Avian Use of Restored Wetlands in the Ridge and Valley Region of Pennsylvania

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ABSTRACT Over the past century, the number of wetlands throughout the United States has been greatly reduced, causing wetland bird abundances to decline. Many efforts were made to mitigate this loss by restoring wetlands throughout the country and re-establishing lost wetland bird communities. I examined avian use of wetlands restored twelve years earlier and compared my data with an equivalent study done by Cashen and Brittingham (1998) immediately post-restoration. My objectives were to observe changes in wetlands and avian use over time at restored wetlands in the Ridge and Valley Region of Pennsylvania. I studied how restored wetlands change over time by resurveying fifteen wetlands, which were surveyed in 1998 for water depths, vegetation, area, and bird use. I detected 81 bird species in the restored wetlands, nine of which were wetland obligate species. Wetland area significantly affected wetland bird species richness ($P < 0.0273$). Since wetland area declined an average of 20% over the last twelve years (P 0.001), numbers of the bird species associated with larger wetlands tended to decline as well. Overall, average water depths changed little since 1998 with except of medium water depths which decreased significantly ($P = < 0.001$). Even though there was a loss of several wetland obligate species, species associated with larger wetlands, and changes in wetland composition, these restored wetlands are continuing to provide habitat for a variety of wetland and upland birds communities. However, management may be needed in the future to minimize further loss in wetland size.

KEY WORDS Pennsylvania, restored wetlands, wetland birds.

Wetland habitats are important to wetland avian communities and are associated with a diversity of ecosystem and economic values. Wetlands, in aggregate, provide all of the following functions and services: flood mitigation and protection, important wildlife habitats, nutrient cycling/storage and related pollution control, landscape and amenity services, recreational services, non-use existence value benefits, shoreline protection, and storm buffer zones (Turner 1991, Mitsch and Gosselink 2000, Turner 2000).

Wetland ecosystems account for 6% of the global land area and are among the most threatened of all environmental resources (Turner 1991, Mitsch and Gosselink 1993). Throughout most of the United States' history, wetlands were viewed as wastelands by a large part of the nation. Farmers tended to drain wetlands as a means to gain more land for their crops.

Many wetlands were also converted into lakes, ponds, or reservoirs. In Pennsylvania, an estimated 56% of wetlands were lost by the mid-1980's (Dahl 1990).

Since the mid-1980's, restoration became an important tool for compensating wetland losses (Ratti et al. 2001). Many organizations and programs such as Ducks Unlimited, United States Fish and Wildlife Service, Wetland Reserve Program, and North American Waterfowl Management Plan contributed millions of dollars in an attempt to restore many of the lost wetlands (Ratti et al. 2001, U.S. Fish and Wildlife Service 2009). Currently, these organizations are trying to evaluate the effectiveness of these wetland restoration projects.

Restored wetlands differ from created wetlands which are sites where wetlands are constructed where no previous wetlands existed. Mitigating wetland loss with created wetlands was generally not very successful and resulted in little contribution to overall wetland and ecosystem function (Hashisaki 1996). However, restored wetland habitats tend to provide better habitat and more ecosystem function than created wetlands due to several advantages including: existing soil types, natural soil hydrology, and the restoration sites were often part of a larger system (Hashisaki 1996, Mitsch et al. 1998).

In 1998, Cashen and Brittingham (1998) documented avian use of restored wetlands in Pennsylvania and examined the relationship between wetland variables (e.g., age, area, depth), and wetland bird species richness, composition, and guild abundance. Their research provided Partners for Wildlife, and others involved in restoring wetlands with information on what bird species to expect at restored wetlands, and guidelines on how to design or manage restored wetlands to attract specific "target" species, or guilds of species.

At the time of the study, these wetlands had all been recently restored and were between one and three years old. Over time, wetlands are expected to change as succession occurs (Galatowitsch and Van Der Valk 1996, Mitsch and Wilson 1996, Snell-Rood and Cristol 2003). Although research has documented successional changes with age at restored and created wetlands, few studies have examined the effects of wetland age on bird use (Delphey and Dinsmore 1993, Cashen and Brittingham 1998). It is important to understand how wetland function and use changes with succession.

My objectives were to determine whether and how restored wetlands changed in twelve years and how this affected bird use. To do this, I resurveyed sites in the original Pennsylvania study (Cashen and Brittingham 1998) and compared the results of my study with the original one. I examined differences in avian use as the restored wetlands age. My specific objectives were to compile a species list for each site indicating use during the breeding season; determine change in wetlands and avian use over time; and determine how wetland area affects wetland species richness and probability of occurrence of specific wetland bird species.

STUDY AREA

During the summer of 2010, I surveyed 15 restored wetlands within the Ridge and Valley region of Pennsylvania. The Ridge and Valley region extends through the center of the state, from Lackawanna County on the northeast, to Bedford County in south-central Pennsylvania (Guinn 1964). The area is largely comprised of mountainous ridges and deep valleys ranging from 199 to 823 m in elevation. The original study's research was done on 18 restored wetlands in the Ridge and Valley region with six wetlands in each of three size categories: < 2 ha, 2 to 4 ha, and

>4 ha (Cashen and Brittingham 1998). In my study, I included 15 of the 18 wetlands. Three were not used because of land owner access issues.

I contacted wetland landowners by mail to request permission to survey their wetlands. Following the letters, I called landowners to provide answers to question or concerns and follow up on requests. All but 3 of the 18 landowners gave permission to conduct research on their wetlands.

METHODS

Bird Surveys

For my research, I used 3 survey techniques to record bird use of the restored wetlands: modified-line transects (Ralph and Scott 1981), modified point counts (Verner and Ritter 1986), and playback recordings (Manci and Rusch 1988). Each wetland was surveyed twice during the breeding season, mid-May to July.

During the breeding season, most avian species are most active and more easily detected in the morning than later in the day (Verner and Ritter 1986, Cashen and Brittingham 1998). All surveys were conducted during the first 4 h following sunrise. Also, no surveys were performed during unfavorable conditions such as: heavy rain, high winds, or low visibility. Each wetland was surveyed once before starting on previously surveyed wetlands.

Modified Line-Transect.— At each wetland site, a researcher walked the entire perimeter of the wetland within 5 m of the wetland-upland boundary (Leschisin et al. 1992, Cashen and Brittingham 1998). The researcher listened for songs and watched for bird sightings. All species detected were recorded along with their distance from the boundary using 4 categories: < 50 m wetland, > 50 m wetland, < 50 m upland, > 50 m upland.

Modified Point Counts.— To account for upland song birds, I used a modified point count method to record species missed by the line-transect method. The first count station was placed on the dike side of the wetland, 30 m from the wetland- upland border in the upland. Any additional stations were added every 200 m from the previous station and remained 30 m from the wetland boundary. At most sites, the number of point count stations varied from 1 to 6 stations depending on the size of the wetland. All birds detected within 100 m during a 10 min period were recorded at each point (Verner and Ritter 1986, Cashen and Brittingham 1998).

Playback Recordings.— Due to some wetland bird species being secretive and seldom vocalizing, I used playback recordings to elicit responses. After completing the line-transect and point count surveys, I used the Marsh Bird Survey Protocol (Lanzone et al. 2006) to broadcast 5 to 9 vocalizations of wetland birds. The number of vocalizations used varied depending on wetlands size. The vocalizations of the secretive nesting marsh birds included: black rail (*Laterallus jamaicensis*), least bittern (*Ixobrychus exilis*), sora (*Porzana carolina*), Virginia rail (*Rallus limicola*), and king rail (*Rallus elegans*) for wetlands 0.5-3 ha; American bittern (*Botaurus lentiginosus*) for wetlands >3-10 ha; and common moorhen (*Gallinula chloropus*), American coot (*Fulica americana*), and pied-billed grebe (*Podilymbus podiceps*) for wetlands >10 ha. During each survey, I recorded each response or detection for species, number of species, and location of the species within the wetland. I conducted all surveys within 3 h after sunrise.

Vegetation Surveys

Many wetlands birds rely heavily on both wetland and upland vegetative growth. Absences of suitable nesting habitat, cover, or food provided by vegetation are all factors that may limit wetland use (Trefethen 1964). To account for avian vegetation needs, I conducted vegetation surveys of wetland and upland areas to calculate percent abundance of essential plant species. All vegetation surveys were concluded within 1 to 20 days of conducting bird surveys to reduce bias associated with vegetative growth.

Upland Vegetation.— I conducted vegetation surveys using line-intercept sampling to evaluate each wetland's upland vegetation (Canfield 1941). Each sample extended perpendicularly from the wetland boundary, 50 m into the upland. The first sample started from the dike side of the wetland. Additional lines were added every 25 m along the boundary, until the final line was within 25 to 50 m of the first line. Along each line, I recorded the length of the line intercepted by each of 6 major vegetation types: short herbaceous (< 40 cm), tall herbaceous (≥ 40 cm), shrub, forest, mud, and agriculture (Cashen and Brittingham 1998).

Wetland Vegetation.— At each wetland, I determined the 3 dominant emergent plant species and visually estimated percent cover of each (Ratti et al. 2001). Any additional plant species detected were recorded for general composition of the wetland.

Wetland Water Depths

During my study, I constructed water depth maps for each of the wetland sites. At each site, I waded through the water along transects drawn via GIS software. Each transect began 1 m off the wetland edge, inside the wetland. Subsequent lines were added every 5 m until the last transect was within 1 to 2 m from the opposite side of the wetland. While walking each transect, I recorded any changes in water depth. After all the measurements were taken, I created water depth maps using GIS software. From the maps, I calculated area of four water depths: emergent (wetland area containing emergent vegetation, ha), shallow (water <0.2 m deep, ha), medium (water 0.2-1.0 m deep, ha), and deep (water >1.0 m deep, ha).

Wetland Area

To obtain an estimate of area and perimeter for each wetland, I used a global positioning system (GPS) to gather data. At each site, I walked the perimeter of the wetland using visible wetland hydrologic characteristics as the boundary. All data was recorded with a GPS unit. The GPS unit was set to record my location every 10 sec.

Statistical Procedures

I conducted all statistical analysis utilizing a statistics software program called Minitab. I used a paired t-test to compare wetland size, water depth, and number of species detected per wetland between the two survey times periods. The paired t-test allowed me to compare how individual wetlands changed over time and reduced potential variability resulting from differences in the individual wetlands. I used a regression model to test for significant relationships between wetland size and species richness. I considered a p-value < 0.05 as significant for all statistical tests.

Some wetland bird species are normally associated with larger wetland sizes (Cashen and Brittingham 1998). To test the affect wetland size had on probability of occurrence of certain wetland species, I used a binary logistic regression. For a selected wetland species, great blue heron (*Ardea herodias*), I used binary data sets to score all occurrences with a value of 1 if the species was detected at a given wetland and 0 if it was not.

RESULTS

Study Sites

Wetland Area.— Wetland area ranged from 0.7 to 6.88 ha (mean 2.35 ± 0.462) in 1998 and 0.3 to 6.1 ha (mean 1.93 ± 0.416) in 2010. Since 1998, wetland area decreased an average of 20% (P = 0.001; Figure 1).

Water Depth.— Water depths varied slightly from one wetland to another (Appendix A). Thirteen of the 15 wetlands had wetland areas containing emergent vegetation. These areas showed the largest range from 0 to 2.9 ha (mean 0.45). Shallow water depths ranged from 0.11 to 0.90 ha (mean 0.32), while medium water depths ranged from 0.15 to 2.61 ha (mean 0.55). Deep water depths were present at all but one wetland and ranged from 0 to 2.59 ha (mean 0.60).

Since 1998, water depths of the fifteen wetlands changed little. Emergent (P = 0.738), shallow (P = 0.550), and deep (P = 0.259) water depths showed little to no change since 1998. However, medium water depths decreased significantly by loosing 55.1% of the area from 1998 to 2010 (P = < 0.001; Table 1).

Wetland Vegetation.— The total amount of emergent wetland vegetation ranged from 0 to 90% (mean 29%). Cattails (*Typha sp.*), rushes (*Juncus sp.*), sedges (*Carex sp.*), and wetland grasses encompassed the majority of the emergent wetland vegetation.

Upland Vegetation.— All fifteen wetlands contained shrub vegetation (range 2.9% to 47.5%; mean 25.1%), and tree cover (range 0.1% to 10.2%; mean 2.4%). In addition, all fifteen wetlands had large quantities of short and tall herbaceous cover (range 43.5% to 96.3%; mean 68.9%). Mud occurred at ten of the fifteen sites (range 1.6% to 13%; mean 6.8%). Agriculture was the least common variable present in only two of the fifteen wetlands (range 9.8% to 13.5%; mean 11.6%).

