Mapping Pelagic Bird Distribution and Abundance as a Decision-Making Tool for Offshore Wind Turbine Development and Conservation Planning

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Observers:

Andy Jones

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Mark Shieldcastle

Andrea Tibbels

Pilots:

Joe Barber

Andy Doll

„Buster' Keaton

Summary

While the greatest wind energy potential for Ohio lies over the waters of Lake Erie (NREL Ohio Offshore Wind Map, 2010), there is very little information regarding the distribution of pelagic (e.g. ducks, loons, gulls, etc.) birds that may potentially be impacted by proposed offshore wind energy facilities. Though Lake Erie does not have the highest wind energy potential of the Great Lakes, its shallow waters and proximity to load centers (Toledo, Cleveland, Detroit, and Buffalo) make it more economically feasible for wind energy than some of the deeper lakes. There are currently no offshore wind turbine facilities within the United States, though European studies have shown that these facilities may have direct (mortalities) and indirect (avoidance and habitat loss) impact on migratory birds. In 2009 and 2010 the Division of Wildlife, in coordination with the U.S. Fish & Wildlife Service (USFWS), flew weekly surveys during the spring and fall migratory period to document the distribution and abundance of pelagic birds using Ohio's portion of Lake Erie. This information will be used to identify vital migratory or over-wintering areas in order to facilitate the siting of wind energy facilities in regions of Lake Erie that would minimize the likelihood of impacting pelagic birds.

Introduction

In the face of a changing climate and a new administration supportive of renewable energy, there is likely to be significant expansion of wind energy facilities. Currently there are no offshore wind energy facilities in the western hemisphere. Europe leads the world in the construction of offshore wind facilities. Of these, only two have been subject to post-construction mortality studies. There are also no offshore wind facilities located in a freshwater environment so it is unclear what impacts offshore wind facilities may pose to Ohio's Lake Erie wildlife resources. At onshore facilities, passerines make up >80% of the birds struck at wind turbine facilities, while waterfowl makeup ~5% of the species struck in the Midwest (Erickson et al. 2008). Conducting surveys to assess the direct impacts of offshore facilities is complicated by the difficulty of monitoring for carcasses in a dynamic aquatic environment. Whether these statistics remain true for offshore facilities is unknown. Therefore, efforts to proactively minimize

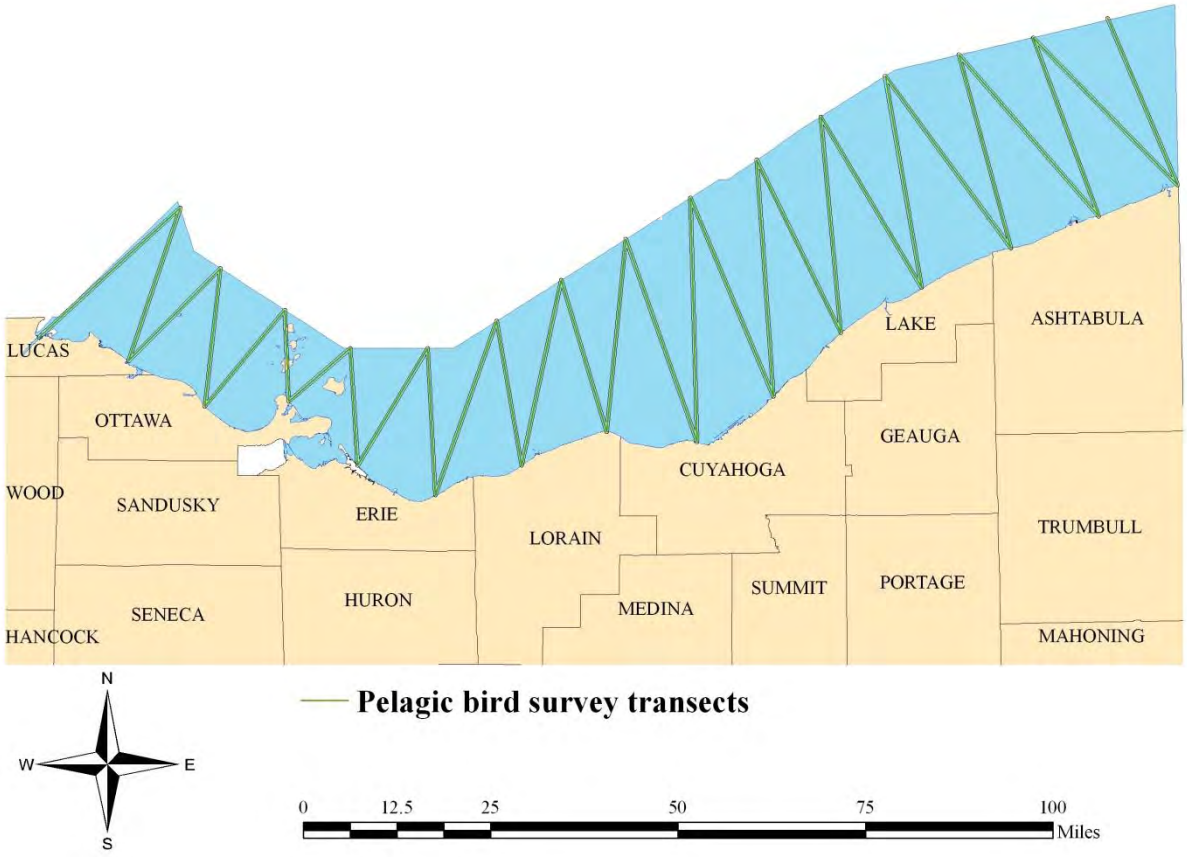
potential take of migratory pelagic birds are particularly important. Siting turbine facilities in those areas thought to have the lowest bird densities is a reasonable first step to take.

Millions of pelagic birds move through Lake Erie during migration, including a globally significant proportion of North America's red-breasted merganser population. Flocks of over 210,000 red-breasted mergansers have been observed on a single day near Sandusky, Ohio (Peterjohn 2001). Estimates from the Division of Wildlife's near-shore waterfowl surveys for scaup exceed 25,000 birds (ODNR bi-weekly aerial waterfowl survey). These surveys indicated that > 100,000 birds can be present at peak times of migration in the Western Basin of Lake Erie (ODNR bi-weekly aerial waterfowl survey). While we have a limited understanding of the quantity and species diversity of birds that occur in the region, the distribution of waterfowl on Lake Erie during the migratory period is unknown due to very limited sampling effort. Since the 1970's the Division of Wildlife has conducted pelagic bird surveying over approximately 5% of Ohio's portion of Lake Erie. These surveys were extensively focused in the Western Basin and Sandusky Bay, and generally extended no more than one mile from shore. In comparison the highest wind energy potential in Lake Erie is over nine miles from shore, a region of the lake with no quantitative data related to pelagic bird abundances. The lack of pelagic bird data in areas of Lake Erie with the highest wind development potential confounds efforts to appropriately site turbines and associated infrastructure in locations that will minimize impacts to these species.

Methods

Twenty-nine transects were established within Ohio's portion of Lake Erie, alternating between the shoreline and the international boundary (Fig. 1).

Figure 1. Aerial survey transects.



Points were evenly spaced along shoreline (~12.5 miles) and international boundary (~11 miles). One complete flight of all transects was equal to one survey. Due to the length of the transects, 664 miles (1,094 km) in total, each survey was flown over a 2-day period. A twin engine Partenavia P68C was used to conduct the flights at an altitude of approximately 250 ft (76.2 m) agl at 120 knots (138 mph). Observations were recorded on a Dell© Axum™ handheld computer using ArcPad Version 7.0, allowing for the simultaneous recording of bird detections and GPS location (Fig 2).

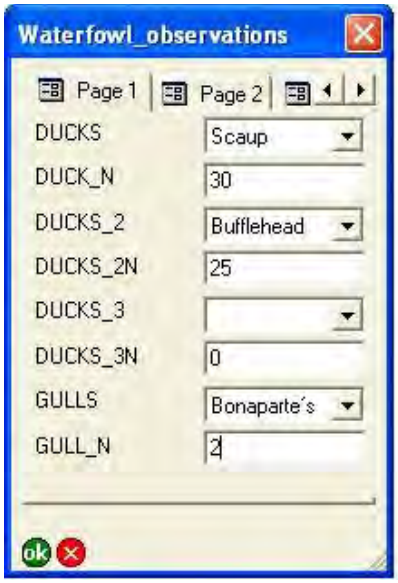


Figure 2. Example of the text box used to enter observations within ArcPad.

Each flock or individual bird was entered with the position relative to the nearest transect. Surveys were flown once weekly from mid-October through mid-December 2009 and mid-March through the end of May 2010. Occasionally transects within the "safety fan" of the Camp Perry Training Center firing zone in Ottawa County were not surveyed. An additional survey was flown once at the beginning of February to document the distribution of birds relative to leads in the ice or warm water discharges such as river mouths or coal fire power plants.

ArcGIS Version 9.3 was used to merge results of various surveys and perform interpolations. Inverse Distance Weighting (IDW) was used to interpolate the values for 1/4 mile (402 m) grid cells. With IDW those points that are closest to a cell have the greatest influence on the value for that particular cell. For our study the closest 20 points were used to derive the value of each grid cell. While correlations between bird abundance and the distance to shore or/and water depth were investigated, it was determined that the results from the IDW provided a more realistic depiction of the distribution observed during surveys.

Results

The DOW conducted 22 surveys, during which 10,644 observations (of individuals or flocks) were recorded. The original flight height was proposed to be 500 ft (152.4 m), but it was found to make species identification and detection more difficult, thus lowered to 250 ft after the 3rd survey. Specifically, the number of horned grebes using Lake Erie would most likely have been underestimated if flights had remained at 500 ft. Forty four species of bird were detected (Table 1.), totaling 458,522 individuals. The highest bird densities were found at the mouths of the Maumee and Cuyahoga rivers, and near the islands within the Western Basin (Fig. 3). Typically the highest densities of birds in the open lake were associated with gulls congregating around commercial fishing vessels. Areas east of Cuyahoga County and greater than five miles from shore had the lowest density of birds (Fig. 4).

Table 1. Species list

Species	
American black duck	Horned grebe
American coot	Jaeger *sp*.
American crow	Lesser black-backed gull
Bald eagle	Long-tailed duck
Black scoter	Mallard
Black-crowned night heron	Mute swan
Bonaparte's gull	Passerine *sp*.
Brant	Pigeon
Bufflehead	Red-breasted merganser
Canada goose	Redhead
Canvasback	Red-necked grebe
Caspian tern	Red-throated loon
Common goldeneye	Red-winged blackbird
Common loon	Ruddy duck
Common merganser	Sandpiper *sp*.
Double-crested cormorant	Scaup *sp*.
Glaucous gull	Snow bunting
Great black-backed gull	Trumpeter swan
Great blue heron	Tundra swan
Ring-billed / Herring gull	Turkey vulture
	White-winged scoter

Figure 3. Number of birds per ½ mile grid cell.

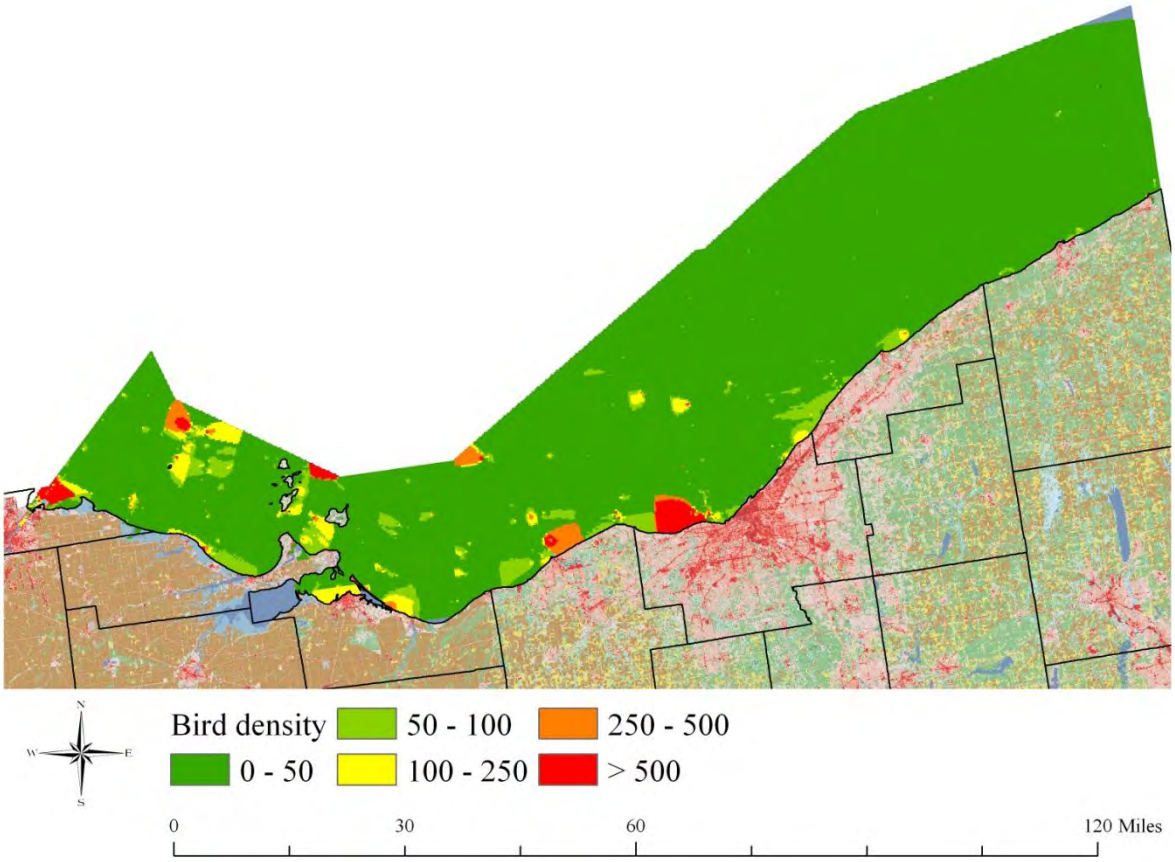
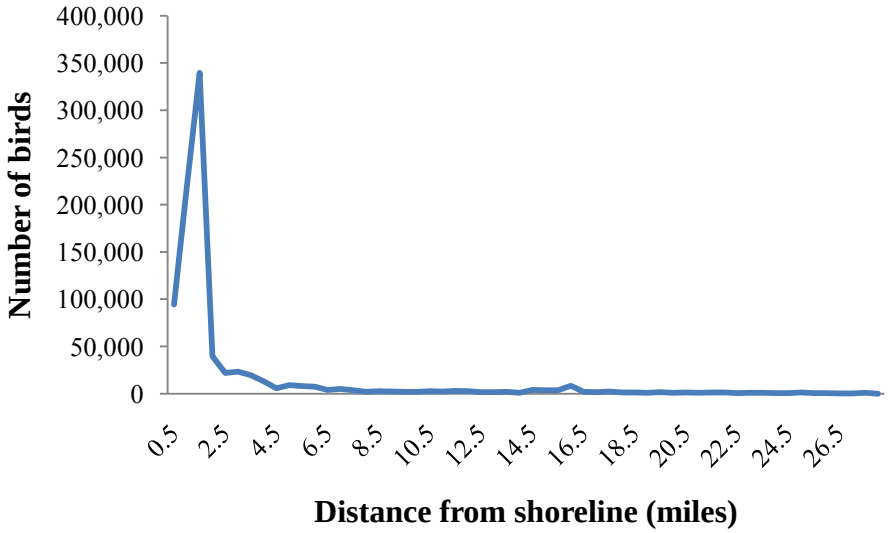


Figure 4. Bird abundances relative to the distance to shoreline.



Discussion

Gulls and terns: Five species of gull (Bonaparte's, ring-billed / herring, great black-backed, lesser black-backed and glaucous gulls) and one species of tern (Caspian) were observed during the 2009/2010 surveys. Due to the difficultly differentiating herring and ring-billed gulls, specifically where large flocks were present, these species were grouped into one category. Gulls were almost ubiquitous across the lake, even present during periods of rough weather and far from the shoreline. Large concentrations of gulls were observed following commercial fishing vessels and flocks could extend for several miles feeding off of bi-catch. Smaller numbers of Bonaparte's gulls were often observed harassing loons, most likely exhibiting kleptoparasitism, attempting to steal food from the loons. Ring-billed / herring and Bonaparte's gulls were common throughout the entire survey period, while glaucous and great black-backed gulls were most prevalent during the middle of the winter. Like gulls, terns can be difficult to differentiate, thus only Caspian terns were identifiable to species due to their large size. Other terns, most likely Forster's or common terns were lumped together as tern *sp*. Terns were exclusively found during the late spring, breeding along marshes, sand spits and islands.

Dabbling ducks: Mallard and American black duck were the only species of dabbling ducks observed during these surveys. These species were typically found close to shore, in small numbers throughout the survey period. Just prior to one survey the temperature dropped dramatically, freezing the inland waters. During that survey close to 2,000 dabbling ducks were observed on the lake adjacent to Ottawa National Wildlife Refuge, suggesting that dabbling ducks may use near-shore open waters of Lake Erie for temporary refugia during freezing events.

Diving ducks: Nine species of diving ducks (scaup sp., common goldeneye, redhead, ruddy, bufflehead, canvasback, long-tailed ducks, black and white-winged scoters) were observed during the surveys. While found throughout the survey area, the highest concentrations of these birds generally occurred near the islands and the mouth of the Maumee River, with one exception. Long-tailed ducks were typically found in the deeper portions of the lake. Large numbers of long-tailed ducks are known to congregate around Long Point, but are relatively

uncommon in Ohio during winter. Scaup were most abundant species detected during surveys; commonly flocks of 10,000 or more were found at the mouth of the Maumee River. Most species of diving ducks were predominately detected in late winter, or early spring.

Geese and swans: Canada geese, brant, mute, tundra, and trumpeter swans were observed during the surveys. These species were normally found close to shore, though on calm days they were observed several miles out into the lake. On numerous occasions Canada geese were observed flying inland to spend their day feeding within agricultural fields. In the evenings they travel back to Lake Erie to spend the night offshore, protected from predators (personal observation). Given the timing of these surveys, typically beginning at 09:00 hrs, many of these birds may have already flown into the fields and thus they would not be accounted for during these surveys. Geese were observed more frequently during the mid-winter and early spring surveys. This is most likely due to inland waters being frozen forcing the geese further out into the lake to find open water. Swans were typically found during the migratory periods, and were rarely detected when there was ice on Lake Erie.

Loons and grebes: Common and red-throated loons, horned and red-necked grebes were observed during the surveys. All of these species infrequently occurred less than 1 mile from shore, which would make detecting them from shoreline impossible. Grebes could not be detected when flying at 500 ft, and can be difficult to detect on rough days due to their small body size which was obscured by larger waves. Both loons are grebes were more likely to be found east of the Lake Erie islands, potentially showing a preference for deeper water. Red-throated loons were observed on several occasions though differentiating between common and red-throated loons was only possible on extremely calm days. These species were typically found only during spring and fall migration; once ice began to form on the lake they were rarely observed.

Colonial waterbirds: Herons, egrets, and cormorants nest on several Lake Erie islands (Green West Sister, and Middle Islands). These birds were commonly observed during the spring commuting to and from the islands. During the fall surveys herons and egrets were almost absent, while small numbers of double-crested cormorants lingered throughout the fall.

Mergansers: Red-breasted and common mergansers were both frequently observed during these surveys. Females of these species are extremely difficult to tell apart from the air. Therefore, when flocks were observed identification of the group was based upon males. If mixed flocks of mergansers were observed, the proportion of males was used to determine the species composition. Mergansers were most frequently observed less than 5 miles from shore, though when ice begins to form they may be found wherever open water occurs. Red-breasted mergansers were generally observed only during fall and spring, whereas common mergansers moved in to the area later in year to overwinter on Lake Erie. During these surveys, it was observed that mergansers were very skittish, and were the only species that actively avoided the approaching aircraft. On calm days flocks of mergansers were observed taking flight up to 3 miles away from the plane. It is unknown whether wind turbines would elicit a similar response from these species.

Eagles and vultures: Some of the highest nest densities for bald eagles in the Great Lakes region are within the counties bordering Lake Erie. After the breeding season large numbers of eagles congregate along the shoreline and inland marshes. During these surveys the highest numbers of eagles were observed during the middle of winter, when inland waterways were frozen. Though eagles were observed flying several miles from shore, typically they were located close to the shoreline and Lake Erie islands. Turkey vultures were only observed during one survey and were most likely migrating northward using the islands to cross Lake Erie.

Several other species of birds were observed during this survey. These birds were detected in low numbers or on few occasions. Most of these were passerines that were observed flying over the

lake during migration or birds that may have had territories along the lake's edge and were commuting between islands.

Though no region of the lake was completely devoid of bird activity, those areas furthest from shore typically had the lowest bird densities. Additionally, these areas generally correlated to those areas of the lake with the highest wind energy potential. This project created a temporal and spatially explicit depiction of pelagic distribution and abundance in Lake Erie. This information will be used to assess the potential impacts of proposed offshore wind developments relative to bird habitat and use patterns. In order to assess yearly variability, the Division of Wildlife has secured funding to conduct an additional year of monitoring; Fall 2010 migration surveys have already been completed and Spring 2011 migration surveys are planned. The results of these studies will be incorporated into the Division of Wildlife's offshore wind power siting guidance and the Ohio Department of Natural Resources Office of Coastal Management Wind Turbine Placement Favorability map. Results from this study may be applicable to other portions of Lake Erie, though extrapolating these trends to the other Great Lakes may be difficult due to the physiographical differences between each of the lakes. Conducting similar studies along the other Great Lakes may provide a more complete picture of how these species migrate across the region.

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Appendix A

Survey Summaries

Date: 14 October 2009

Distance: 300 miles

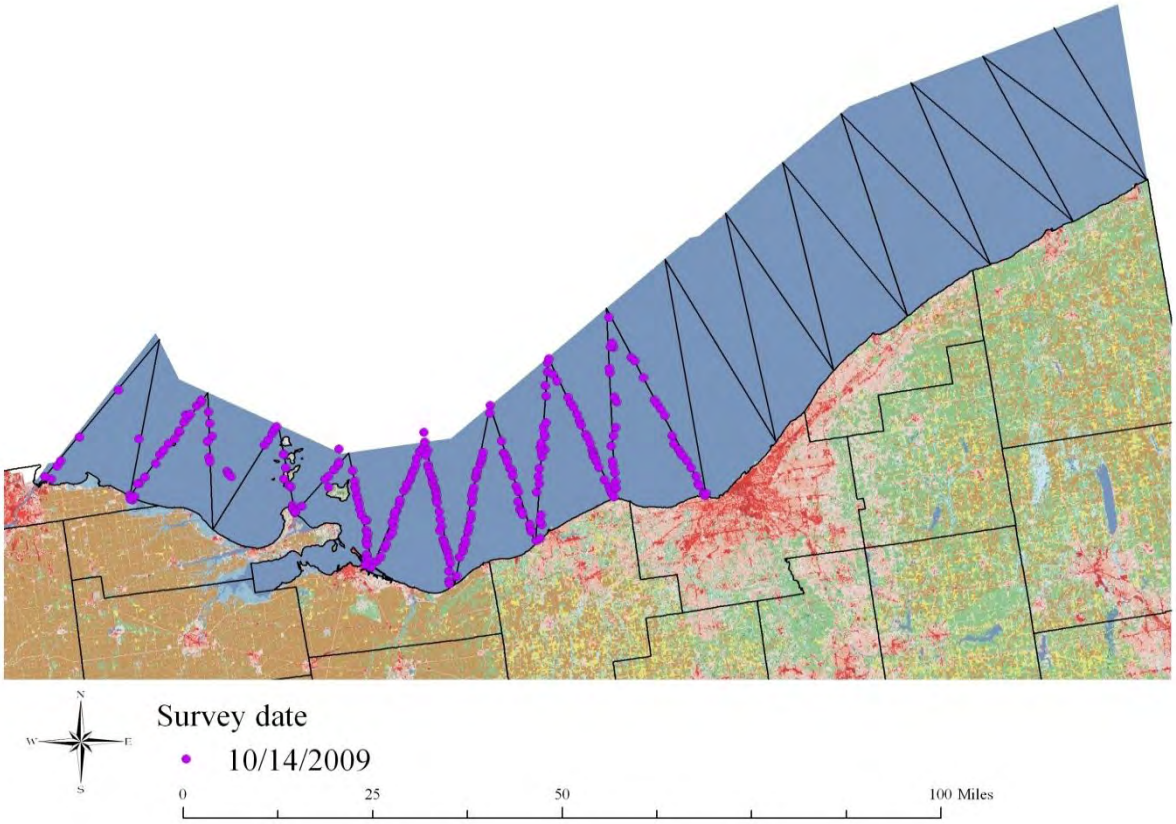
Species observed

Total species: 8

Number of individuals: 15,875

Birds per mile: 52.9

Species	Number
Double-crested cormorant	11,045
Ring-billed/Herring gull	3,481
Scaup sp.	1,125
Bonaparte's gull	132
American black duck	78
Mute swan	10
Common loon	3
Red breasted merganser	1



Date: 19 & 21 October 2009

Distance: 664 miles

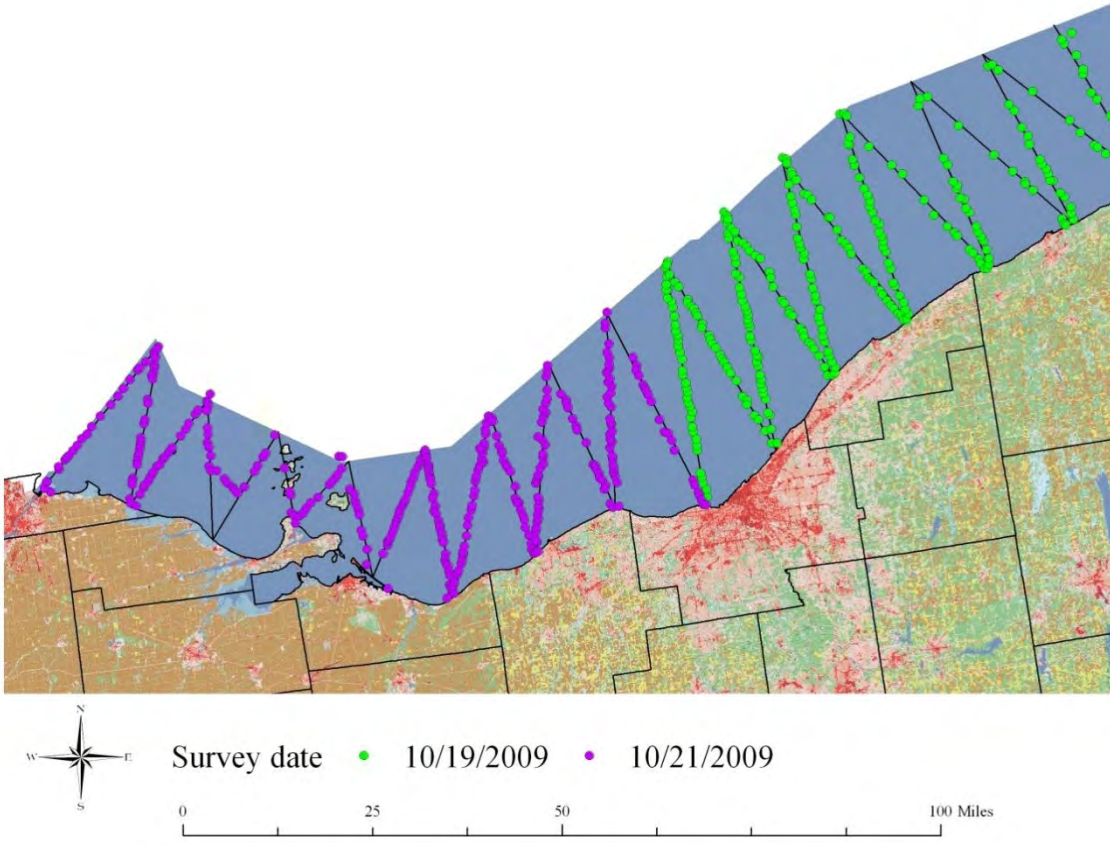
Total species: 10

Number of individuals: 10,379

Birds per mile: 15.6

Species observed

Species	Number
Ring-billed / Herring gull	5,148
Double-crested cormorant	2,229
Bonaparte's gull	2,165
Scaup sp.	600
Canada goose	126
Common loon	86
Ruddy duck	16
Trumpeter swan	3
Great blue heron	3
Duck sp.	3



Date: 27 & 29 October 2009

Distance: 564

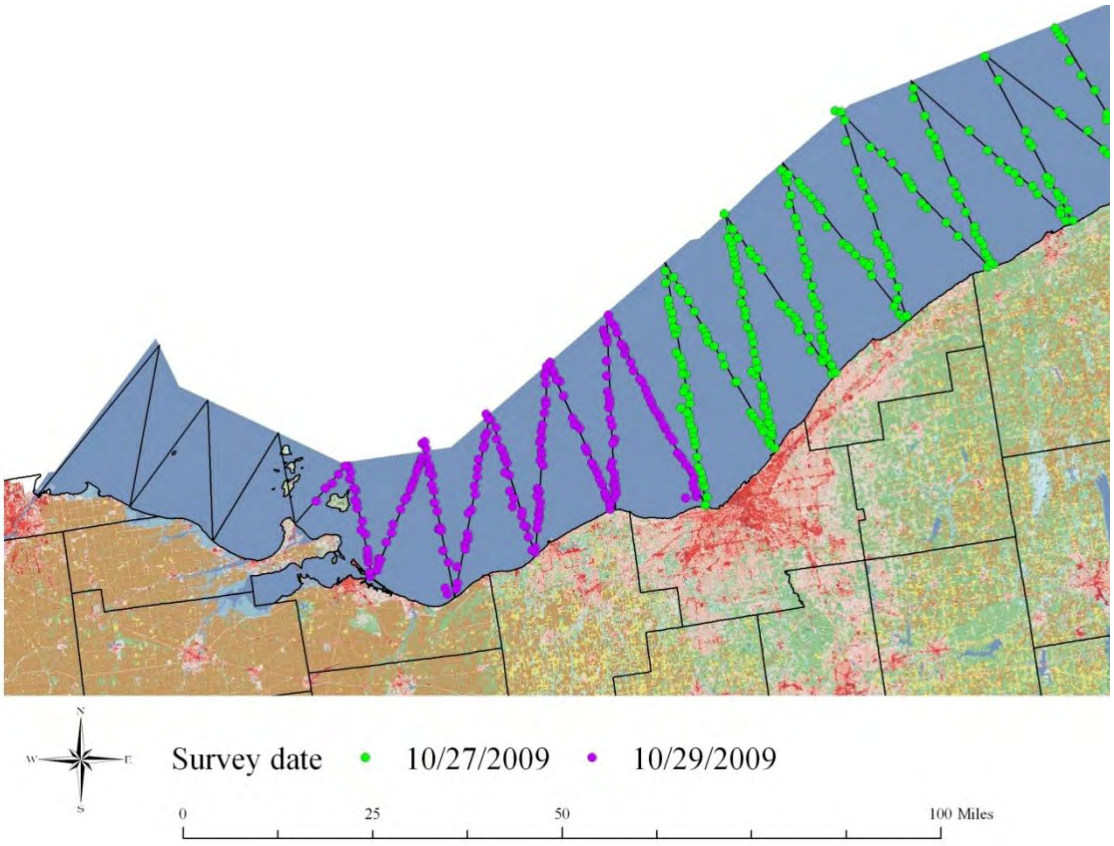
Species observed

Total species: 14

Number of individuals: 6,300

Birds per mile: 11.2

Species	Number
Ring-billed / Herring gull	3,927
Bonaparte's gull	1,843
Common loon	290
Scaup sp.	106
Duck sp.	44
Long-tailed duck	31
White-winged scoter	20
Horned grebe	11
Double-crested cormorant	9
Canada goose	5
Great black-backed gull	4
Bufflehead	4
Red-breasted merganser	3
Snow bunting	3



