo	2	2			2	1	1		1				1	1	
White-throated Sparrow	3							3			1		1		1
Wild Turkey								1							
Wilson's Snipe				1		1	1	2				1			
Winter Wren															
Wood Duck	2	7	2	10	3	7	12		3			4	1	7	1
Wood Thrush															
Yellow Warbler	1	3	1	3	2	1	1	2	1	1		2	1	1	1
Yellow-bellied Sapsucker		1					1								2
Yellow-billed Cuckoo															
Yellow-breasted Chat					1				1	1					
Yellow-rumped Warbler	1	1			1						1				
Yellow-throated Vireo									2						
Yellow-throated Warbler	1	1			1			2	2				1		

APPENDIX B

Water chemistry data

Phosphorous	Jun	Jul	Aug	Sept	Nov	Dec	Mar	May
Reference	0.023	0.025	0.028	0.026	0.131	0.13	0.066	0.037
1	0.021	0.882	0.197	1.385	0.219	0.632	No Data	0.94
7	0.002	0.004	0.004	0.02	0.056	0.072	No Data	0.023
11	0.021	0.022	0.117	0.005	0.097	0.025	0.71	0.009
14	0.019	0.017	0.019	0.056	0.077	0.038	0.041	0.013
16	0.031	0.017	0.041	0.014	0.069	0.042	0.02	0.005
17	0.036	0.014	0.063	0.043	0.104	0.002	0.027	0.008
20	0.004	0.031	0.043	0.024	0.028	0.074	No Data	0.032
25	0.003	0.023	0.052	0.01	0.048	0.103	0.053	0.013
33	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
34	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
35	0.026	0.016	0.066	0.022	0.177	0.06	0.112	0.134
36	0.03	0.025	0.033	0.191	0.064	0.065	1.243	0.087
38	0.023	0.012	0.044	0.026	0.096	0.047	0.148	0.014
40	0.011	0.021	0.049	0.048	0.221	0.105	0.051	0.025

Ammonium	Jun	Jul	Aug	Sept	Nov	Dec	Mar	May
Reference	0.098	0.094	0.102	0.099	0.024	0.038	0.136	0.093
1	0.024	0.927	1.028	0.893	0.074	0.115	No Data	0.502
7	0.091	0.128	0.047	0.033	0.011	0.115	No Data	0.221
11	0.207	0.114	1.635	0.118	0.062	0.189	0.082	0.119
14	0.087	0.36	0.094	0.157	0.117	0.132	0.035	0.139
16	0.181	0.03	1.519	0.156	0.046	0.143	0.117	0.126
17	0.089	0.077	0.342	0.113	0.244	0.158	0.099	0.174
20	0.12	0.078	0.105	0.035	0.016	0.095	No Data	0.254
25	0.056	0.049	0.041	0.075	0.011	0.089	0.045	0.234
33	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
34	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
35	0.176	0.07	0	0.22	0.029	0.135	0.081	0.197
36	0.325	0.285	0.014	0.016	0.024	0.167	0.056	0.135
38	0.168	0.037	0	0.115	0.069	0.12	0.056	0.159
40	0.13	0.057	0	0.121	0.06	0.164	0.041	0.174

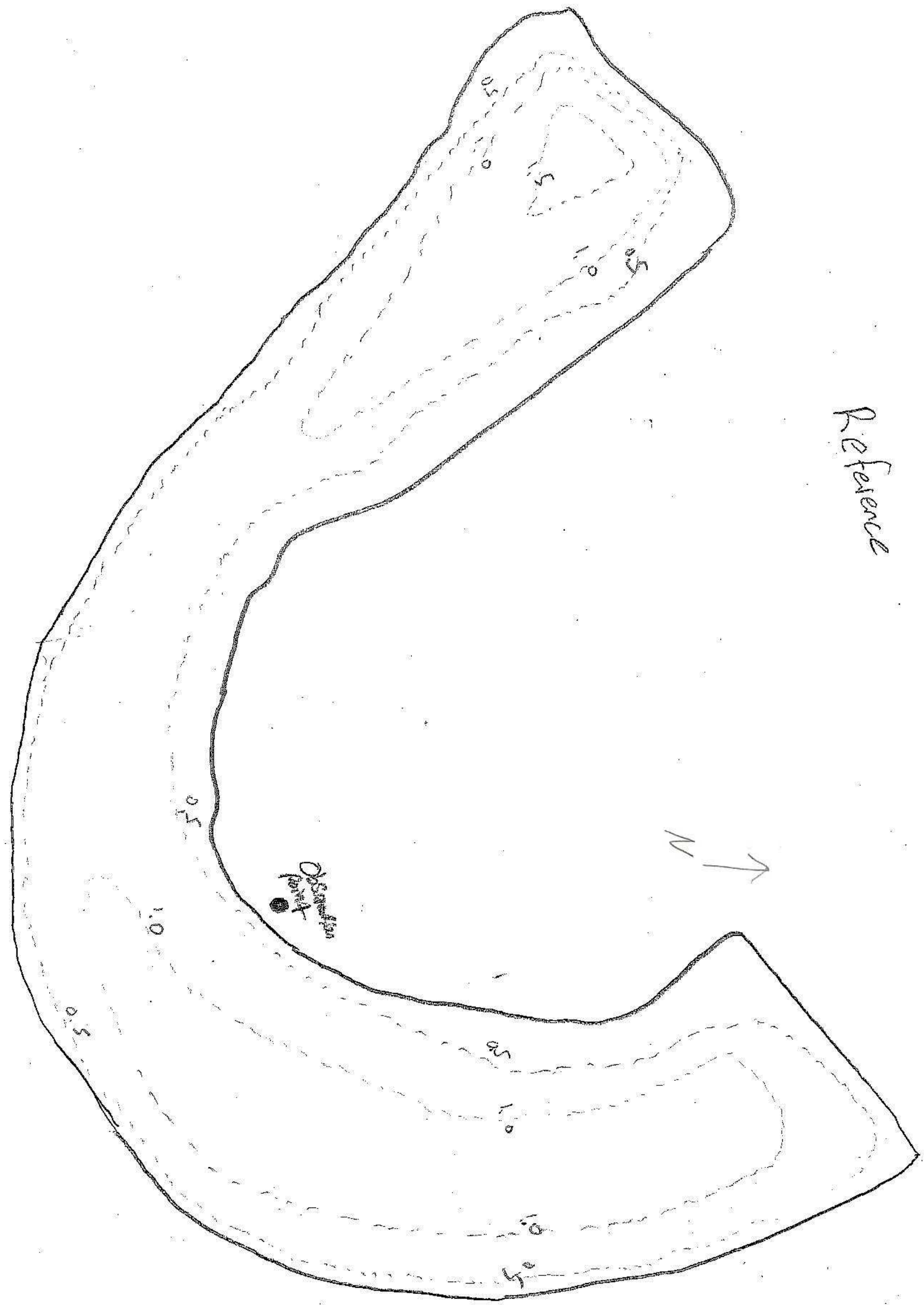
Iron	Jun	Jul	Aug	Sept	Nov	Dec	Mar	May
Reference	0.06	0.001	0.01	0.012	0.008	0.002	0.014	0.004
1	0.82	0.039	0.071	1.105	0.045	0.076	No Data	0.056
7	0.691	0.057	0.034	0.05	0.042	0.035	No Data	0.074
11	0.544	0.387	0.031	0.308	0.134	0.13	0.183	0.061
14	3.3	0.134	0.059	0.081	0.124	0.064	0.098	0.017
16	1.986	0.018	0.134	0.486	0.067	0.089	0.067	0.059
17	1.119	0	0.034	0.076	0.083	0.044	0.075	0.034
20	1.414	0.083	0.096	0.095	0.063	0.103	No Data	0.083
25	0.266	0.025	0.039	0.058	0.087	0.066	0.105	0.067
33	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
34	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
35	0.117	0.131	0.039	0.091	0.093	0.071	0.089	0.063
36	0.61	0.162	0.144	0.521	0.064	0.083	0.115	0.045
38	0.069	0	0.019	0.106	0.102	0.075	0.065	0.051
40	0.136	0.006	0.012	0.082	0.099	0.035	0.7	0.06

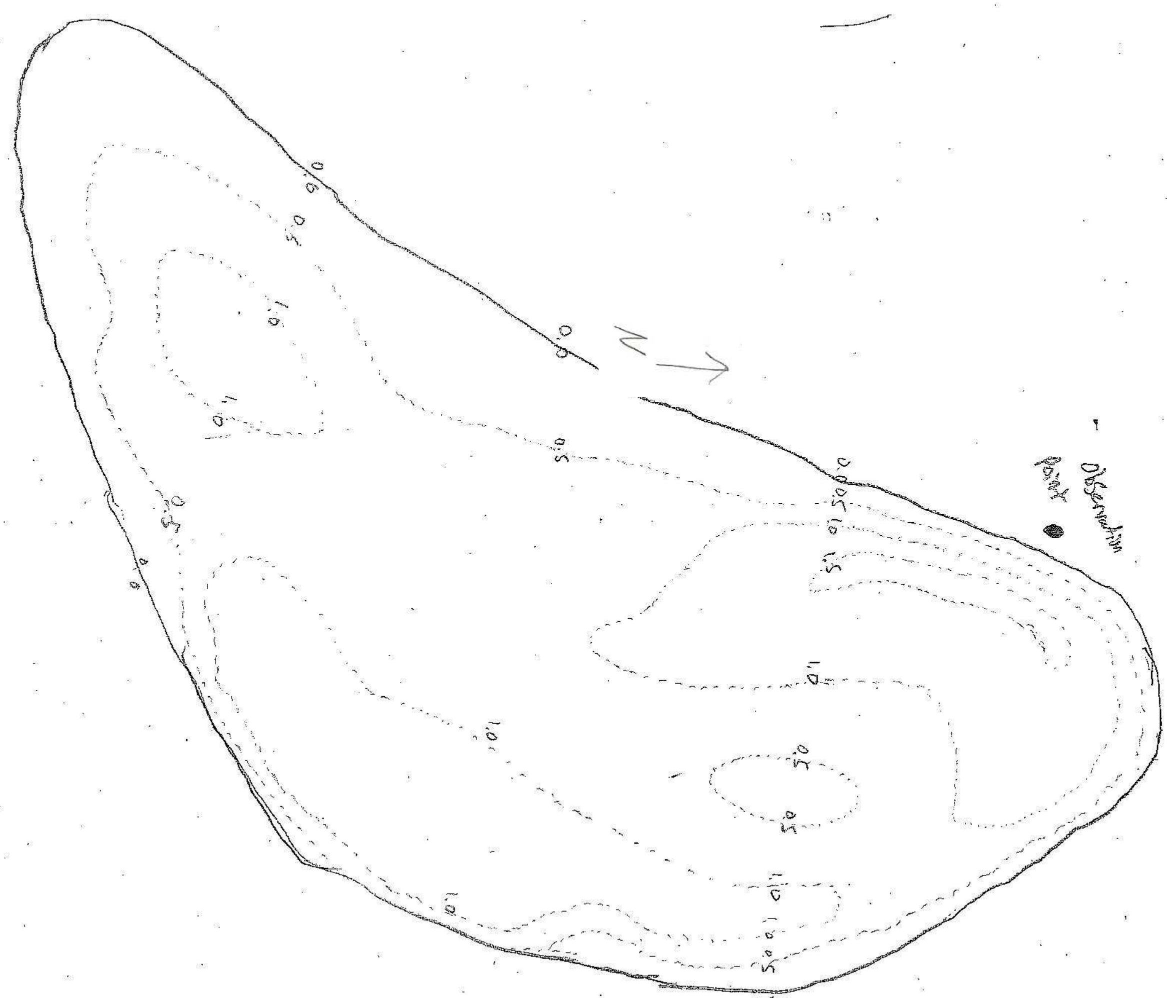
Sulfate	Jun	Jul	Aug	Sept	Nov	Dec	Mar	May
Reference	30.8	32	29.3	30.9	39.7	36.7	21.4	25.8
1	1.3	2	1.9	2.9	5.6	8.3	No Data	3.4
7	1	1.9	0.7	1.2	3.8	4.5	No Data	1.2
11	5.4	2.3	0.016	2.1	5.5	7.2	8.7	1.8
14	0.07	1.9	0.8	0.9	6	0.9	1.1	1.4
16	1.3	1	1.8	5.4	0.7	10.3	11.1	2.3
17	1.1	1.5	1.2	8.8	11.3	14.1	12.4	1.7
20	2.7	1.9	1	3.3	15.7	10.1	No Data	4.1
25	6.1	2.2	1.4	12.8	12.5	9.6	9.4	3.3
33	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
34	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
35	4.8	1.8	14	19.9	10.3	9.2	10.4	6.3
36	7.7	2.2	0.9	7.3	31.6	8.9	28.5	5.1
38	2.7	1.1	0.6	1.2	9.2	0.9	1.3	3.6
40	3.2	1.7	1.4	3.8	7.9	8.7	10.4	4.8