Compared to 1998 surveys, upland vegetation types showed successional changes over the last twelve years (Figure 2). Two-thirds (4) of vegetation variables showed a percent decrease over time including agriculture (88%), trees (81%), short herbaceous (84%), and mud (21%). However, shrub vegetation exhibited a percent increase at 60%. Also, tall herbaceous vegetation revealed a percent increase of >250%.

Avian Use

During the survey, I identified 81 avian species from 31 families at one or more wetlands. The total number of avian species detected at each wetland ranged from 21 to 41 (mean 30 ± 5.6). The mean number of avian species detected at each wetland decreased 35% from 1998 (P < 0.001; Figure 3; Table 2).

Wetland Species.— Eleven of 81avian species detected in my study were “wetland obligate” or “facultative wetland” species (Brooks and Croonquist 1990). Sixty percent (6) of those species were found at >50% of the wetlands including great blue heron (*Ardea herodias*), green heron (*Butorides virescens*), Canada goose (*Branta canadensis*), wood duck (*Aix sponsa*), mallard (*Anas platyrhynchos*). and red-winged blackbird (*Agelaius phoeniceus*).

Forest Species.— I detected 37 species from 22 different families associated with forested habitat types. Eighteen percent (7) of those species were found at >50% of the wetlands including: red-bellied woodpecker (*Melanerpes carolinus*), blue jay (*Cyanocitta cristata*), tufted titmouse (*Parus bicolor*), cedar waxwing, red-eyed vireo (*Vireo olivaceus*), and chipping sparrow (*Spizella passerina*).

Open Habitat Species.— I observed seven species from seven different families commonly found in open herbaceous habitats. I found Twenty-nine percent (2) of those species at > 50% of the sites including killdeer (*Charadrius vociferous*) and eastern kingbird (*Tyrannus tyrannus*).

Generalist Species.— Four generalist species from four different families were observed at my wetland sites including American crow (*Corvus brachyrhynchos*), common grackle (*Quiscalus quiscula),* European starting (*Sturnus vulgaris),* and American robin (*Turdus migratorius).* Most of those species, except European starting were observed at >90% of the wetland sites.

Shrub/Mid-Successional Habitat Species.— Eleven species from eight different families detected at my wetlands were species usually found in mid-successional habitat. Five of those species were detected at >50% of the sites including gray catbird (*Dumetella carolinesis*), northern cardinal (*Cardinalis cardinalis*), alder flycatcher (*Empidonax alnorum*), field sparrow (*Spizella pusilla*), and American goldfinch (*Carduelis tristis*). Three of the species detected were found at all fifteen wetland sites including yellow warbler (*Dendroica petechia*), common yellowthroat (*Geothlypis trichas*), and song sparrow (*Melospiza melodia).*

Urban Species.— The only species detected at my wetland study sites commonly found in urban areas was the house sparrow (*Passer domesticus).* I only found this species at one of my wetland sites.

Species of Concern.— I detected one of Pennsylvania's species of special concern (Brauning et al. 1994) who is also considered a wetland obligate species at 1 of the wetland sites, great egret (*Caserodius albus*) (Cashen and Brittingham 1998).

Comparison of Survey Years.— 70 of 81 avian species identified in my study were also found in 1998 (Table 2). Eight of those species found in both survey years were wetland obligates (Brooks and Croonquist 1990). I detected one wetland obligate species which was not present in 1998, common merganser (*Mergus merganser*). Cashen and Brittingham (1998) detected eight wetland obligates species which were not present in my study. Overall, I observed eleven species which were not present in 1998. However, 30 species found in the 1998 study were not present in my study.

Effect of Wetland Area on Species Richness

I found a positive relationship between wetland area and species richness ($P = < 0.05$).

Effect on Wetland Area on Probability of Occurrence

I tested species-area relationships for one wetland species of interest, great blue heron (*Ardea Herodias).* In both cases I found a positive trend between individual species and wetland area ($P = 0.219$) (Figure 5).

DISCUSSION

Study Sites

After twelve years, succession indubitably altered the appearance and function of all fifteen wetlands. Wetland area decreased an average of 20% over the last twelve years. Some of this change was not entirely due to succession though. Several of the dike structures at some of the wetlands showed evidence of rodent destruction reducing water holding capacity. Some wetland owners also stated they intentionally drew back their wetlands for recreational purposes. Furthermore, the wetland area was affected by an abnormally dry summer potentially distorting my results.

In addition to wetland area, succession also affected vegetation composition. Trees, short herbaceous, and agricultural vegetation all decreased an average of 84% while shrub vegetation increased by 60%. Furthermore, tall herbaceous vegetation showed the largest change with an increase of >250%. Although vegetation composition changed similarly, individual wetlands showed variable results in each vegetation type. Hemesath and Dinsmore (1993) and Galatowitsch and Van Der Valk (1996) found similar changes in wetland area and vegetation that varied from site to site. This variability indicates wetland area and vegetation development may be site-specific and vary with factors other succession. Duration of drainage, past usage, past herbicide use, effectiveness of drainage, and isolation may all impact vegetation response (VanRees-Siewert and Dinsmore 1996).

Avian Use

Breeding bird communities appeared slightly less diverse in 2010 than in 1998. Cashen and Brittingham (1998) detected 100 different species at one or more of the wetland sites. In 2010, I detected 81 species within my study wetlands. During the 1998 study, the researchers found eight wetland obligate species that were not present in my study, but three of those species were either late migrants or only possible breeders including lesser yellowlegs (*Tringa flavipes*), solitary sandpiper (*Tringa solitaria*), and osprey (*Pandion haliaetus*). In addition to detecting late migrants, the differences in survey years could be attributed to several factors including observer differences and changes in wetland size. Four of the five confirmed breeding wetland obligates missing in my study that was present in the 1998 study were associated with larger wetland area including Virginia rail (*Rallus limicola*), marsh wren (*Cistothorus palustris*), common moorhen (*Gallinula chloropus*), and spotted sandpiper (*Actitis macularius*); while some of the species common in both studies were associated with smaller wetland sizes. Also, the 1998 study included three visits to each wetland while my study only included two visits. However, whether this difference is due to increasing site age, or is merely a reflection of year-to-year fluctuations cannot be determined from my data (Hotaling et al. 2002).

I detected a significant relationship between wetland area and the number of wetland bird species. Other researchers have also detected similar relationships between wetland area and species richness (Hemesath and Dinsmore 1993). The reason for this relationship could be attributed to several reasons including: migrating and breeding species that seek stopover points have a better chance of finding larger wetlands than smaller ones; higher density of vegetation and water depths; some species are area-sensitive; or larger sites required more sampling effort resulting in increased probability of detecting some species (Cashen and Brittingham 1998).

Although my study was not comparing results with other wetlands, existing data on distribution and abundance of bird species suggests restored wetlands are being utilized at similar frequencies to other wetlands (Delphey and Dinsmore 1993, VanRees-Siewert and Dinsmore 1996, Cashen and Brittingham 1998, Ratti et al. 2001, Hotaling et al. 2002, Snell-

Rood and Cristol 2003,). Species such as great blue heron, green heron, Canada goose, mallard, wood duck, and red-winged blackbird which were frequently found in 1998 are also common in my study. Wetland area is still significantly related to wetland bird species richness. Overall, these wetlands are still providing beneficial habitat to a variety of flora and fauna.

Management Implications

My data suggests that changes in restored wetlands as a result of succession are variable. Most wetlands still provide quality habitat for a variety of bird species. However, there may be a need to actively manage these wetlands in the future in order to sustain or restore habitat for lost wetland obligate species and species associated with larger wetland size.

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Table 1. Comparison of mean water depth changes from 1998 to 2010 of 15 restored wetlands in the Ridge and Valley Region of Pennsylvania.

Water Depth	Mean Depth		P
	1998 Study	2010 Study	
EMERG	0.51 ± SE 0.15	0.45 ± SE 0.21	0.738
SHALL	0.41 ± SE 0.14	0.32 ± SE 0.07	0.550
MED	1.22 ± SE 0.24	0.55 ± SE 0.15	0.000
DEEP	0.73 ± SE 0.22	0.60 ± SE 0.20	0.259

Table 2. Species list of all species detected at 15 restored wetlands in the Ridge and Valley Region of Pennsylvania during the 1998 and 2010 study.

Species	Guild	Study Found		
		Both Studies	1998	2010
Cooper's Hawk	Forest			x
Red-shouldered Hawk	Forest	x		
Broad-winged Hawk	Forest		x	
Ruffed Grouse	Forest		x	
Wild Turkey	Forest			x
American Woodcock	Forest		x	
Barred Owl	Forest	x		
Hairy Woodpecker	Forest	x		
Pileated Woodpecker	Forest	x		
Acadian Flycatcher	Forest		x	
Common Raven	Forest		x	
White-breasted Nuthatch	Forest	x		
Blue-headed Vireo	Forest			x
Hermit Thrush	Forest	x		
Yellow-throated Vireo	Forest	x		
Northern Parula	Forest			x
Yellow-rumped Warbler	Forest		x	
Black-throated Green Warbler	Forest			x
Black-and-White Warbler	Forest	x		

Louisiana Waterthrush	Forest		x	
Ovenbird	Forest	x		
Hooded Warbler	Forest			x
Scarlet Tanager	Forest		x	
Black-billed Cuckoo	Forest		x	
Yellow-billed Cuckoo	Forest	x		
Great Horned Owl	Forest	x		
Ruby-throated Hummingbird	Forest	x		
Red-bellied Woodpecker	Forest	x		
Red-headed Woodpecker	Forest	x		
Downy Woodpecker	Forest	x		
Northern Flicker	Forest	x		
Eastern Wood-pewee	Forest	x		
Least Flycatcher	Forest		x	
Eastern Phoebe	Forest	x		
Great Crested Flycatcher	Forest	x		
Blue Jay	Forest	x		

Table 2. Continued

Species	Guild	Study Found		
		Both Studies	1998	2010
Black-capped Chickadee	Forest	x		
Tufted Titmouse	Forest	x		
Carolina Wren	Forest	x		
Blue-gray Gnatcatcher	Forest		x	
Wood Thrush	Forest	x		
American Robin	Forest	x		
Cedar Waxwing	Forest	x		
Warbling Vireo	Forest	x		
Red-eyed Vireo	Forest	x		
Golden-winged Warbler	Forest		x	
Nashville Warbler	Forest			x
American Redstart	Forest	x		

Wilson's Warbler	Forest		x	
Rose-breasted Grosbeak	Forest		x	
Indigo Bunting	Forest	x		
Chipping Sparrow	Forest	x		
Brown-headed Cowbird	Forest	x		
Baltimore Oriole	Forest	x		
Orchard Oriole	Forest	x		
Great Blue Heron	Wetland Obligate	x		
Great Egret	Wetland Obligate	x		
Green Heron	Wetland Obligate	x		
Canada Goose	Wetland Obligate	x		
Wood Duck	Wetland Obligate	x		
Mallard	Wetland Obligate	x		
Blue-winged Teal	Wetland Obligate		x	
Virginia Rail	Wetland Obligate		x	
Belted Kingfisher	Wetland Obligate	x		
Common Merganser	Wetland Obligate			x
Osprey	Wetland Obligate		x	
Marsh Wren	Wetland Obligate		x	
Common Moorhen	Wetland Obligate		x	
Swamp Sparrow	Wetland Obligate	x		
Lesser Yellowlegs	Wetland Obligate		x	
Solitary Sandpiper	Wetland Obligate		x	
Spotted Sandpiper	Wetland Obligate		x	
Rusty Blackbird	Facultative Wet			x

Table 2. Continued

Species	Guild	Study Found		
		Both Studies	1998	2010
Red-winged Blackbird	Facultative wet	x		
Bank Swallow	Facultative	x		
Tree Swallow	Facultative	x		
Red-tailed Hawk	Open Habitat	x		

American Kestrel	Open Habitat		x	
Ring-necked Pheasant	Open Habitat	x		
Killdeer	Open Habitat	x		
Mourning Dove	Open Habitat	x		
Barn Swallow	Open Habitat	x		
Eastern Kingbird	Open Habitat	x		
Eastern Bluebird	Open Habitat	x		
Grasshopper Sparrow	Open Habitat		x	
Bobolink	Open Habitat		x	
Eastern Meadowlark	Open Habitat	x		
Turkey Vulture	Open Habitat	x		
Northern Mockingbird	Open Habitat	x		
American Crow	Generalist	x		
American Robin	Generalist	x		
European Starting	Generalist	x		
Common Grackle	Generalist	x		
Alder Flycatcher	Shrub/Mid-successional			x
Willow Flycatcher	Shrub/Mid-successional		x	
House Wren	Shrub/Mid-successional	x		
Gray Catbird	Shrub/Mid-successional	x		
Brown Thrasher	Shrub/Mid-successional	x		
Northern Cardinal	Shrub/Mid-successional	x		
White-eyed Vireo	Shrub/Mid-successional		x	
Blue-winged Warbler	Shrub/Mid-successional		x	
Yellow Warbler	Shrub/Mid-successional	x		
Common Yellowthroat	Shrub/Mid-successional	x		
Yellow-breasted Chat	Shrub/Mid-successional		x	
Chestnut-sided Warbler	Shrub/Mid-successional	x		
Eastern Towhee	Shrub/Mid-successional	x		
Field Sparrow	Shrub/Mid-successional	x		
Song Sparrow	Shrub/Mid-successional	x		
American Goldfinch	Shrub/Mid-successional	x		