Date: 4 & 5 November 2009

Distance: 664

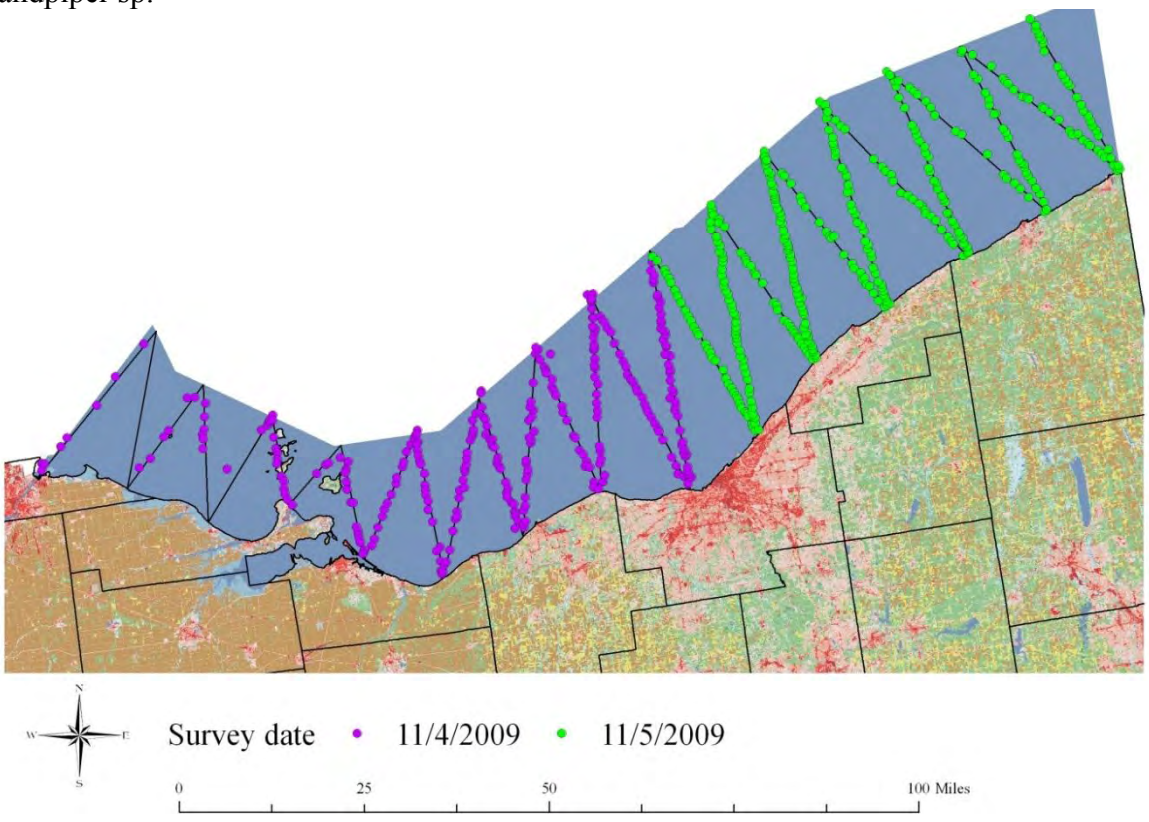
Species observed

Total species: 18

Number of individuals: 48,242

Birds per mile: 72.6

Species	Number
Scaup sp.	40,573
Ring-billed / Herring gull	2,989
Bonaparte's gull	2,737
Common loon	605
Double-crested cormorant	486
Horned grebe	225
Canada goose	120
Mallard	75
Ruddy duck	75
Goldeneye	54
Trumpeter swan	18
Bufflehead	16
Common merganser	15
American black duck	7
Great black-backed gull	3
Scoter sp.	2
Canvasback	1
Sandpiper sp.	



Date: 10 & 13 November 2009

Distance: 684

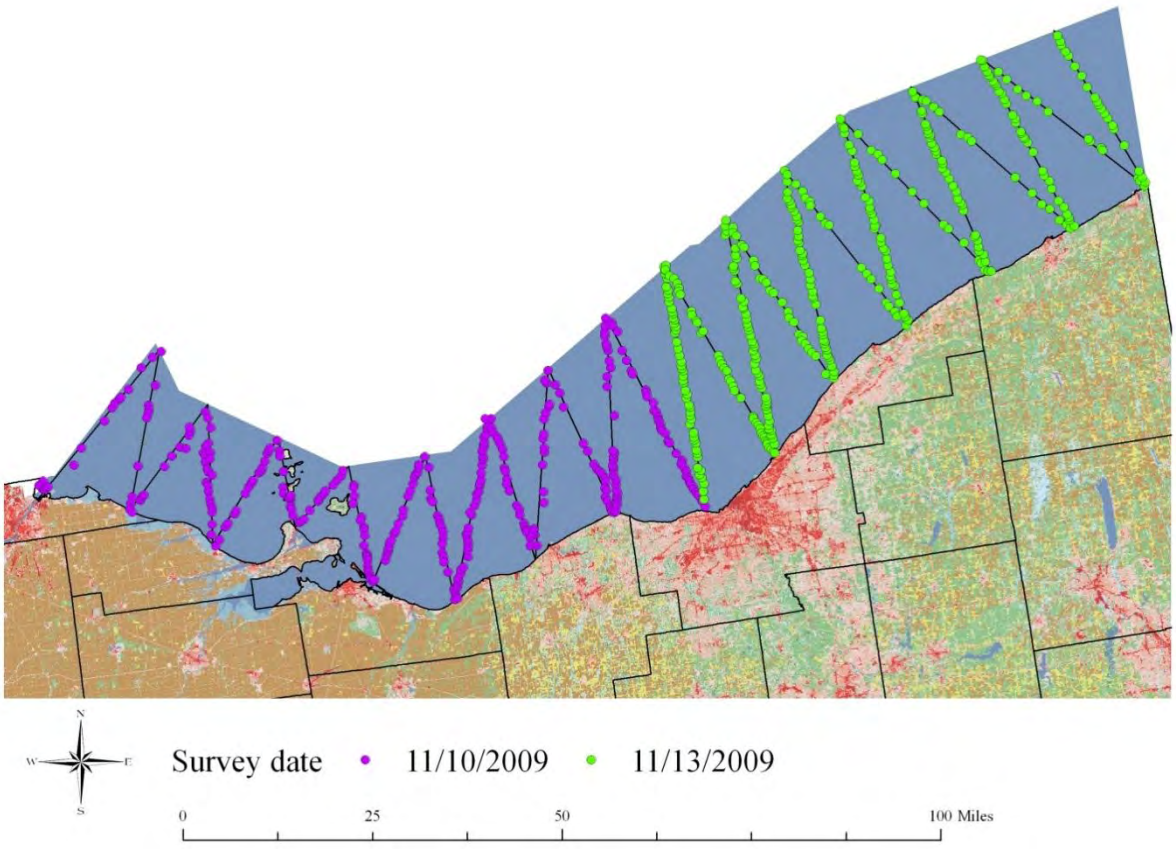
Species observed

Total species: 14

Number of individuals: 32,894

Birds per mile: 48.1

Species	Number
Scaup sp.	28,518
Ring-billed / Herring gull	1,711
Bonaparte's gull	1,323
Red-breasted merganser	513
Common loon	359
Horned grebe	220
Bufflehead	100
Double-crested cormorant	94
Goldeneye	25
Great black-backed gull	16
Black scoter	12
Canada goose	1
Bald eagle	1
Glaucous gull	1



Date: 17 & 18 November 2009

Distance: 664

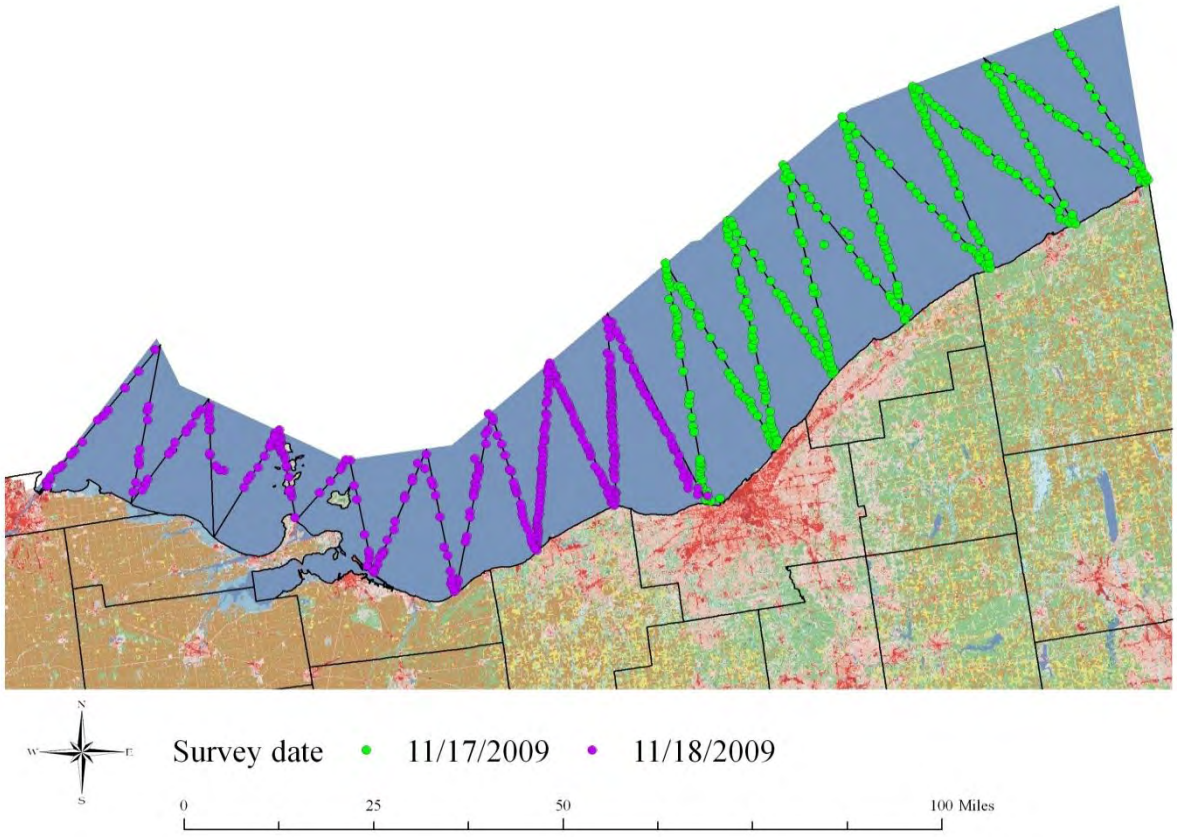
Species observed

Total species: 16

Number of individuals: 30,723

Birds per mile: 46.3

Species	Number
Scaup sp.	18,470
Red-breasted merganser	8,844
Bonaparte's gull	1,385
Ring-billed / Herring gull	1,012
Common loon	446
Bufflehead	285
Horned grebe	129
Tundra swan	46
Canada goose	32
Mallard	31
Double-crested cormorant	26
Trumpeter swan	5
American black duck	5
Great black-back gull	4
Scoter sp.	2
Long-tailed duck	1



Date: 23 & 24 November 2009

Distance: 664

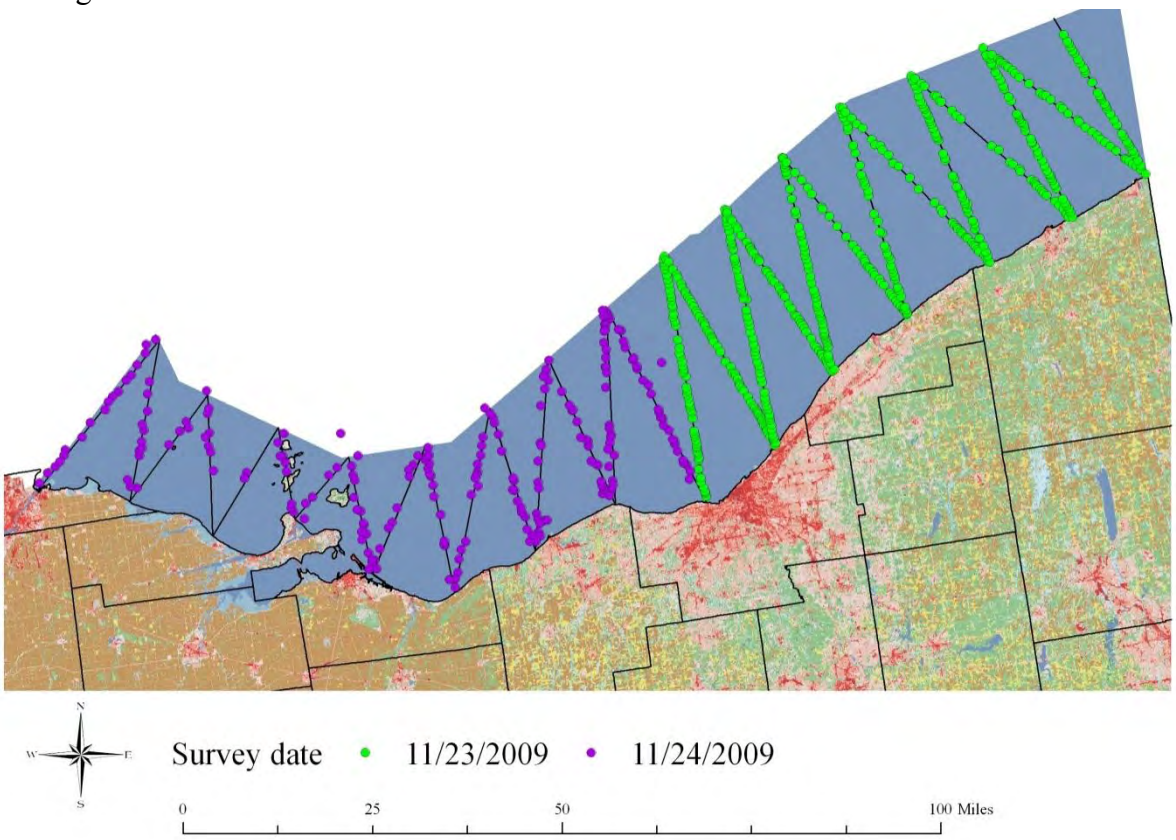
Species observed

Total species: 17

Number of individuals: 90,089

Birds per mile: 134.9

Species	Number
Scaup sp.	75,910
Red-breasted merganser	6,767
Bonaparte's gull	3,538
Redhead	1,312
Common loon	1,024
Ring-billed / Herring gull	743
Canvasback	500
Horned grebe	89
Canada goose	89
Bufflehead	52
Double-crested cormorant	25
Scoter sp.	14
Red-throated loon	13
Great black-backed gull	5
American black duck	4
Glaucous gull	3
Bald eagle	1



Date: 1 & 2 December 2009

Distance: 664

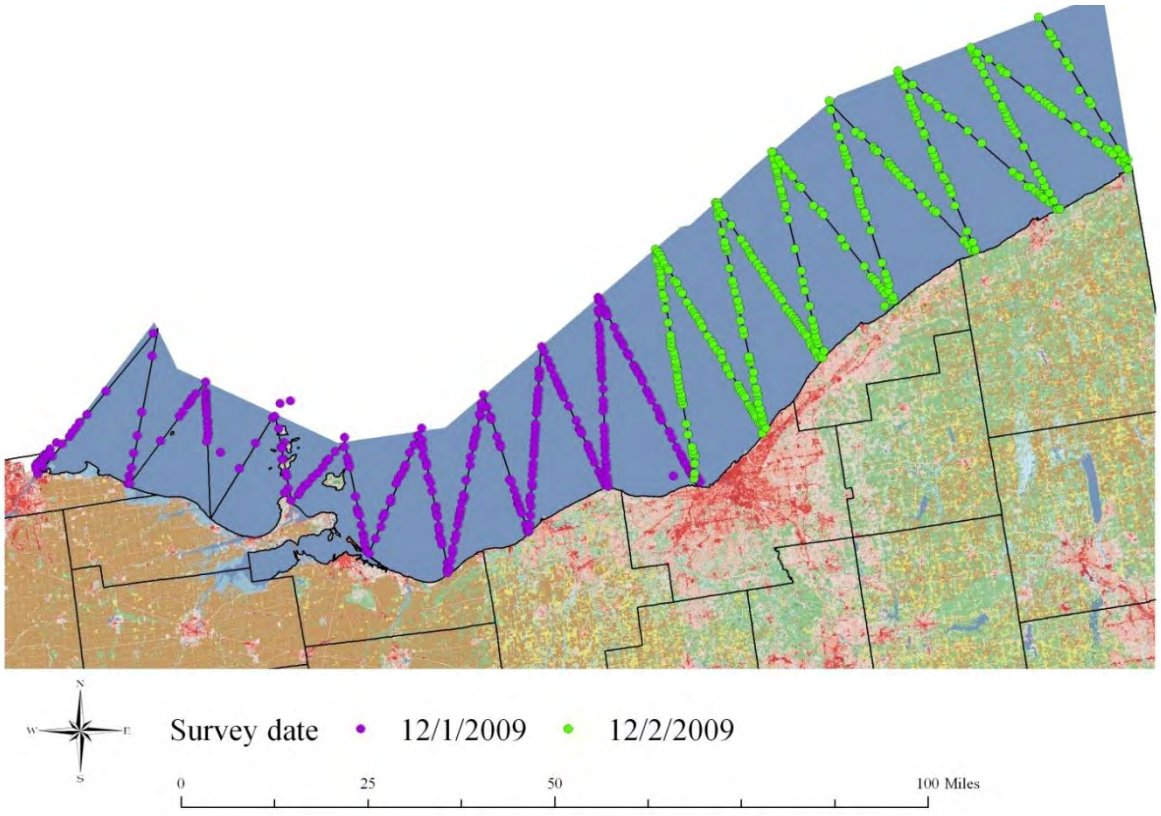
Total species: 18

Number of individuals: 22,339

Birds per mile: 33.6

Species observed

Species	Number
Red-breasted merganser	14,863
Scaup sp.	4,785
Ring-billed / Herring gull	1,133
Bonaparte's gull	986
Canada goose	160
Common loon	121
Bufflehead	102
Horned grebe	53
Mallard	41
American black duck	30
Snow bunting	25
Great black-back gull	12
Scoter sp.	8
Red-throated loon	7
Goldeneye	5
Canvasback	5
White-winged scoter	2
Double-crested cormorant	1
Brant	1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Date: 8 & 11 December 2009

Distance: 324

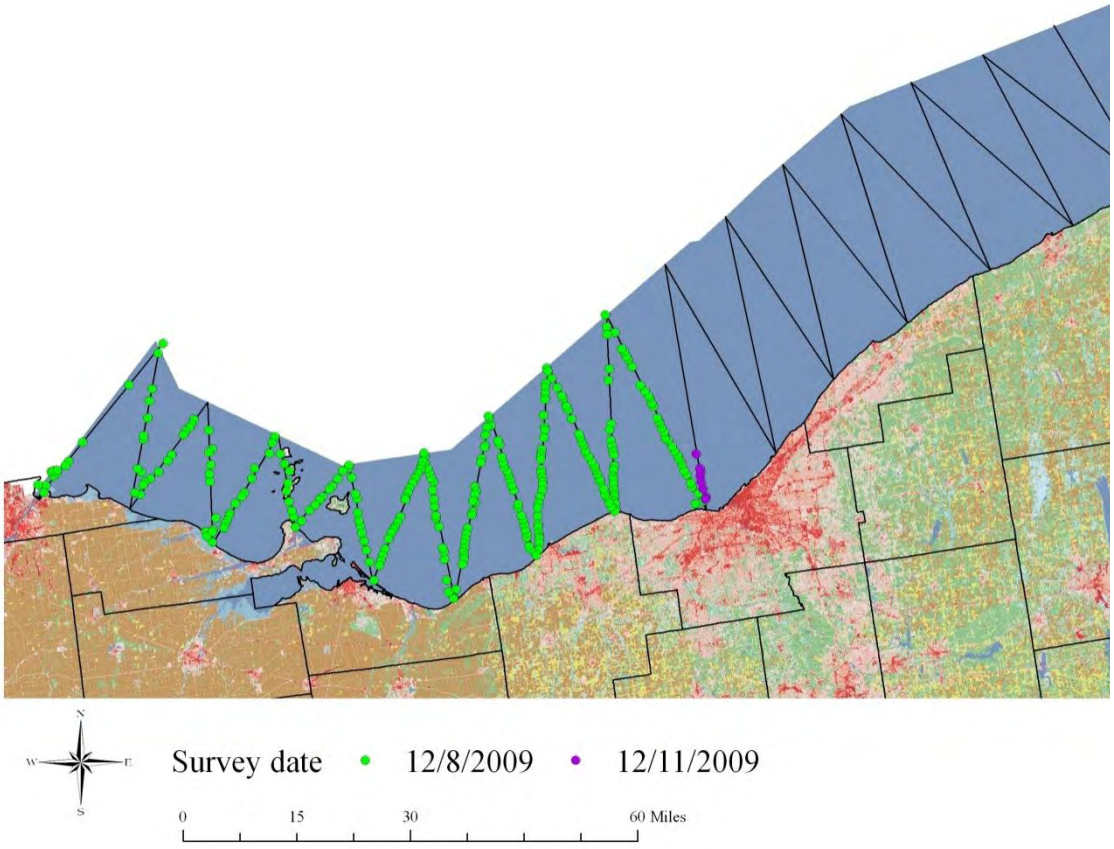
Species observed

Total species: 13

Number of individuals: 37,534

Birds per mile: 115.8

Species	Number
Scaup sp.	18,999
Red-breasted merganser	13,279
Mallard	2,515
Ring-billed / Herring gull	1,345
Bonaparte's gull	877
American black duck	292
Canada goose	124
American coot	100
Common loon	86
Horned grebe	11
Bufflehead	3
Great black-back gull	1
Scoter sp.	1
Red-throated loon	1



Date: 15, 16 & 18 December 2009

Distance: 664

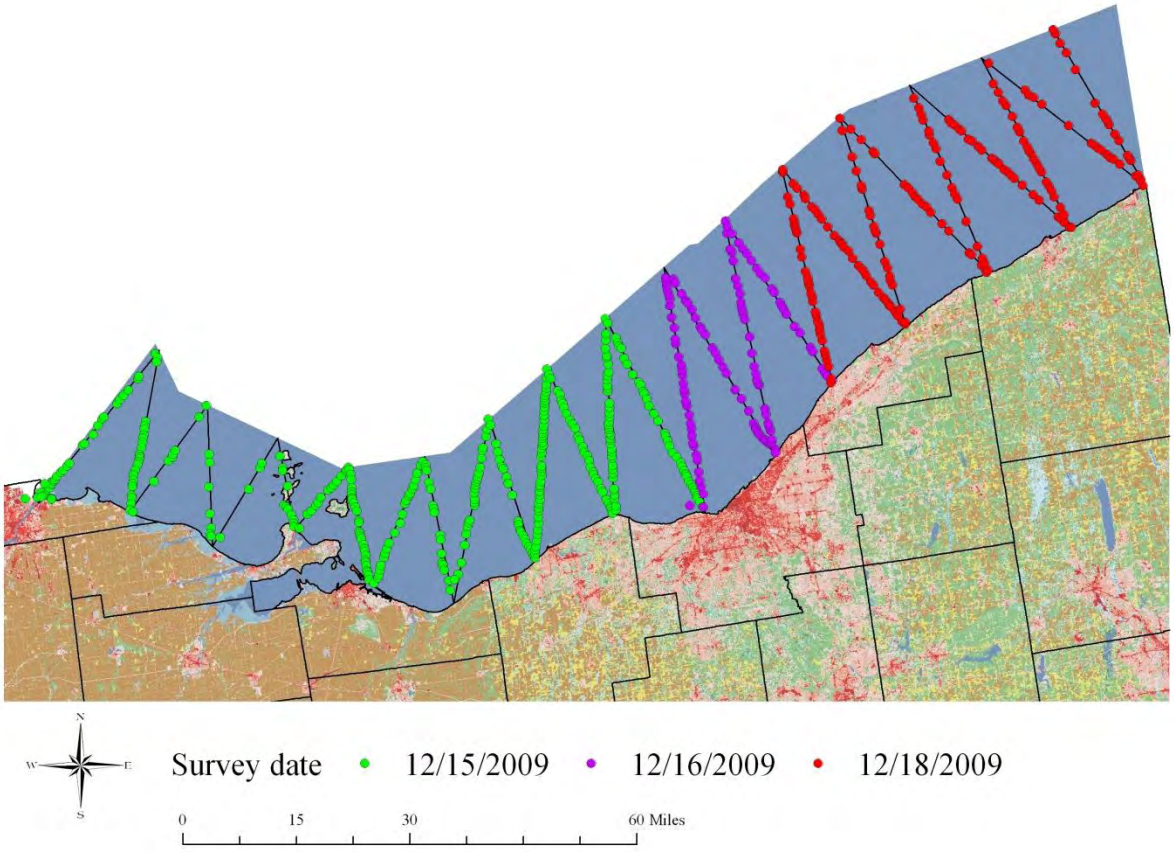
Species observed

Total species: 23

Number of individuals: 11,725

Birds per mile: 17.1

Species	Number
Scaup sp.	5,623
Bonaparte's gull	1,703
Ring-billed / Herring gull	1,175
Red-breasted merganser	1,101
Mallard	916
Canada goose	411
Goldeneye	333
American black duck	116
Common loon	100
Bufflehead	80
Horned grebe	78
American coot	50
Common merganser	26
Canvasback	25
Redhead	13
Great black-backed gull	7
Tundra swan	6
Red-throated loon	5
Scoter sp.	2
Double-crested cormorant	2
Jaeger sp.	2
Black scoter	1
Red-necked grebe	1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Date: 2 & 4 February 2010

Distance: 664

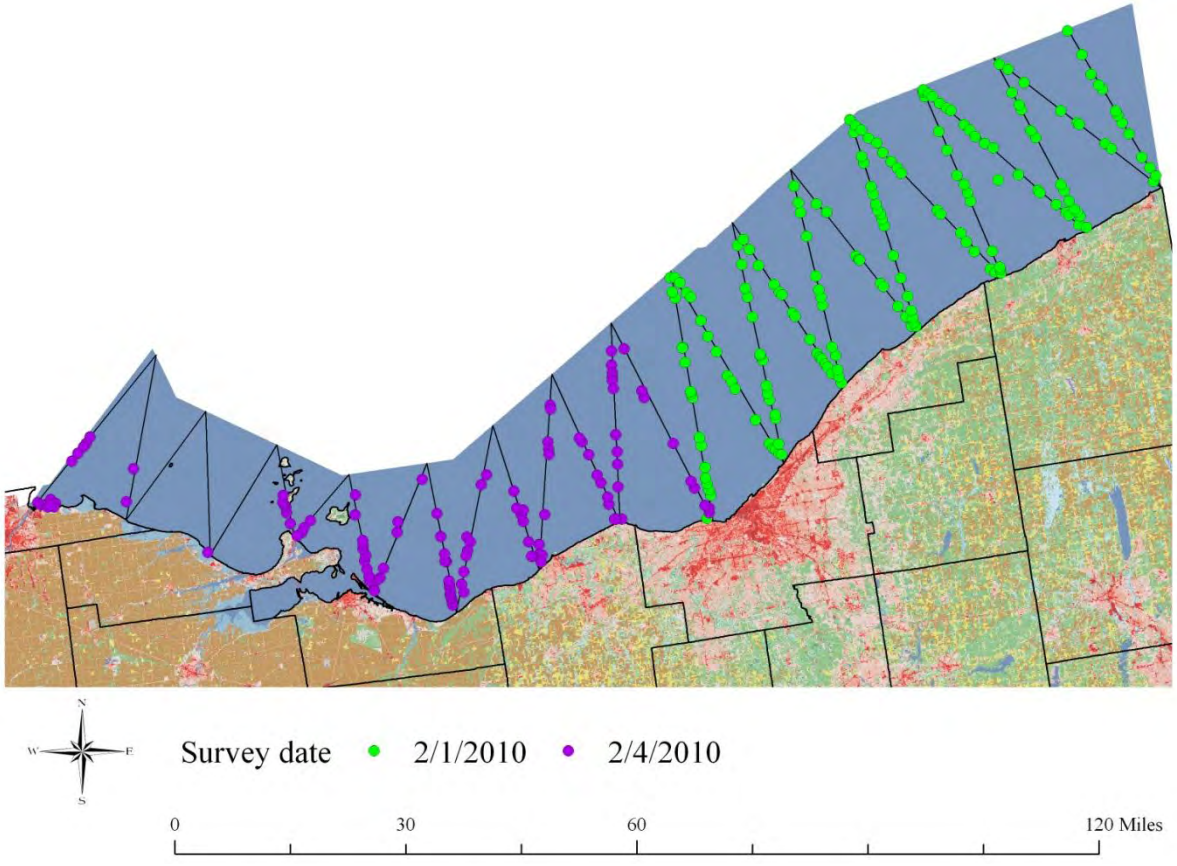
Species observed

Total species: 14

Number of individuals: 57,788

Birds per mile: 87.0

Species	Number
Scaup sp.	35,000
Common merganser	11,049
Ring-billed / Herring gull	8,084
Goldeneye	1,659
Canada goose	990
Red-breasted merganser	528
Mallard	300
American black duck	75
Great black-backed gull	58
Duck sp.	15
Bald eagle	10
Bufflehead	10
Glaucous gull	6
Common loon	3
Canvasback	1