Nitrate	Jun	Jul	Aug	Sept	Nov	Dec	Mar	May
Reference	0.047	0.00	0.01	0.02	0.1	0.12	0.03	0.052
1	0.051	0.01	0.01	0.08	0.07	0.49	No Data	0.118
7	0.013	0.02	0.02	0.1	0.33	0.04	No Data	0.02
11	0.021	0.01	0	0.04	0.06	0.02	0.01	0.03
14	0.014	0.01	0.01	0.2	0.13	0.05	0.01	0.01
16	0.005	0.45	0.02	0.24	0.02	0.01	0.02	0.01
17	0.009	0.03	0	0.04	0.08	0.04	0.04	0.01
20	0.012	0.02	0.02	0.14	0.19	0.13	No Data	0.02
25	0.017	0.01	0.03	0.06	0.07	0.04	0.01	0.04
33	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
34	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
35	0.098	0.06	0.01	0.06	0.2	0.02	0.06	0.02
36	0.017	0.02	0.05	0.11	0.14	0.01	0.02	0.01
38	0.074	0.00	0.03	0.27	0.03	0.02	0.25	0.01
40	0.046	0.04	0.04	0.08	0.17	0.01	0.03	0.01

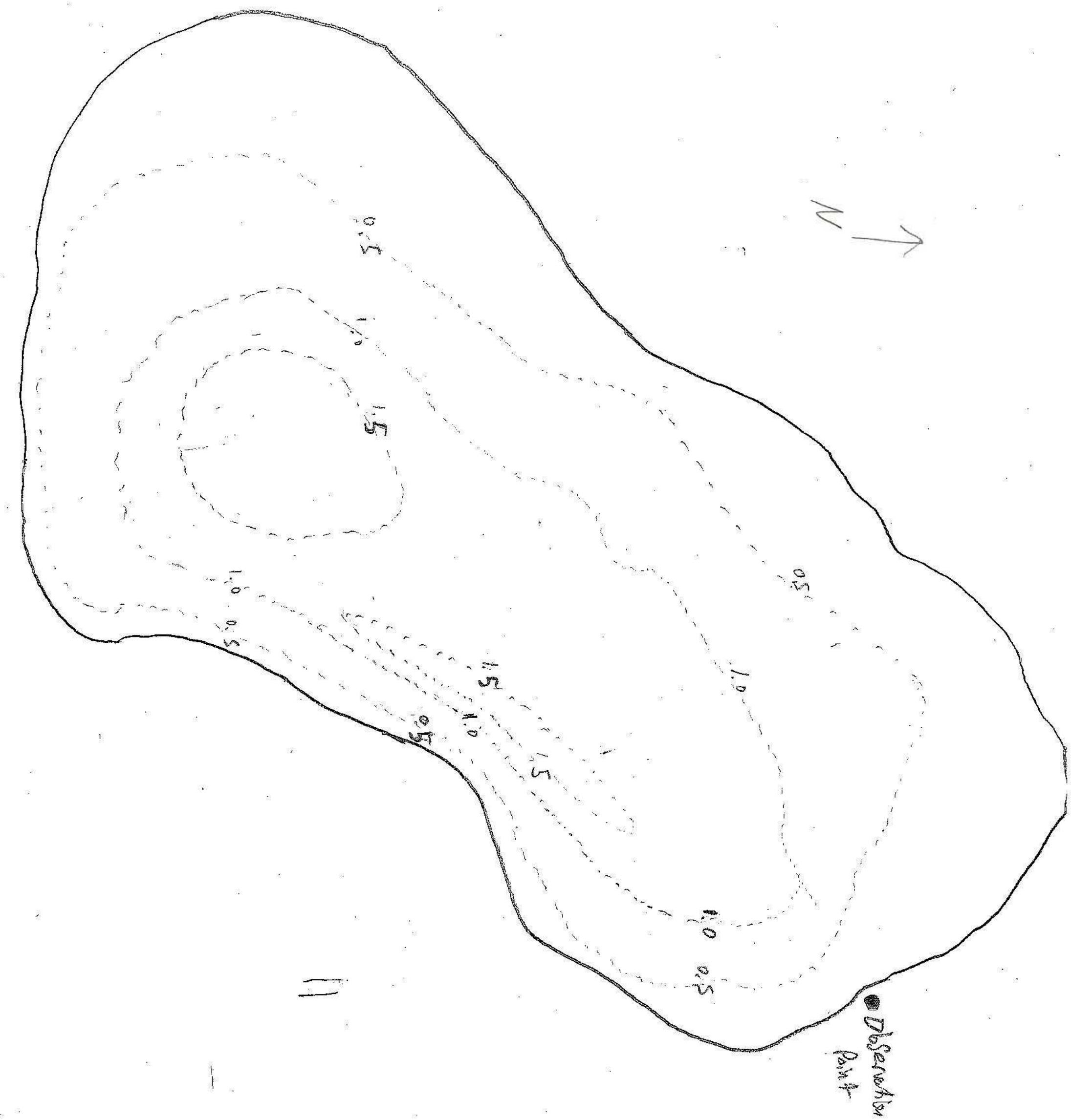
APPENDIX C

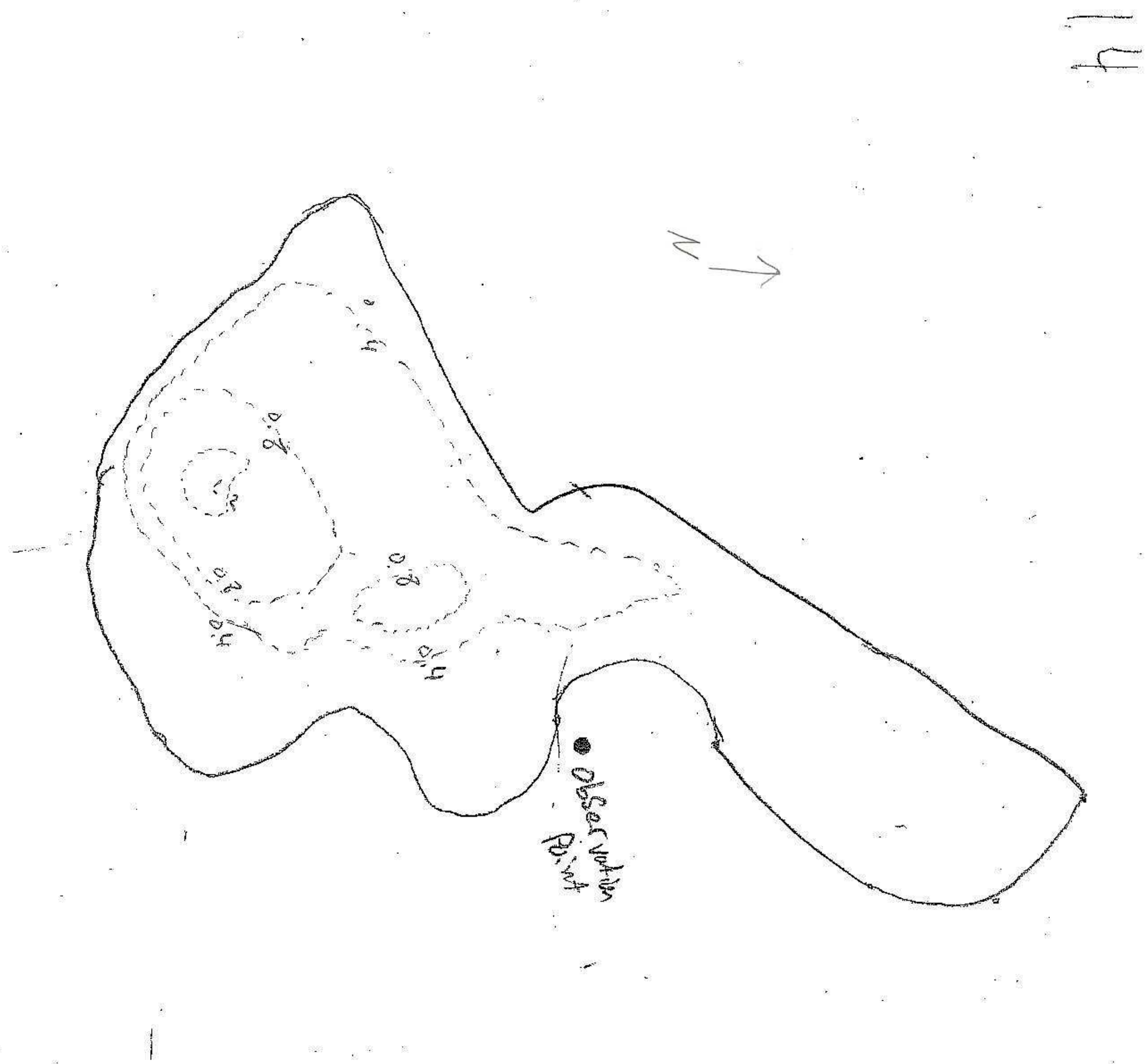
Wetland microtopography