House Sparrow	Urban		x
Chimney Swift	urban	x	

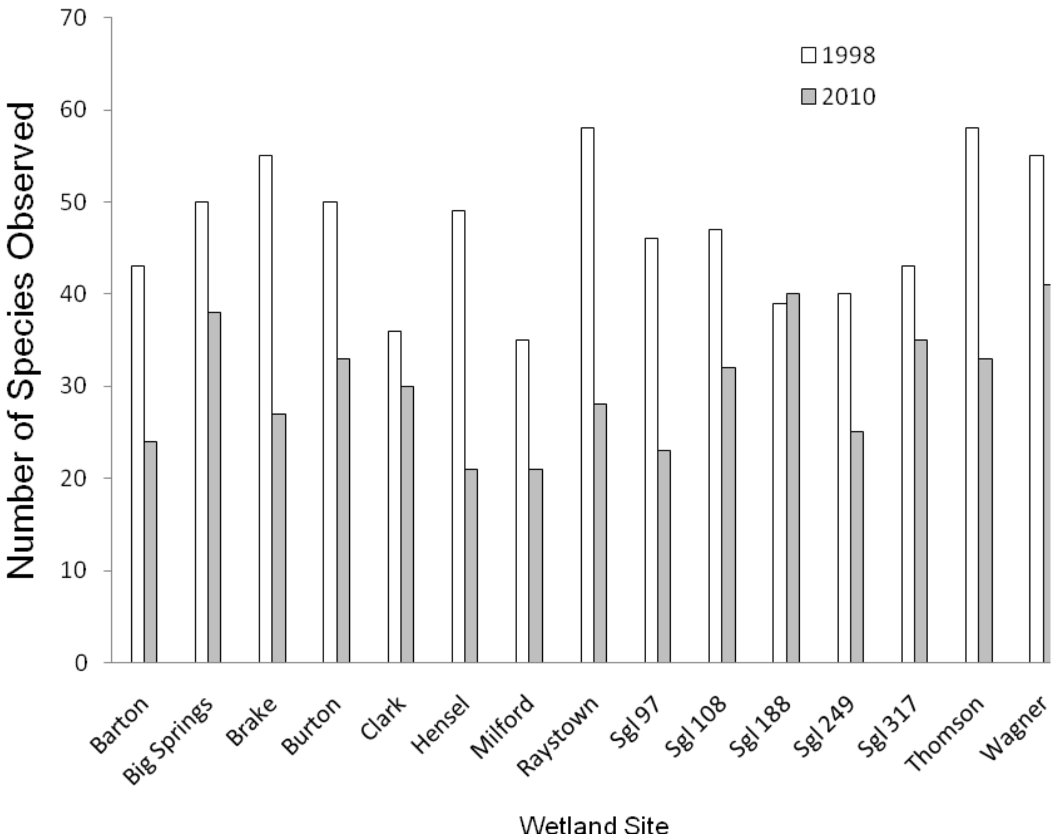


Figure 1. Comparison of wetland size per site observed in a study done on 15 restored wetlands in the Ridge and Valley Region of Pennsylvania between 1998 and 2010 (P 0.001).

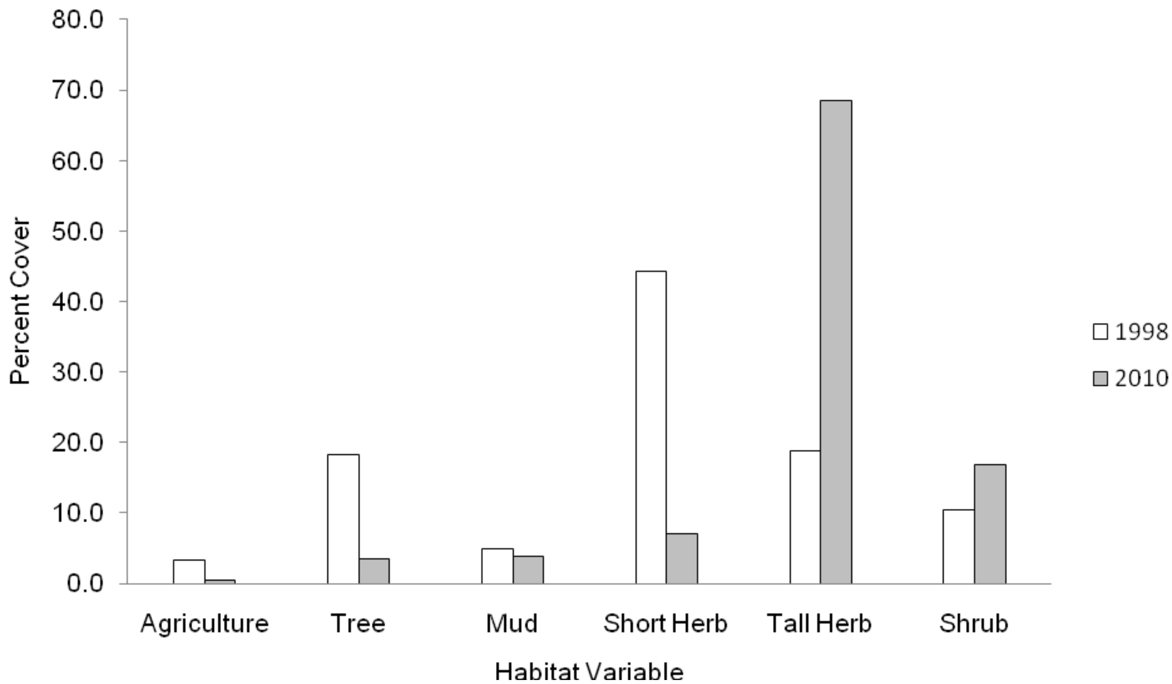


Figure 2. Comparison of percent cover of upland habitat variables observed in a study done on 15 restored wetlands in the Ridge and Valley Region of Pennsylvania between 1998 and 2010.

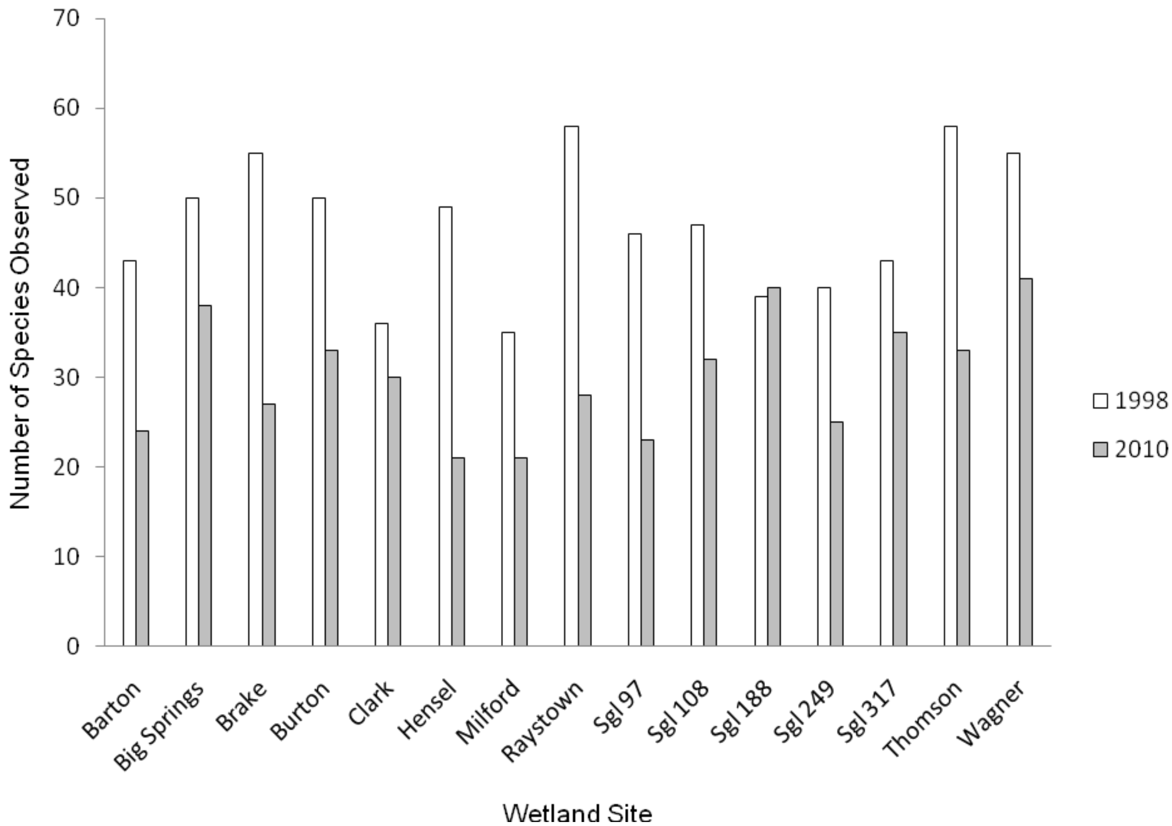


Figure 3. Comparison of the number of species observed per site between 1998 and 2010 (P= 5.412e-07) in a study of 15 restored wetlands in Ridge and Valley Region of Pennsylvania.

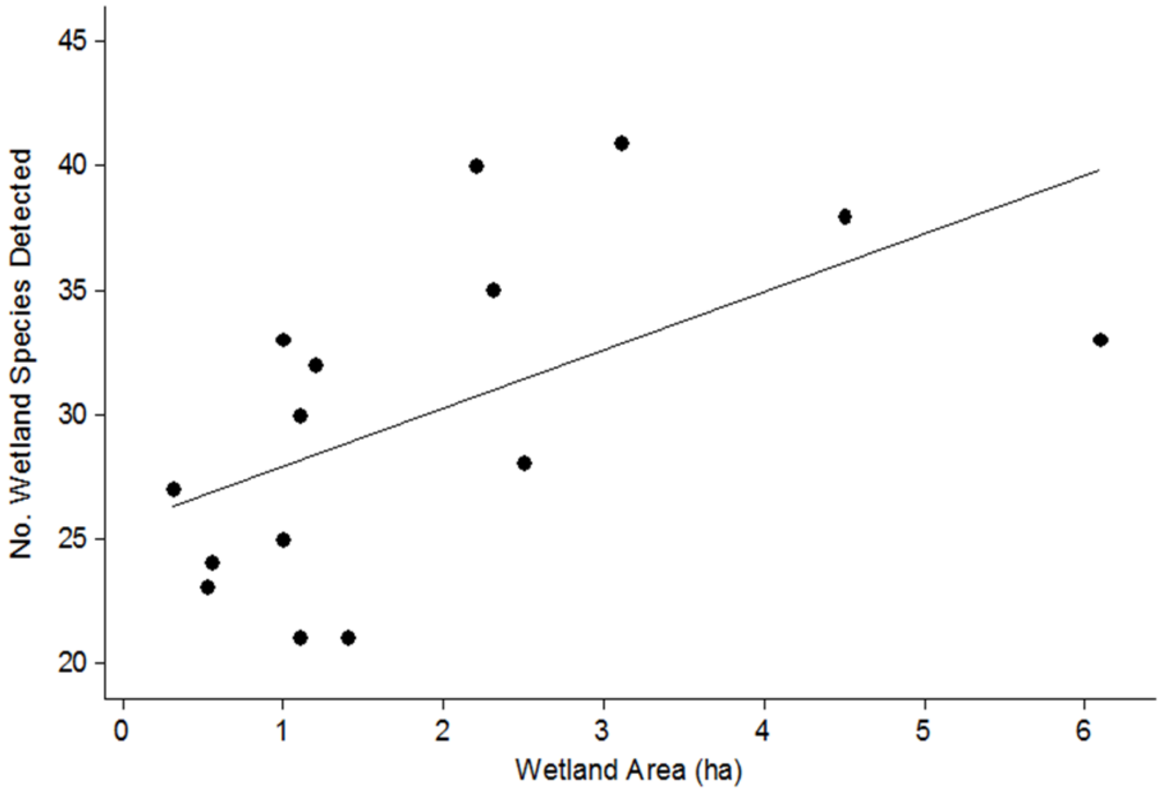


Figure 4. Relationship between avian species richness and wetland area at 15 wetlands in the Ridge and Valley region of Pennsylvania, 2010. All relationships are significant at $P < 0.05$.