Date: 17 & 18 March 2010

Distance: 664

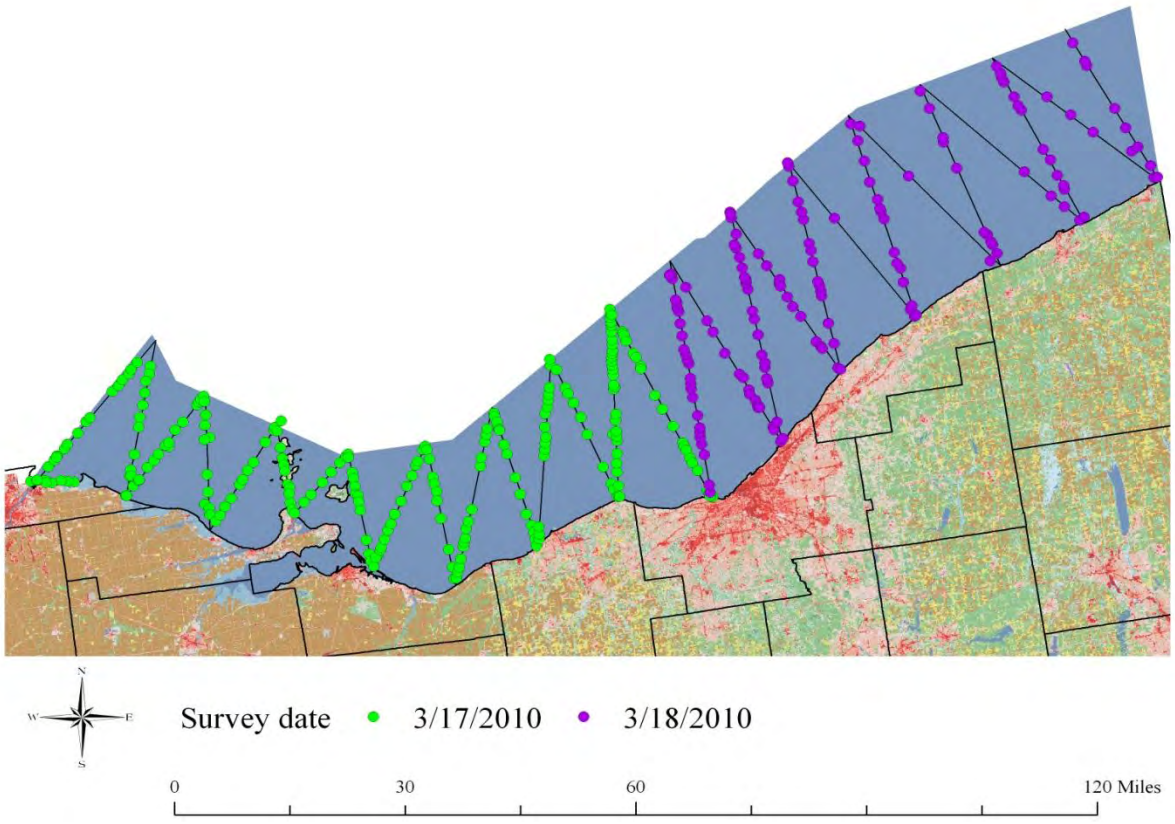
Species observed

Total species: 21

Number of individuals: 33,408

Birds per mile: 50.3

Species	Number
Scaup sp.	24,639
Redhead	3,000
Red-breasted merganser	2,040
Canvasback	1,251
Herring / Ring-billed gull	1,155
Canada goose	654
Goldeneye	214
Ruddy duck	150
Duck sp.	133
Tundra swan	47
Double-crested cormorant	46
Bufflehead	23
Mallard	15
Common loon	13
Great black-backed gull	11
Common merganser	4
Bald eagle	4
American crow	3
Scoter sp.	3
Glaucous gull	1
Great blue heron	1
Pigeon	1


N
W
E
S
Survey date
3/17/2010
3/18/2010
0
30
60
120 Miles

Date: March 21

Distance: 664

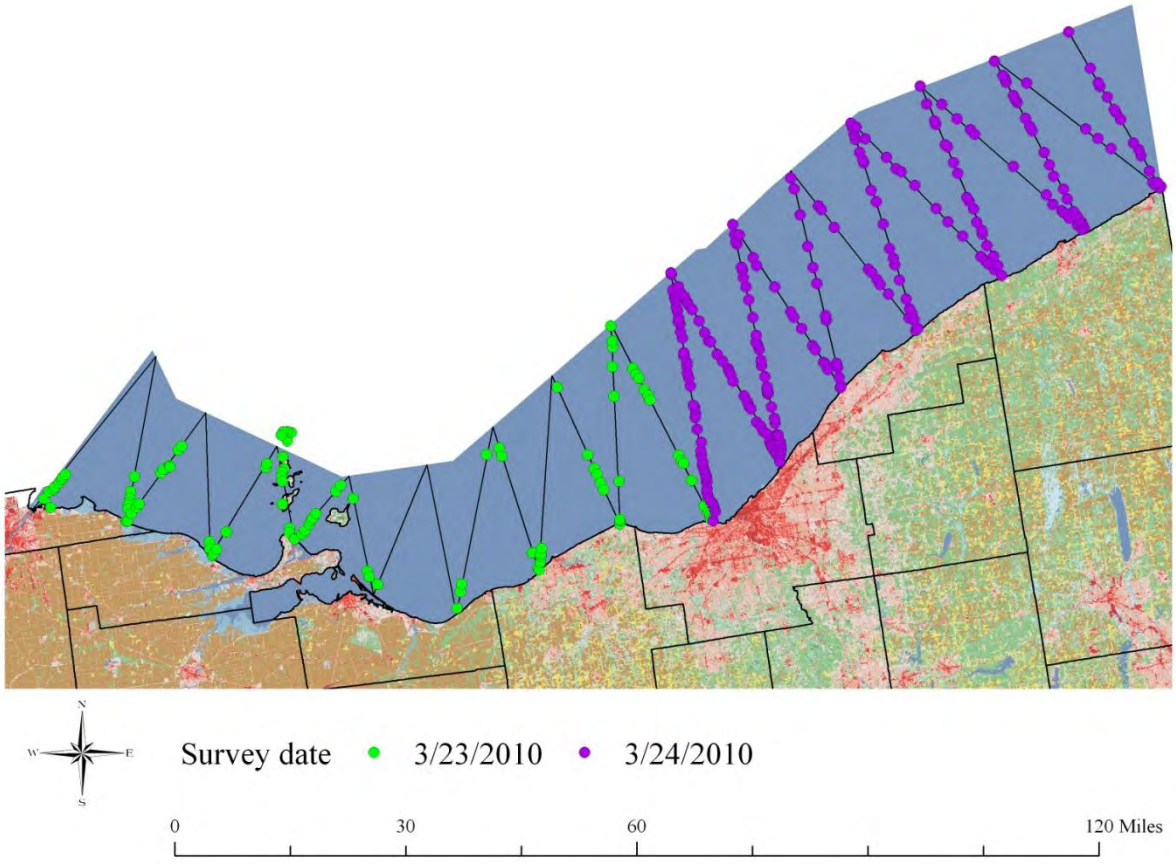
Species observed

Total species: 17

Number of individuals: 15,228

Birds per mile: 22.9

Species	Number
Scaup sp.	13,828
Herring / Ring-billed gull	693
Red-breasted merganser	365
Goldeneye	83
Canada goose	74
Double-crested cormorant	53
Common merganser	42
Horned grebe	24
Bonaparte's gull	17
Bufflehead	11
Great black-backed gull	11
Great blue heron	11
Scoter sp.	7
Common loon	6
Duck sp.	1
Glaucous gull	1
American black duck	1


N
W
E
S
Survey date
3/23/2010
3/24/2010
0
30
60
120 Miles

Date: 31 May 2010

Distance: 300

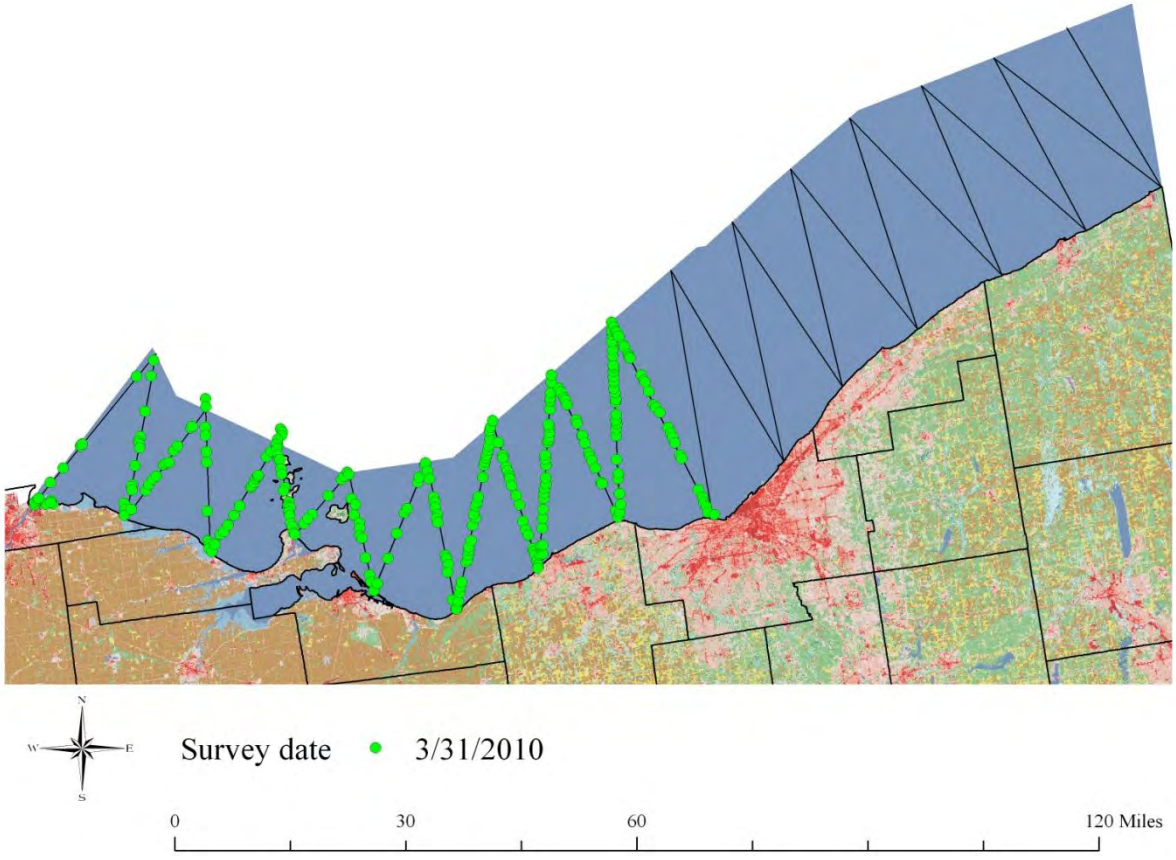
Species observed

Total species: 16

Number of individuals: 6262

Birds per mile: 20.9

Species	Number
Red-breasted merganser	2,232
Ring billed / Herring gull	1,799
Scaup sp.	1,710
Bonaparte's gull	133
Double-crested cormorant	116
Canada goose	89
Goldeneye	49
Horned grebe	29
Mallard	26
Turkey vulture	25
Common loon	22
Great blue heron	17
Long-tailed duck	6
Duck sp.	4
American crow	2
Bald eagle	2
Great black-backed gull	1



Date: 5 & 6 April 2010

Distance: 664

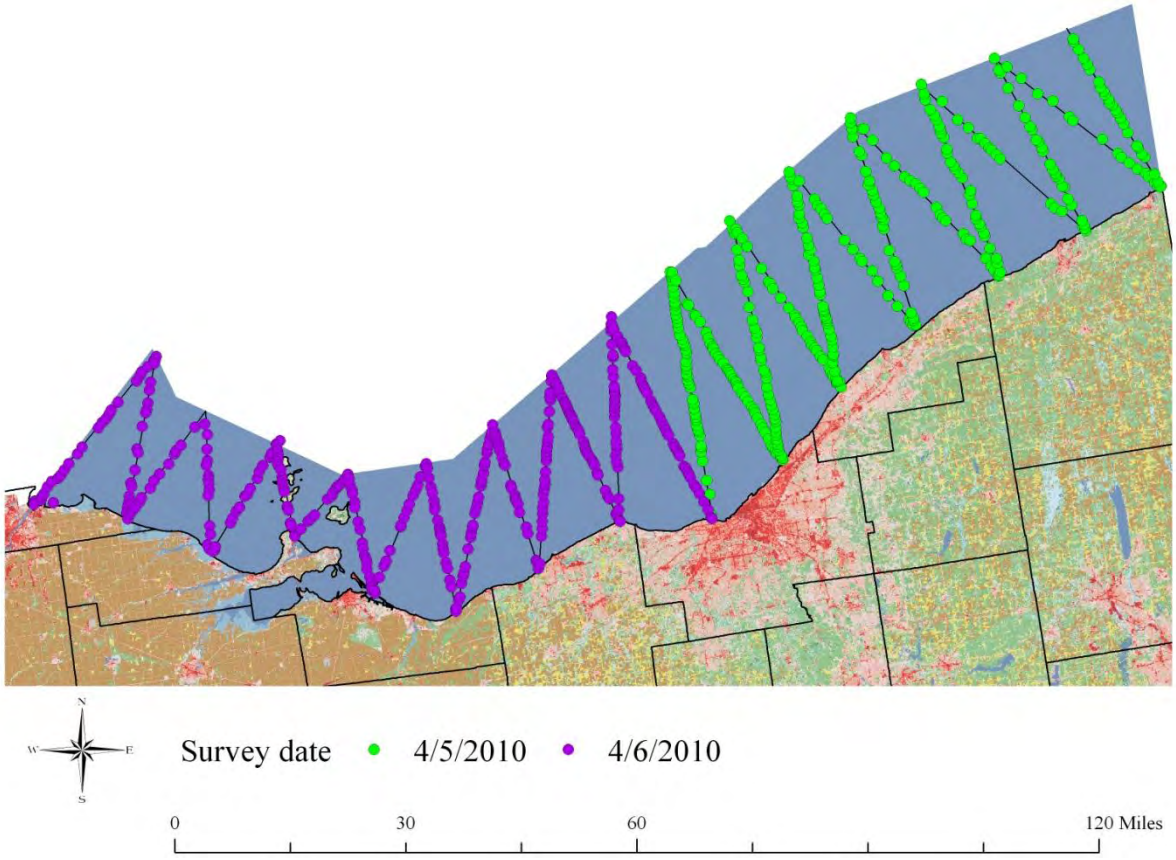
Total species: 19

Number of individuals: 5,318

Birds per mile: 8.0

Species observed

Species	Number
Scaup sp.	1,936
Red-breasted merganser	1,172
Herring / Ring-billed gull	1,055
Bonaparte's gull	679
Common loon	176
Horned grebe	118
Double-crested cormorant	87
Canada goose	24
Goldeneye	21
Great black-backed gull	18
Mallard	10
Common merganser	7
Bufflehead	5
Mute swan	3
American black duck	2
Tundra swan	2
Black-crowned night heron	1
Green heron	1
Red-winged blackbird	1


N
W
E
S
Survey date
4/5/2010
4/6/2010
0
30
60
120 Miles

Date: 12 & 13 April 2010

Distance: 664

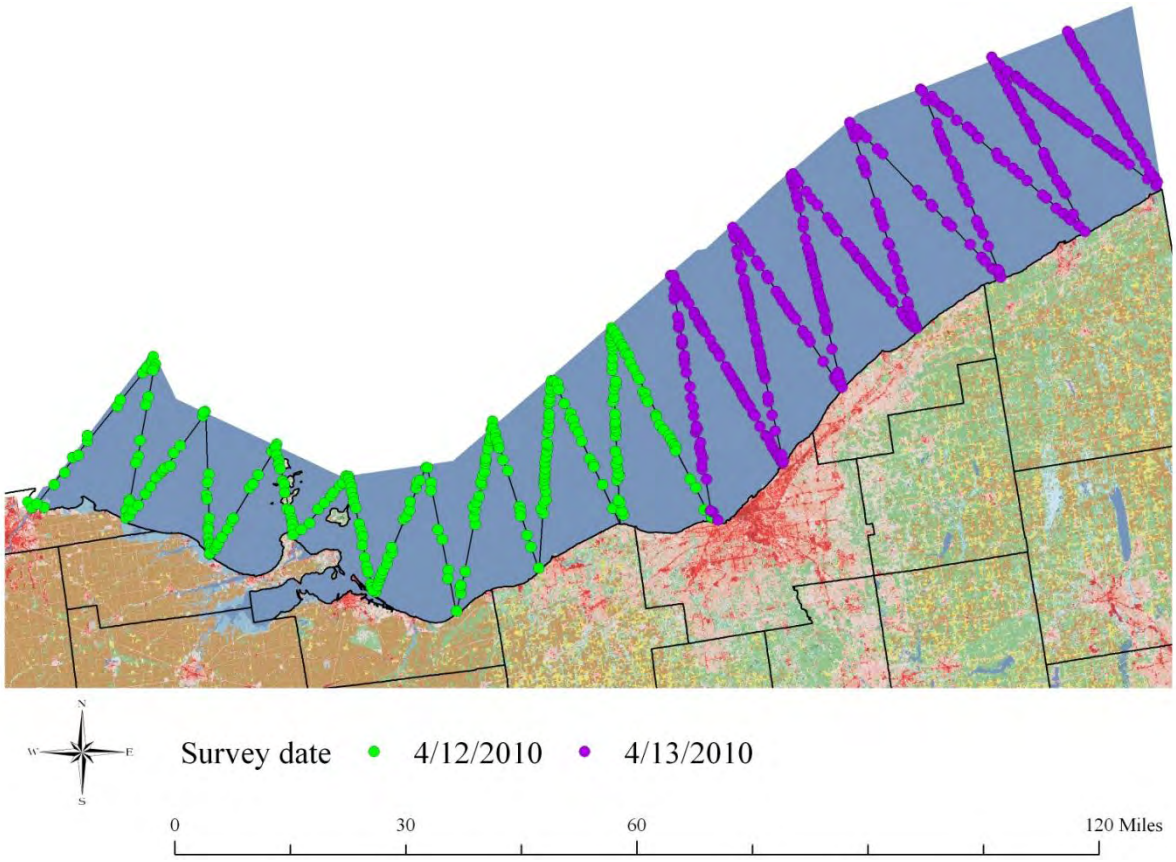
Total species: 22

Number of individuals: 4,375

Birds per mile: 6.6

Species observed

Species	Number
Herring / Ring-billed gull	1,323
Double-crested cormorant	825
Bonaparte's gull	685
Red-breasted merganser	611
Scaup sp.	425
Common loon	323
Bufflehead	37
Ruddy duck	26
Horned grebe	25
Canada goose	25
Duck sp.	13
Canvasback	12
Great black-backed gull	11
Great blue heron	11
Mallard	8
Goldeneye	4
Caspian tern	4
Great egret	2
Passerine sp.	2
Glaucous gull	1
Bald eagle	1
Tern sp.	1


N
W
E
S
Survey date
4/12/2010
4/13/2010
0
30
60
120 Miles

Date: 19 & 20 April 2010

Distance: 664

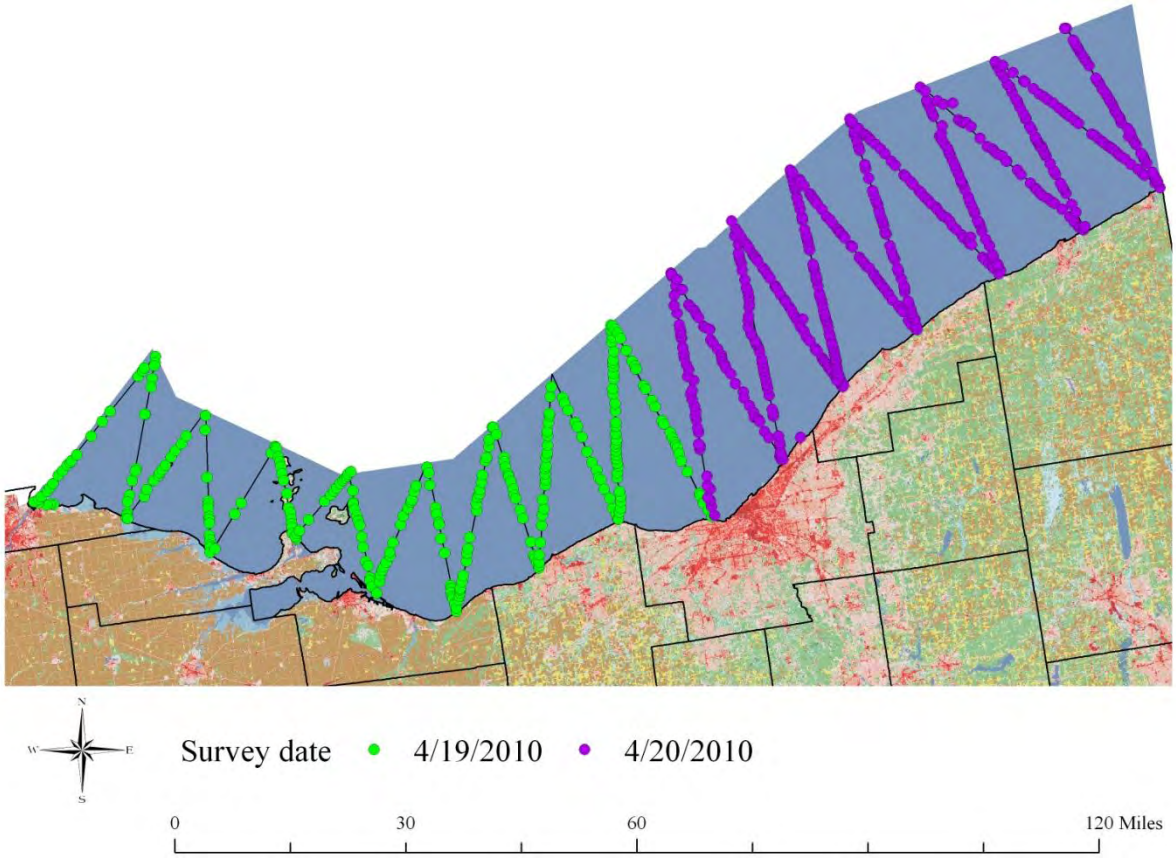
Total species: 20

Number of individuals: 5,312

Birds per mile: 8.0

Species observed

Species	Number
Red-breasted merganser	1,372
Herring / Ring-billed gull	1,263
Bonaparte's gull	1,128
Common loon	806
Double-crested cormorant	480
Scaup sp.	142
Horned grebe	37
Canada goose	21
Canvasback	12
Great blue heron	12
Bufflehead	11
Goldeneye	11
Caspian tern	5
Great black-backed gull	4
Great egret	3
Passerine sp.	1
Bald eagle	1
Scoter sp.	1
Red-throated loon	1
Snowy egret	1


N
W
E
S
Survey date
4/19/2010
4/20/2010
0
30
60
120 Miles

Date: 26 & 27 April 2010

Distance: 664

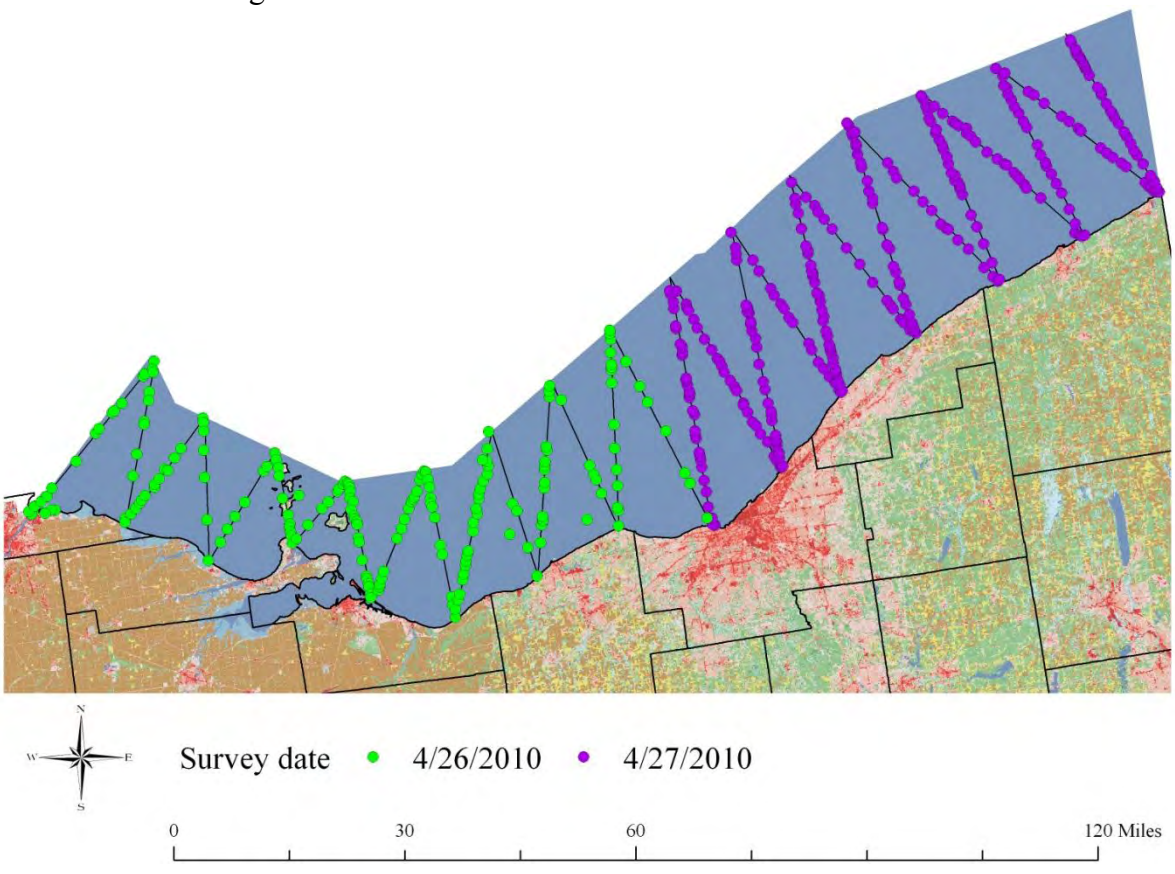
Species observed

Total species: 12

Number of individuals: 3,628

Birds per mile: 5.5

Species	Number
Herring / Ring-billed gull	2,778
Common loon	360
Double-crested cormorant	236
Bonaparte's gull	146
Red-breasted merganser	84
Great egret	8
Great blue heron	7
Mallard	4
Caspian tern	2
Horned grebe	1
Bald eagle	1
Lesser black-backed gull	1



Date: 4 May 2010

Distance: 364

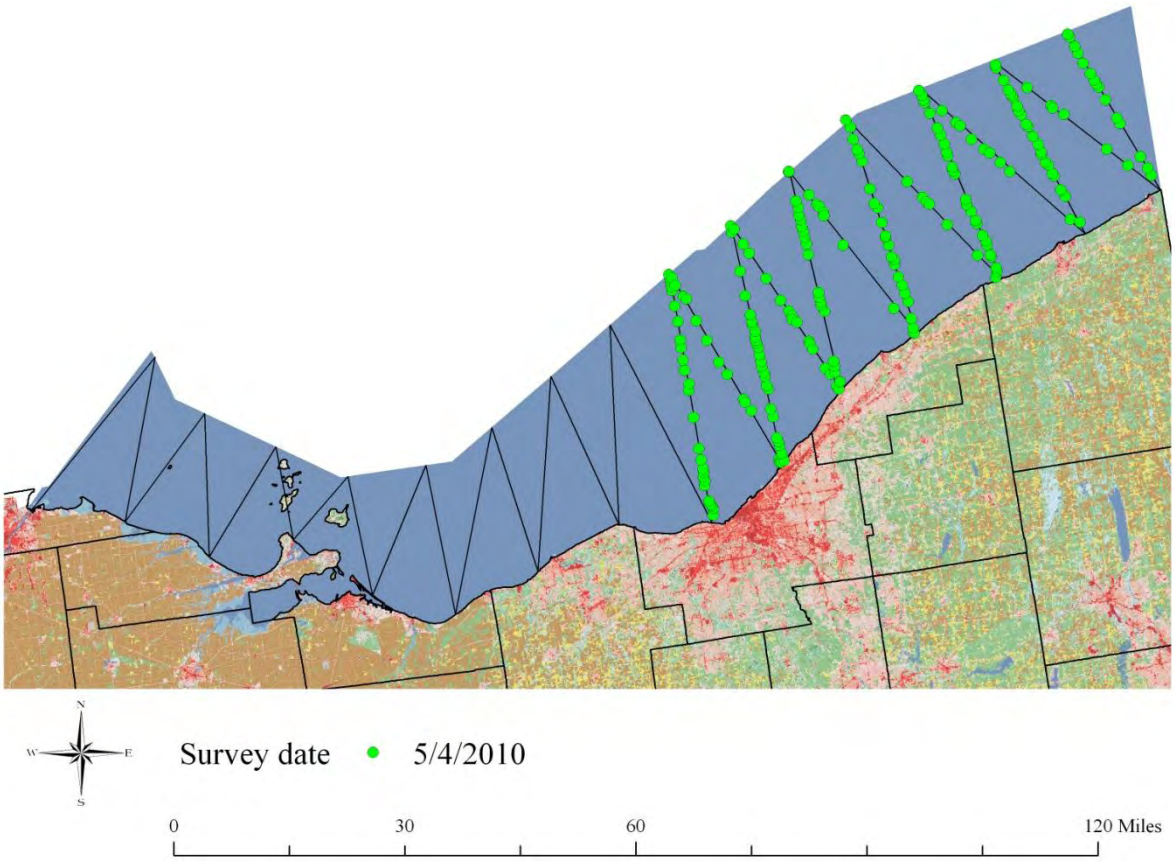
Species observed

Total species: 4

Number of individuals: 380

Birds per mile: 1.0

Species	Number
Herring / Ring-billed gull	371
Red-breasted merganser	4
Bonaparte's gull	3
Double-crested cormorant	2