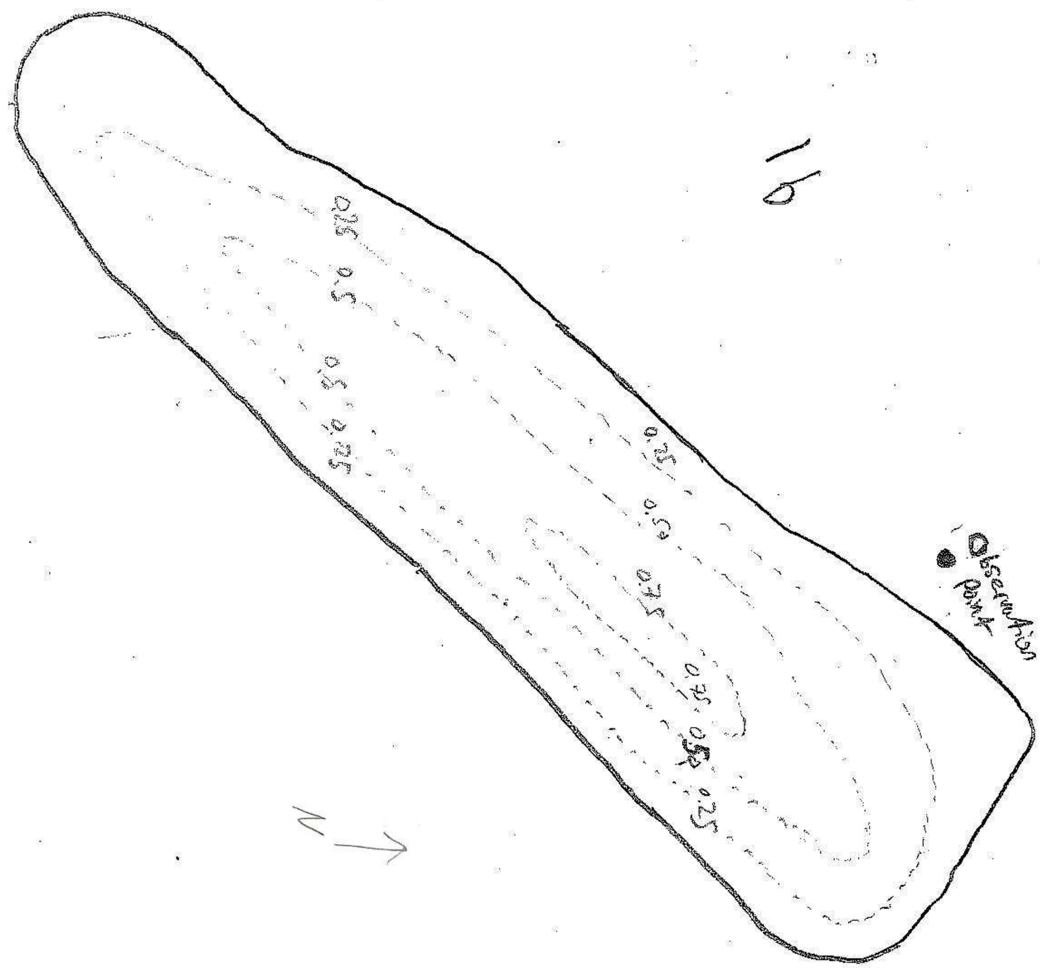

Reference
Observation Point
N
0.5
1.0
1.5

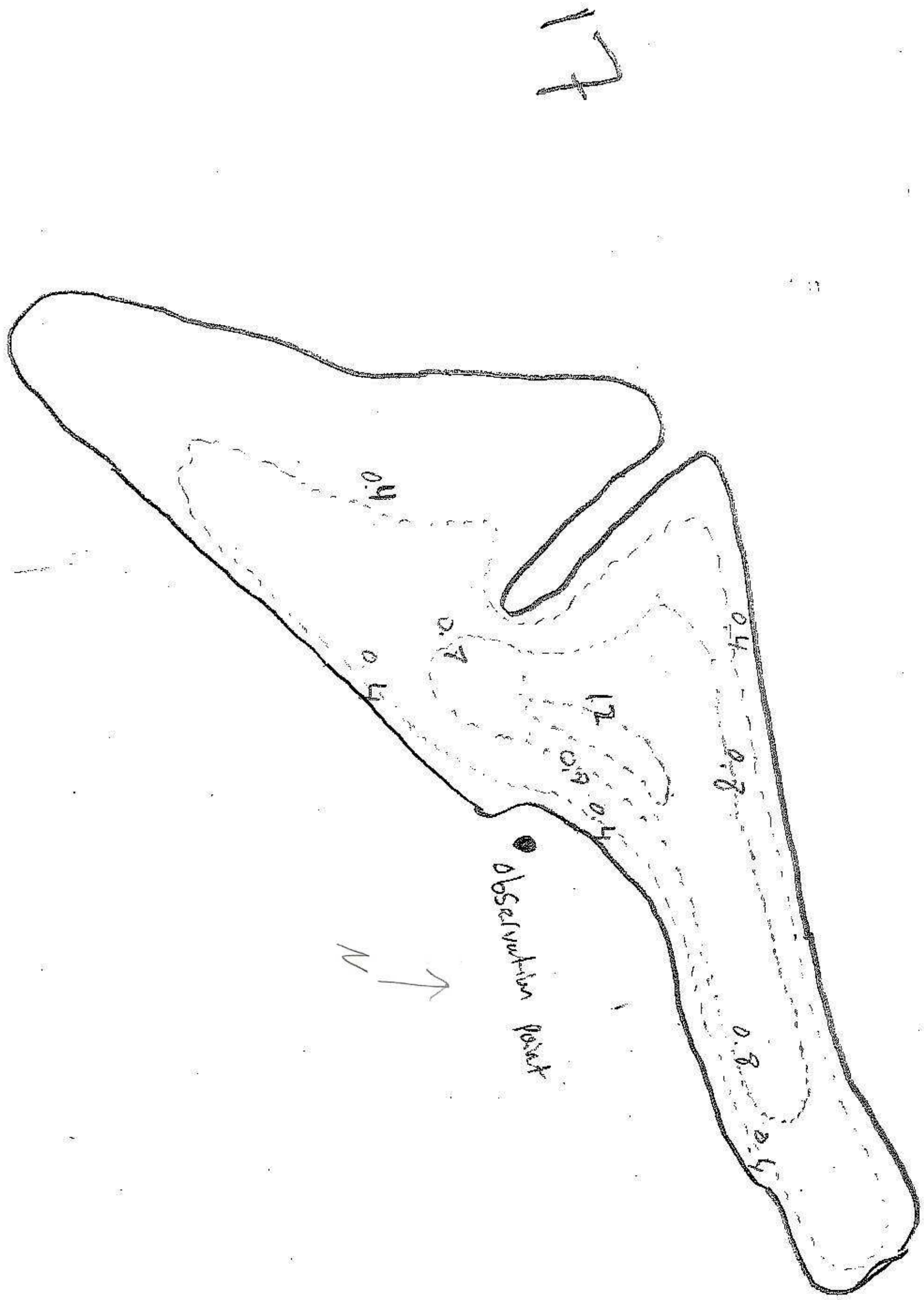

Observation point

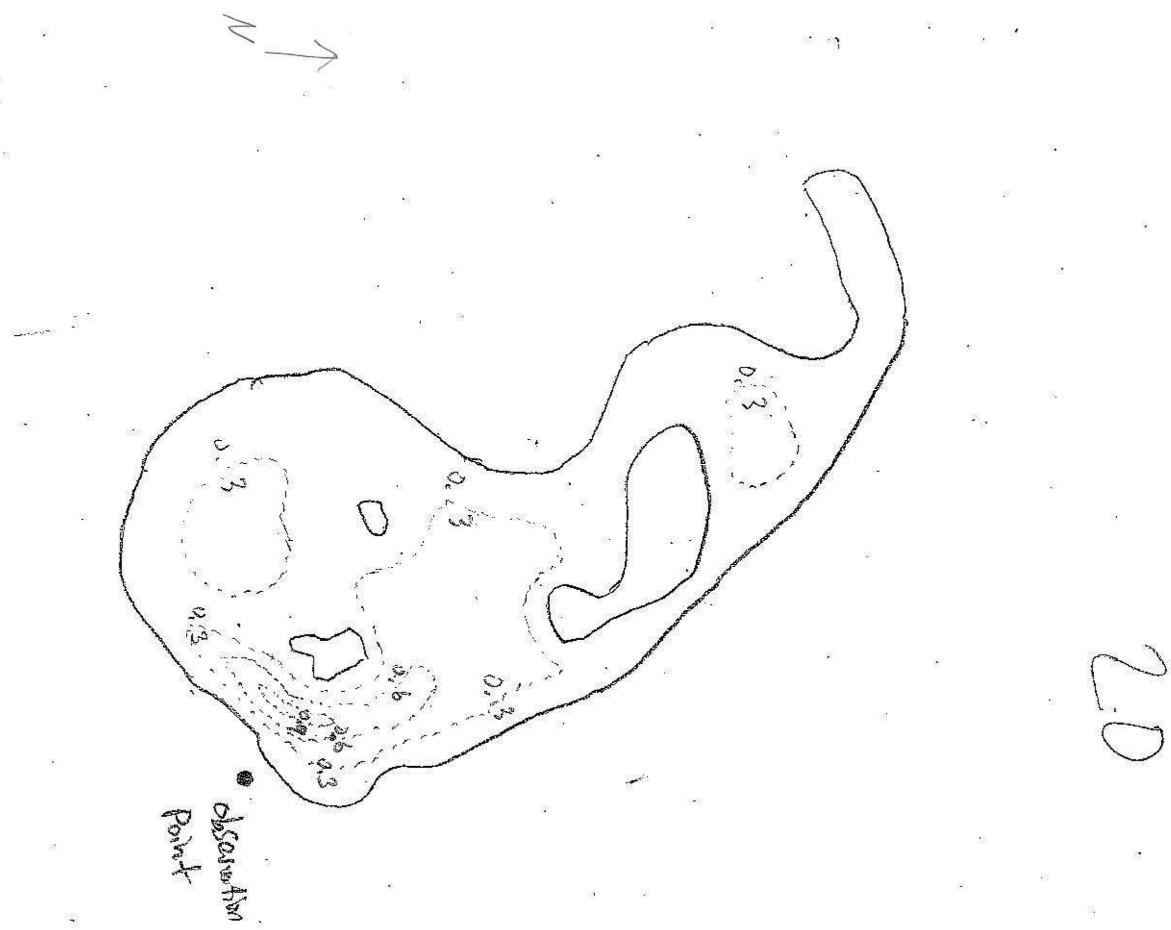

Observation Point

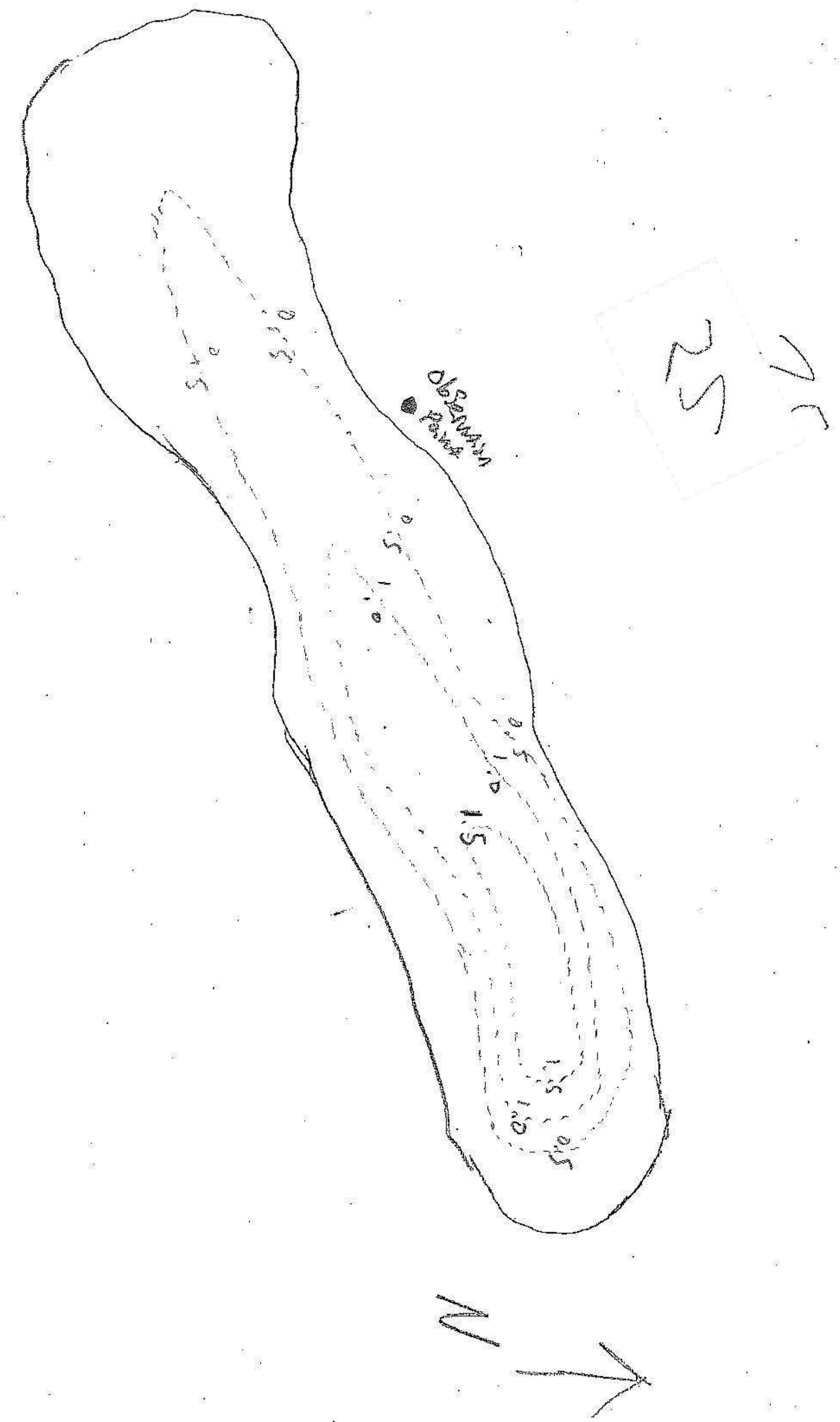

N
0.5
1.0
1.5
Observation Point

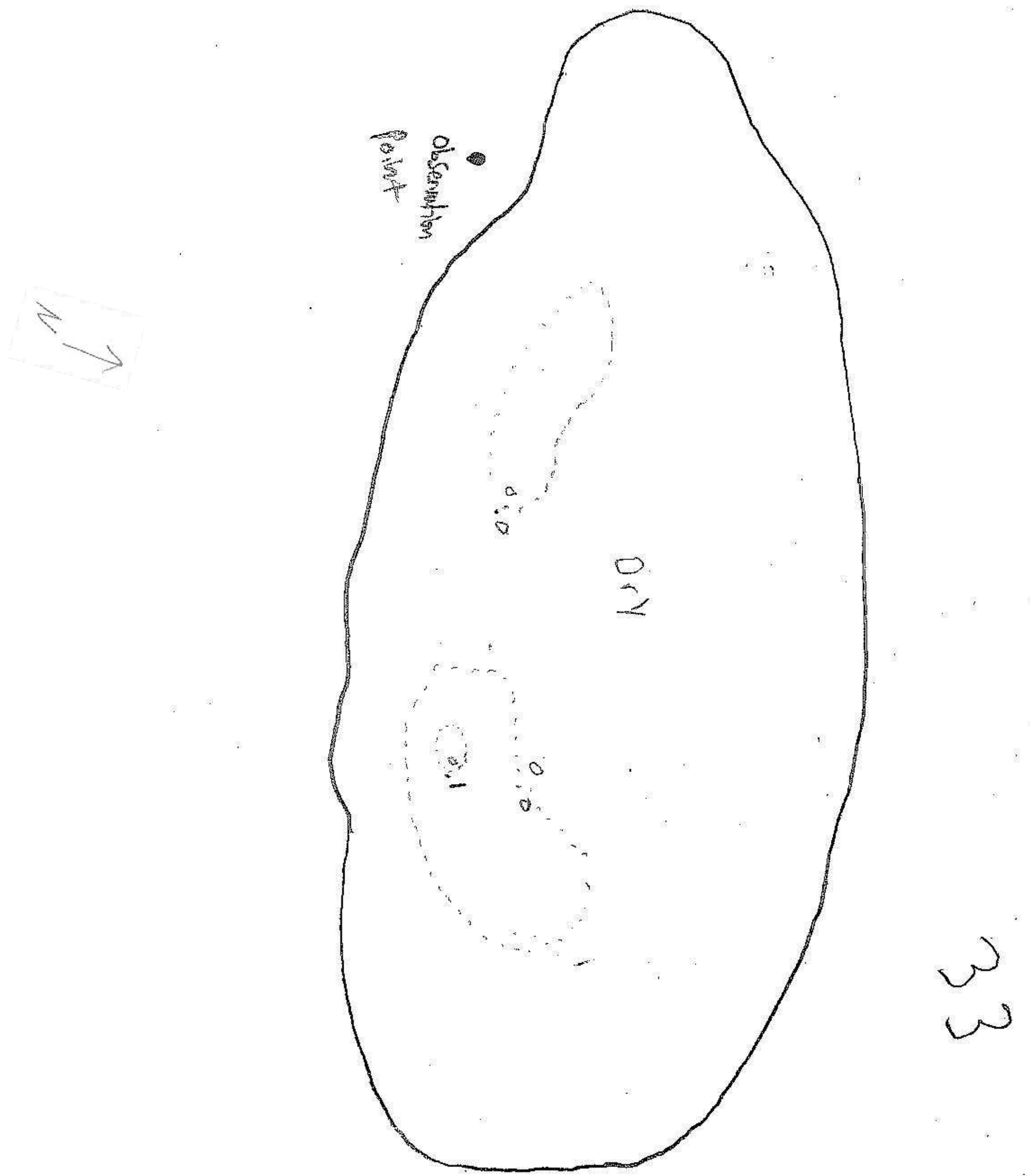

N
Observation Point

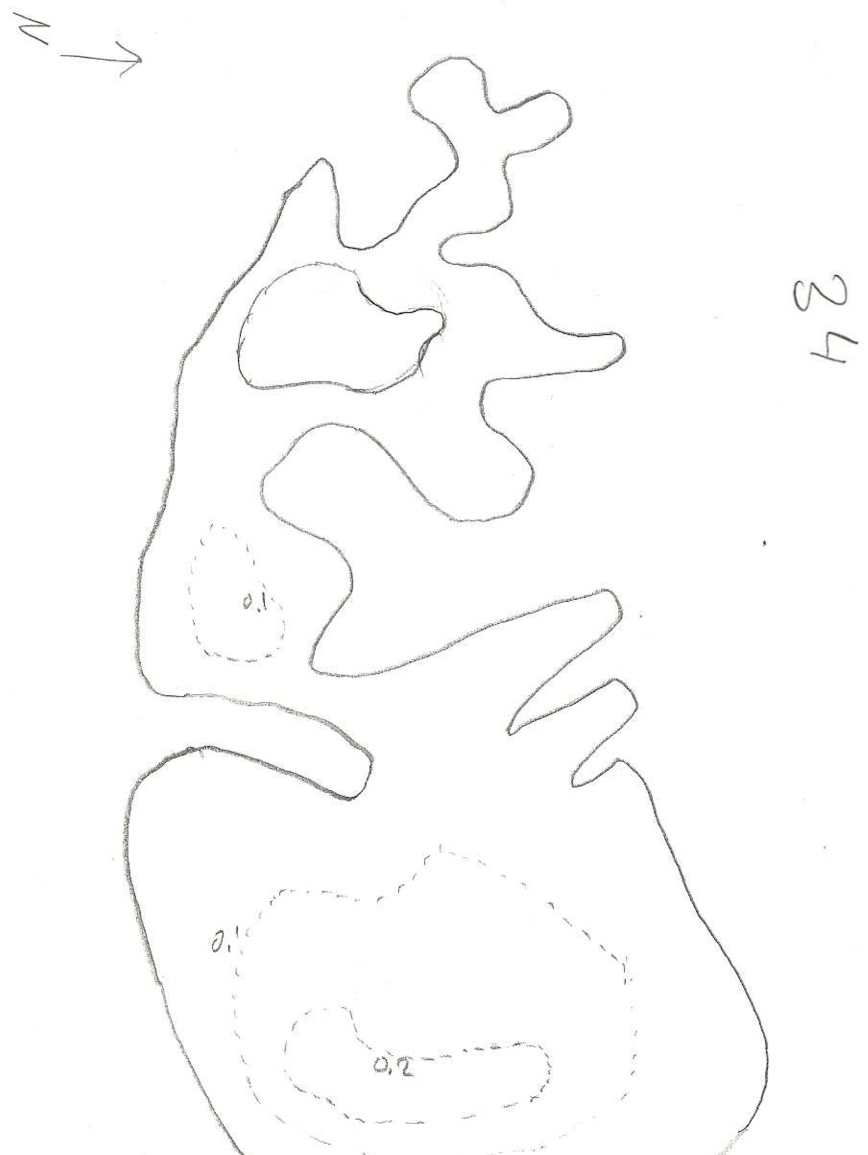

1b
Observation point
N