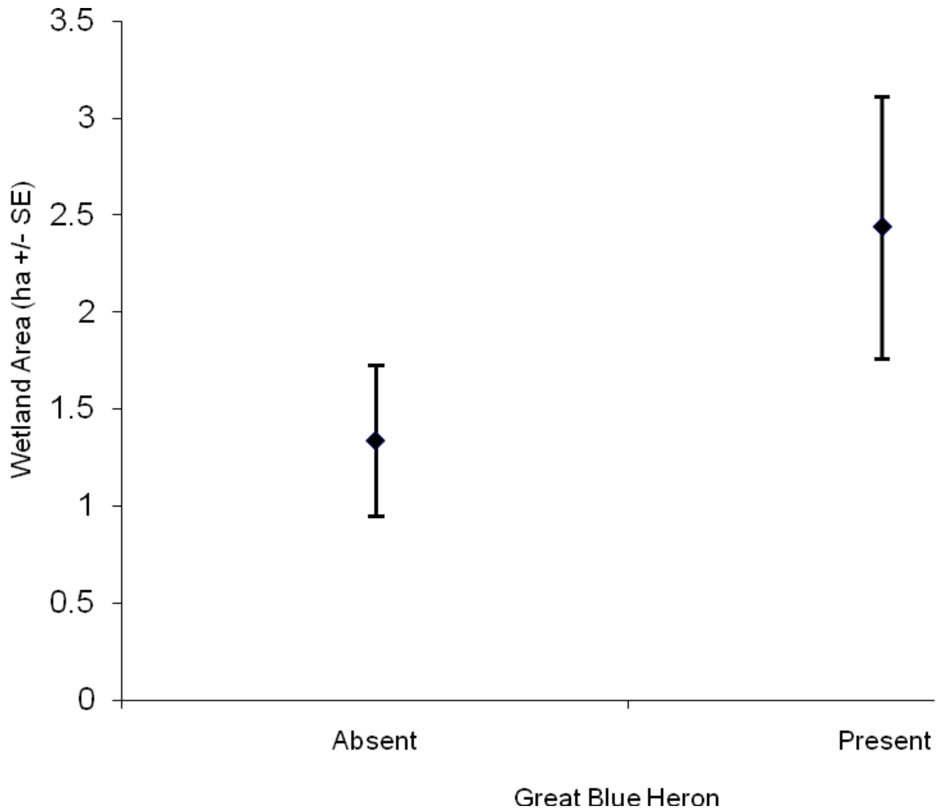
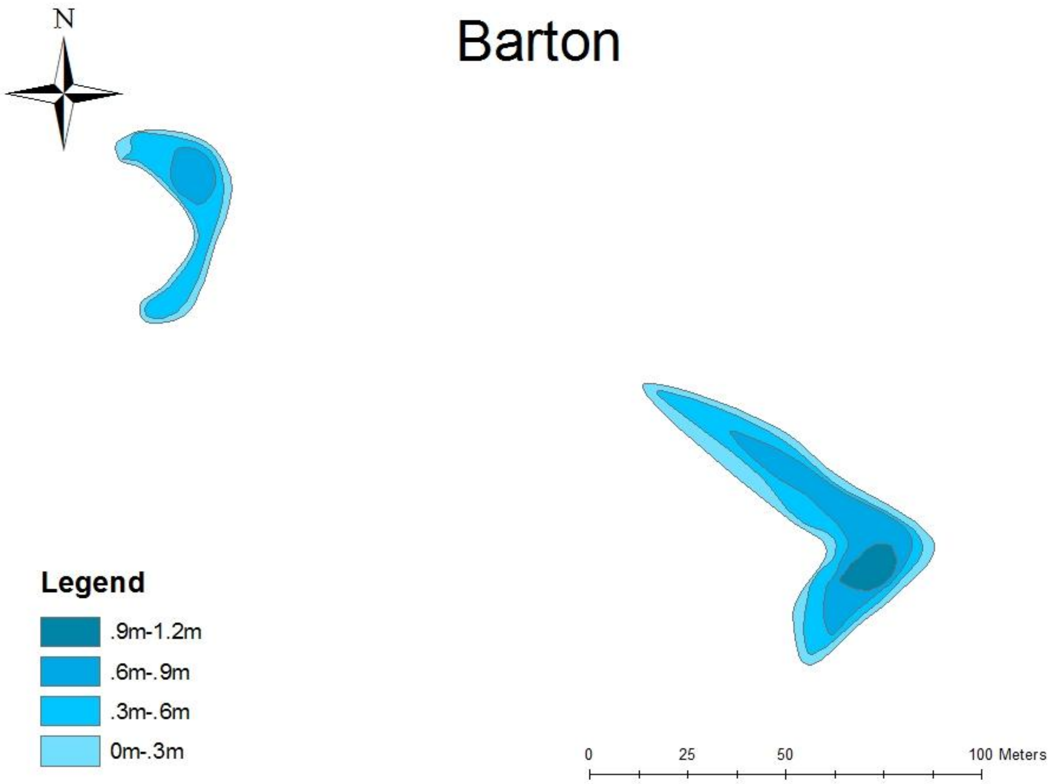
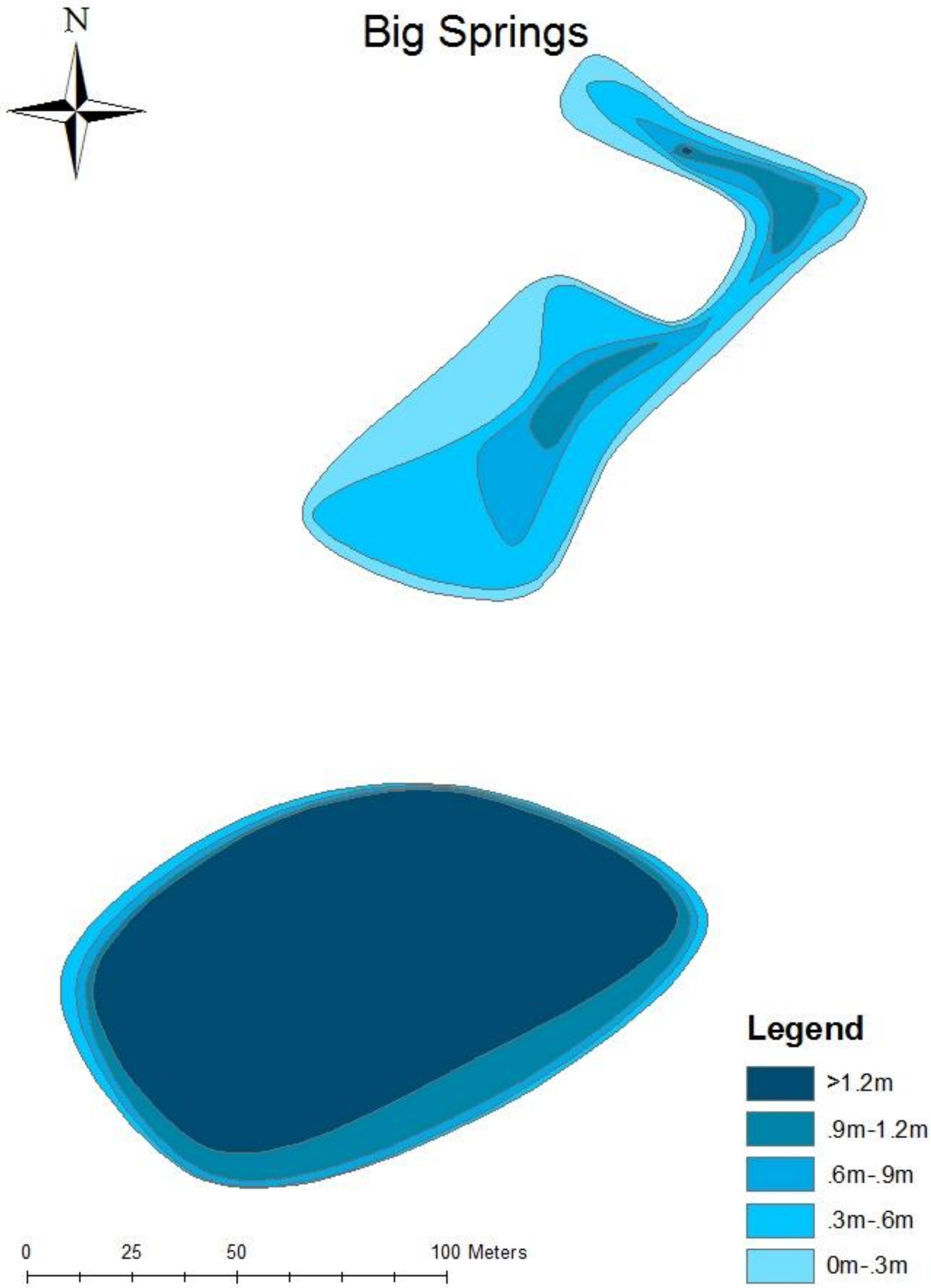
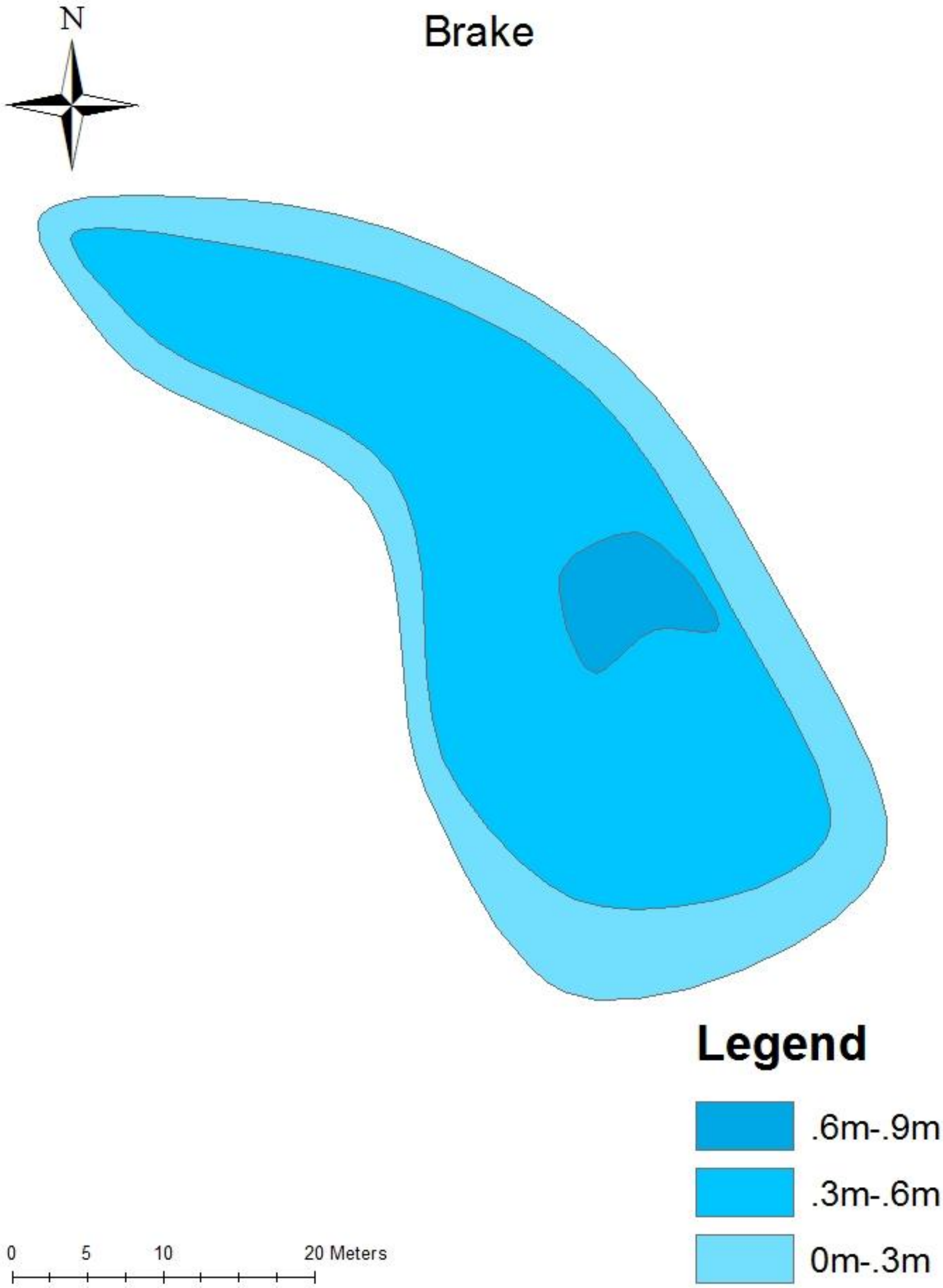


Figure 5. Probability of occurrence of great blue heron (*Ardea herodias*) in a 2010 study done on 15 restored wetlands in the Ridge and Valley Region of Pennsylvania.