Date: 10 & 14 May 2010

Distance: 315

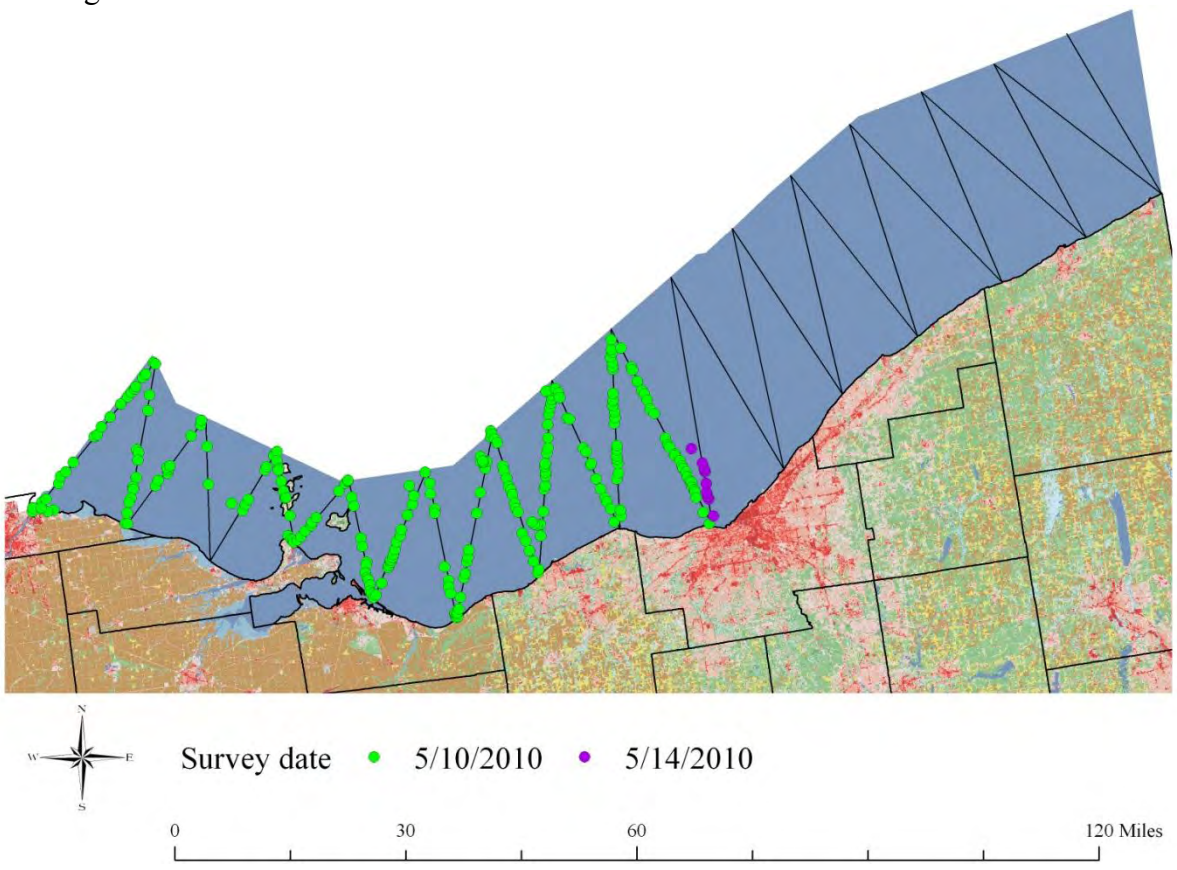
Species observed

Total species: 7

Number of individuals: 5,933

Birds per mile: 18.8

Species	Number
Herring / Ring-billed gull	5,416
Double-crested cormorant	301
Tern sp.	120
Bonaparte's gull	72
Great blue heron	10
Great egret	9
Canada goose	5



Date: 17 & 20 May 2010

Distance: 664

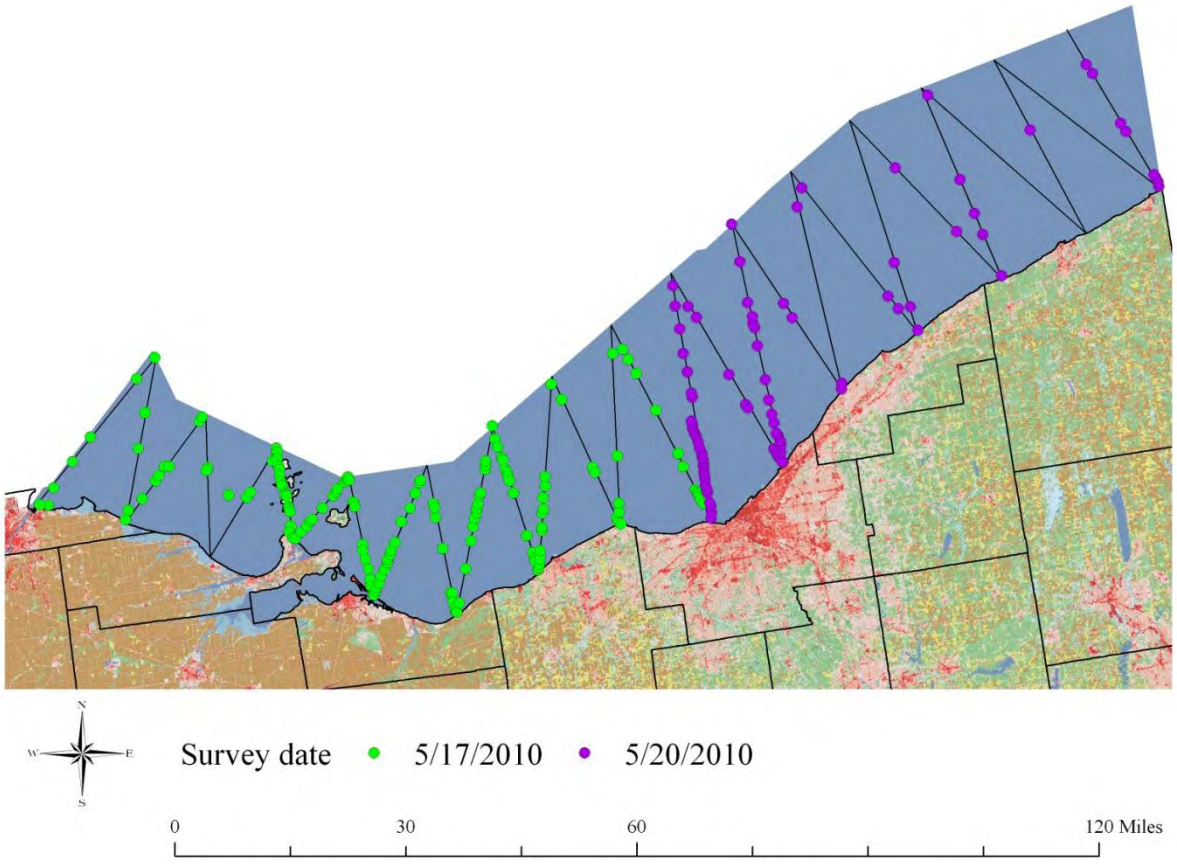
Species observed

Total species: 6

Number of individuals: 1,521

Birds per mile: 2.3

Species	Number
Herring / Ring-billed gull	914
Double-crested cormorant	420
Tern sp.	150
Great egret	24
Great blue heron	9
Duck sp.	4



Date: 24 & 27 May 2010

Distance: 664

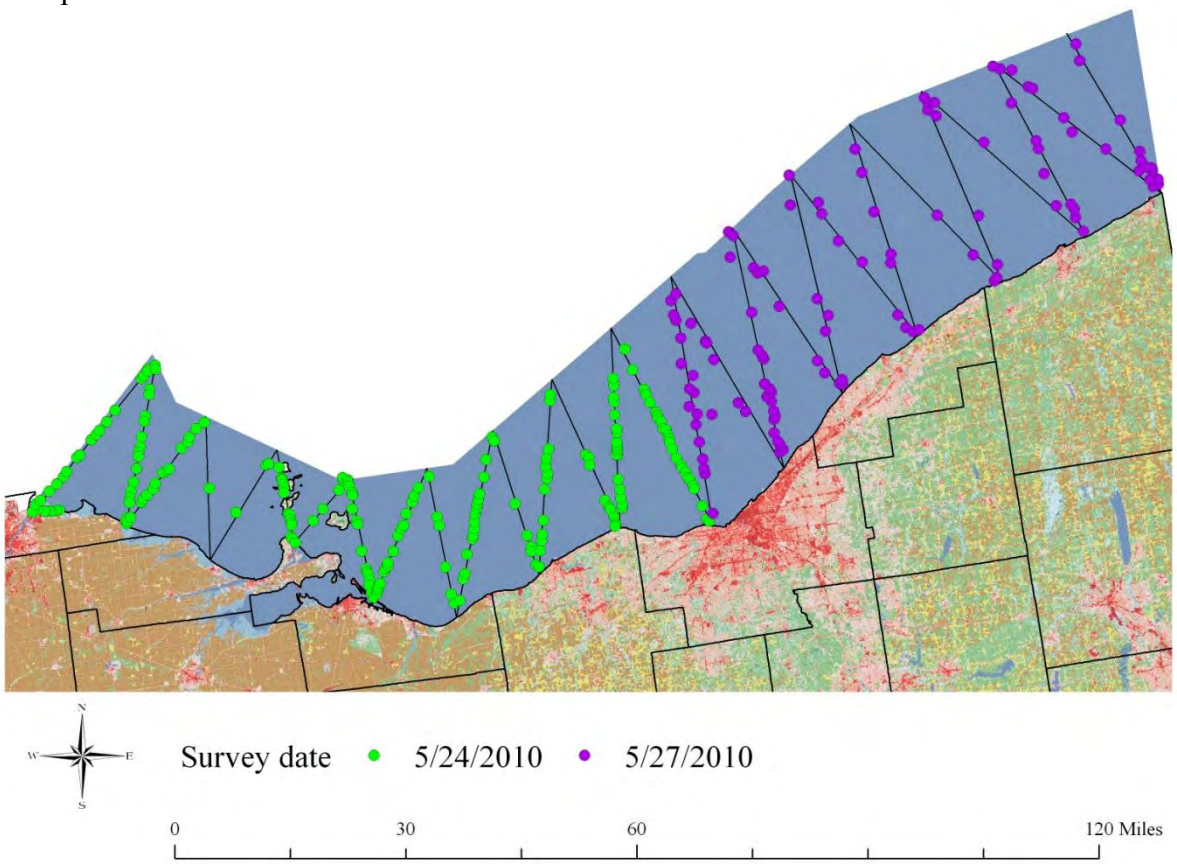
Species observed

Total species: 7

Number of individuals: 1,582

Birds per mile: 2.4

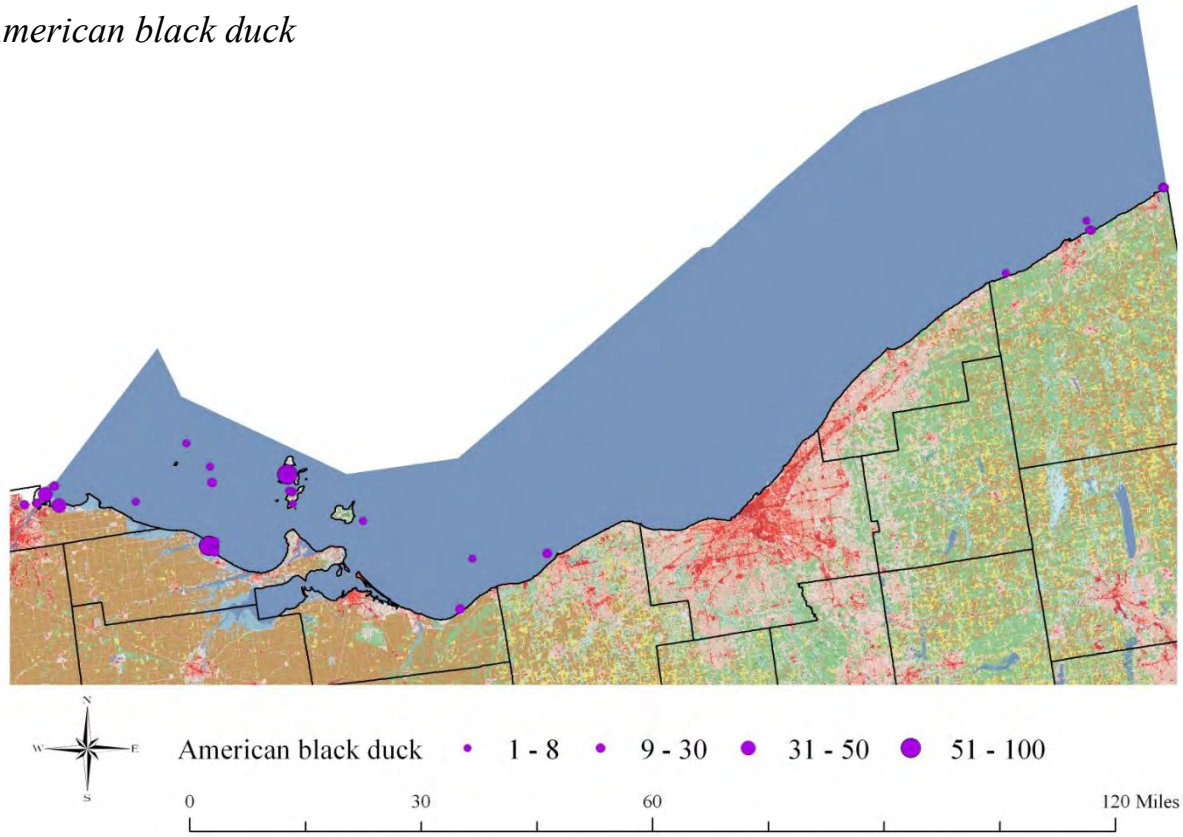
Species	Number
Herring / Ring-billed gull	1,194
Double-crested cormorant	257
Canada goose	108
Great blue heron	12
Great egret	8
Bald eagle	2
Tern sp.	1

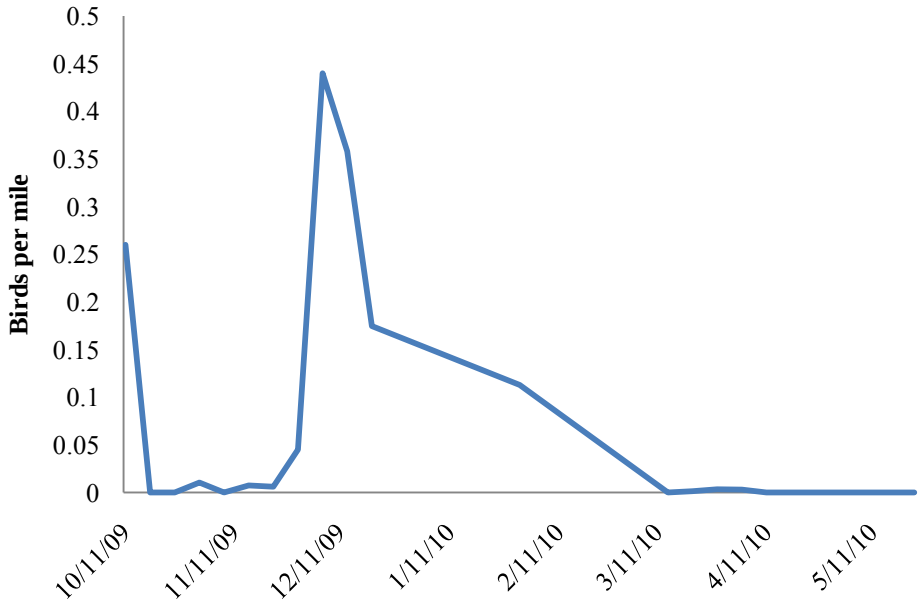


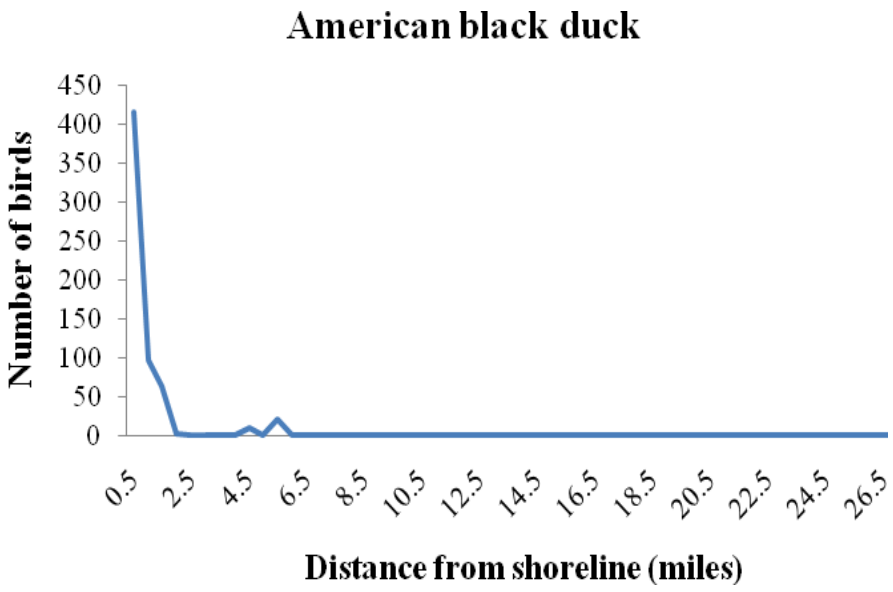
Appendix B

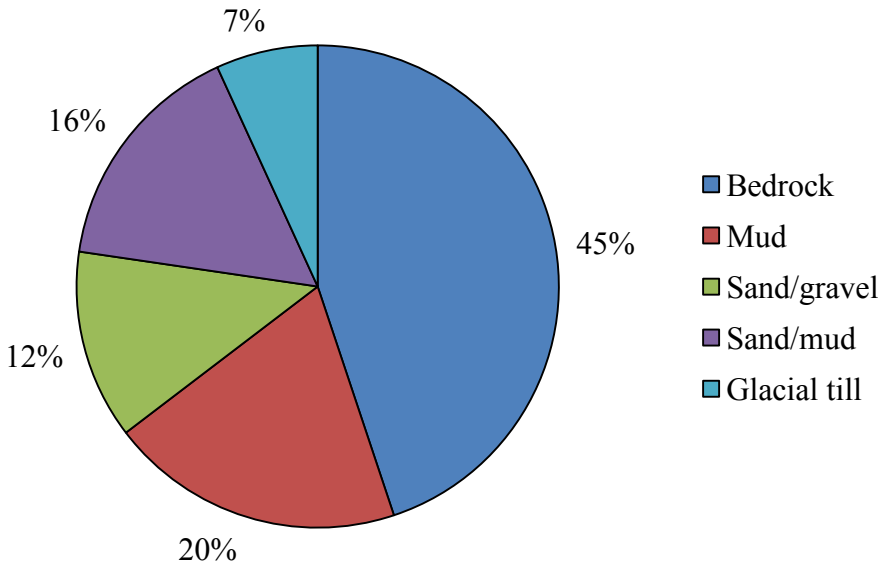
Species Summaries

American black duck

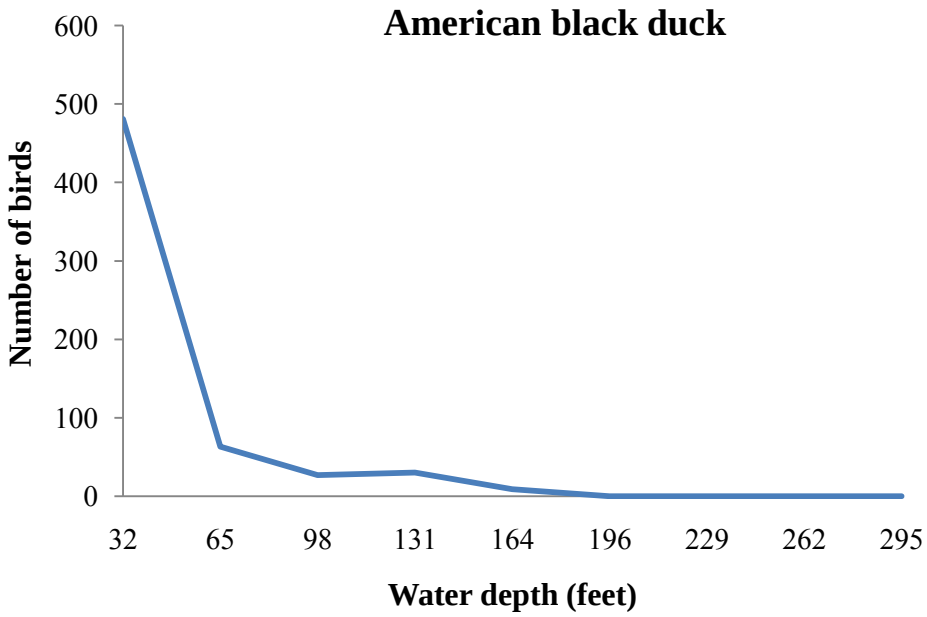




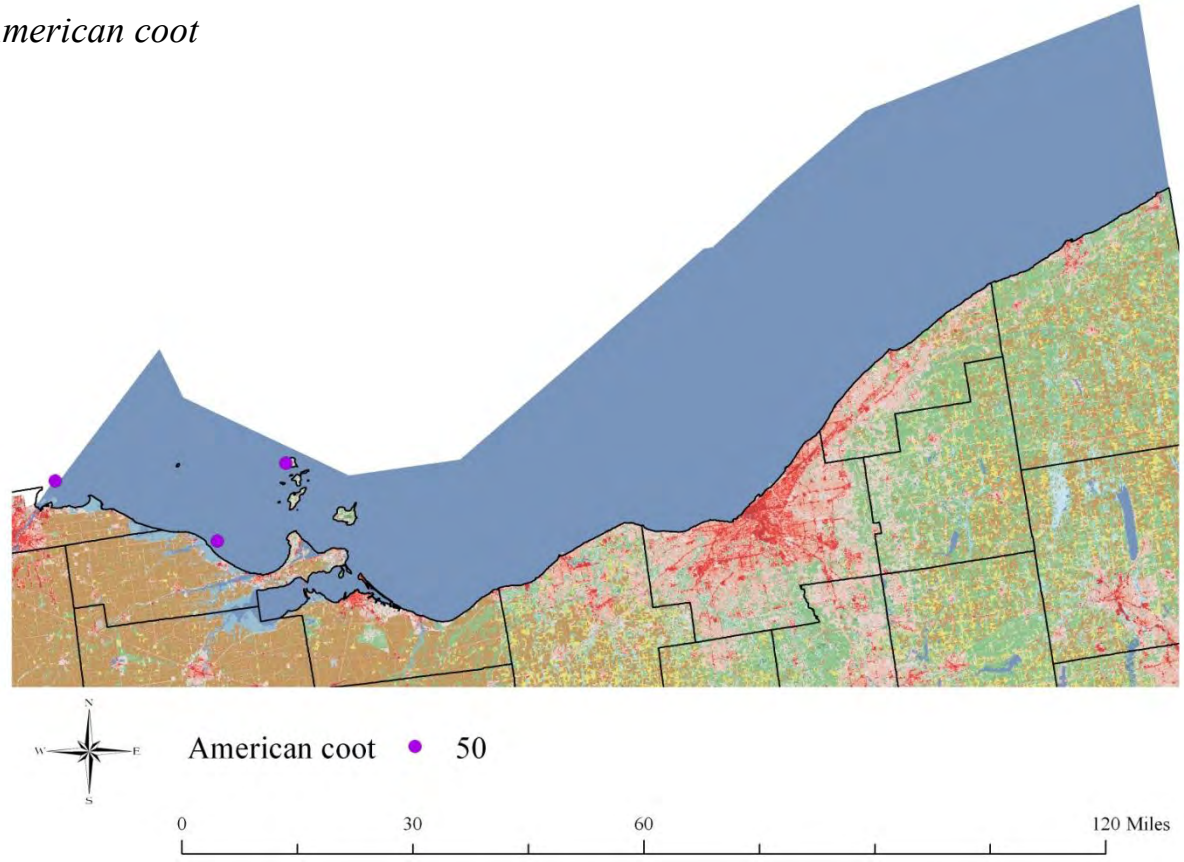


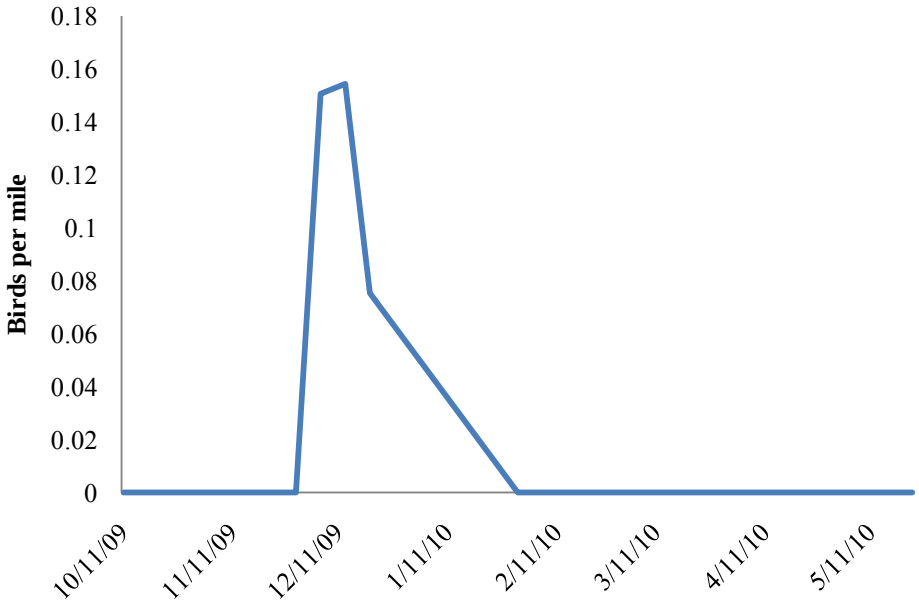


Number of American black duck observations by substrate type

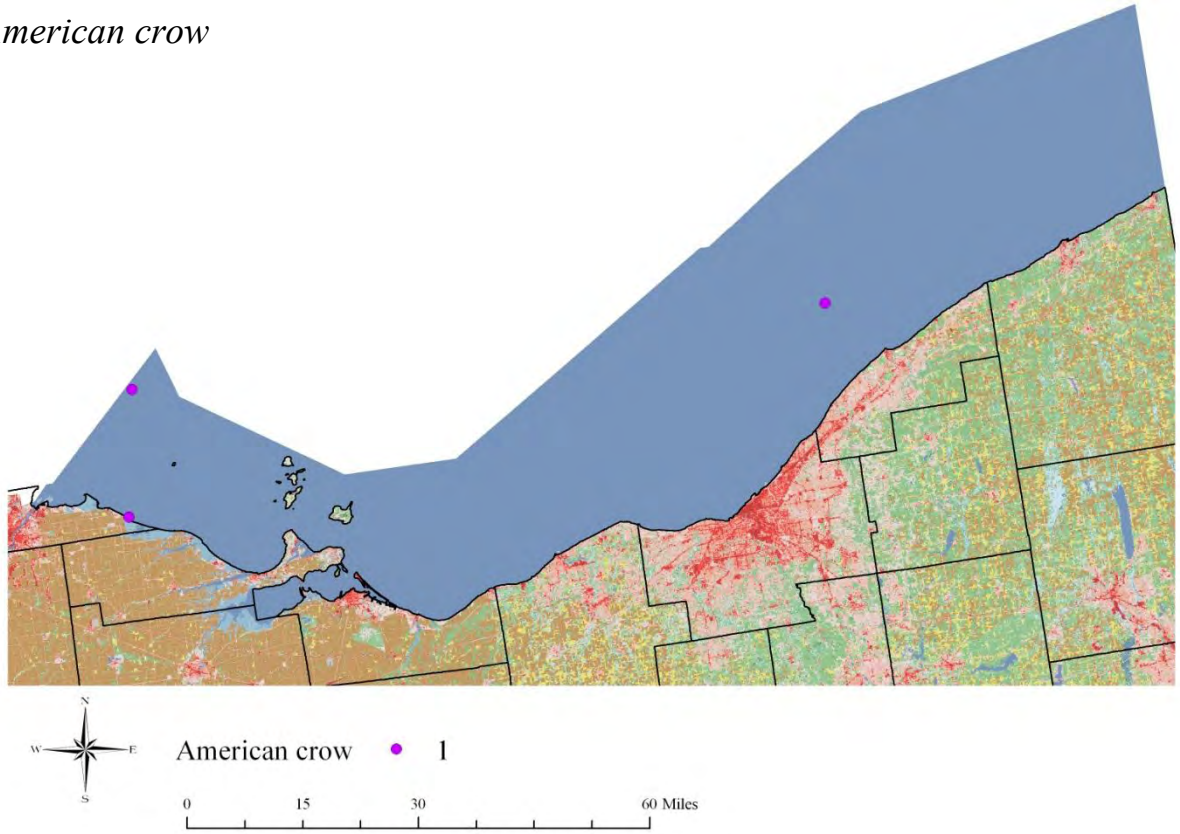

American black duck
600
500
400
300
200
100
0
Number of birds
32
65
98
131
164
196
229
262
295
Water depth (feet)