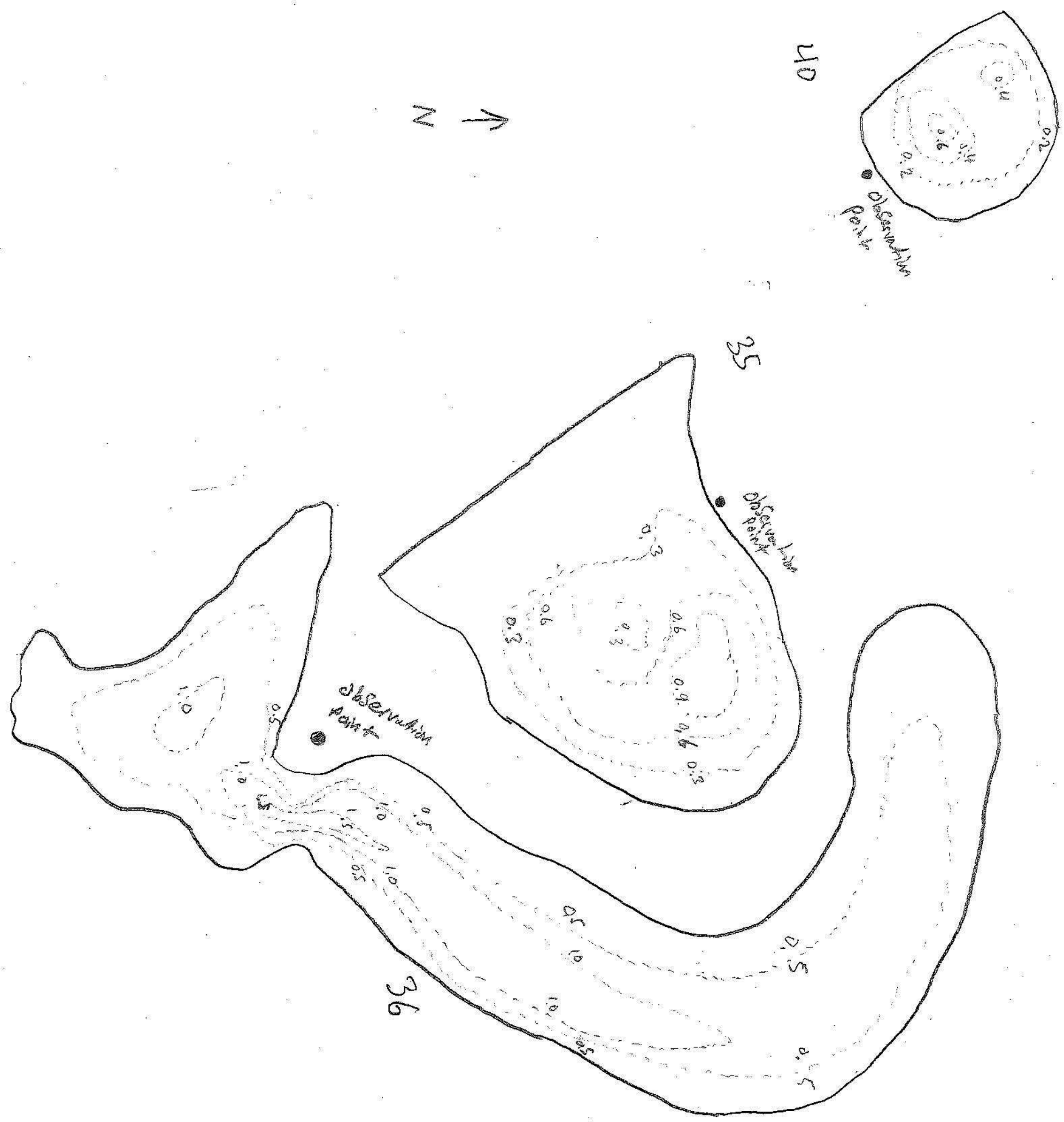

17
0.4
0.8
1.2
observation point
N

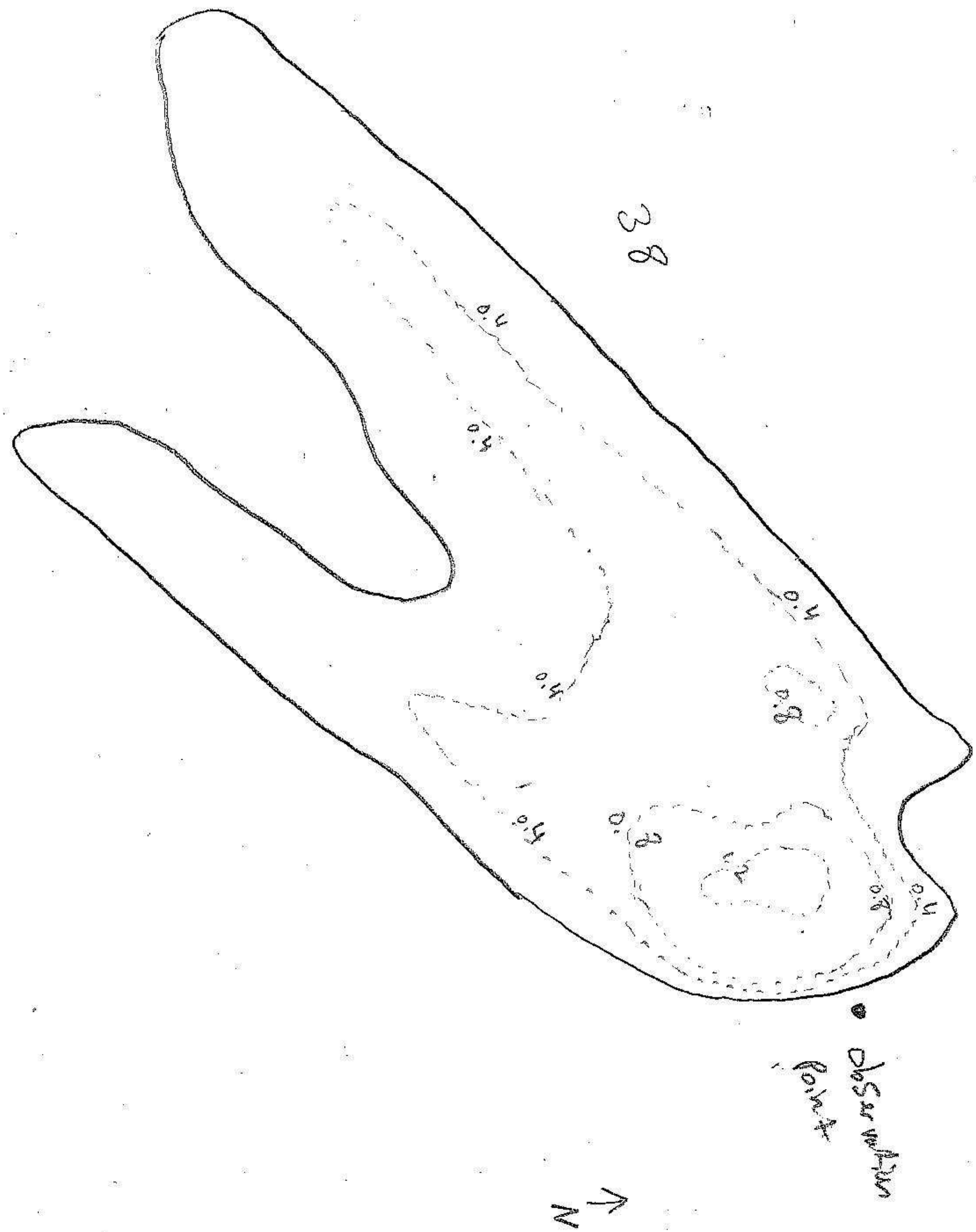

N
0.3
0.6
2.0
Observation Point


1.5
N


observation Point
Dry
33

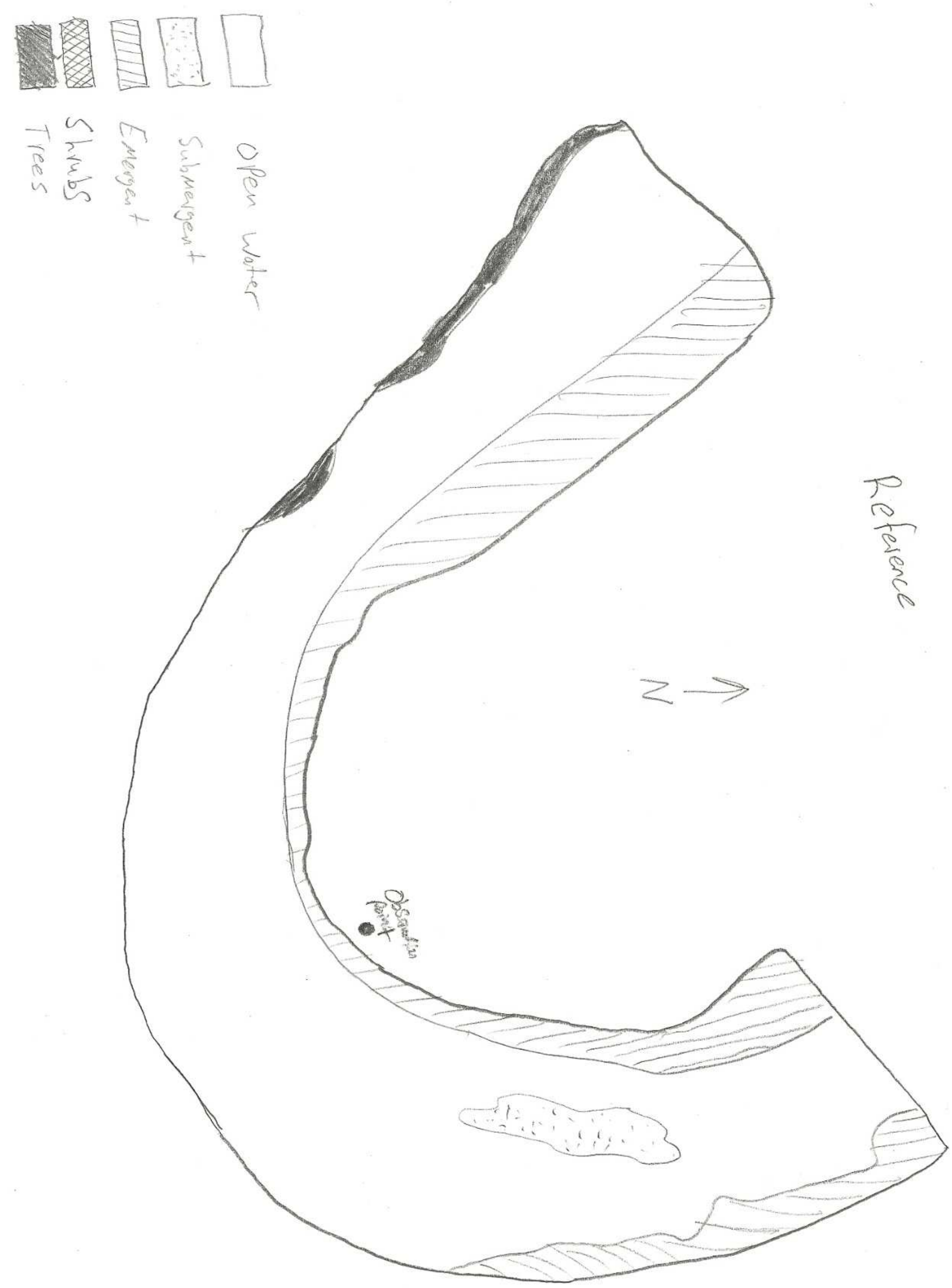

N
34
0.1
0.1
0.2

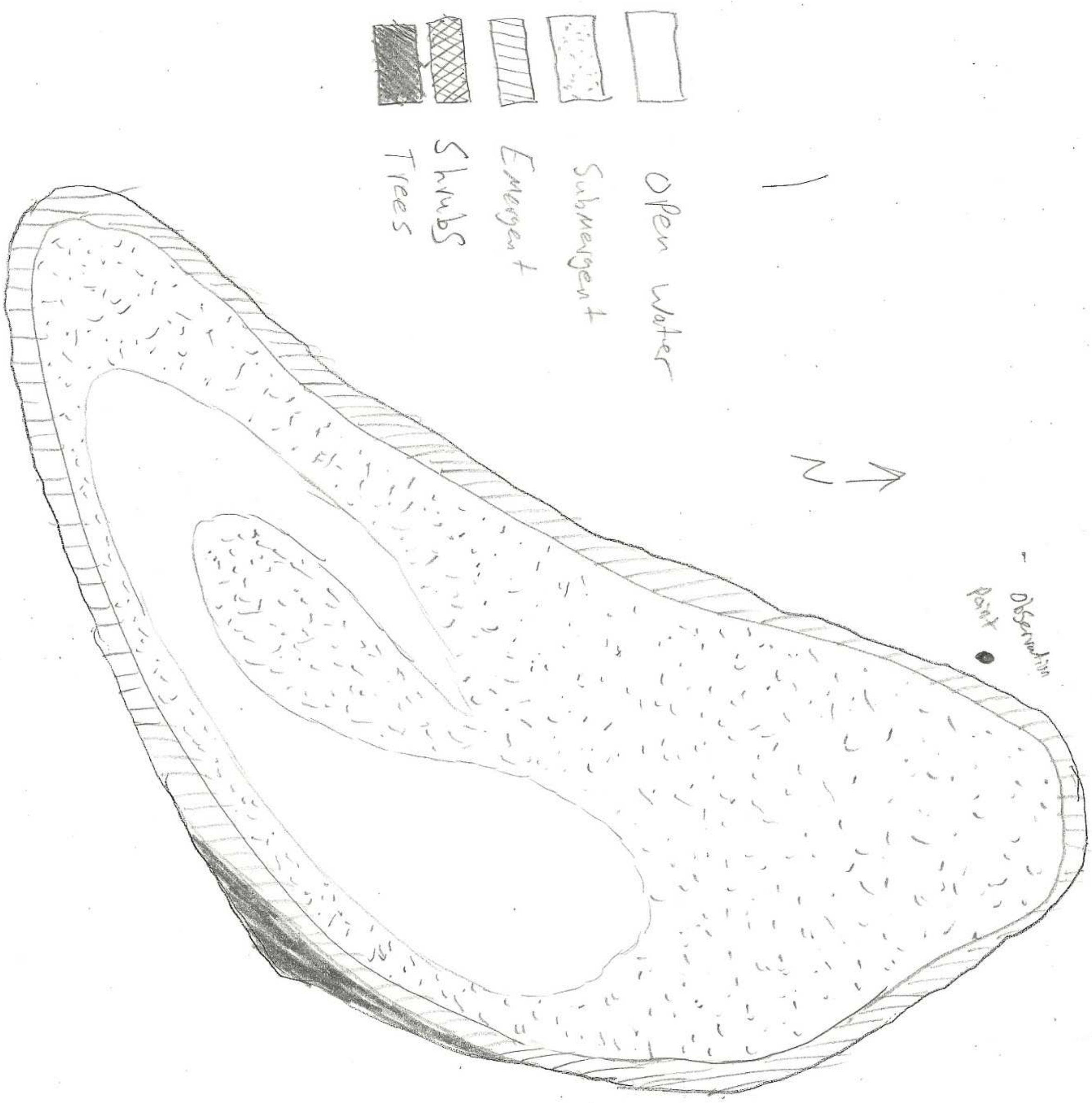

N
40
35
36
observation point
observation point
observation point

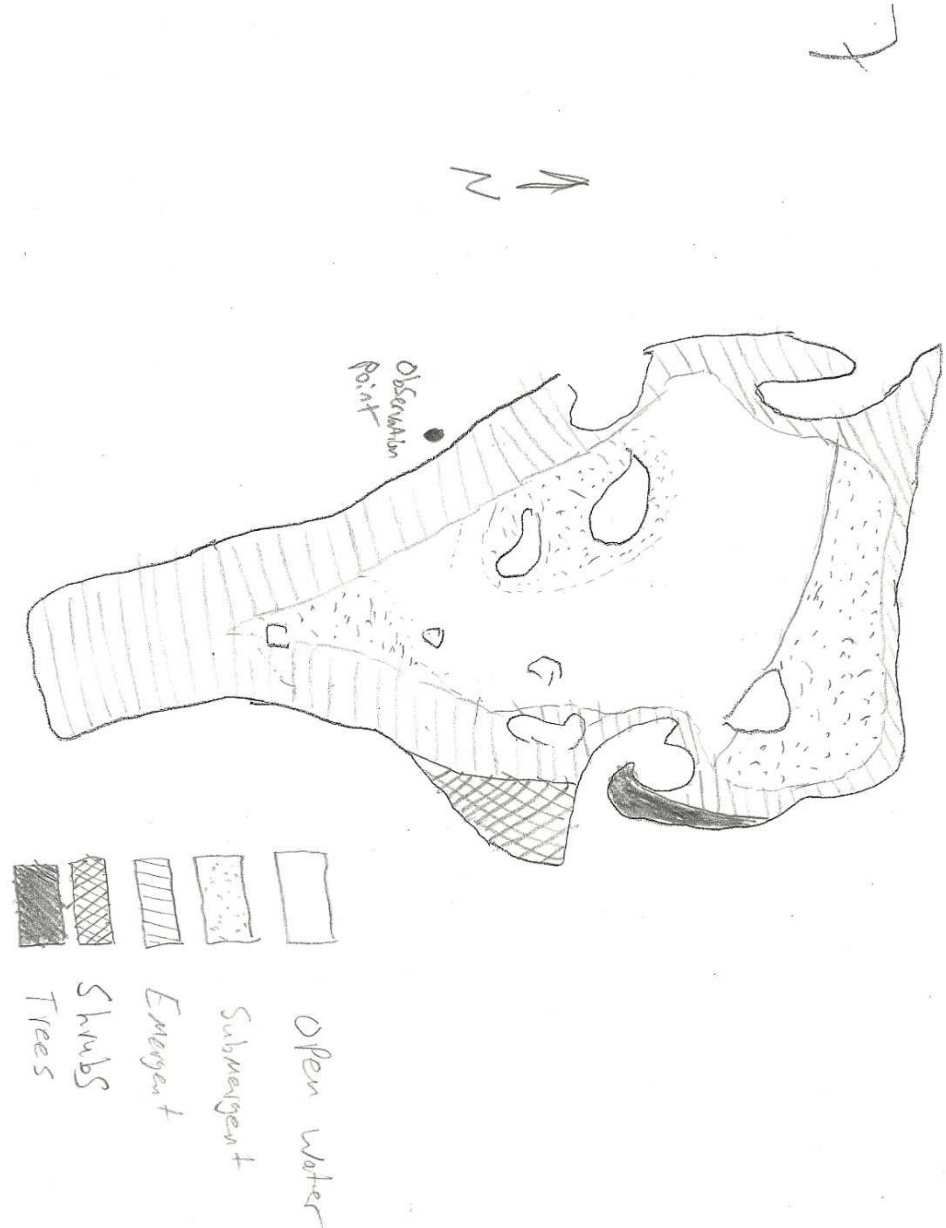

38
0.4
0.8
Observation Point
N