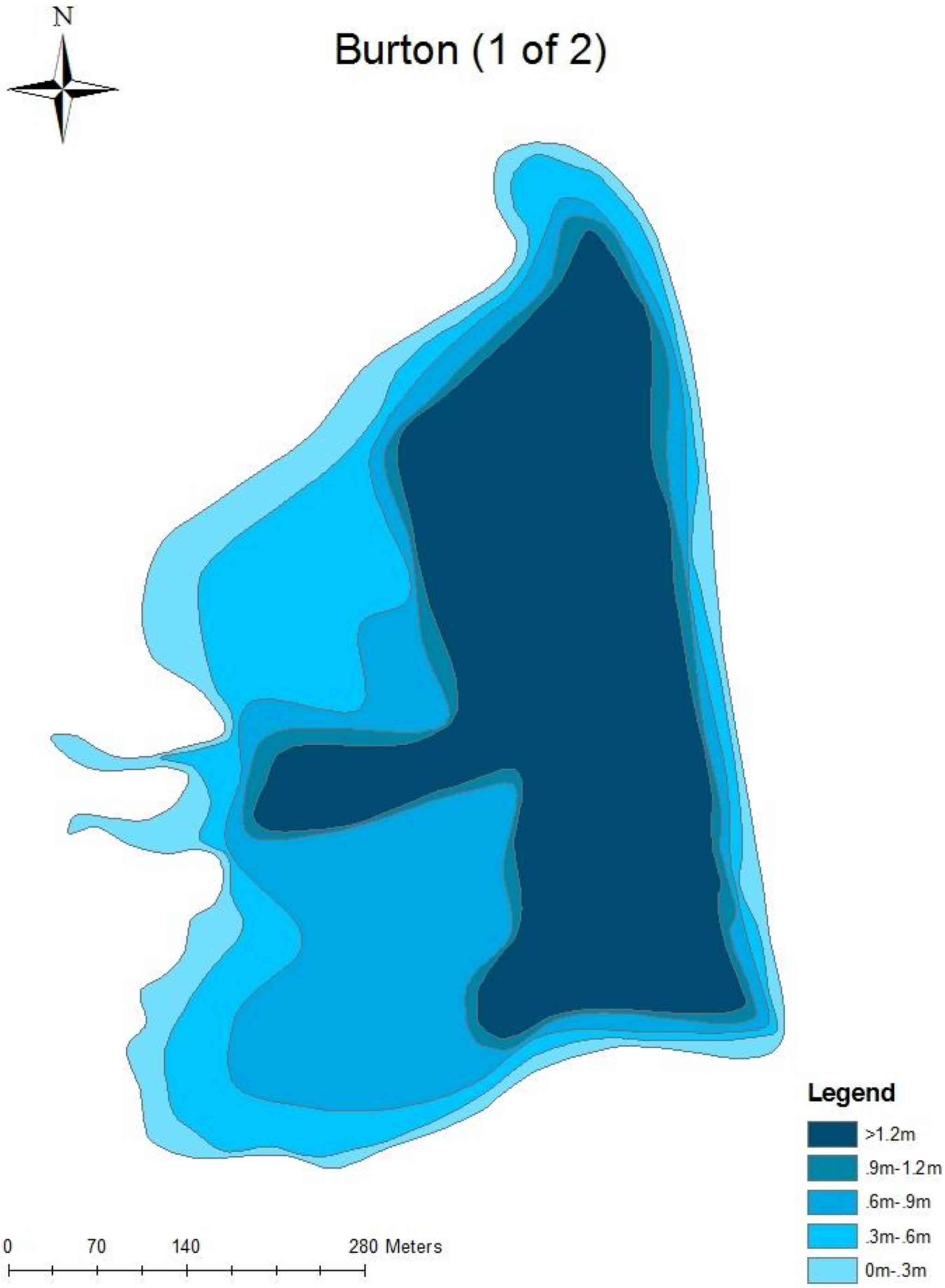
Appendix A. Water depth maps of 15 restored wetlands surveyed in the Ridge and Valley Region of Pennsylvania in 2010.

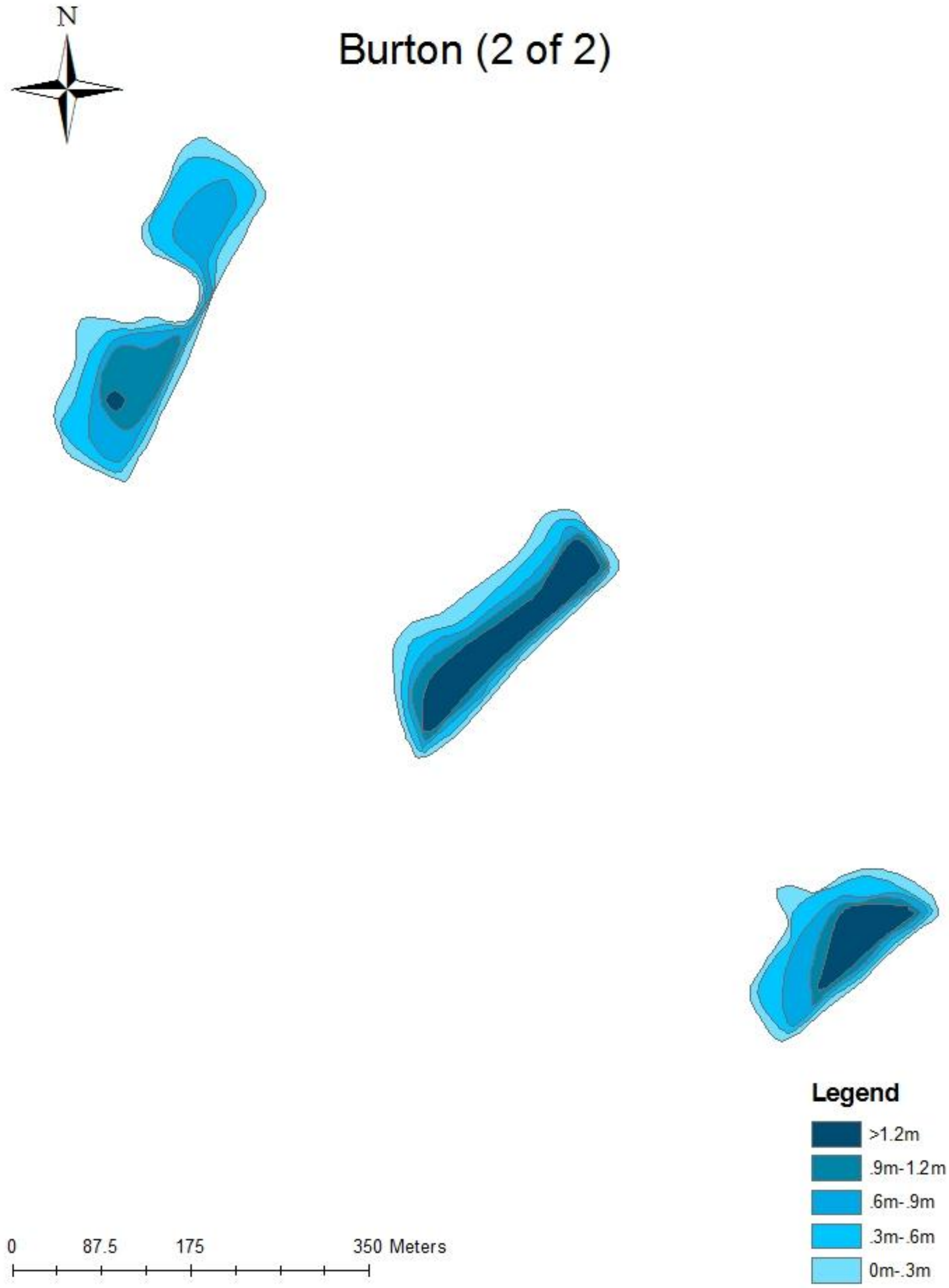

N
Barton
Legend
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
25
50
100 Meters

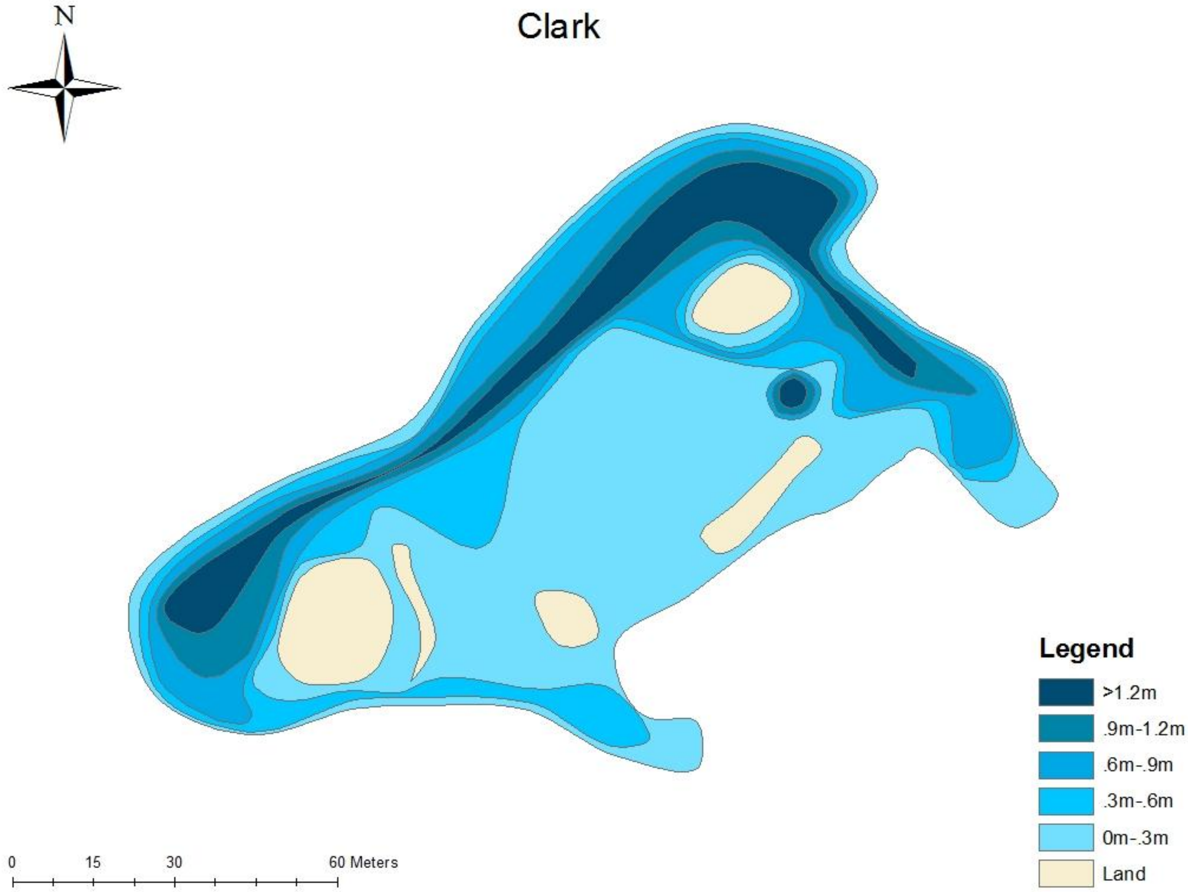

N
Big Springs
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
25
50
100 Meters