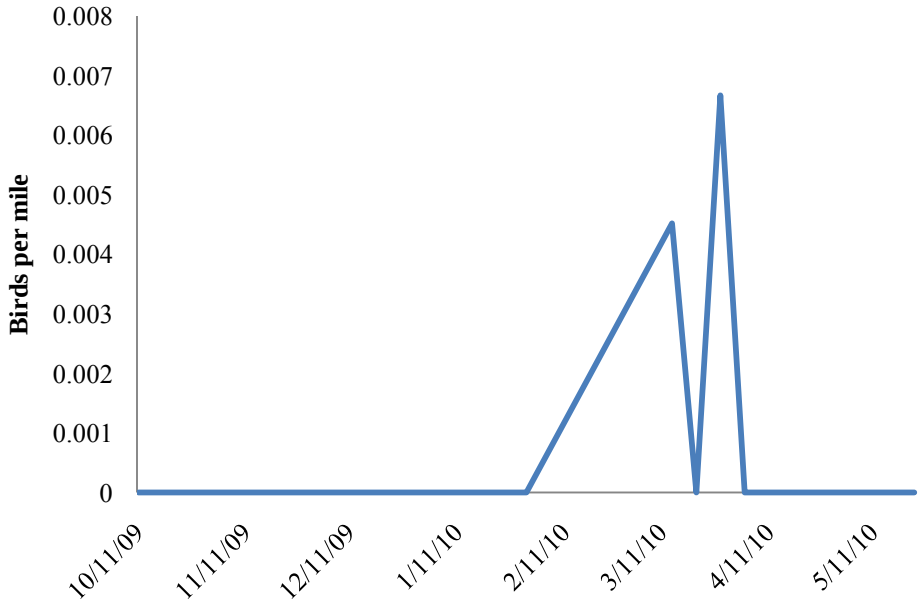
American coot



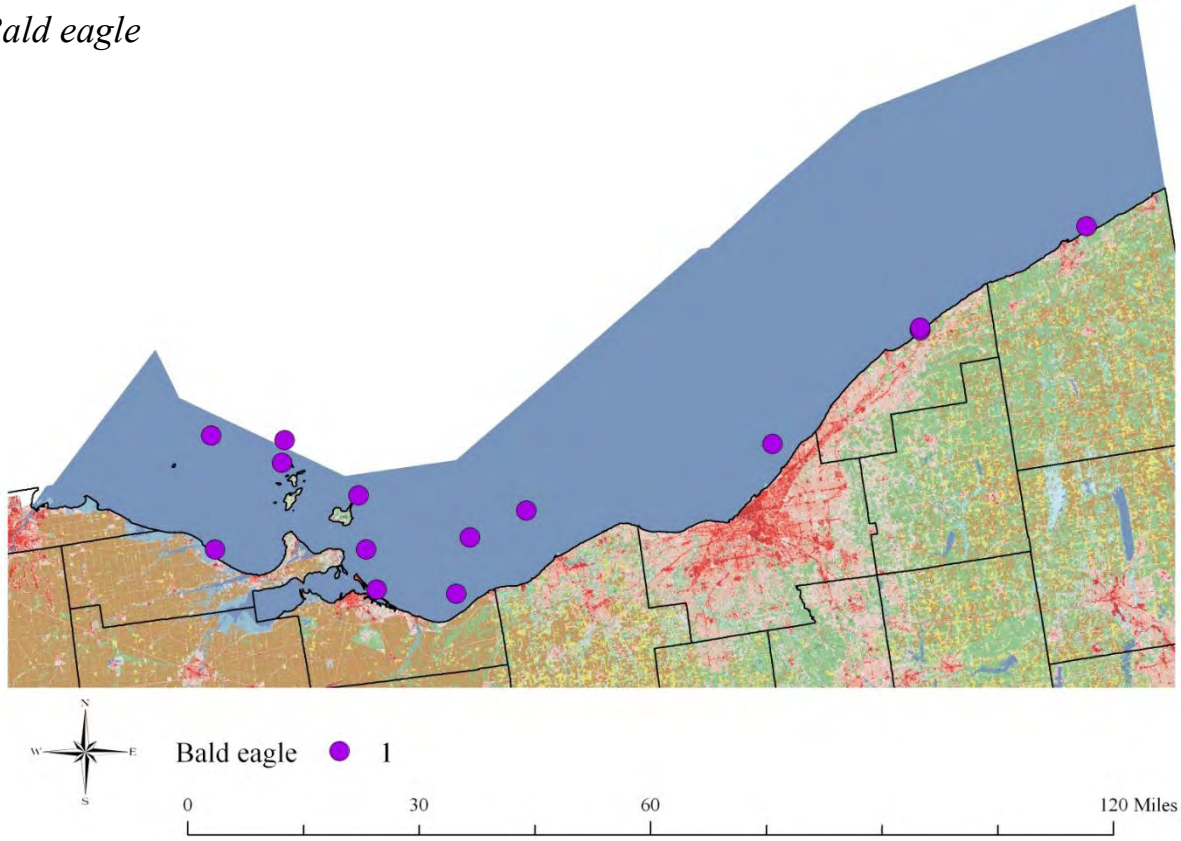


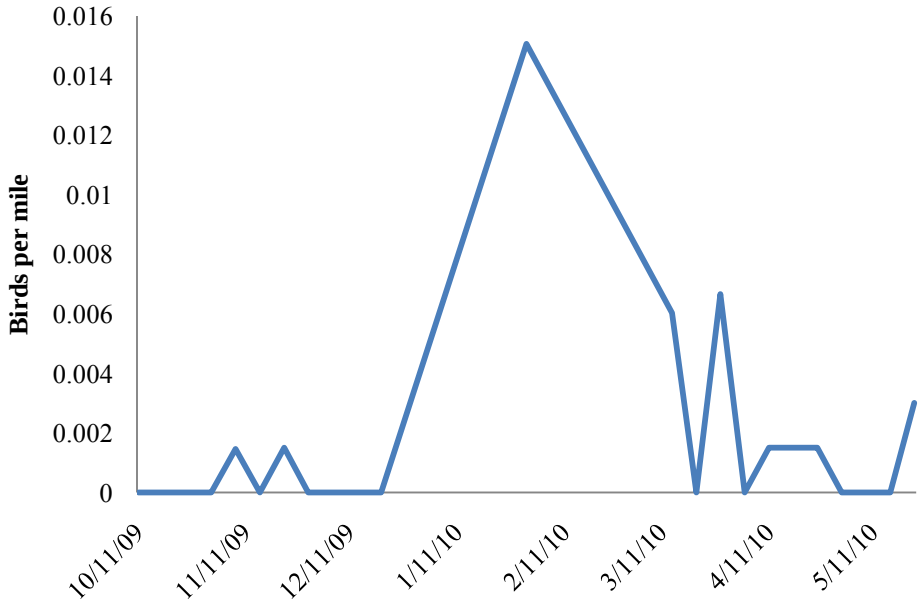
American crow

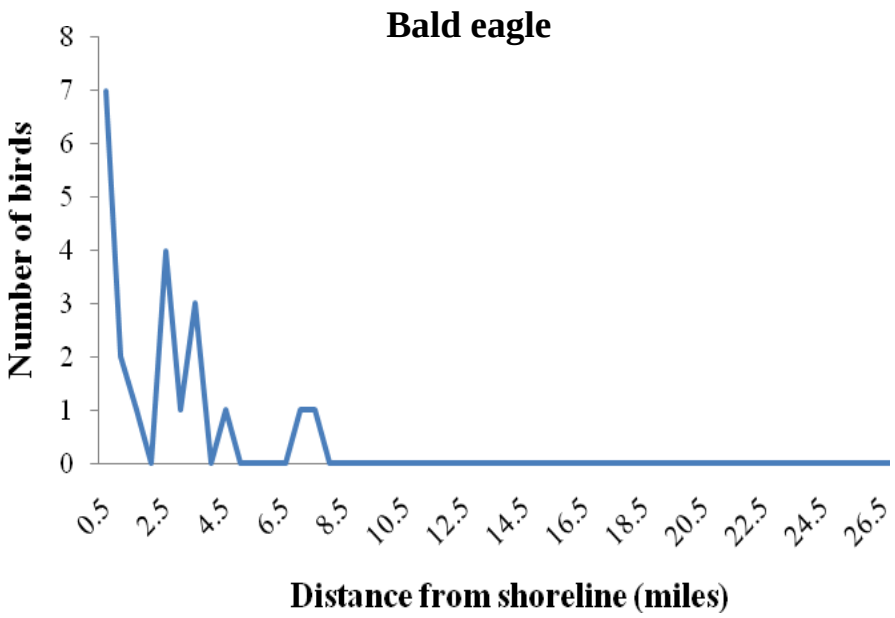




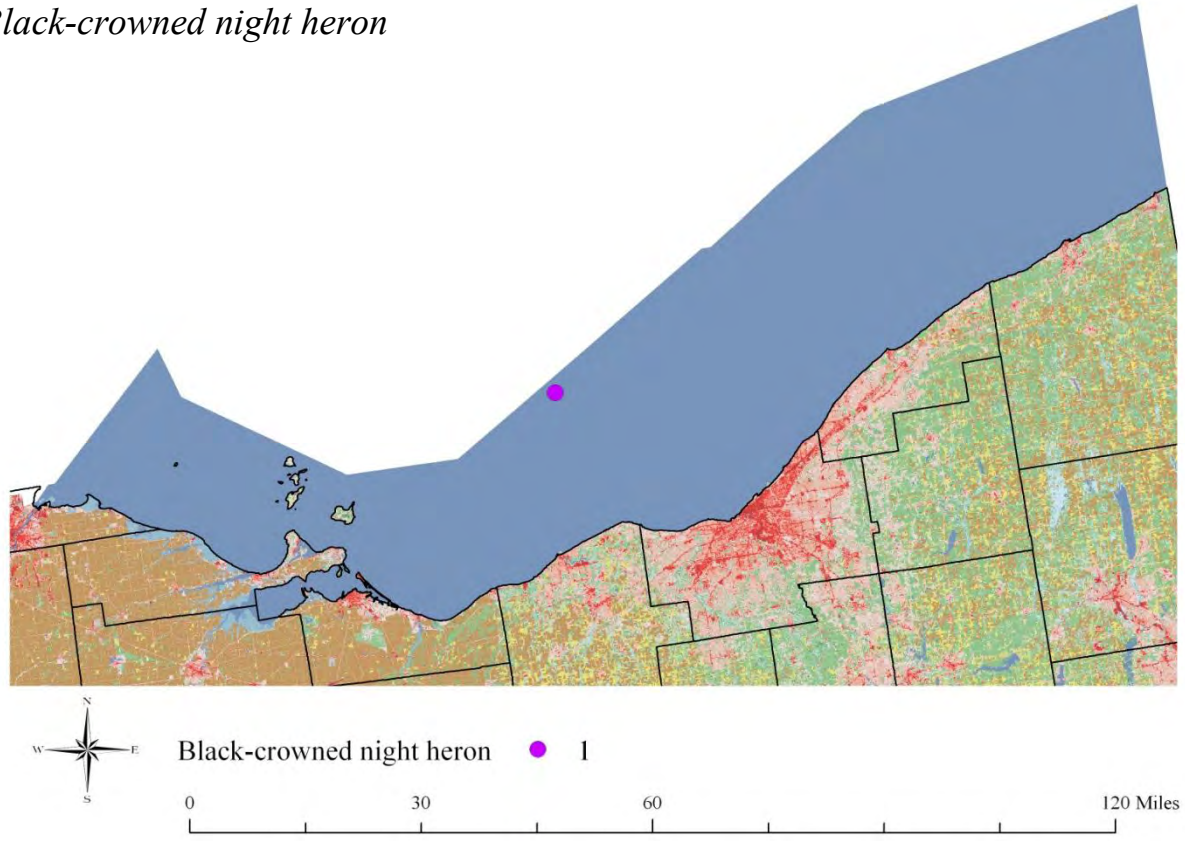
Bald eagle

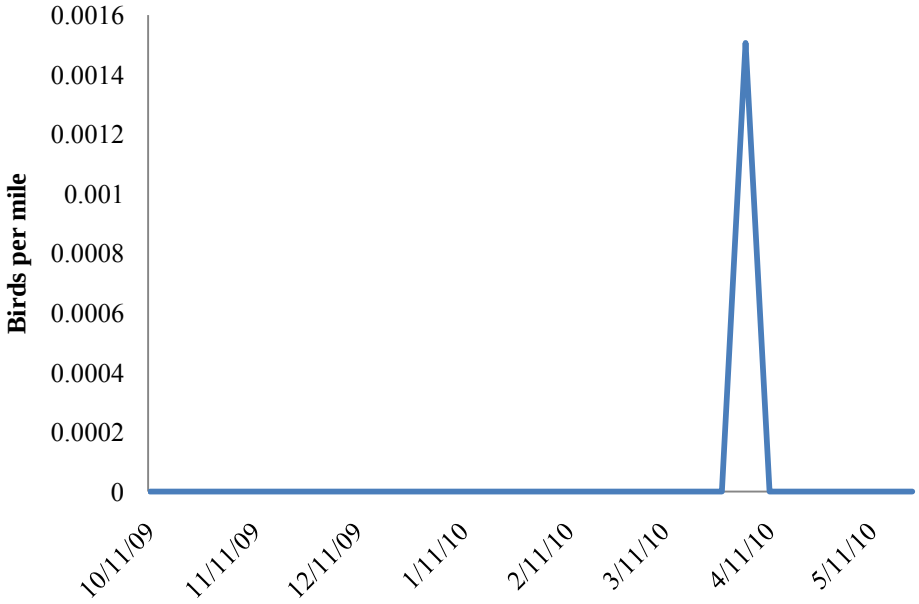

N
W
E
S
Bald eagle
1
0
30
60
120 Miles


Birds per mile
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

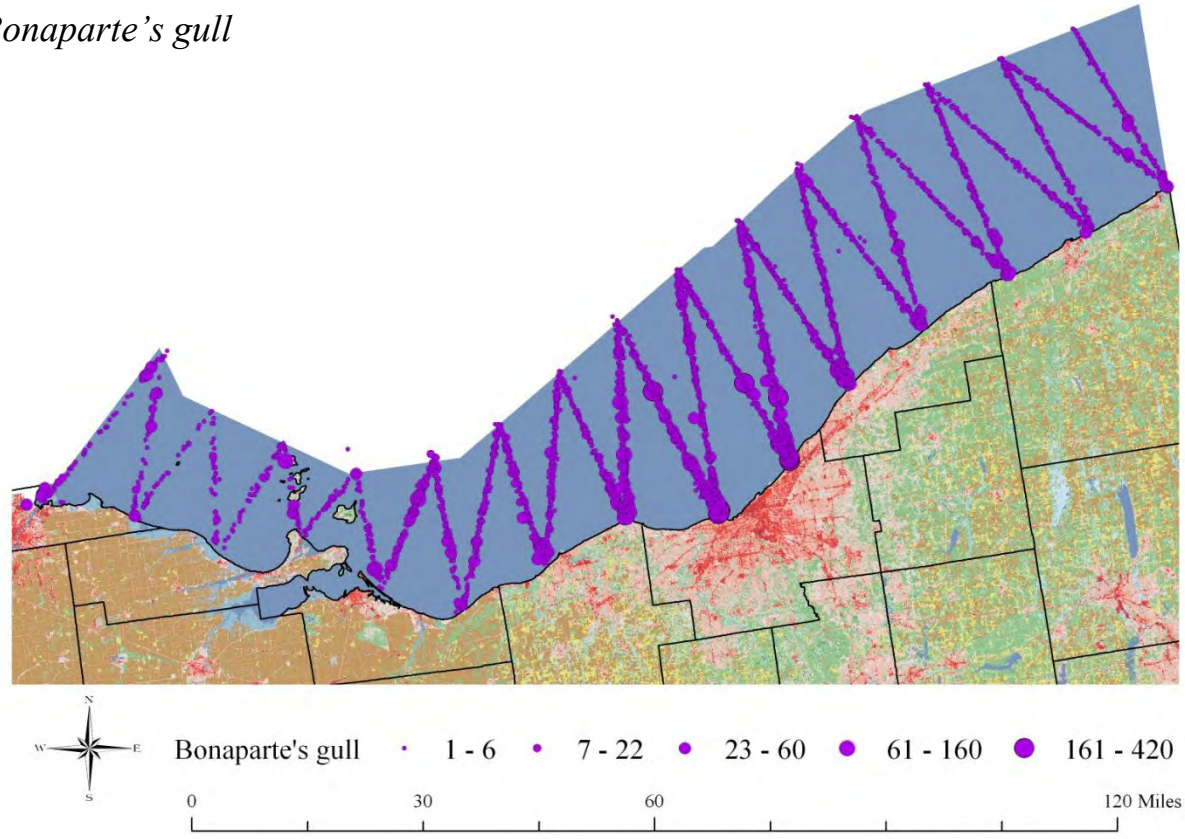

Bald eagle
Number of birds
8
7
6
5
4
3
2
1
0
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
18.5
20.5
22.5
24.5
26.5
Distance from shoreline (miles)

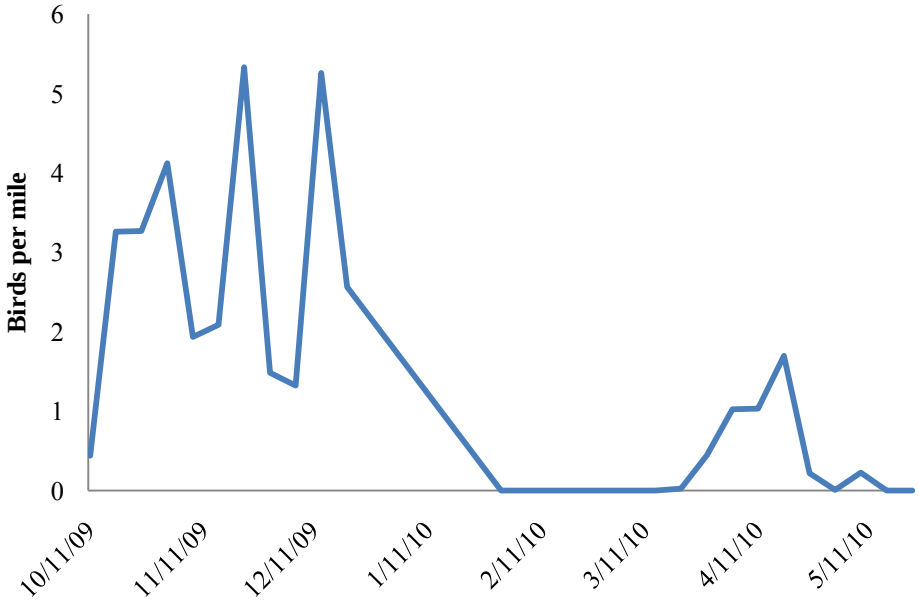
Black-crowned night heron

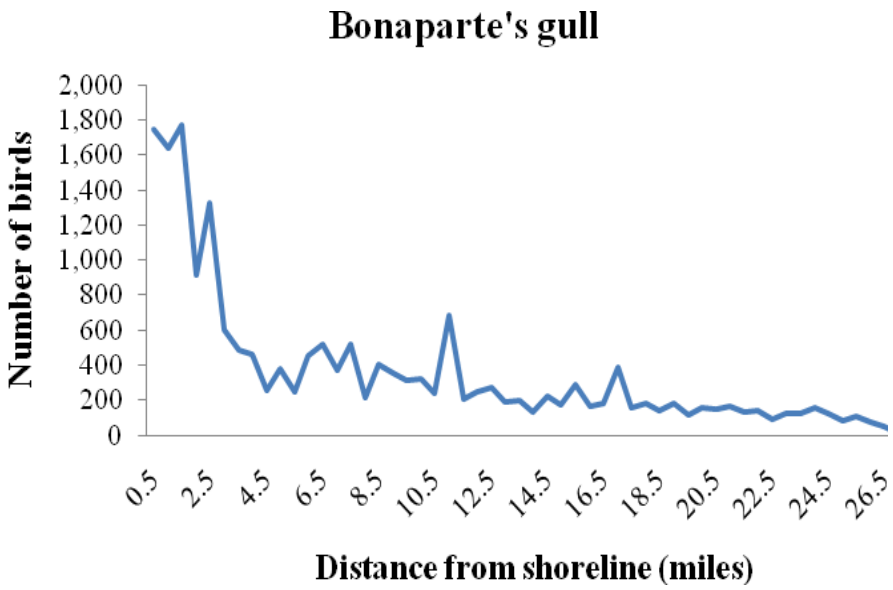




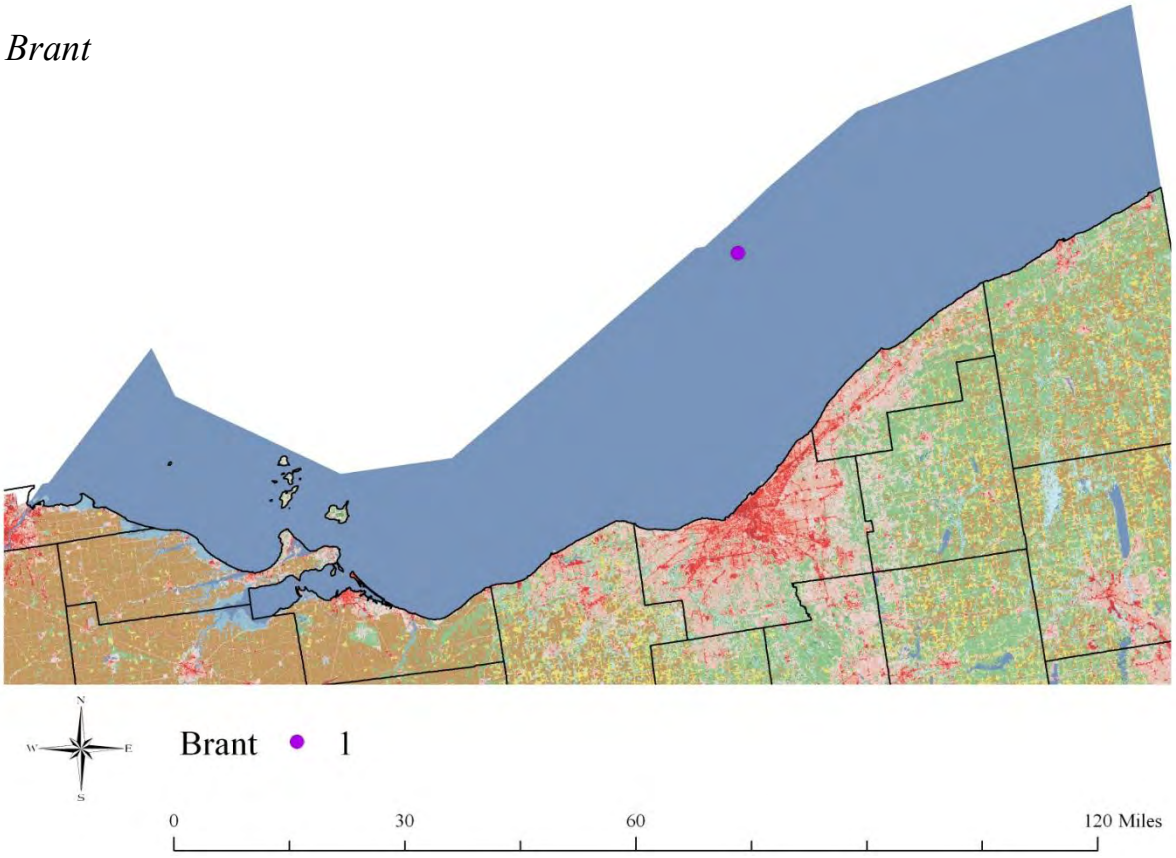
Bonaparte's gull

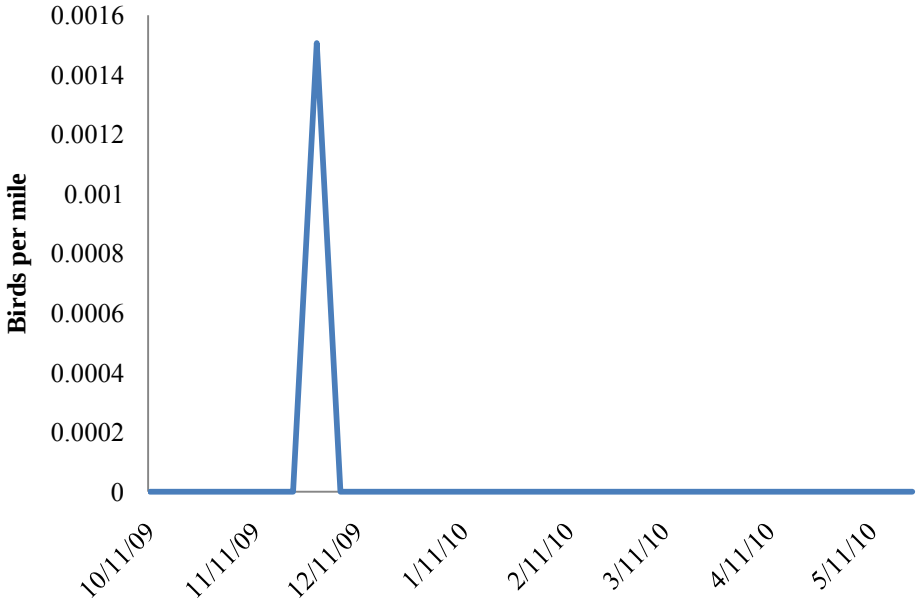




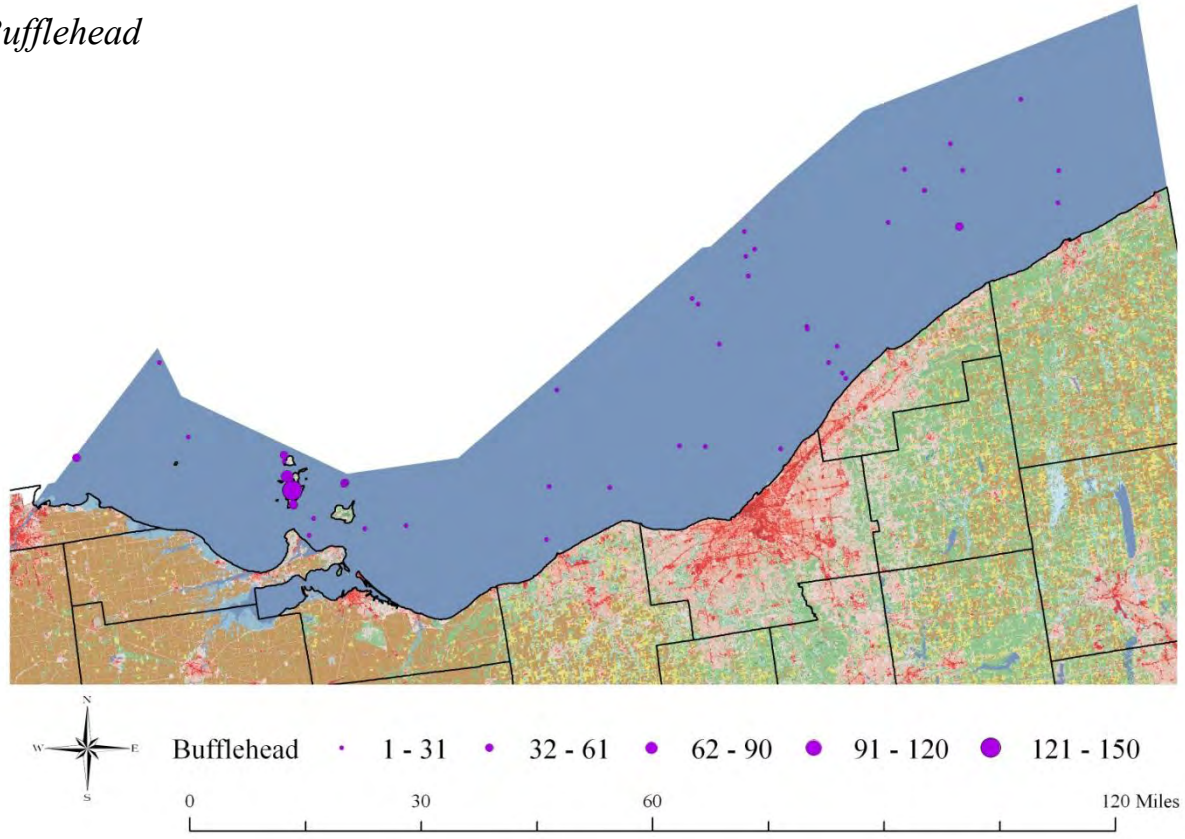

Bonaparte's gull
Number of birds
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
18.5
20.5
22.5
24.5
26.5
Distance from shoreline (miles)