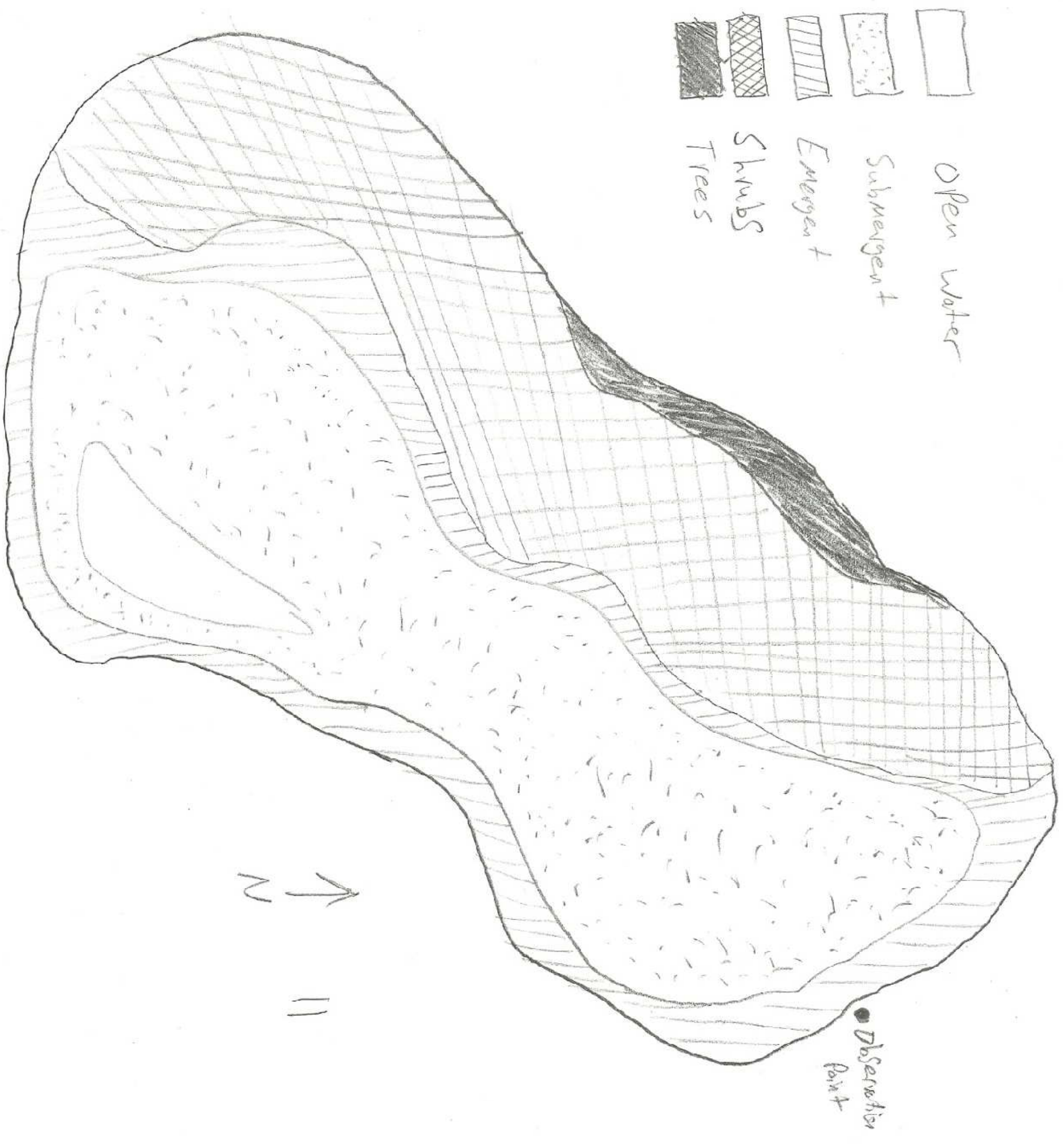
APPENDIX D

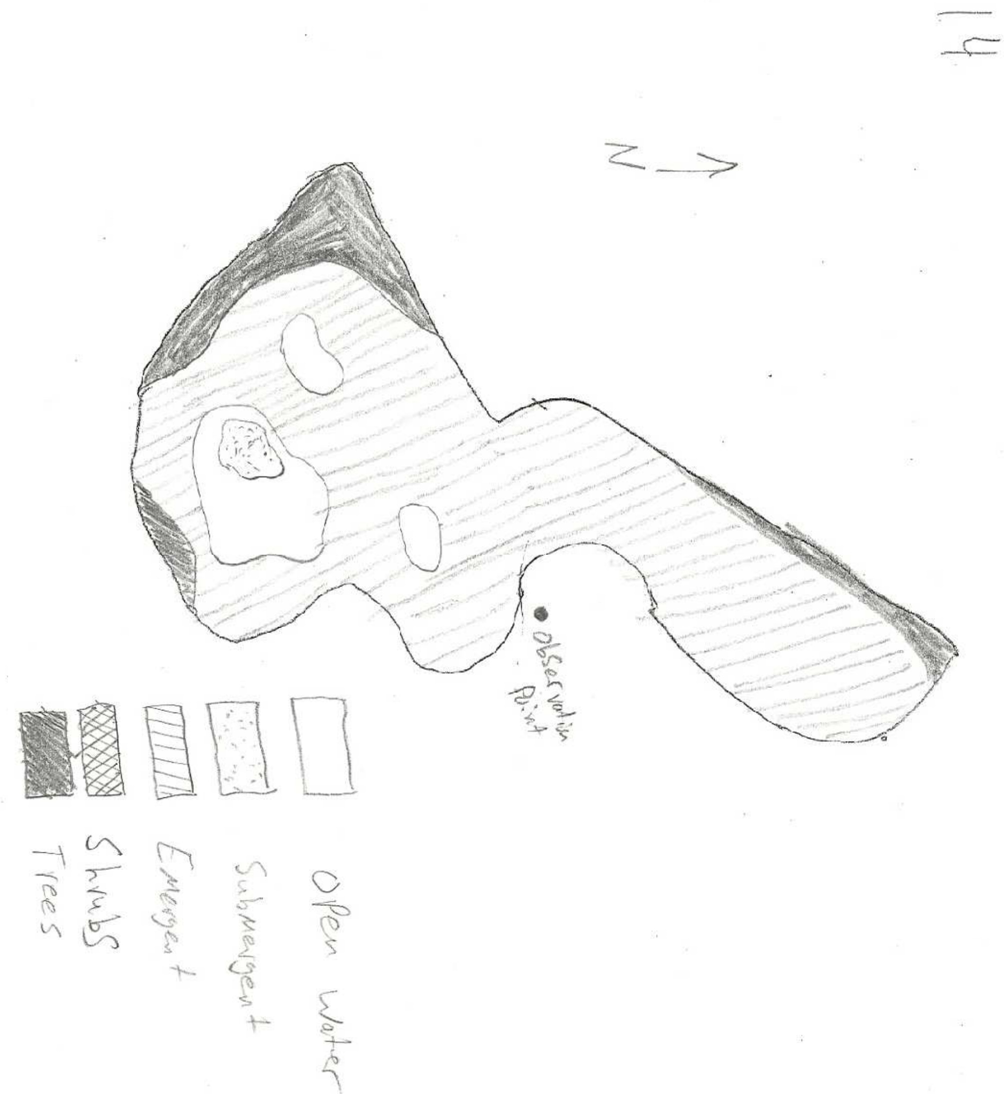
Wetland habitat cover types

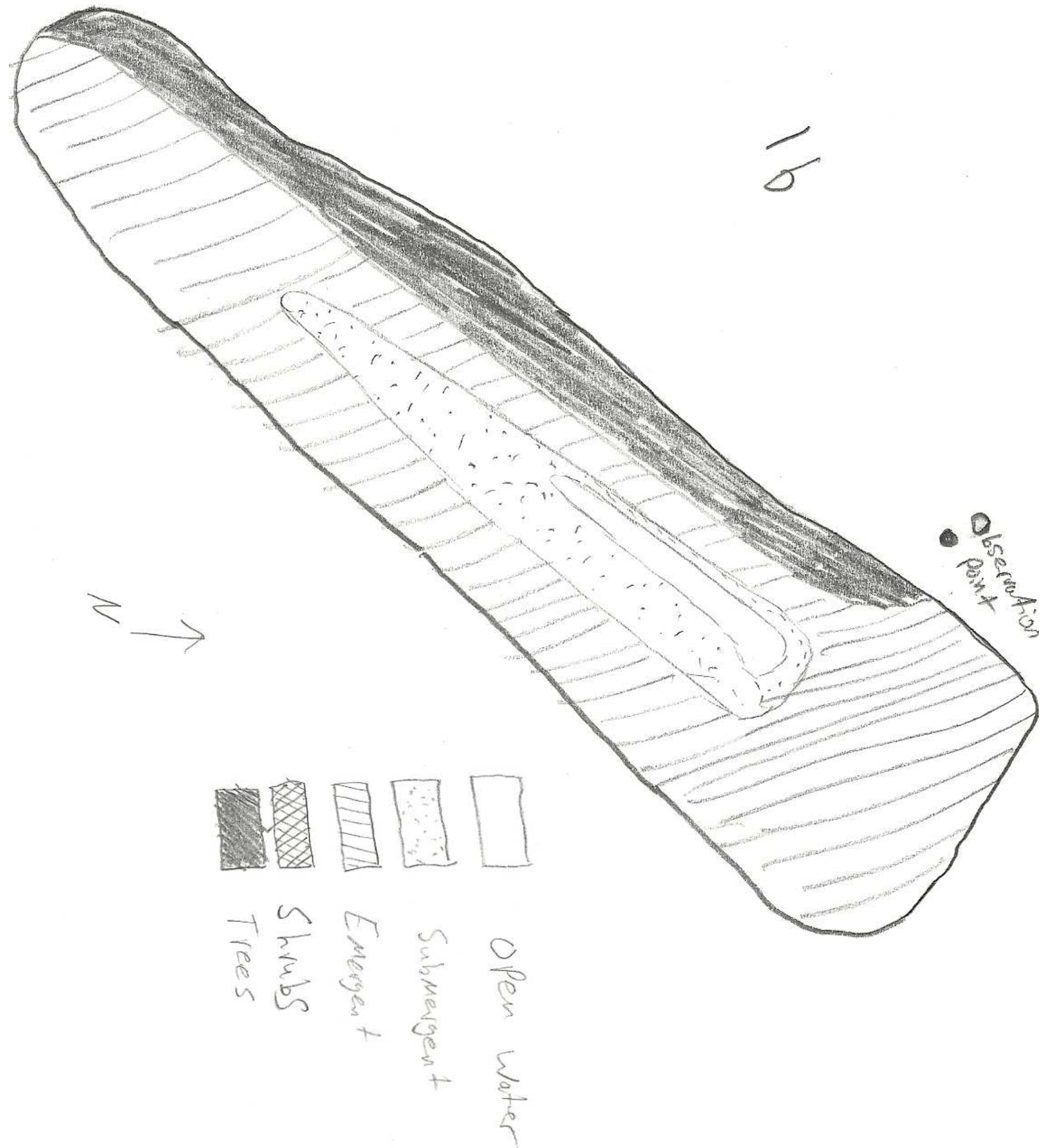

Open Water
Submergent
Emergent
Shrubs
Trees
Reference
N
Observation Point

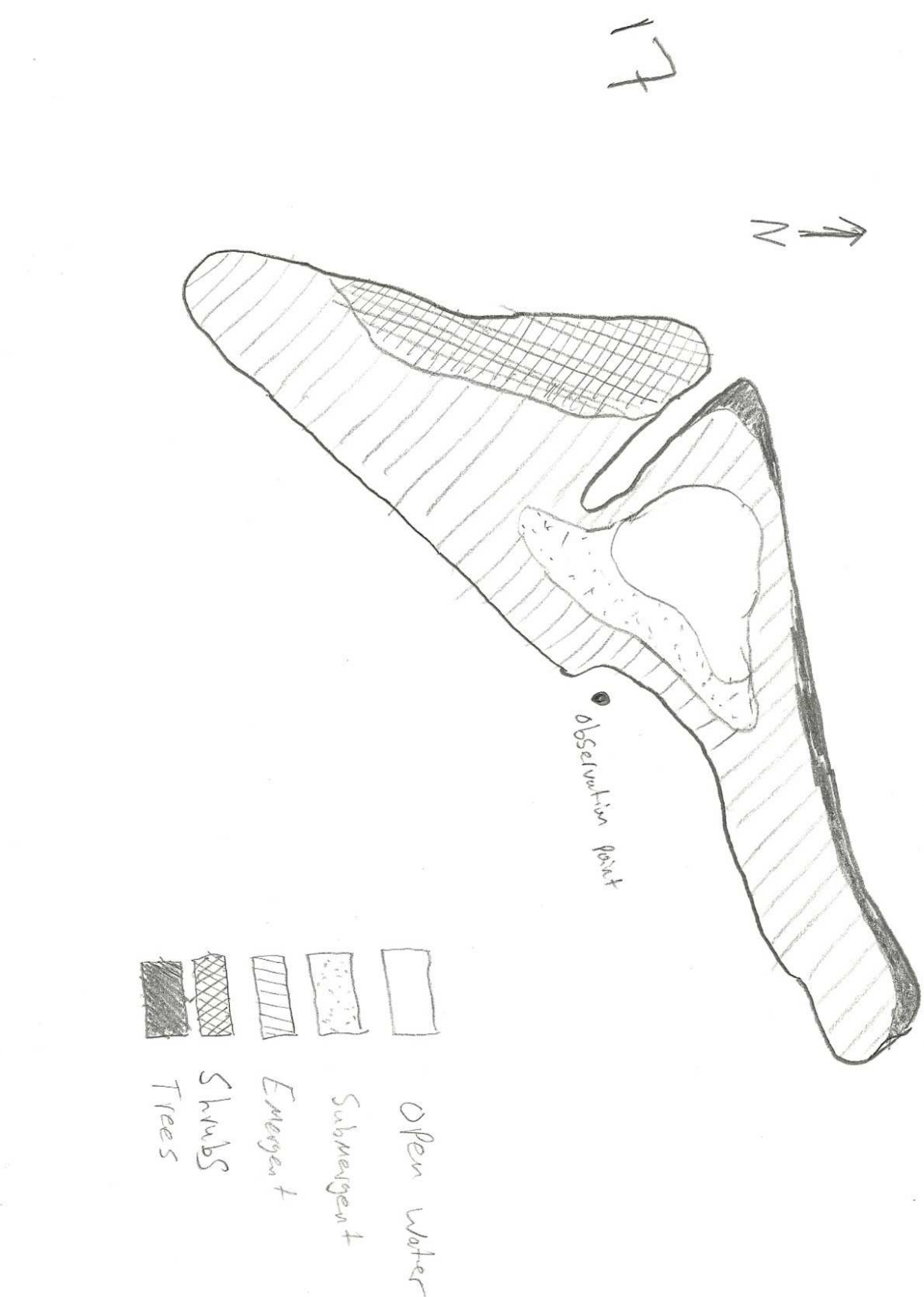

Open Water
Submergent
Emergent
Shrubs
Trees
N
Observation Point

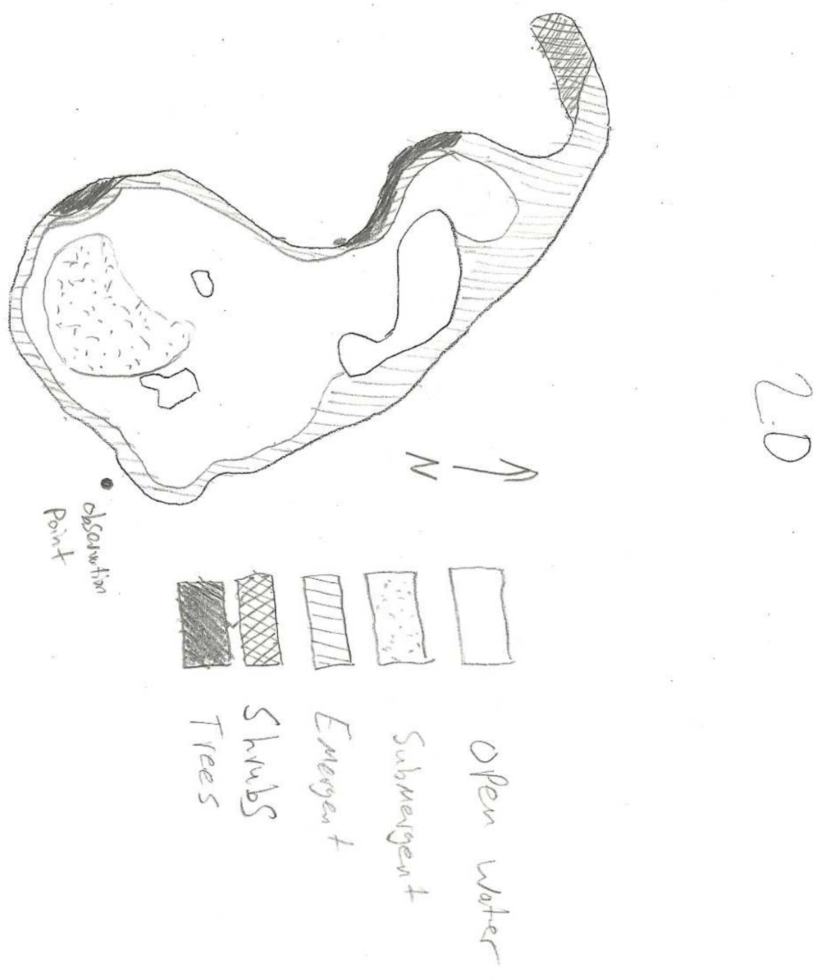

Observation Point
N
Open Water
Submergent