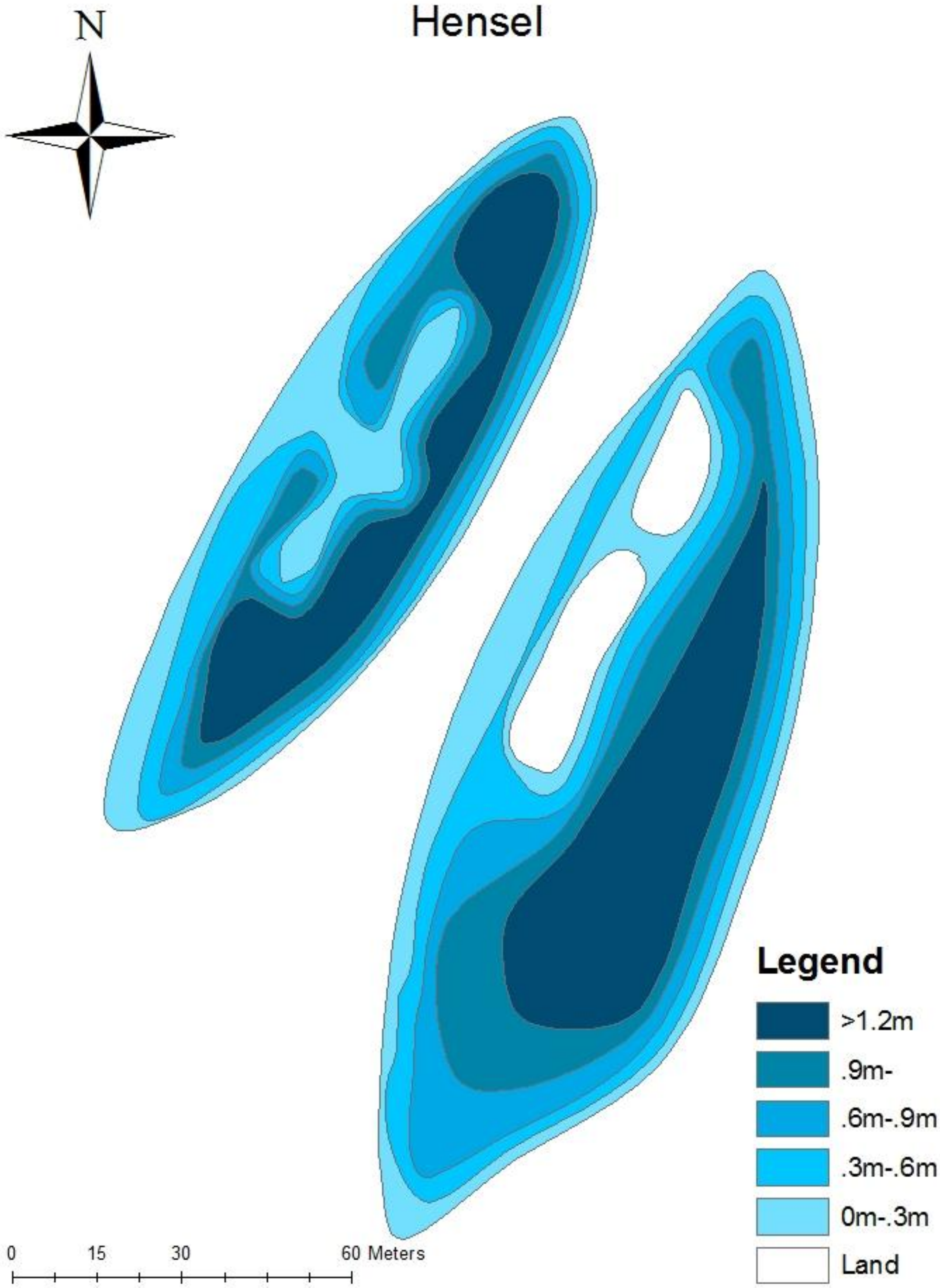


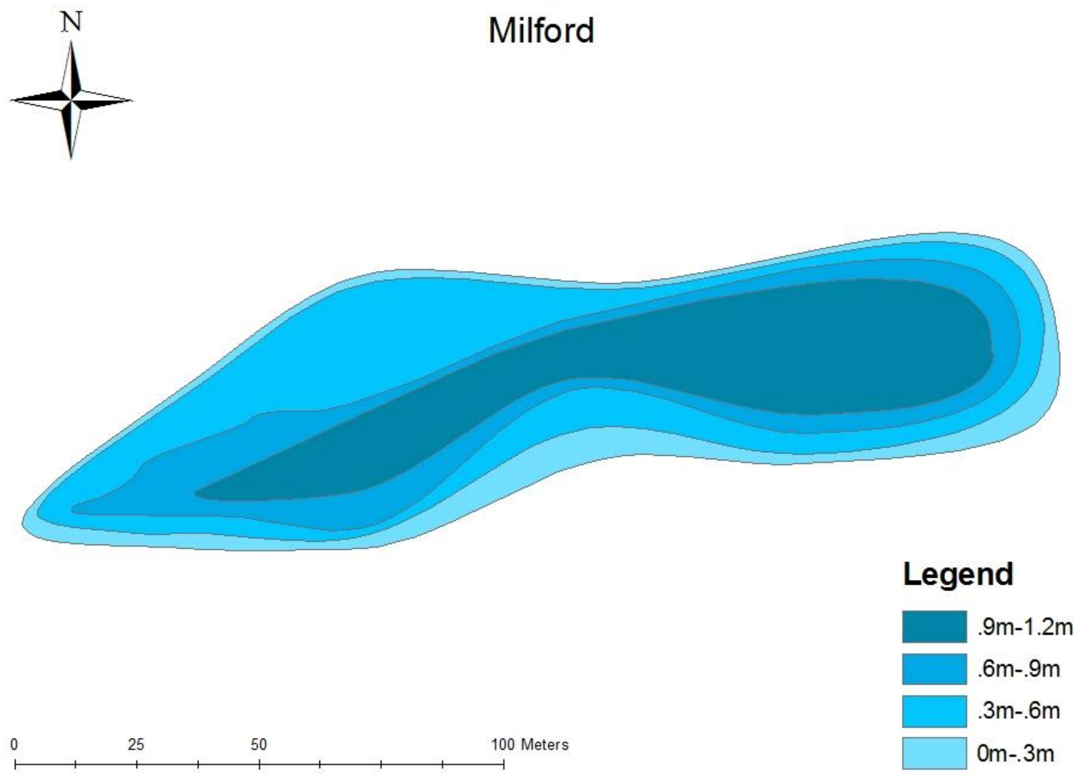
N
Brake
Legend
.6m-.9m
.3m-.6m
0m-.3m
0
5
10
20 Meters


N
Burton (1 of 2)
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
70
140
280 Meters

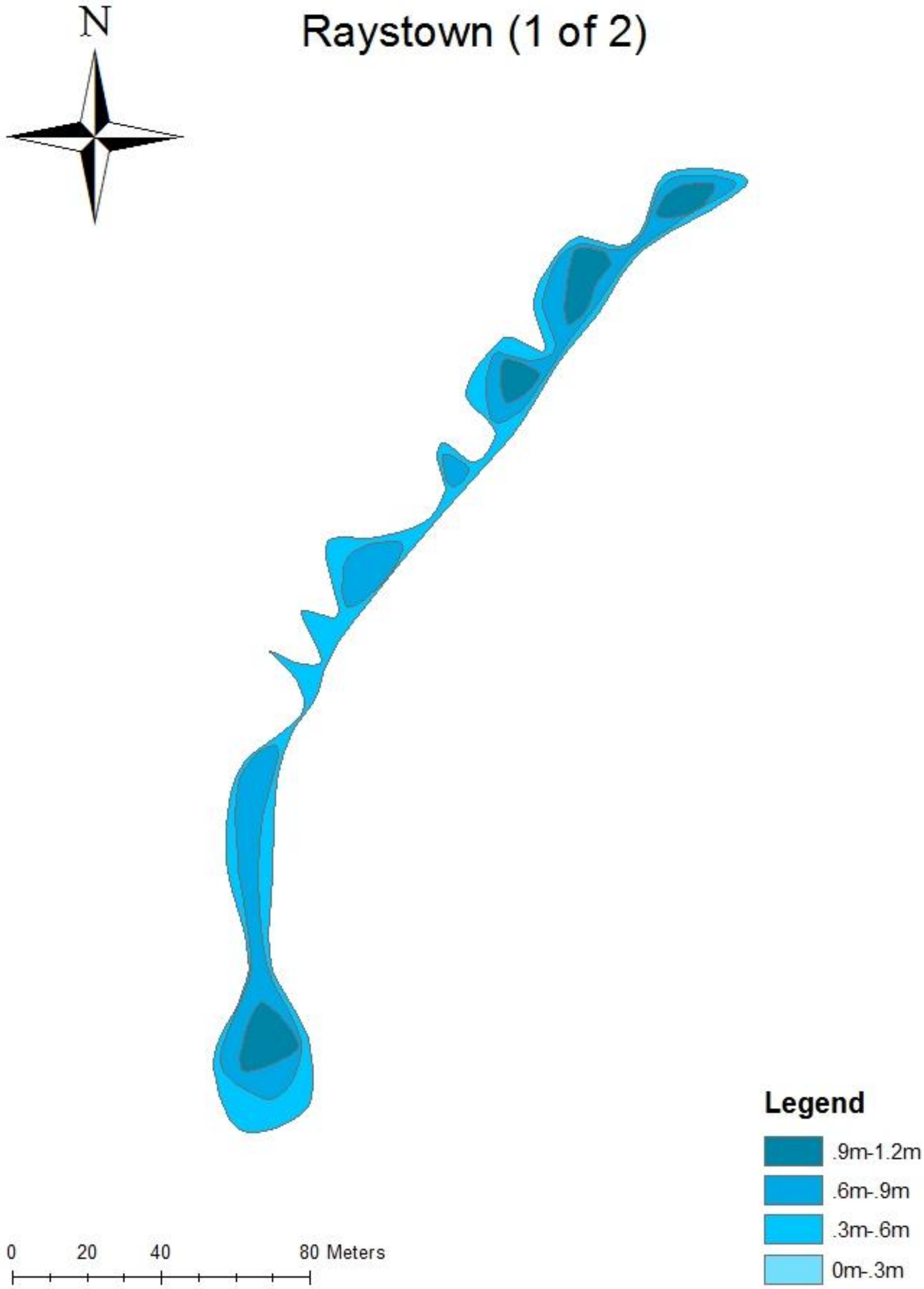

N
Burton (2 of 2)
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
87.5
175
350 Meters


Clark
N
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
Land
0
15
30
60 Meters