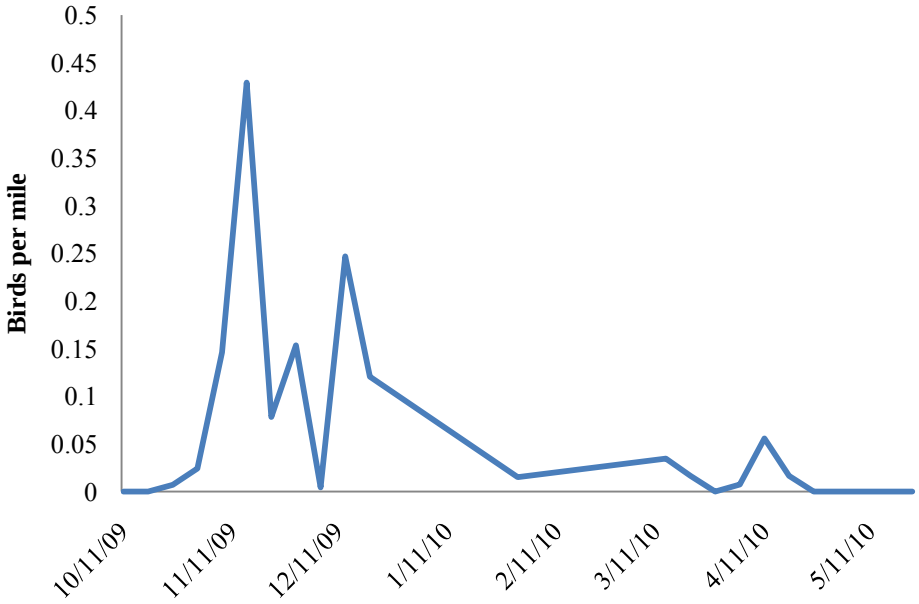
Brant

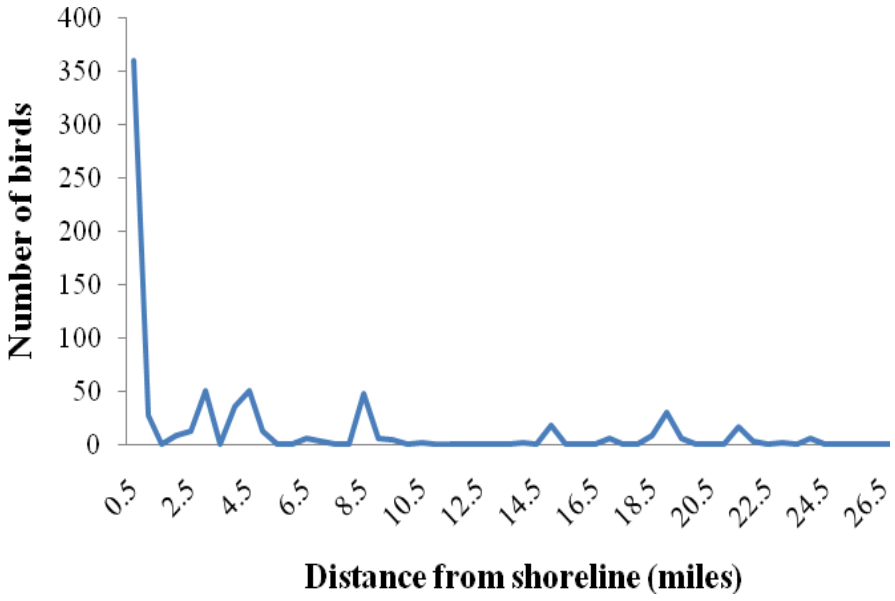

N
W
E
S
Brant
1
0
30
60
120 Miles

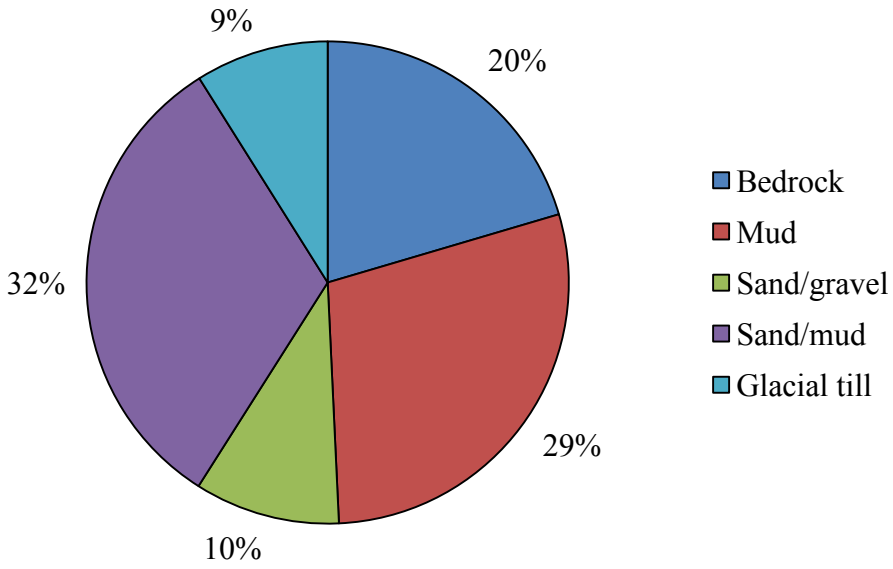

Birds per mile
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

Bufflehead

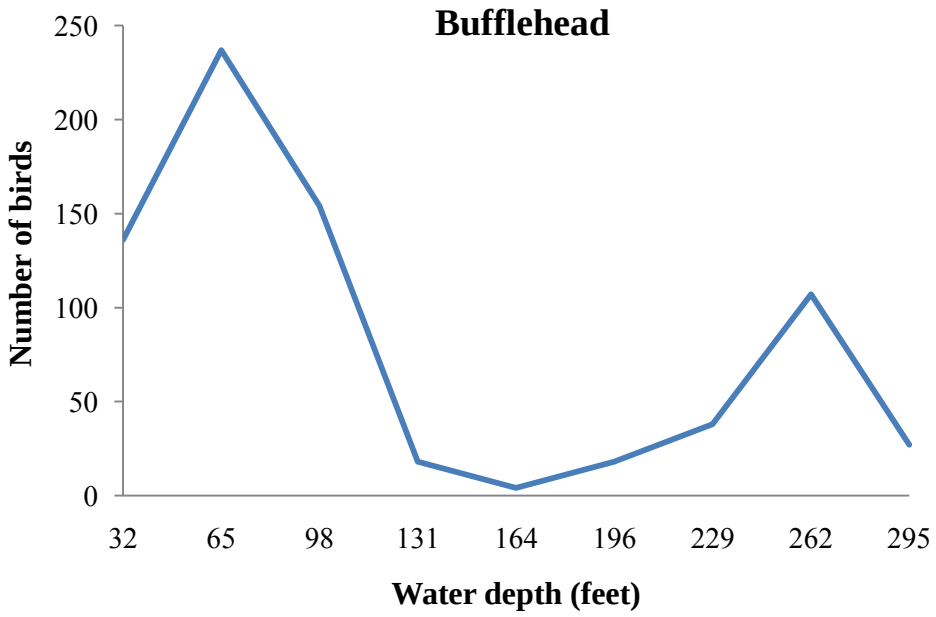

N
W
E
S
Bufflehead
1 - 31
32 - 61
62 - 90
91 - 120
121 - 150
0
30
60
120 Miles


Birds per mile
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

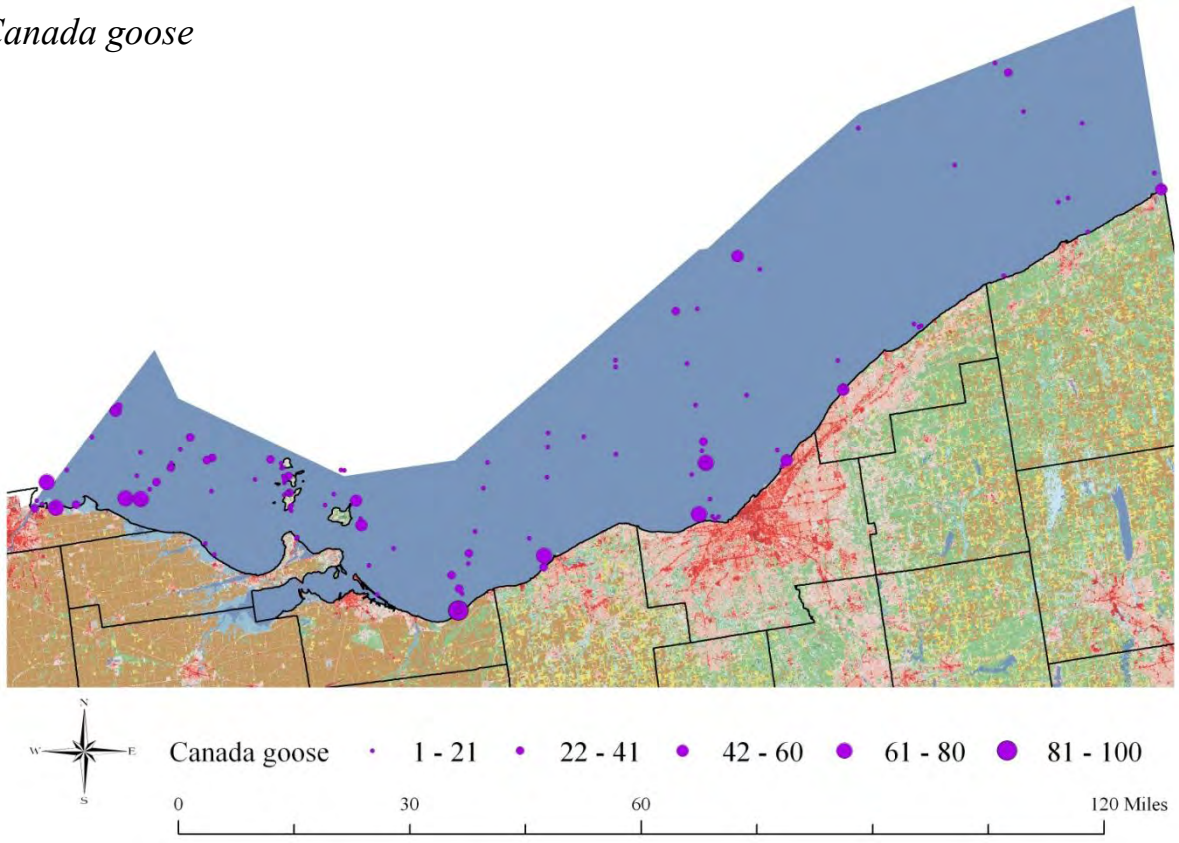


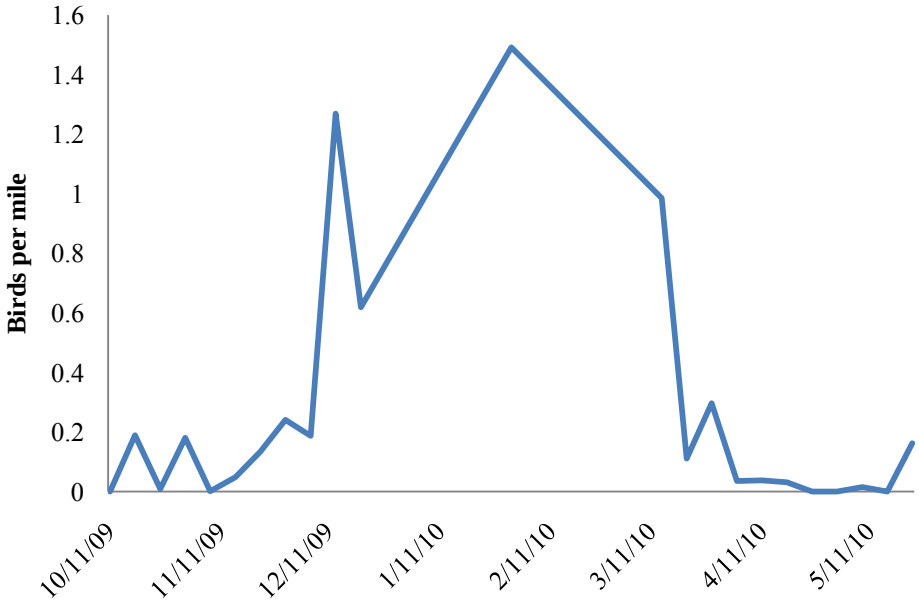


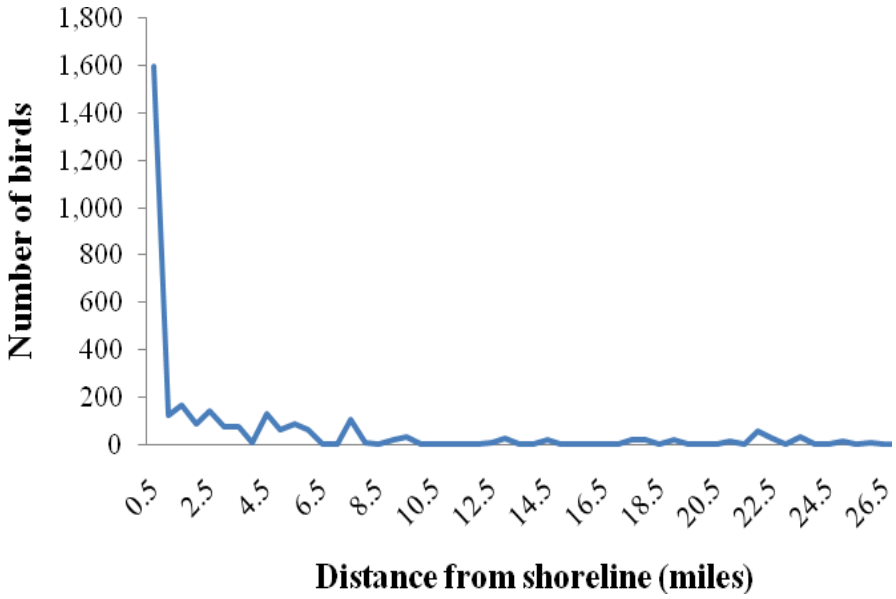
Number of bufflehead observations by substrate type

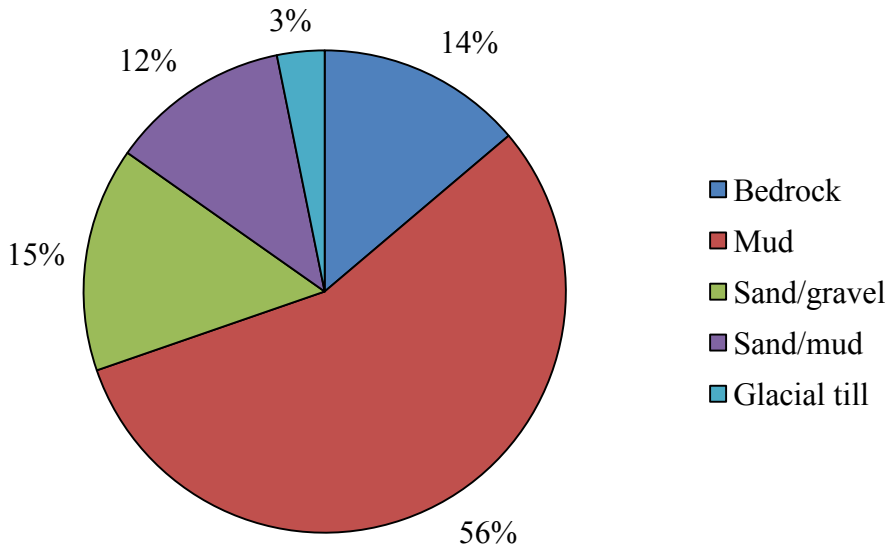

Bufflehead
Number of birds
250
200
150
100
50
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

Canada goose

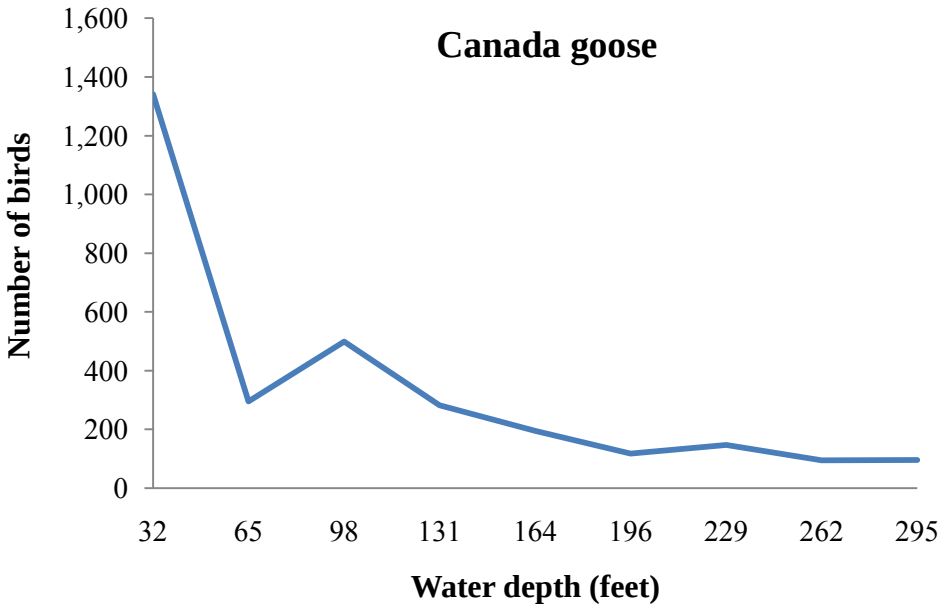




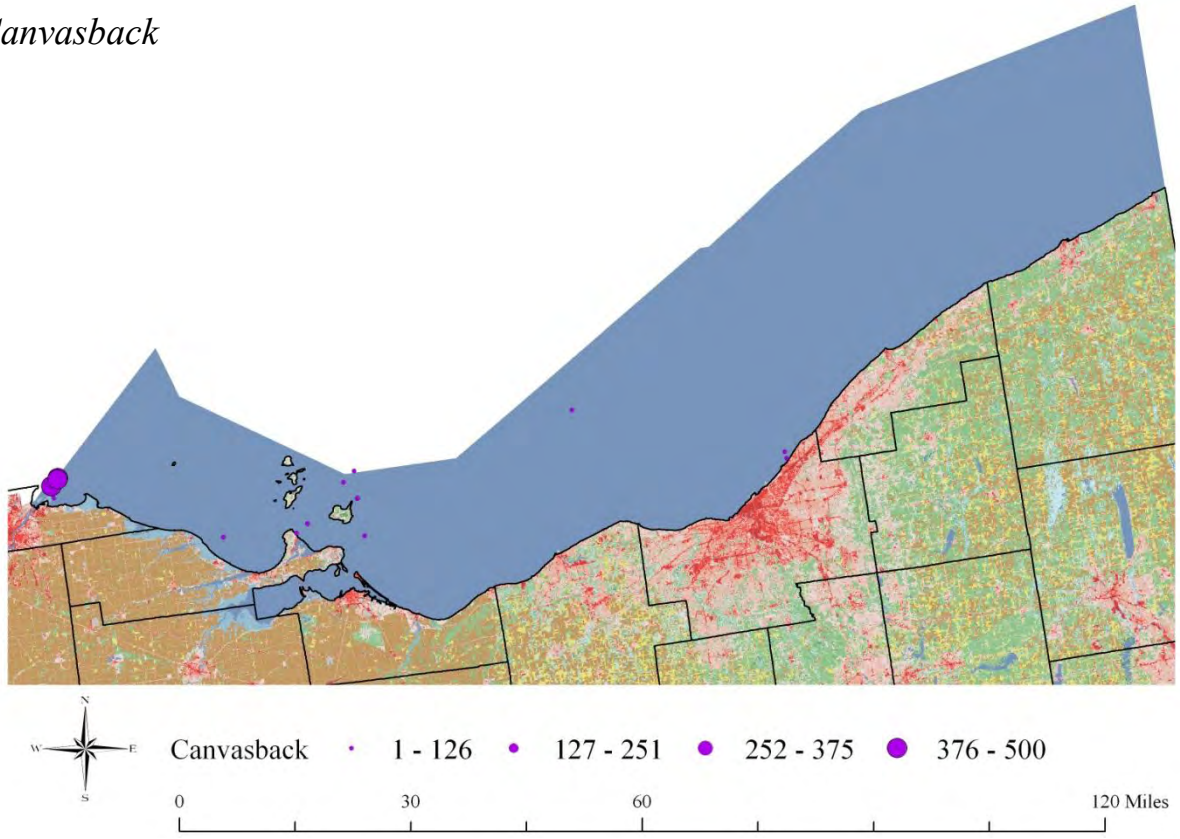


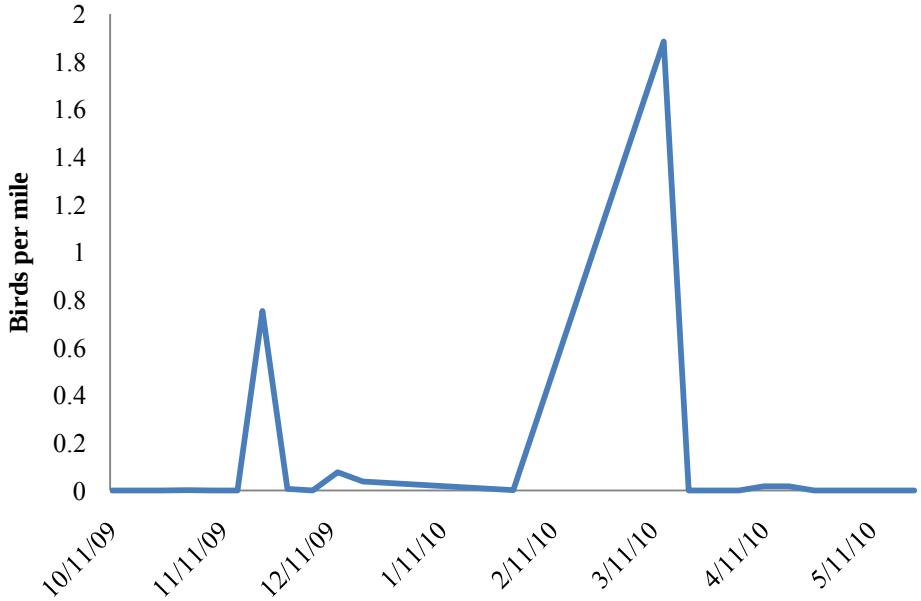


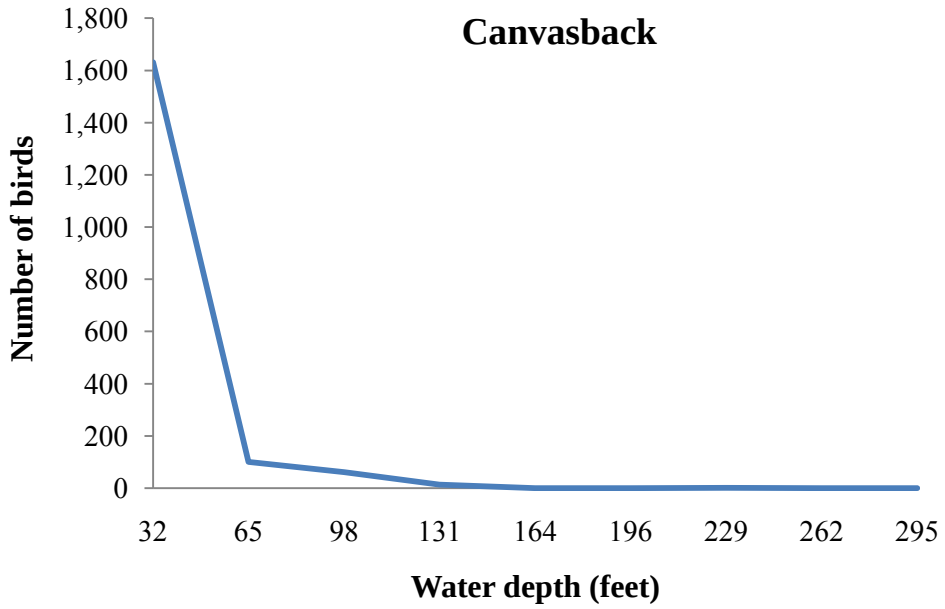
Number of Canada goose observations by substrate type


Canada goose
Number of birds
1,600
1,400
1,200
1,000
800
600
400
200
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