Emergent
Shrubs
Trees

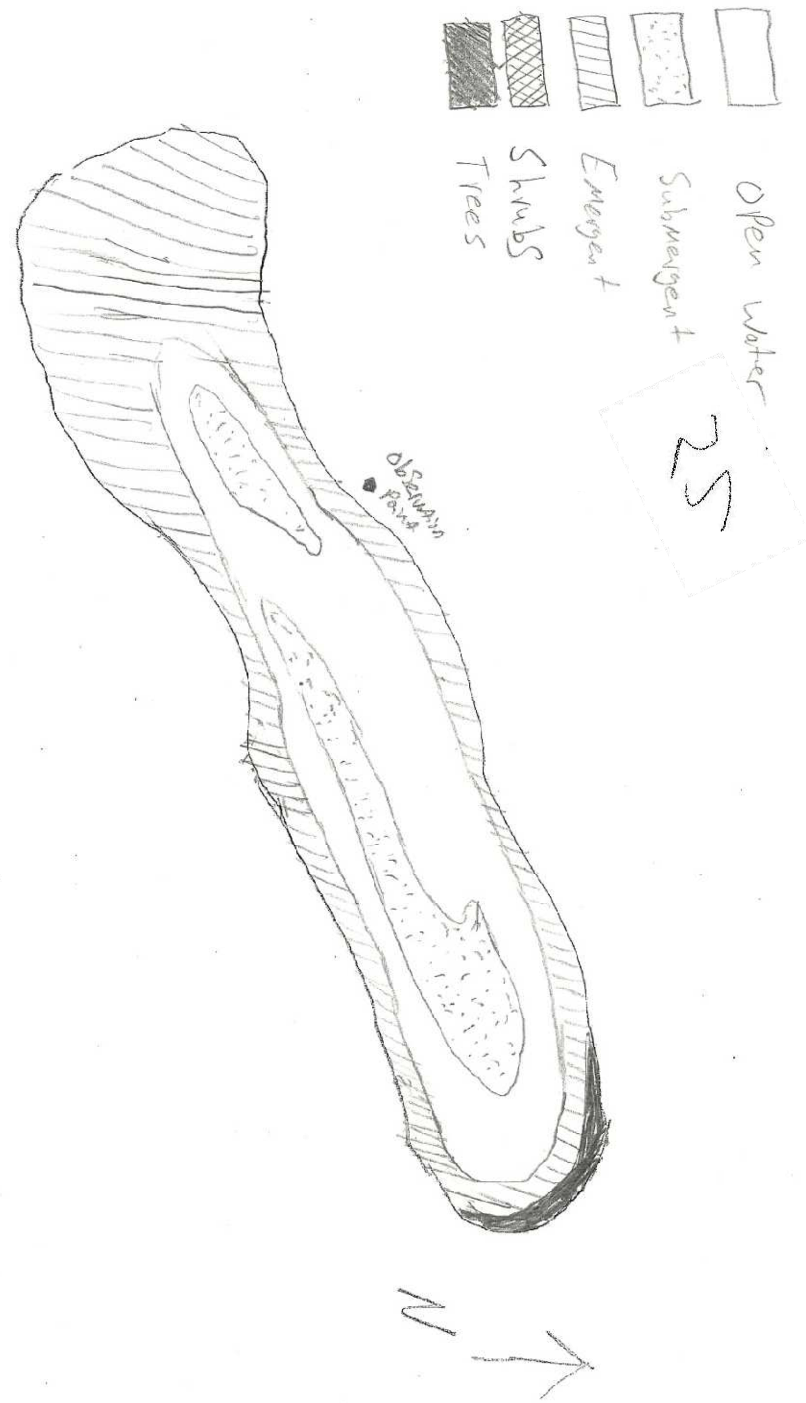

Open Water
Submergent
Emergent
Shrubs
Trees
N
Observation Point

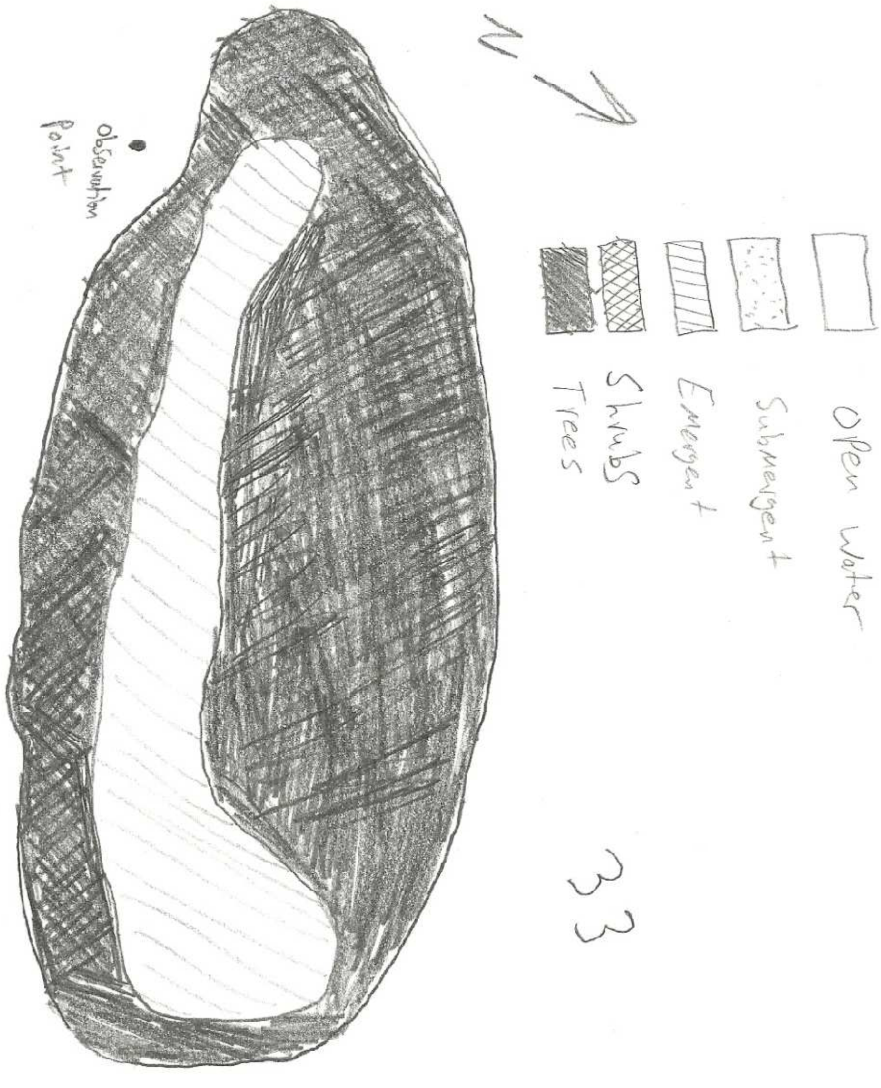

14
N
Observation Point
Open Water
Submergent
Emergent
Shrubs
Trees


1b
Observation Point
N
Open Water
Submergent
Emergent
Shrubs
Trees

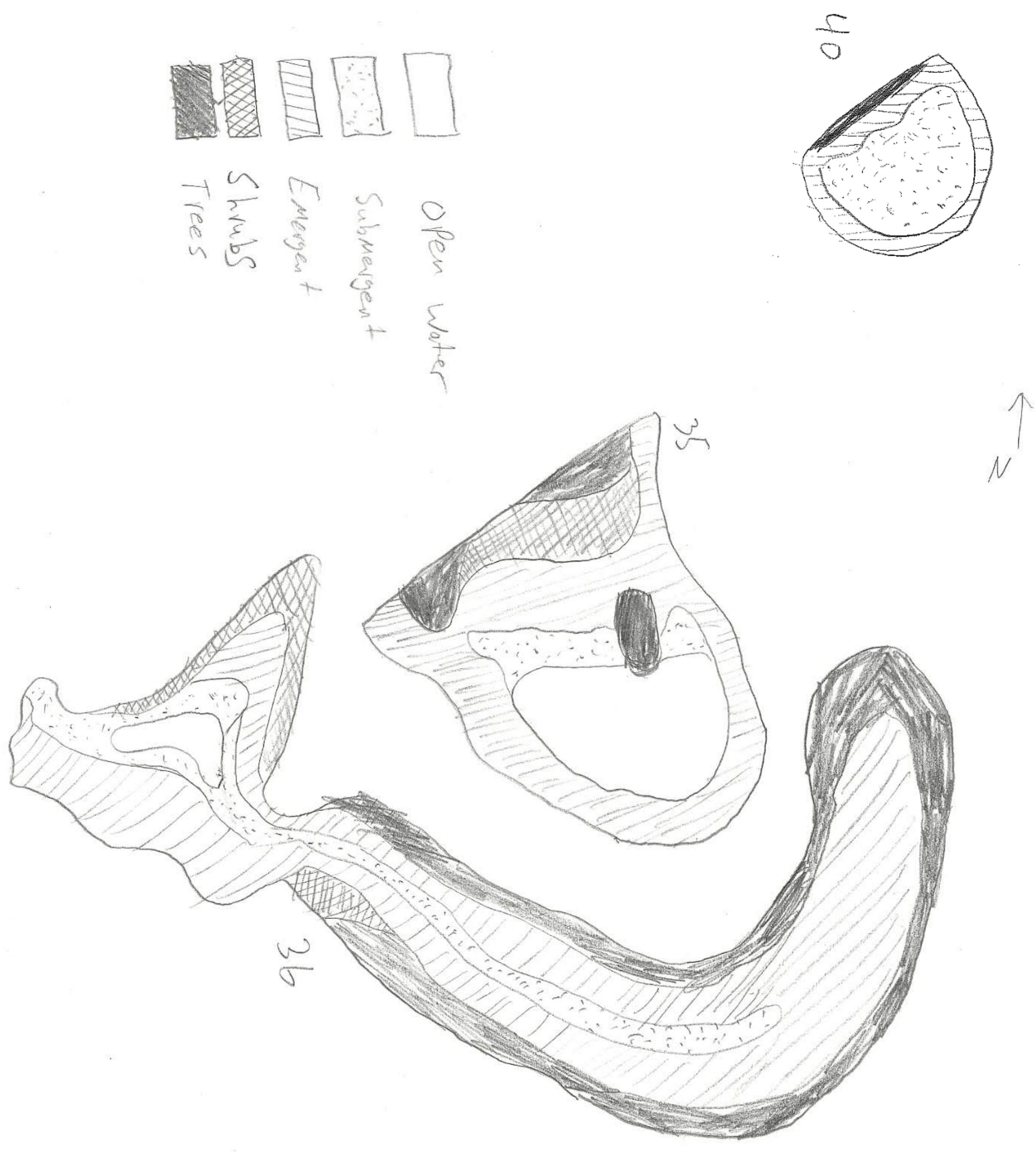

17
N
observation point
Open Water
Submergent
Emergent
Shrubs
Trees