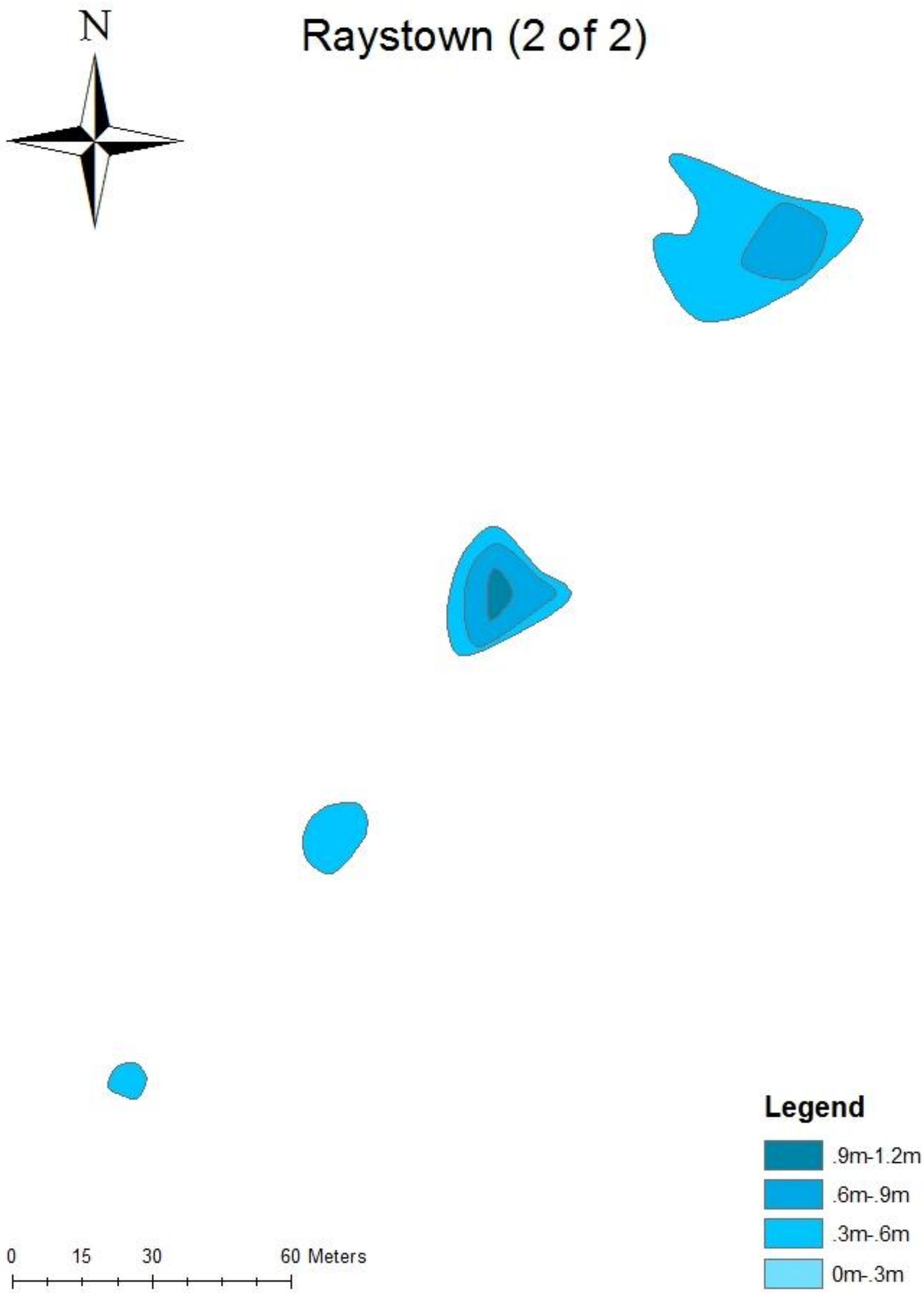

Hensel
N
Legend
>1.2m
.9m-
.6m-.9m
.3m-.6m
0m-.3m
Land
0
15
30
60 Meters

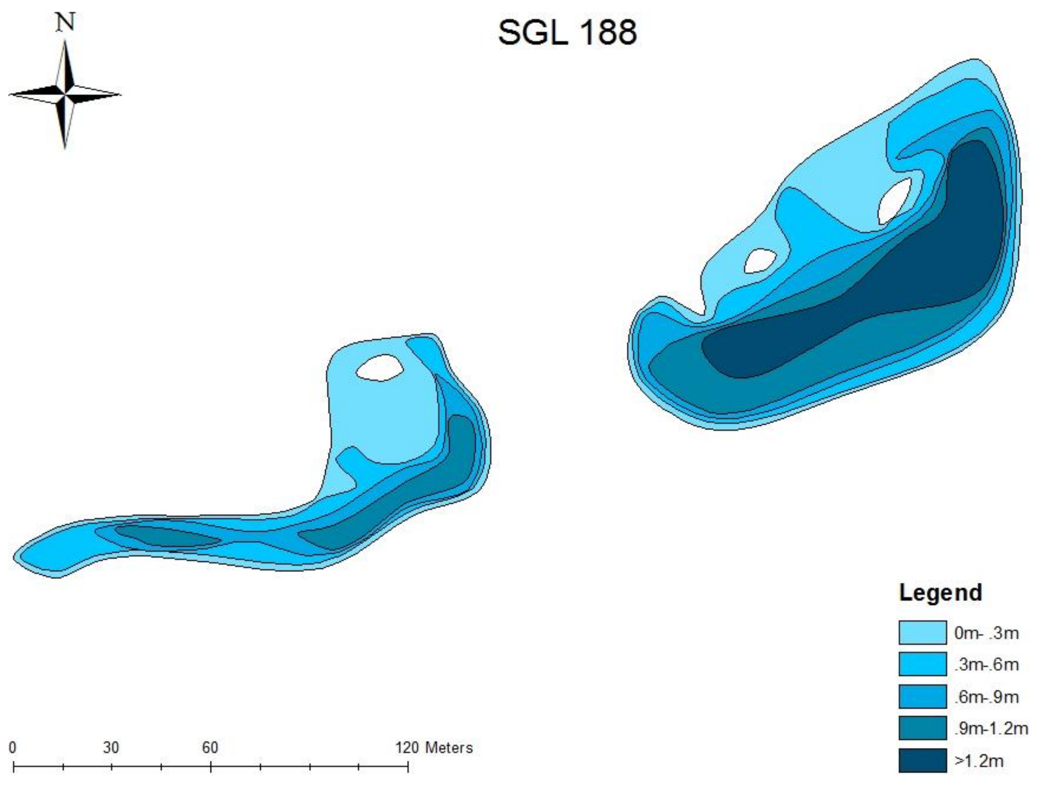


Milford
N
Legend
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
25
50
100 Meters

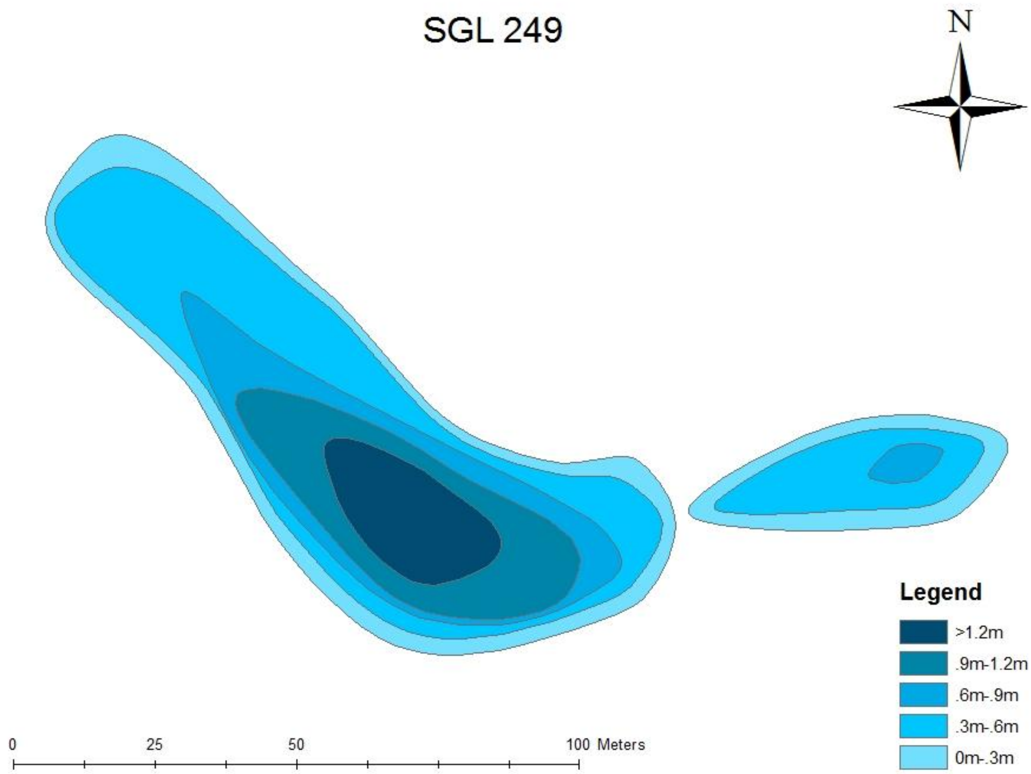


N
Raystown (1 of 2)
Legend
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
20
40
80 Meters

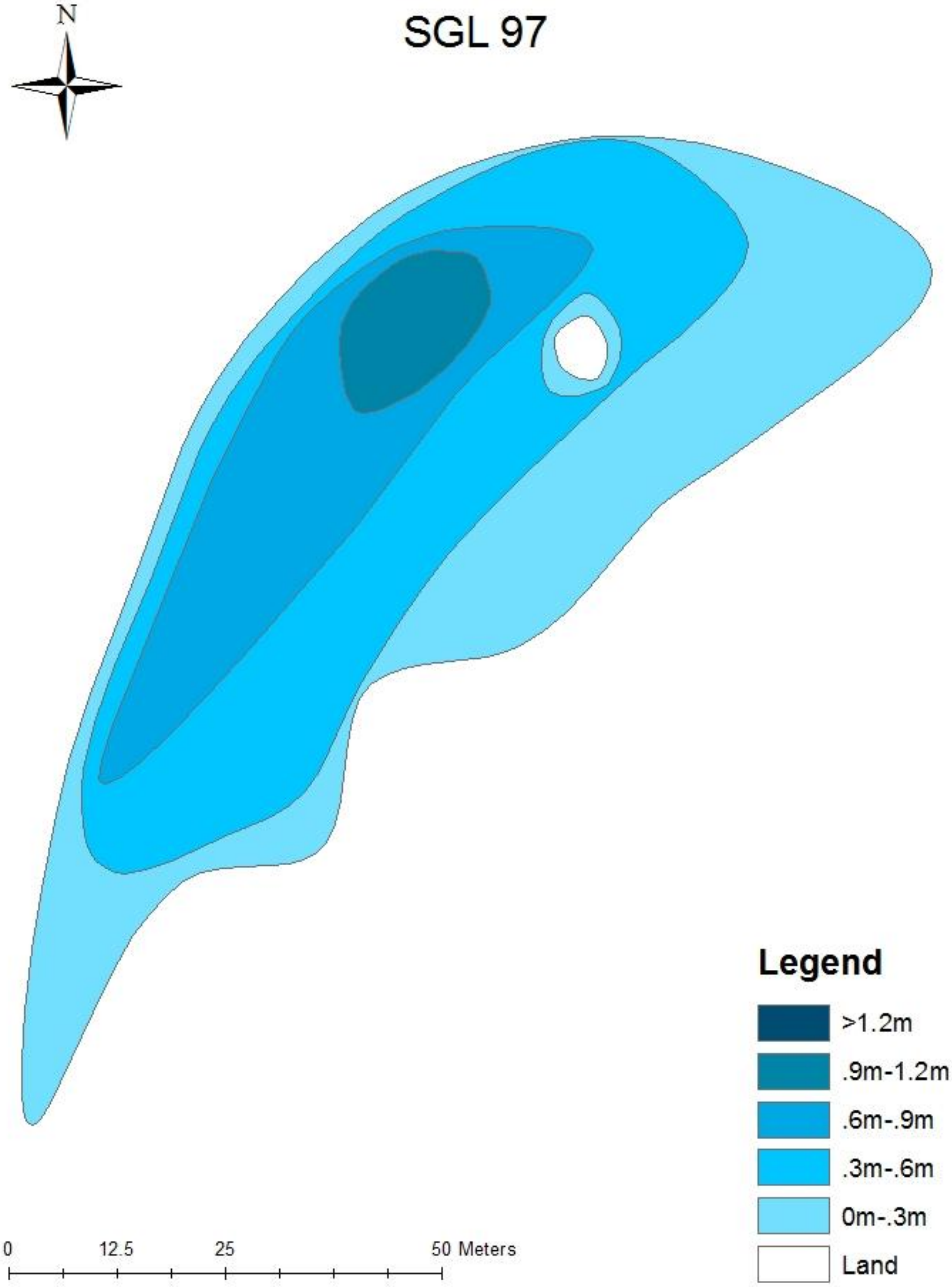

Raystown (2 of 2)
N
Legend
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
15
30
60 Meters