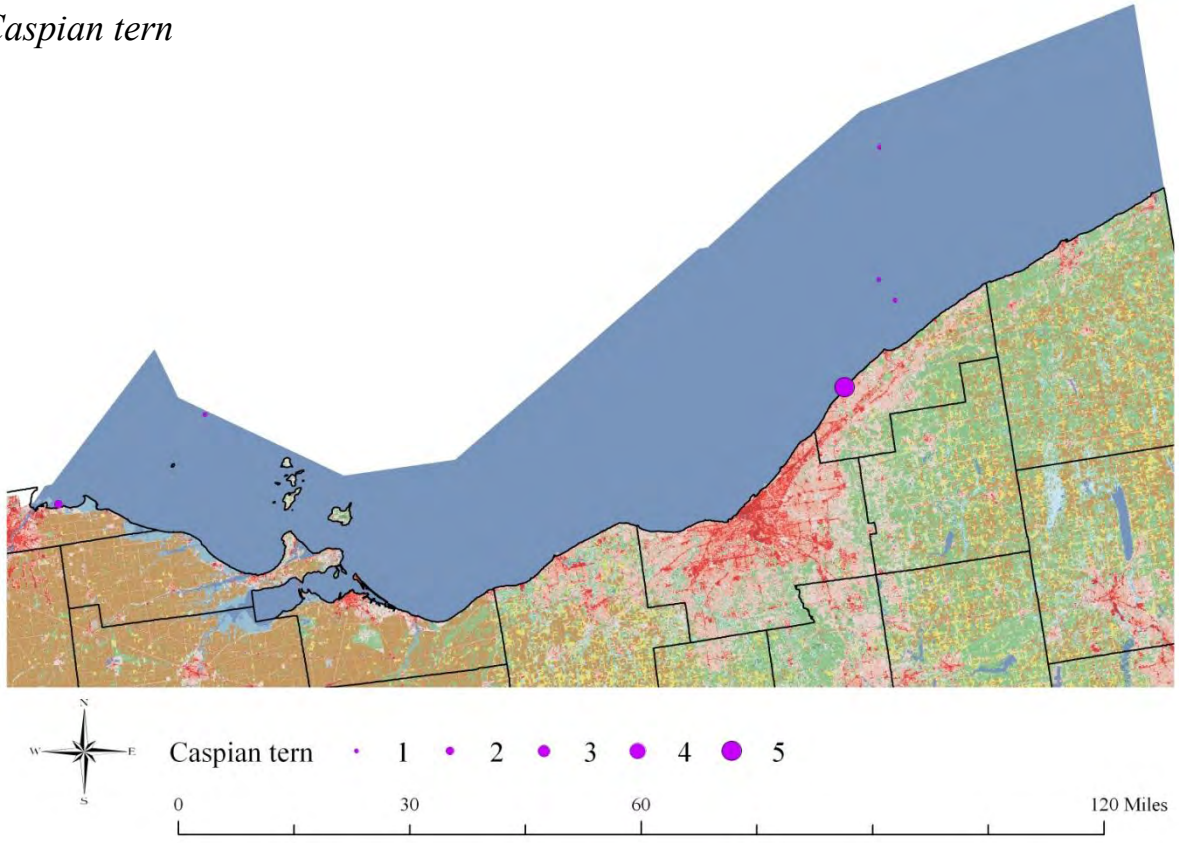
Canvasback

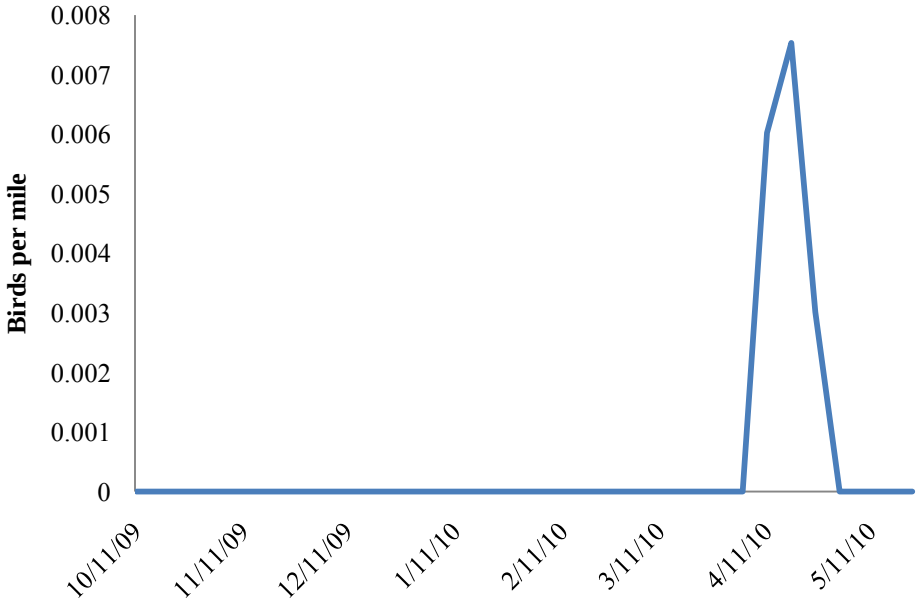

N
W
E
S
Canvasback
1 - 126
127 - 251
252 - 375
376 - 500
0
30
60
120 Miles


Birds per mile
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

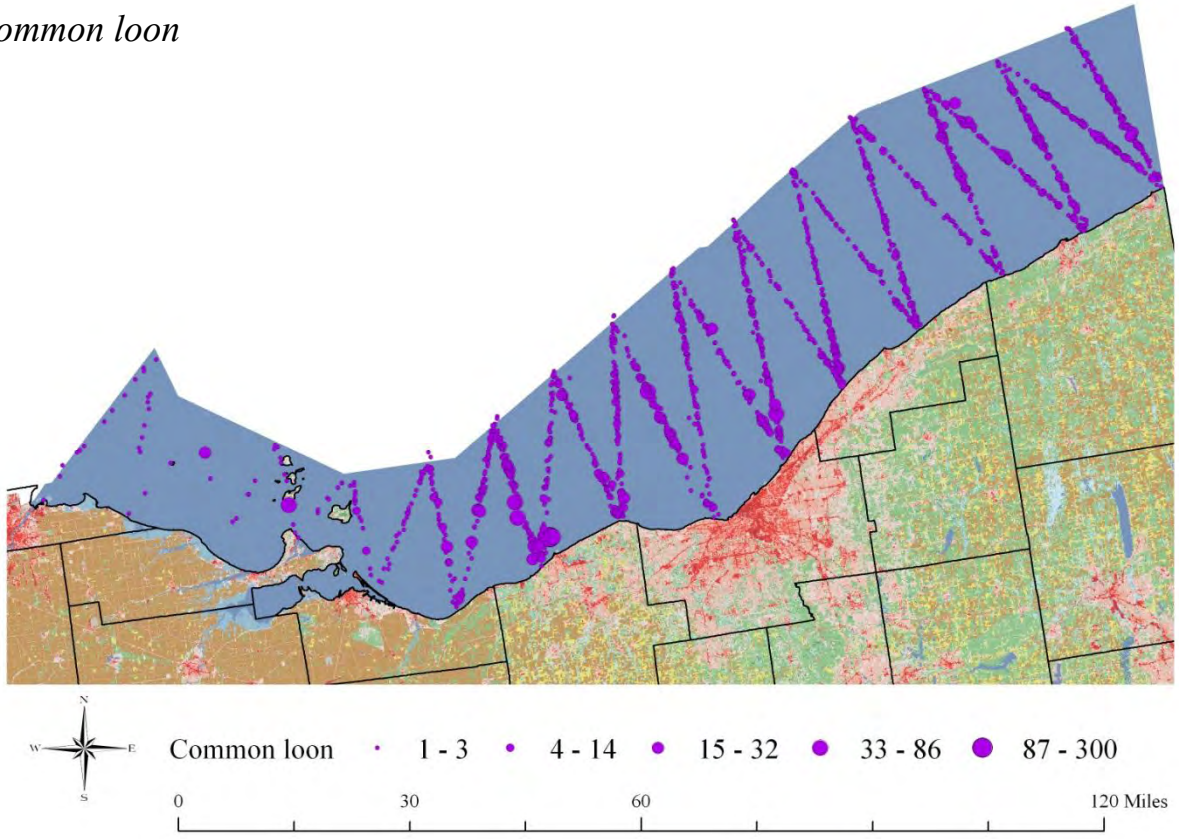

Canvasback
Number of birds
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

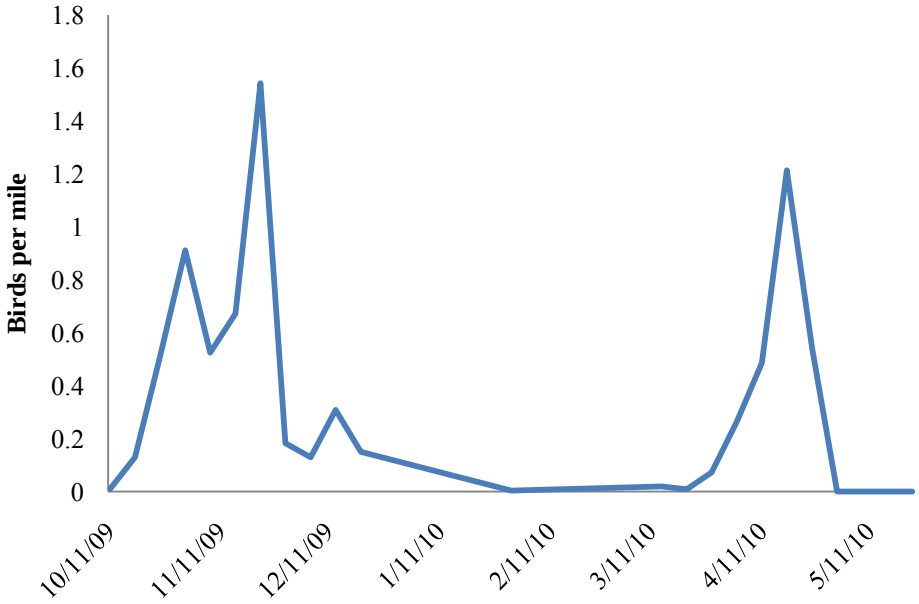
Caspian tern

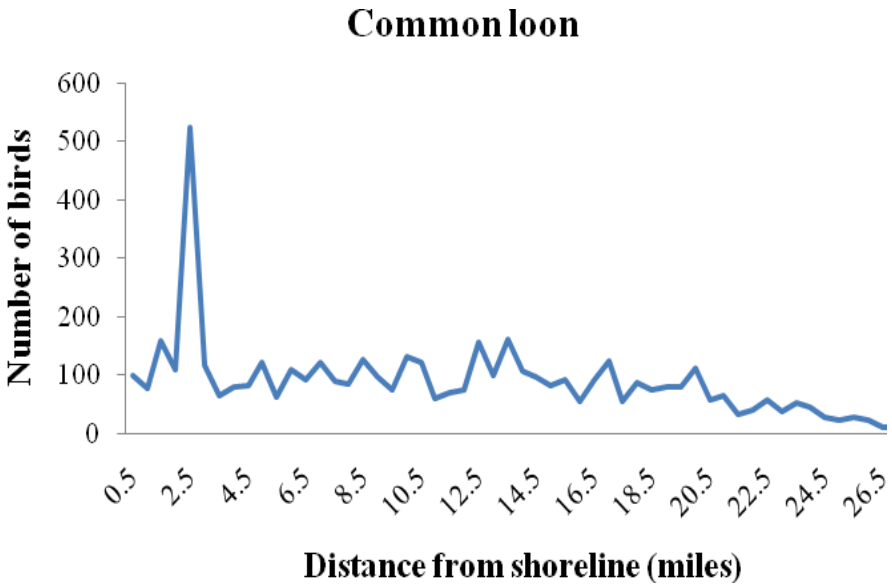


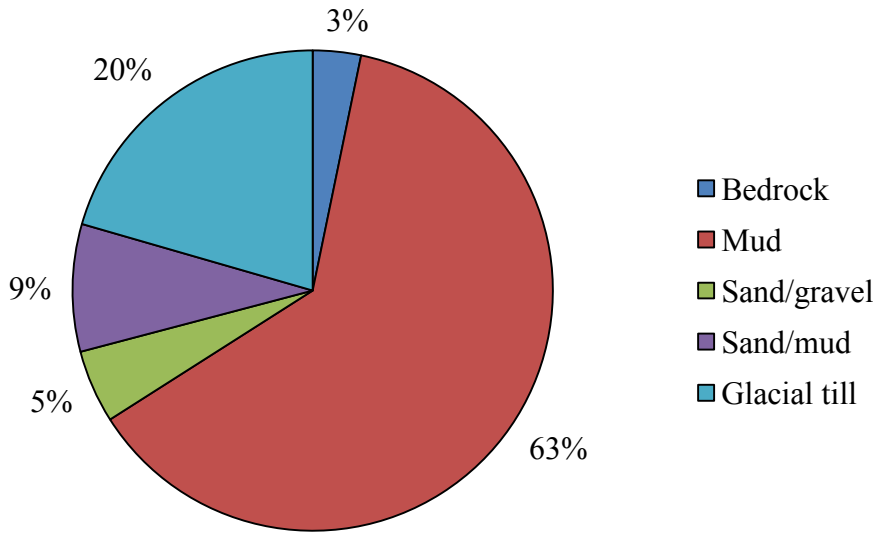


Common loon

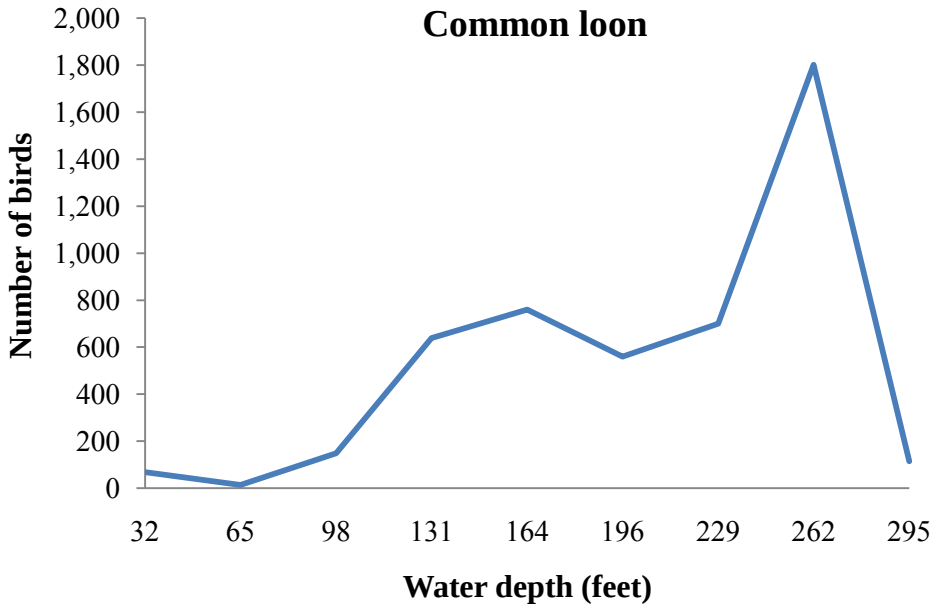

N
W
E
S
Common loon
1 - 3
4 - 14
15 - 32
33 - 86
87 - 300
0
30
60
120 Miles


Birds per mile
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

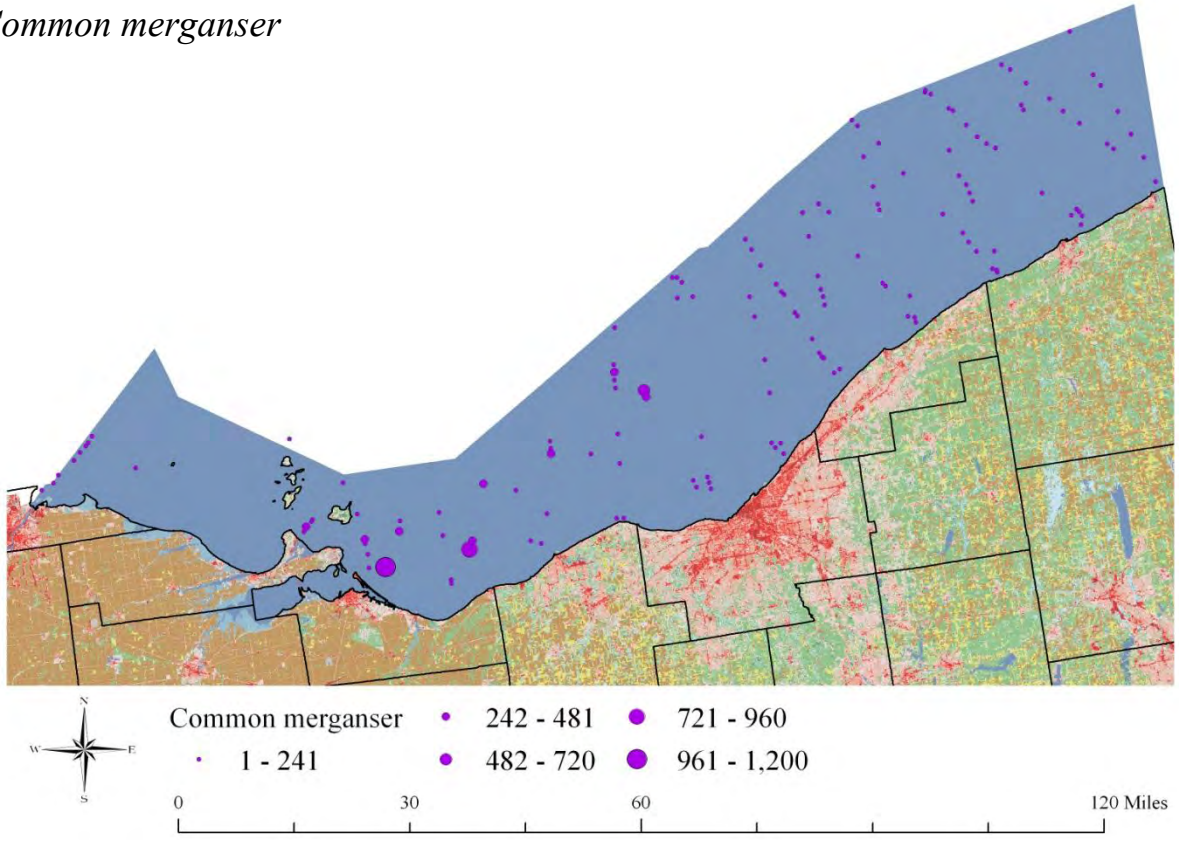


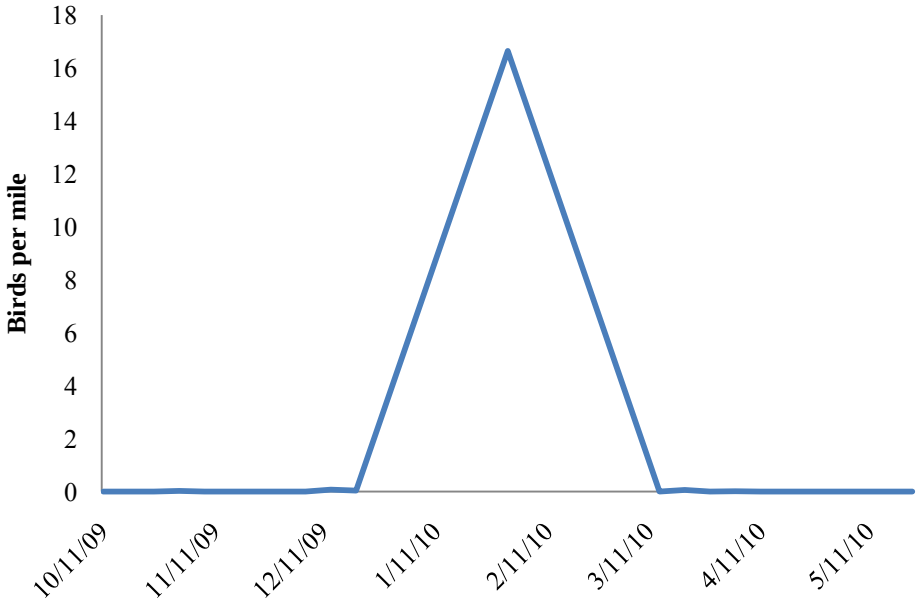


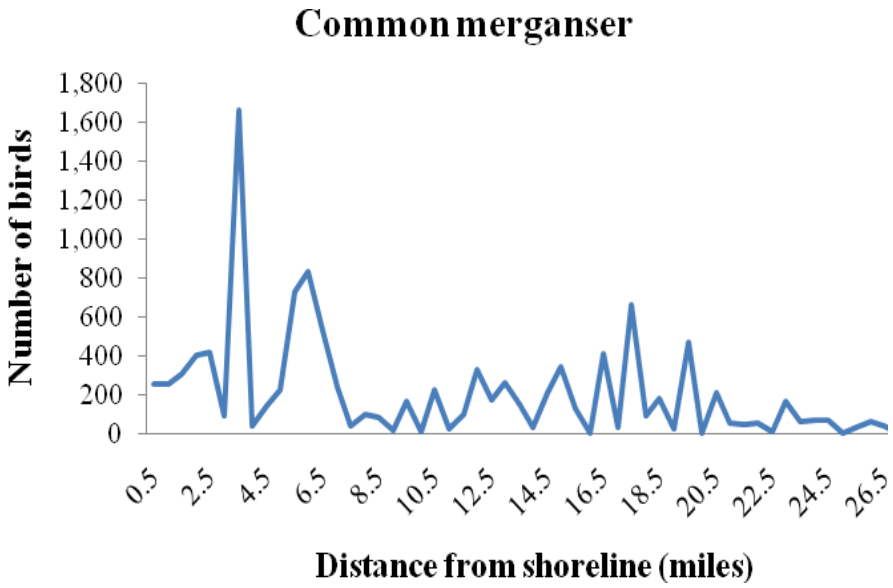
Number of common loon observations by substrate type

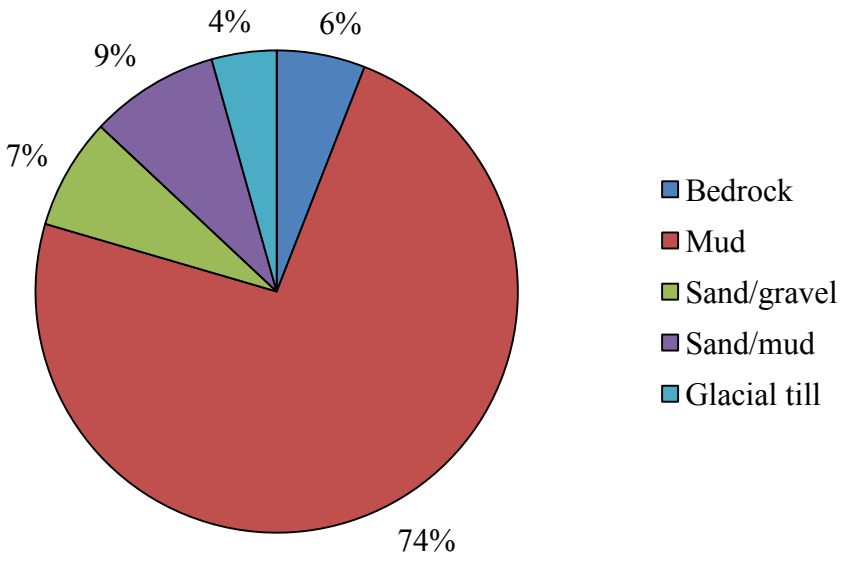

Common loon
Number of birds
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

Common merganser

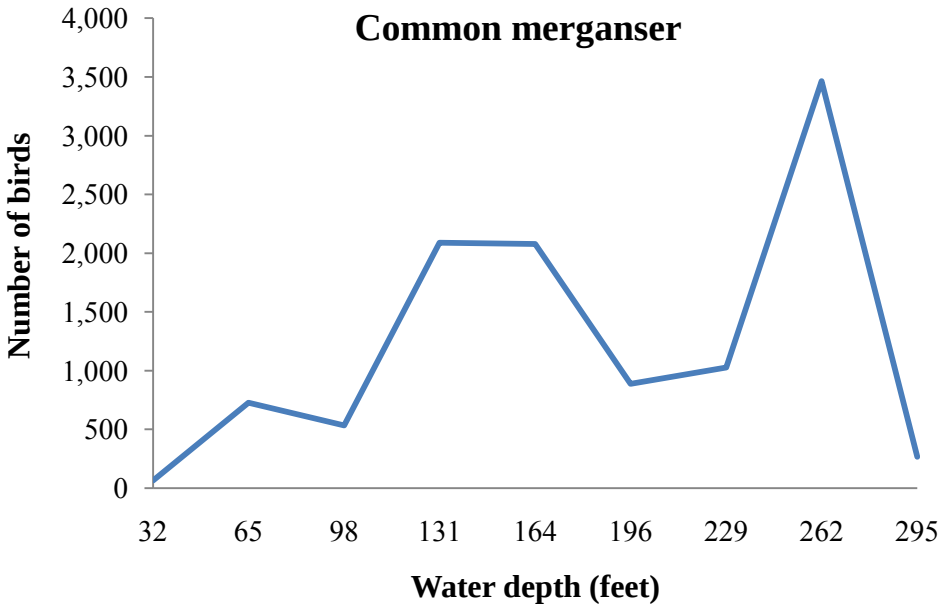




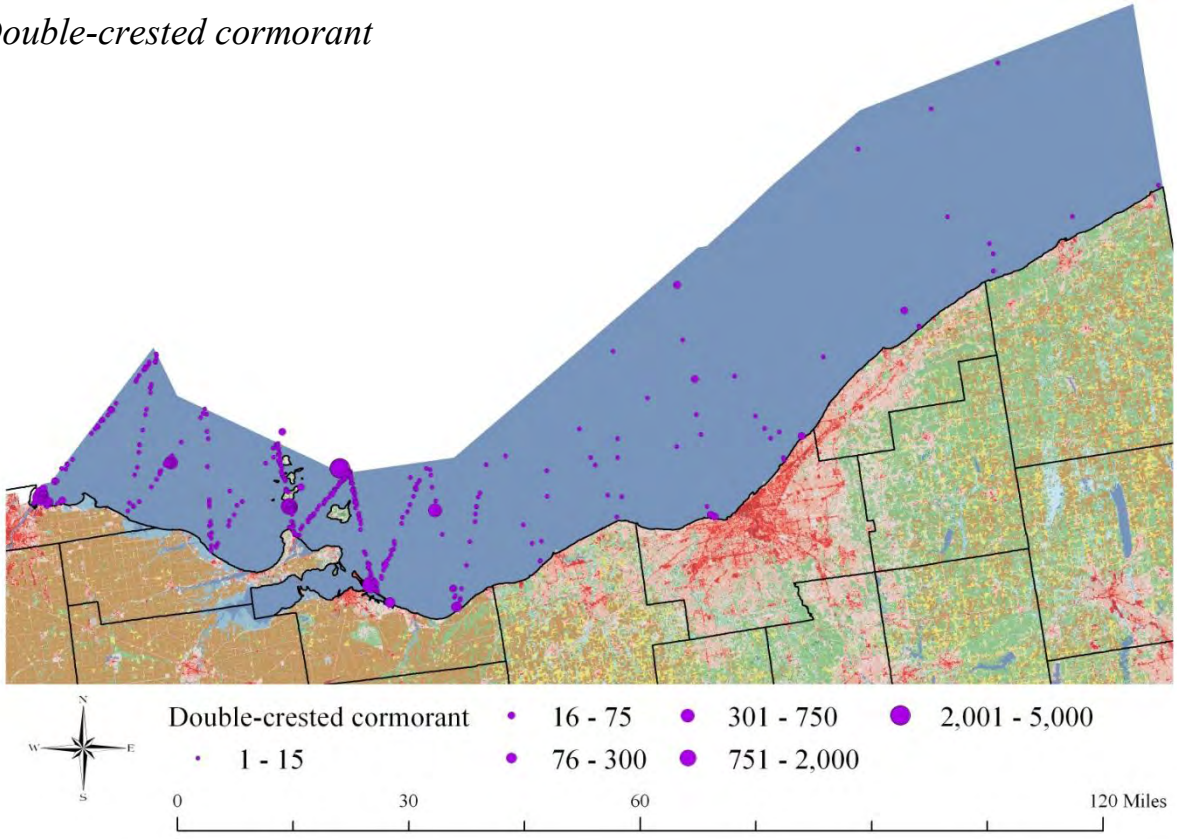


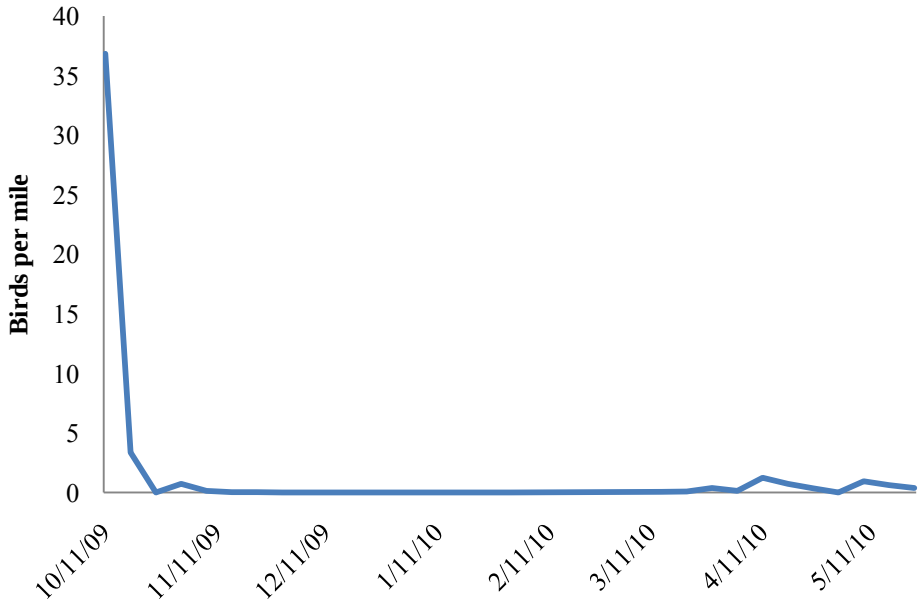


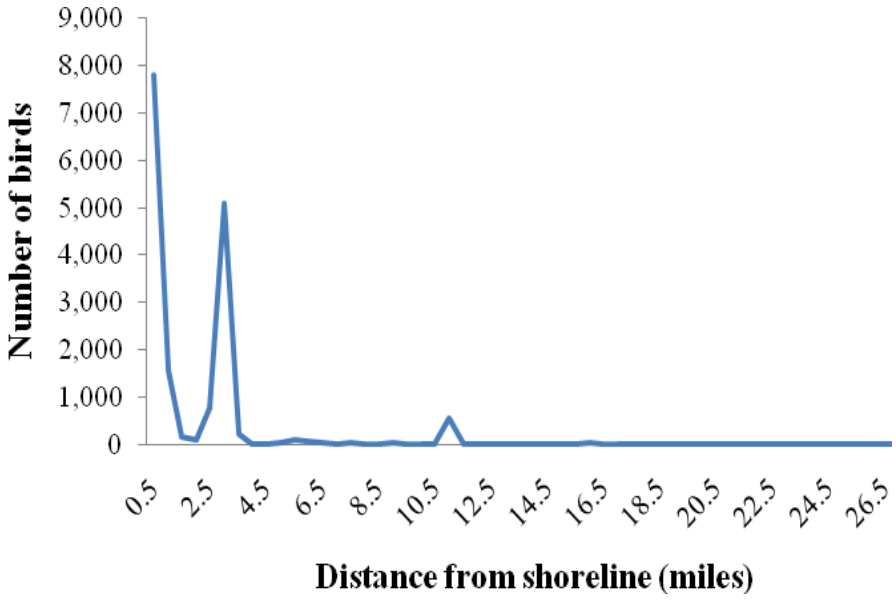
Number of common merganser observations by substrate type

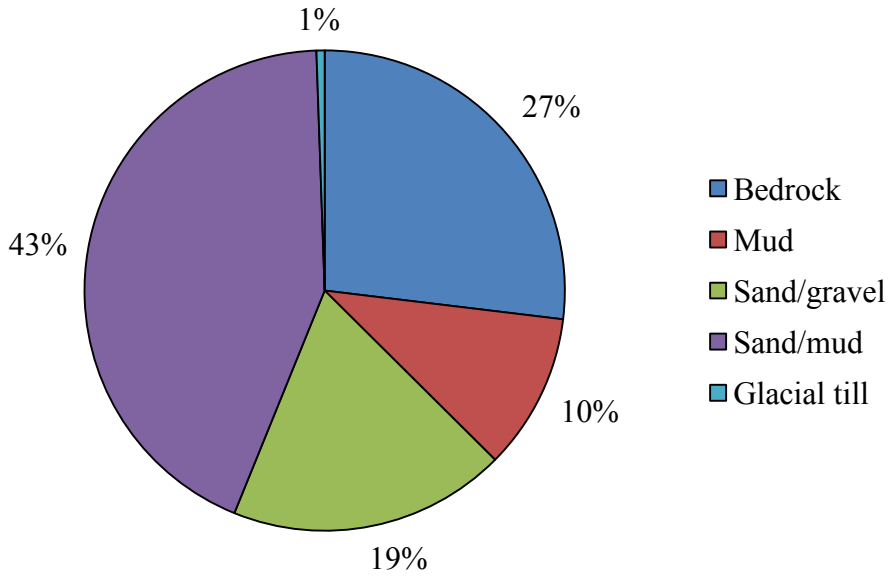

Common merganser
Number of birds
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

Double-crested cormorant

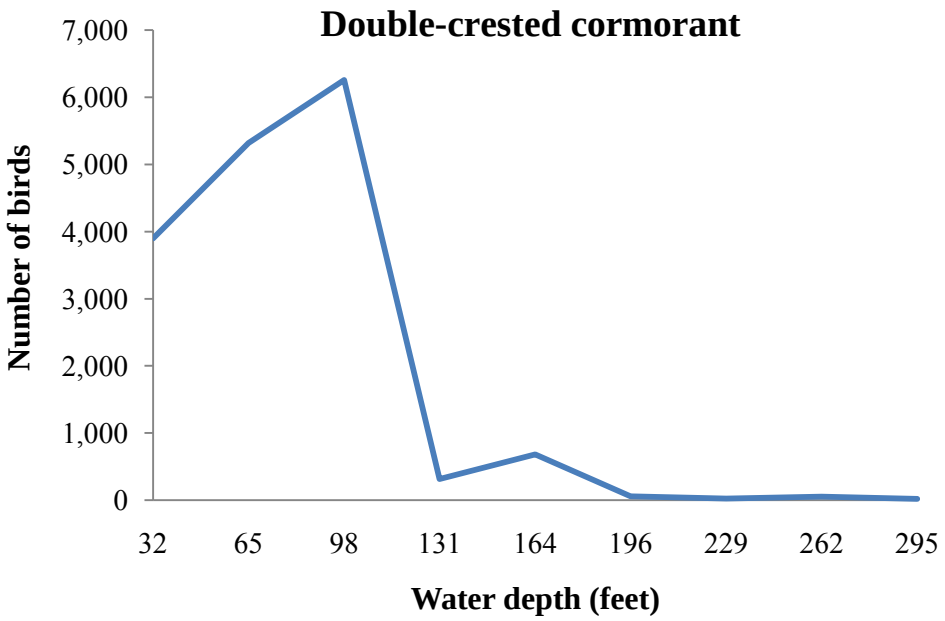




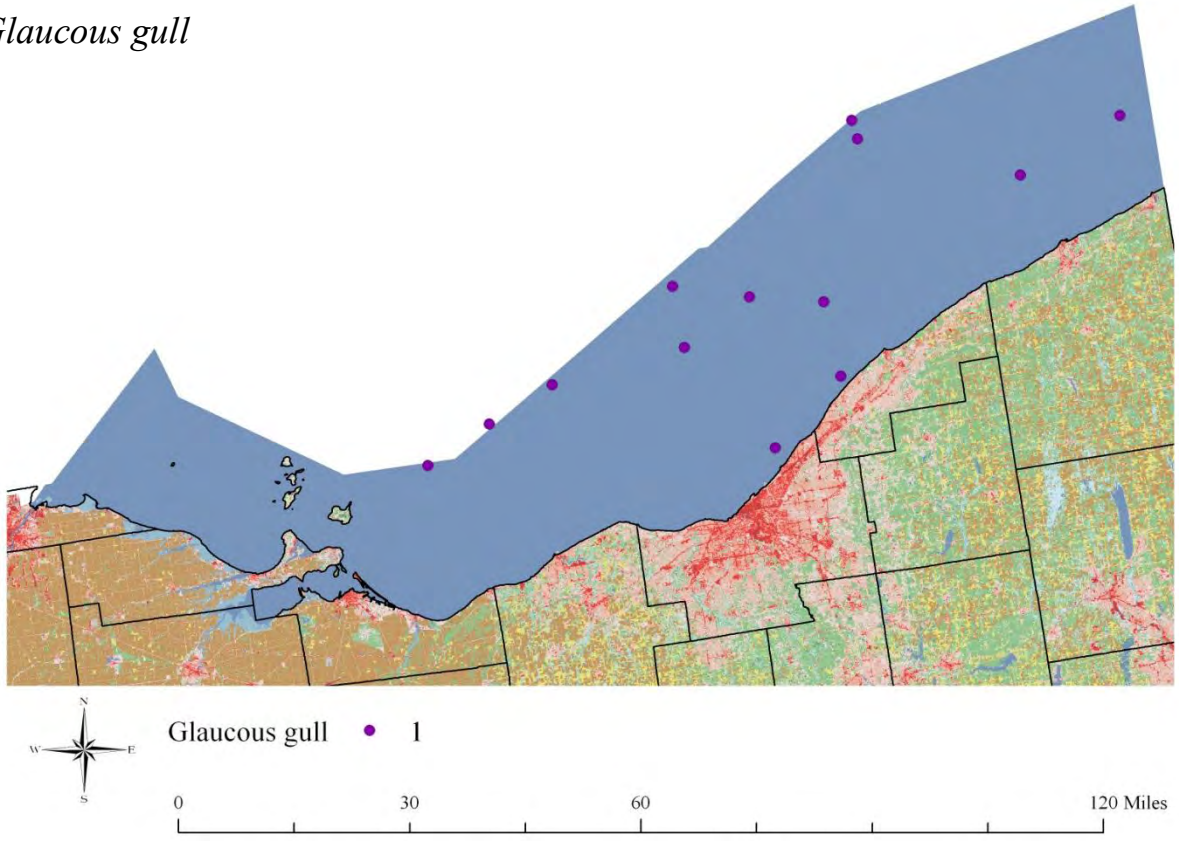


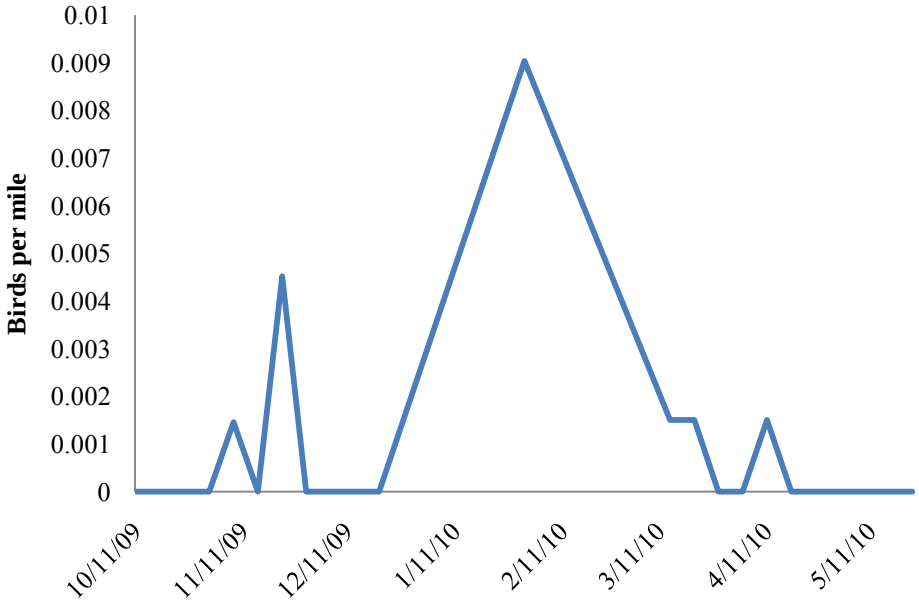


Number of double-crested cormorant observations by substrate type

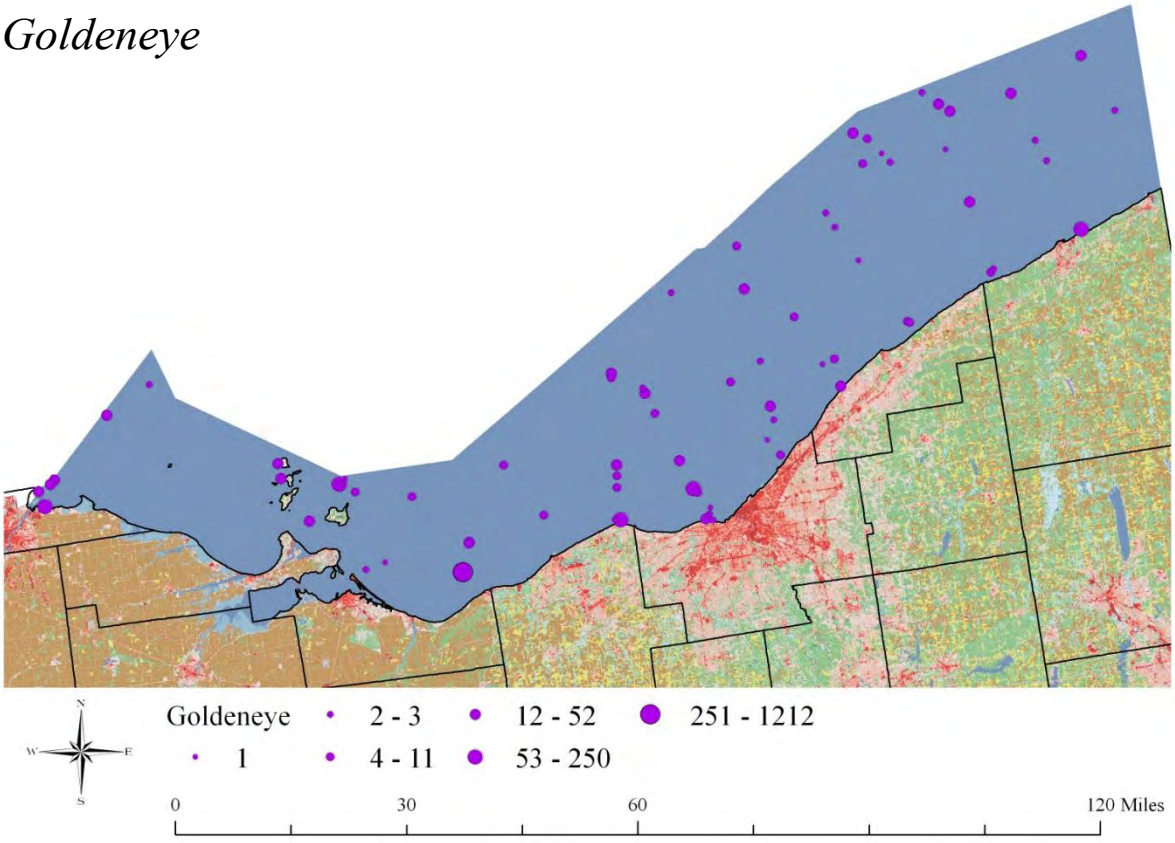

Double-crested cormorant
Number of birds
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