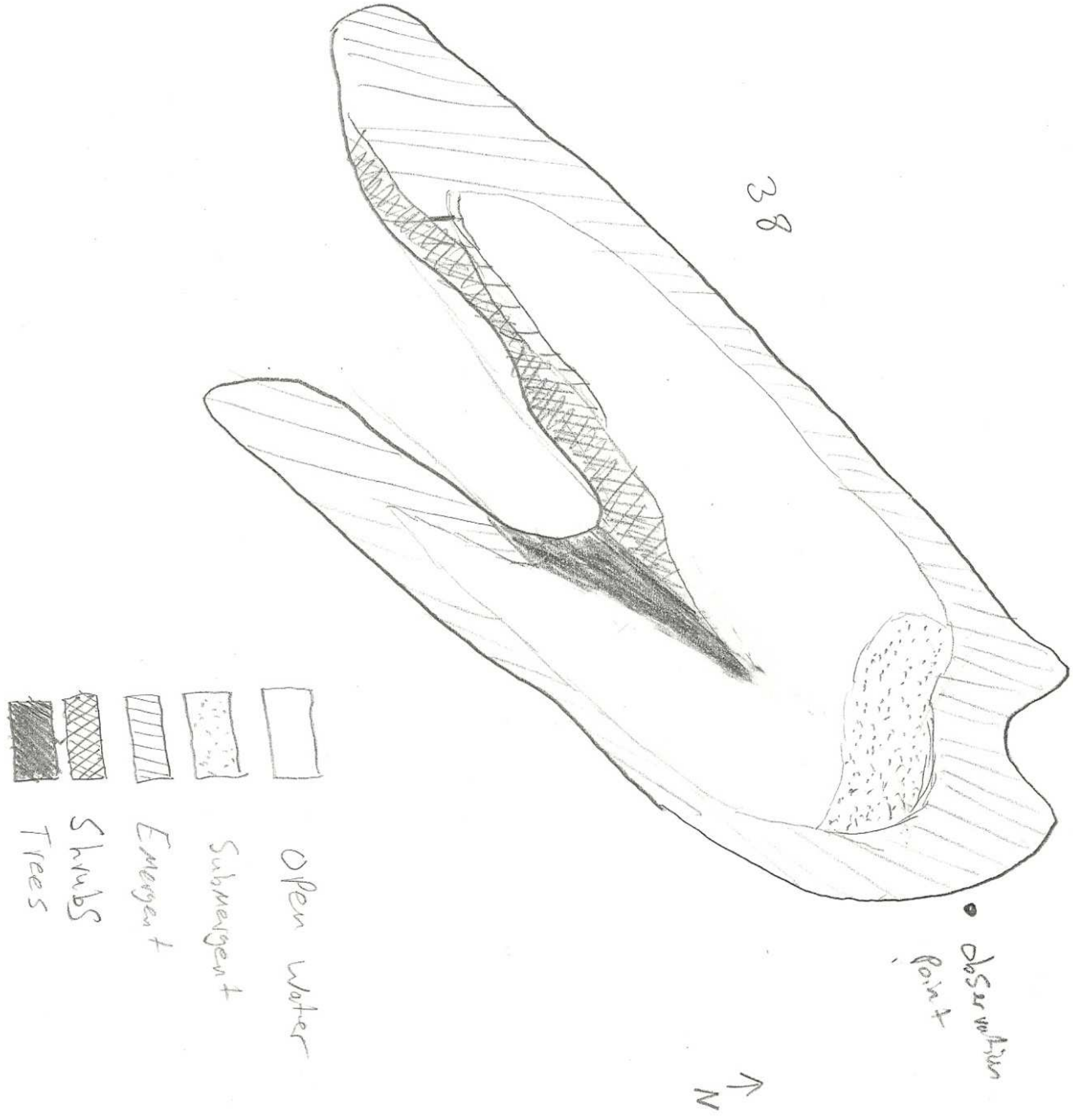

2D
N
observation Point
Open Water
Submergent
Emergent
Shrubs
Trees


Open Water
Submergent
Emergent
Shrubs
Trees
25
Observation Point
N


Observation Point
N
Open Water
Submergent
Emergent
Shrubs
Trees
33


Open Water
Submergent
Emergent
Shrubs
Trees
N
Upland
Upland
34


Open Water
Submergent
Emergent
Shrubs
Trees
40
35
36
N


38
Open Water
Submergent
Emergent
Shrubs
Trees
Observation Point
N