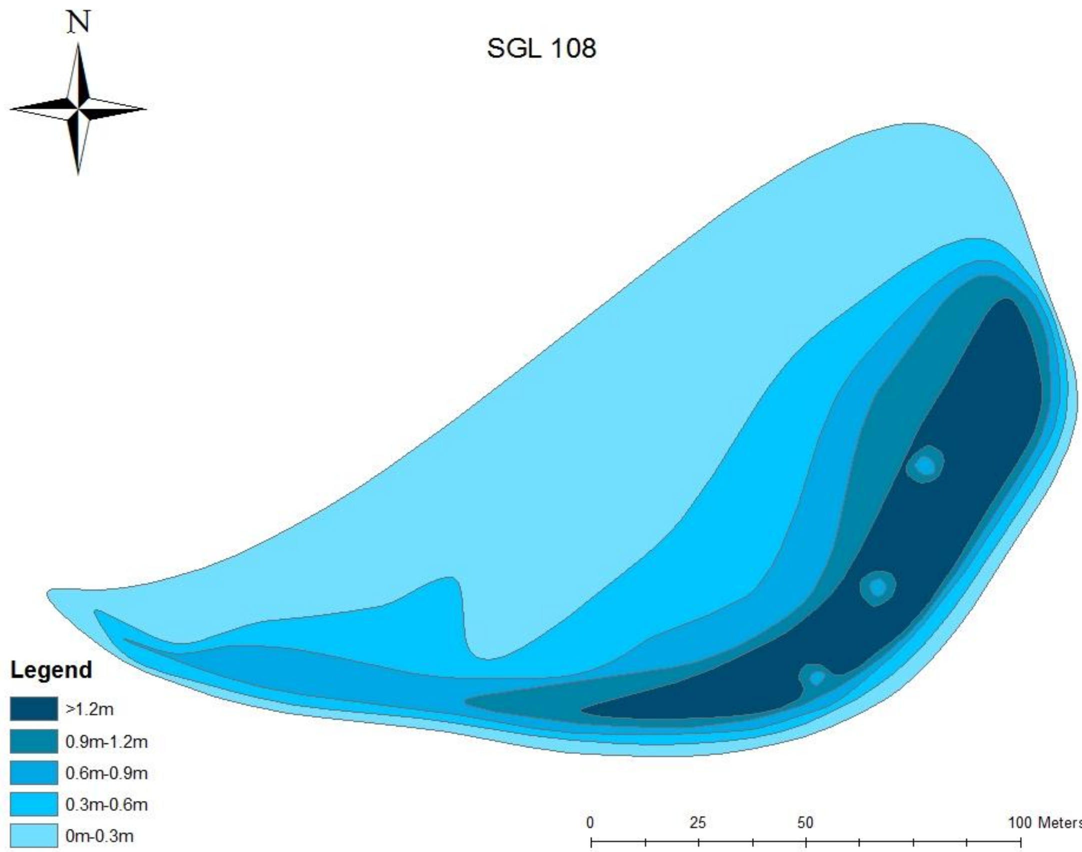


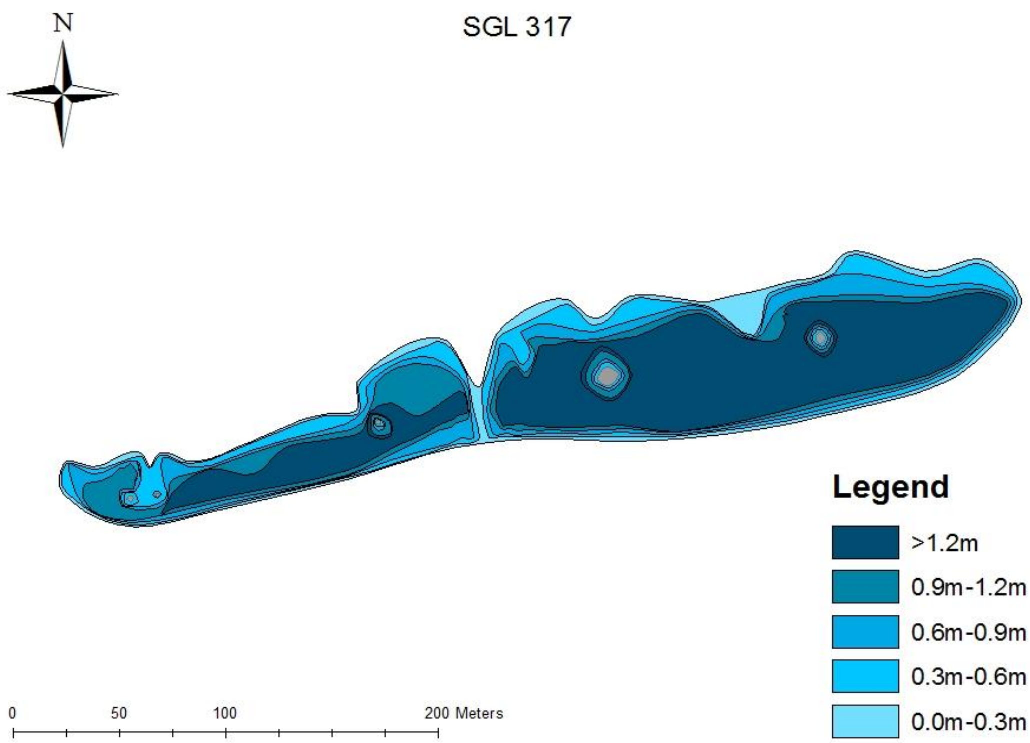
N
SGL 188
Legend
0m- .3m
.3m-.6m
.6m-.9m
.9m-1.2m
>1.2m
0
30
60
120 Meters

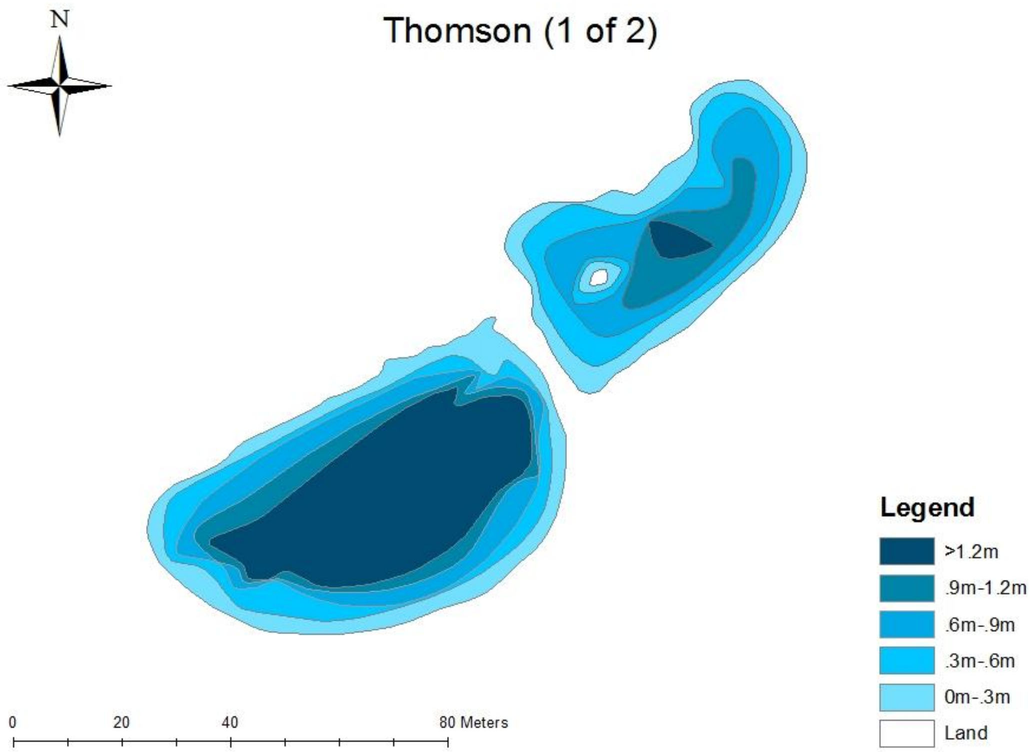


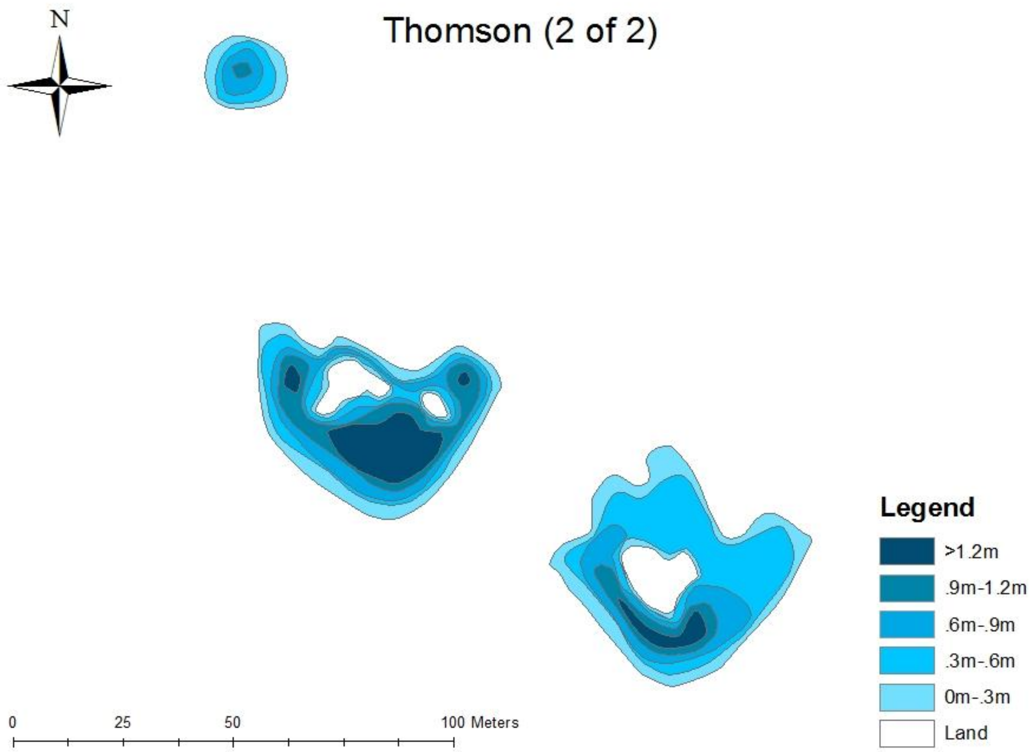
SGL 249
N
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
25
50
100 Meters

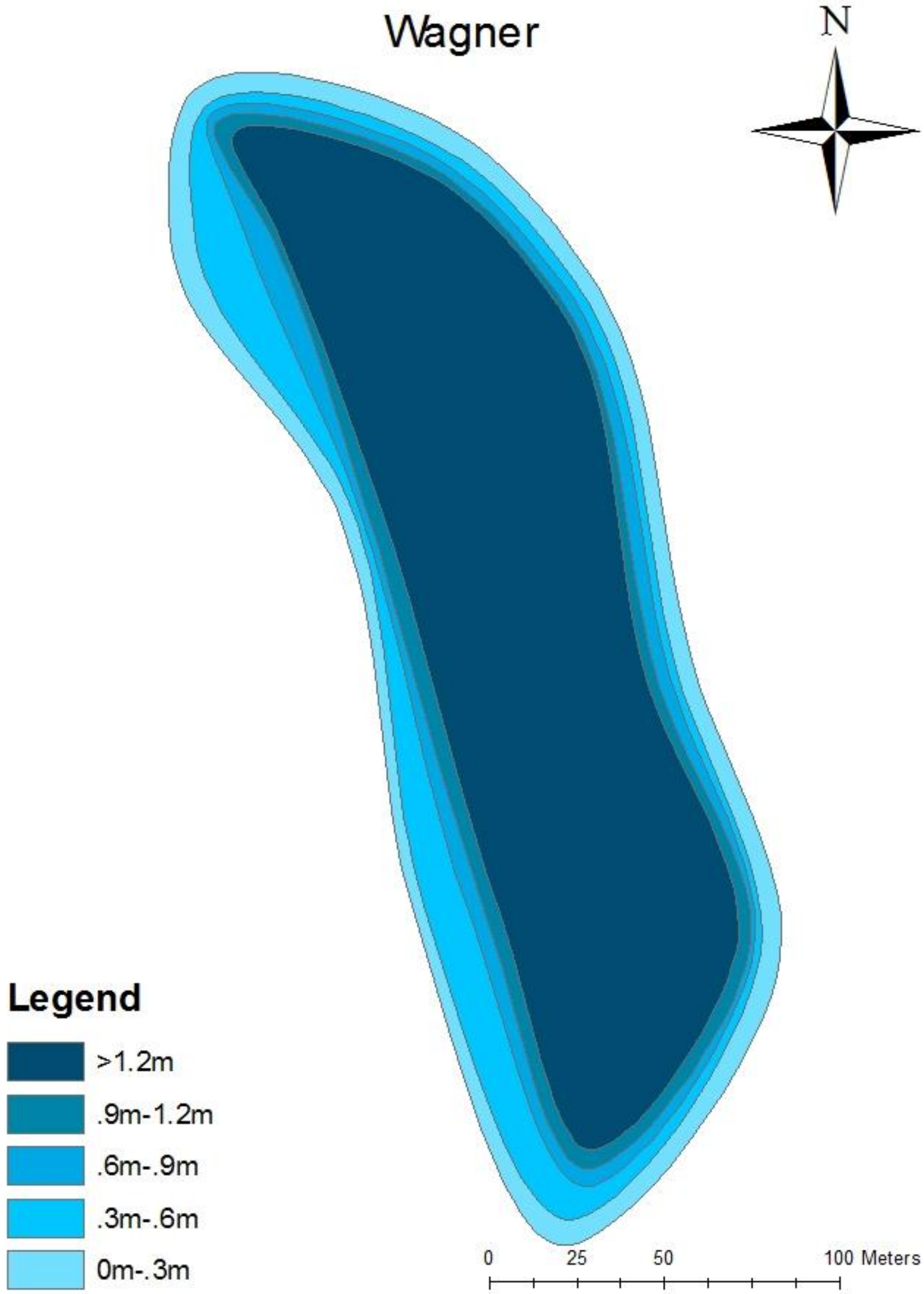

SGL 97
N
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
Land
0
12.5
25
50 Meters


N
SGL 108
Legend
>1.2m
0.9m-1.2m
0.6m-0.9m
0.3m-0.6m
0m-0.3m
0
25
50
100 Meters


N
SGL 317
Legend
>1.2m
0.9m-1.2m
0.6m-0.9m
0.3m-0.6m
0.0m-0.3m
0
50
100
200 Meters


Thomson (1 of 2)
N
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
Land
0
20
40
80 Meters


N
Thomson (2 of 2)
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
Land
0
25
50
100 Meters



Wagner
N
Legend
>1.2m
.9m-1.2m
.6m-.9m
.3m-.6m
0m-.3m
0
25
50
100 Meters