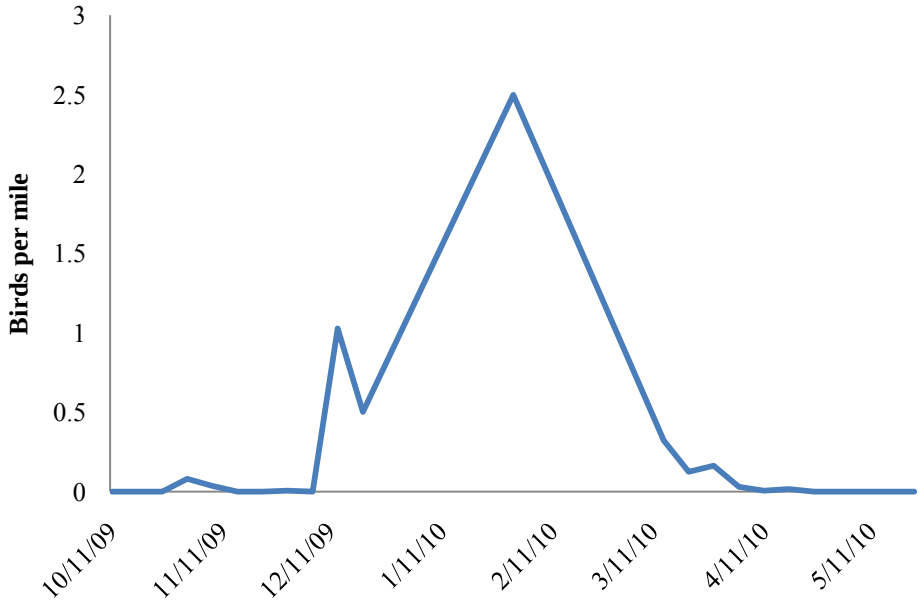
Glaucous gull

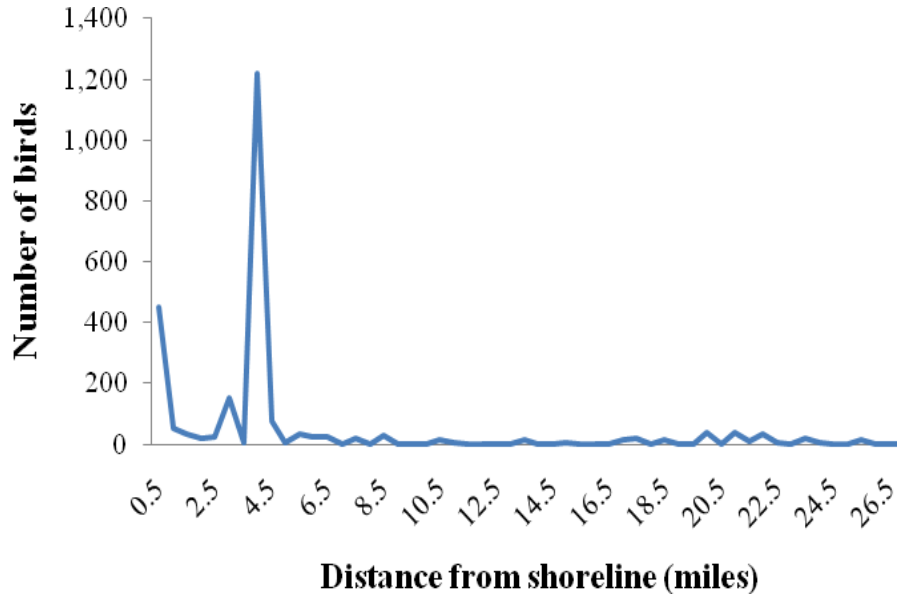


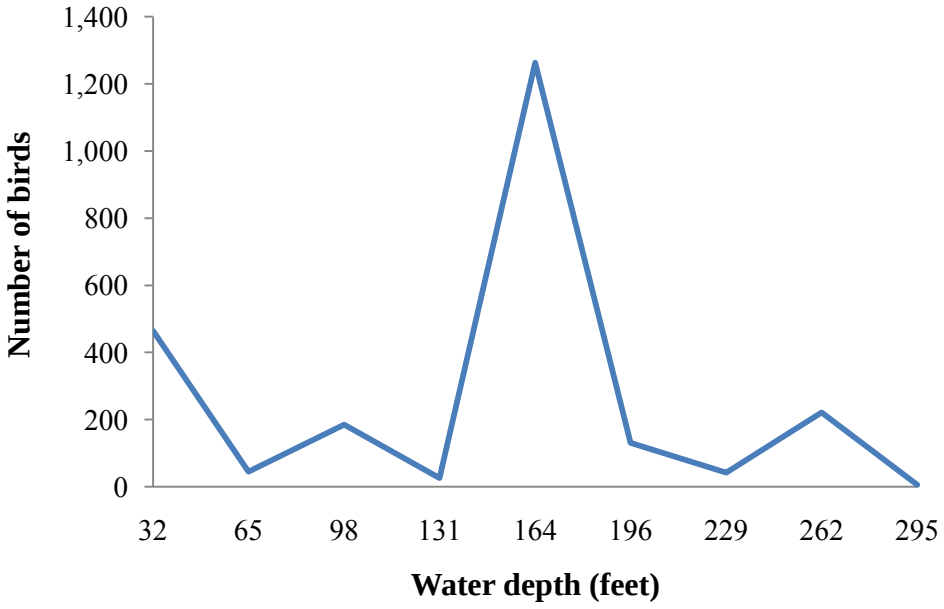


Goldeneye

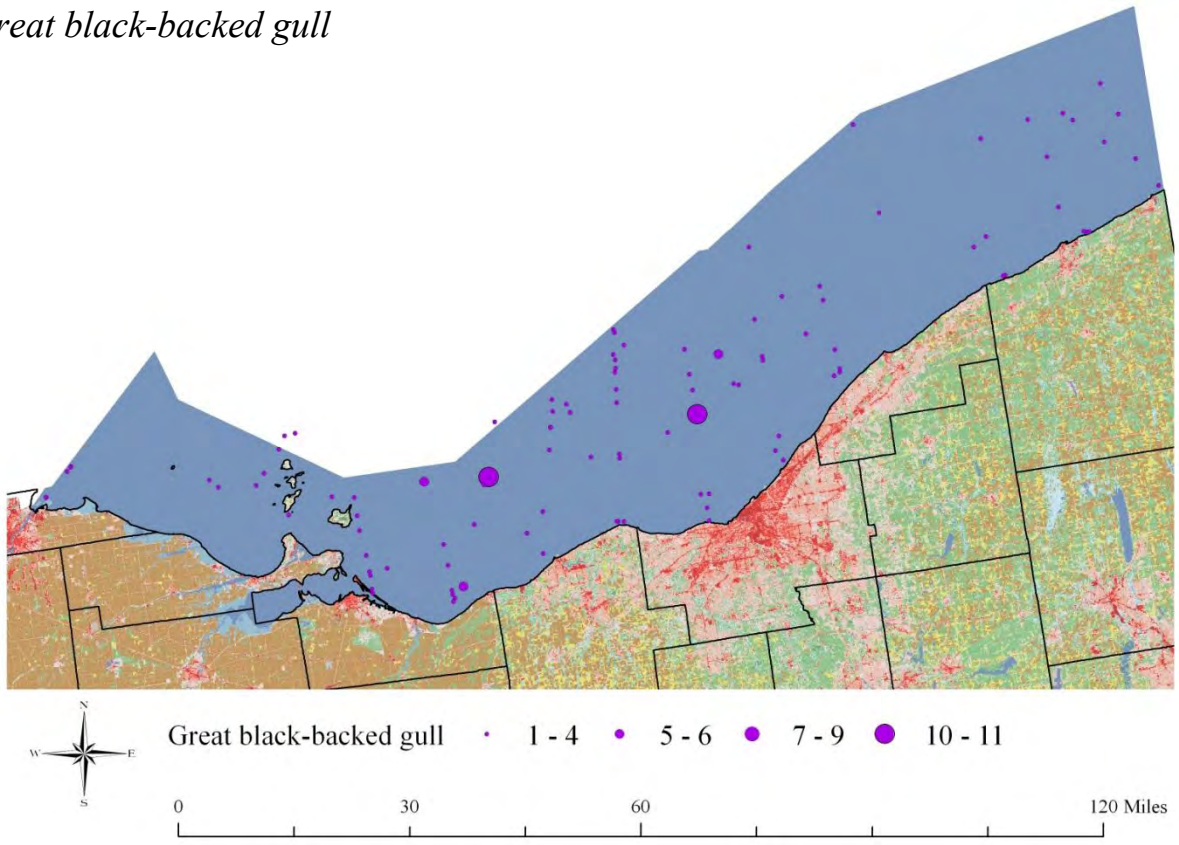

Goldeneye
1
2 - 3
4 - 11
12 - 52
53 - 250
251 - 1212
0
30
60
120 Miles

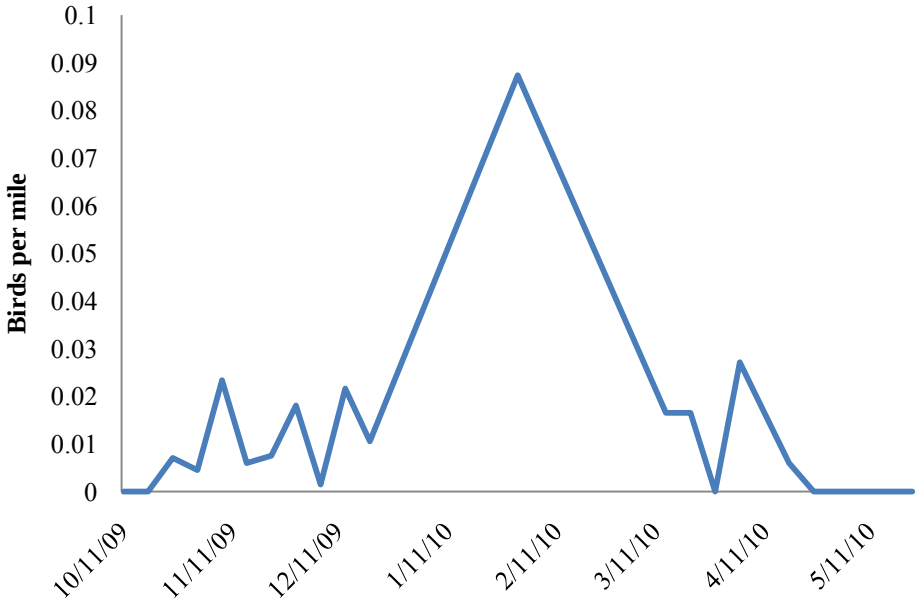

Birds per mile
3
2.5
2
1.5
1
0.5
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10


1,400
1,200
1,000
800
600
400
200
0
Number of birds
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
18.5
20.5
22.5
24.5
26.5
Distance from shoreline (miles)

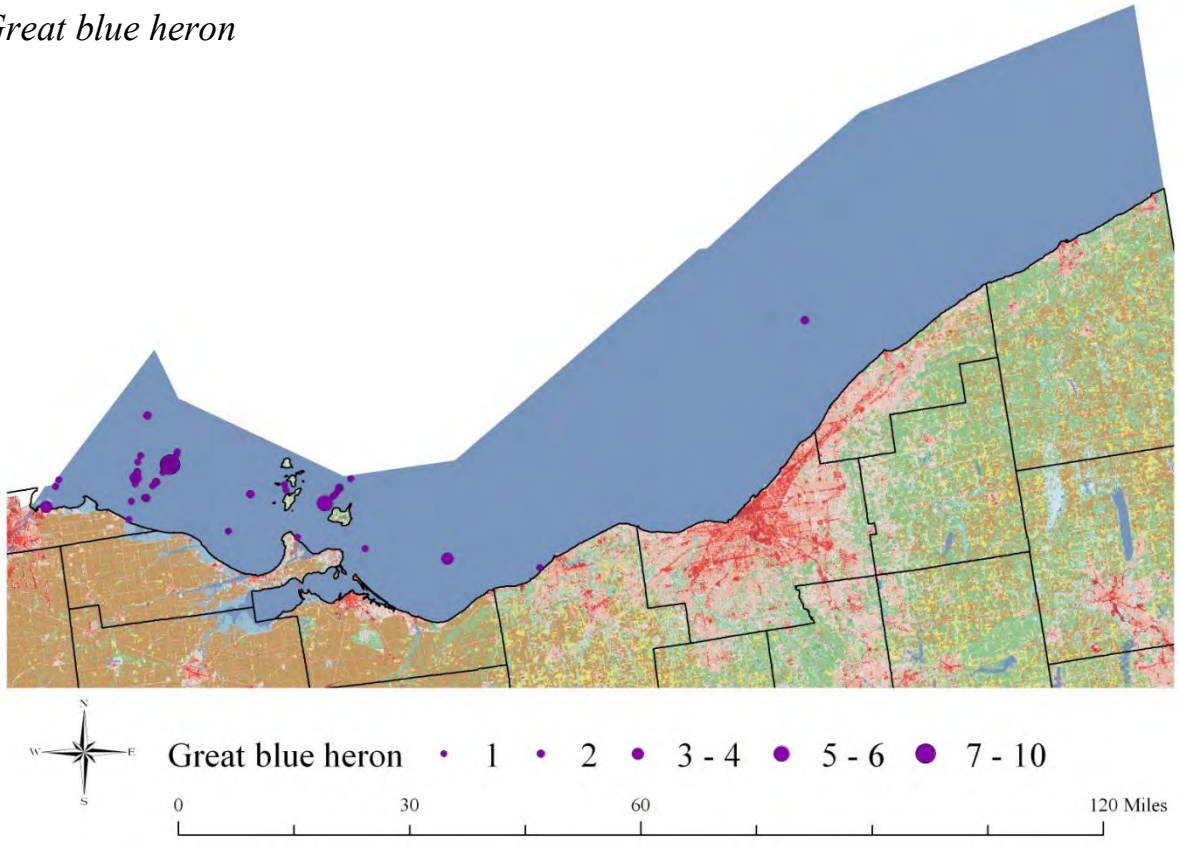

1,400
1,200
1,000
800
600
400
200
0
Number of birds
32
65
98
131
164
196
229
262
295
Water depth (feet)

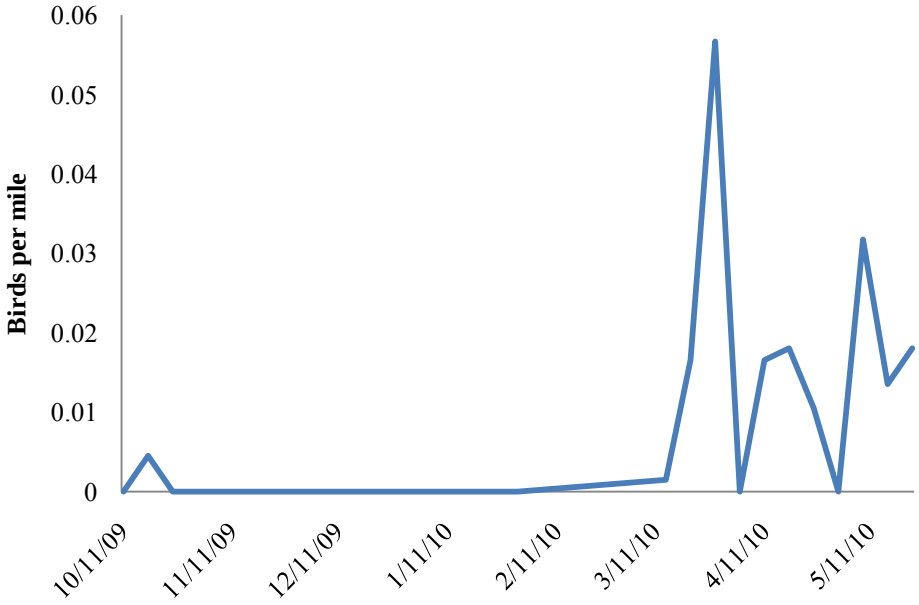
Great black-backed gull



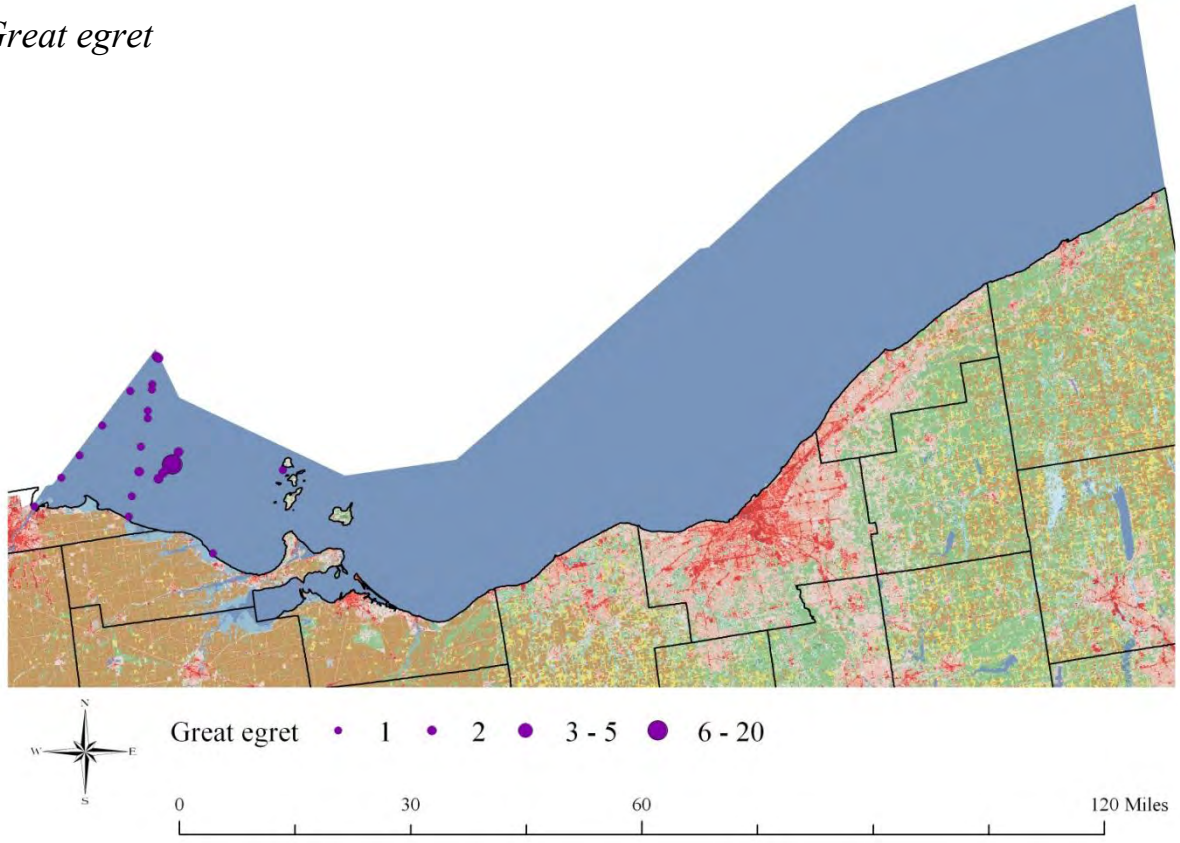


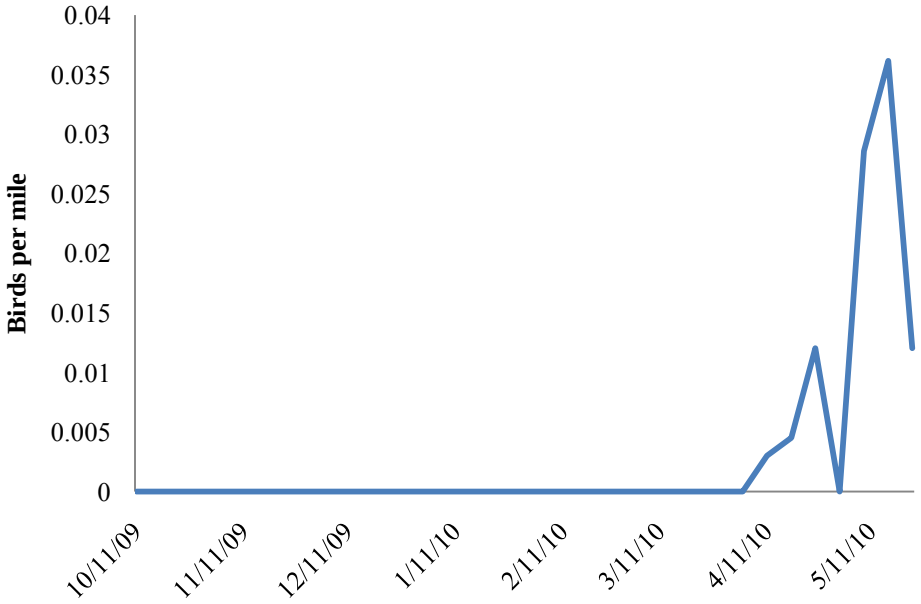
Great blue heron



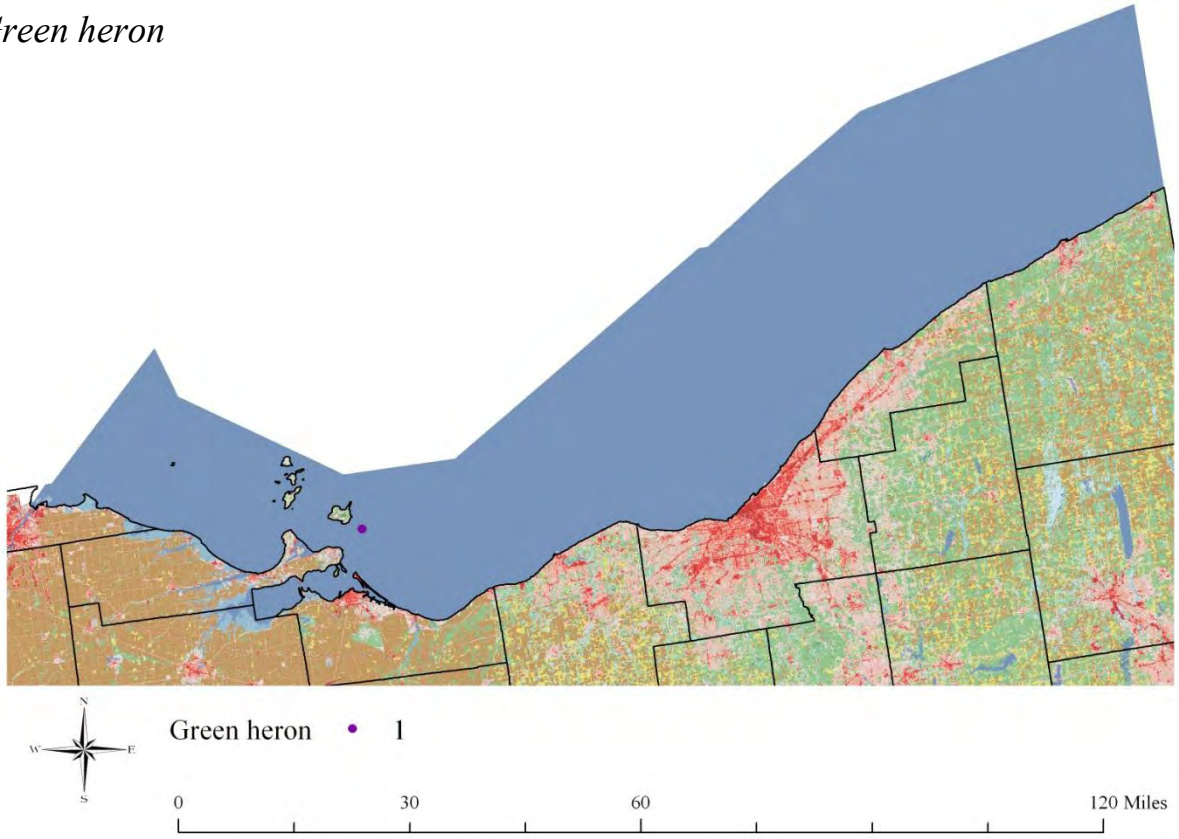


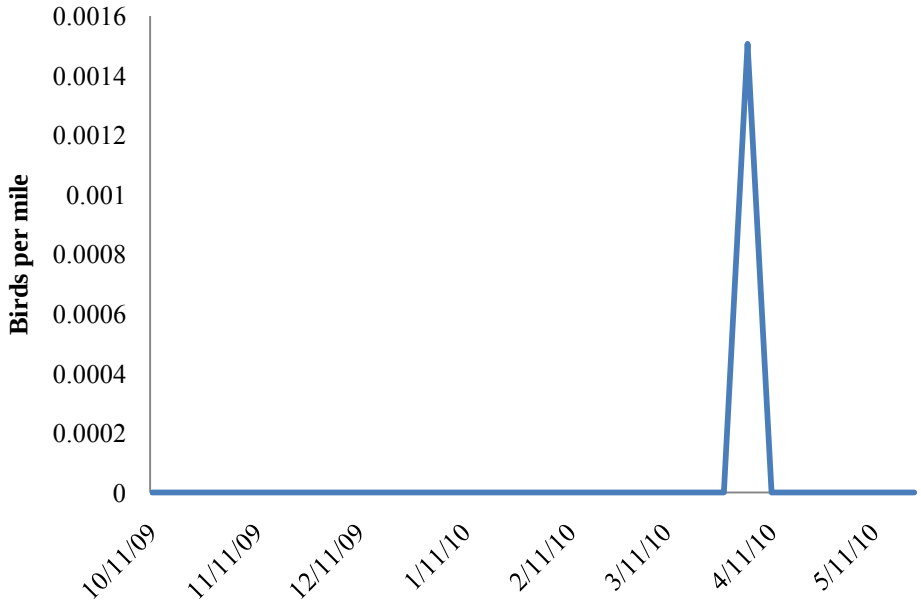
Great egret


Great egret
1
2
3 - 5
6 - 20
0
30
60
120 Miles

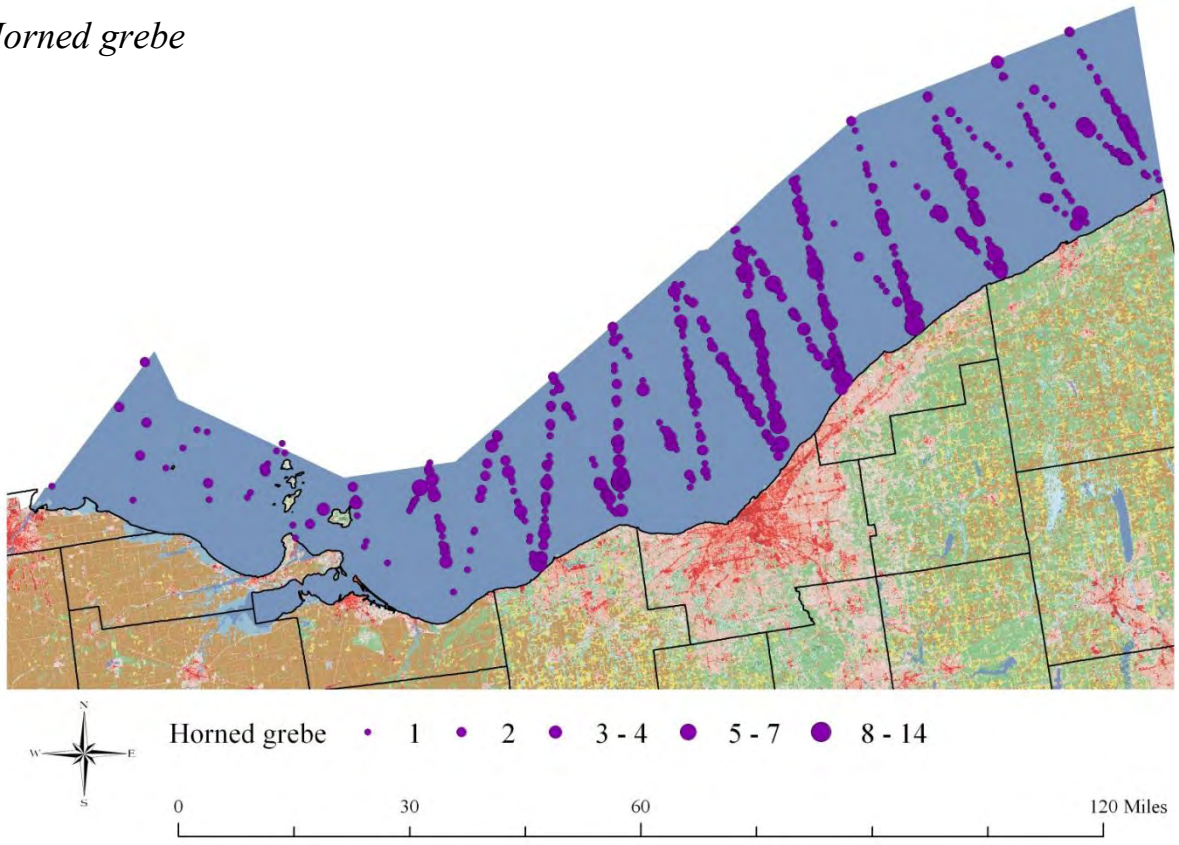

Birds per mile
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

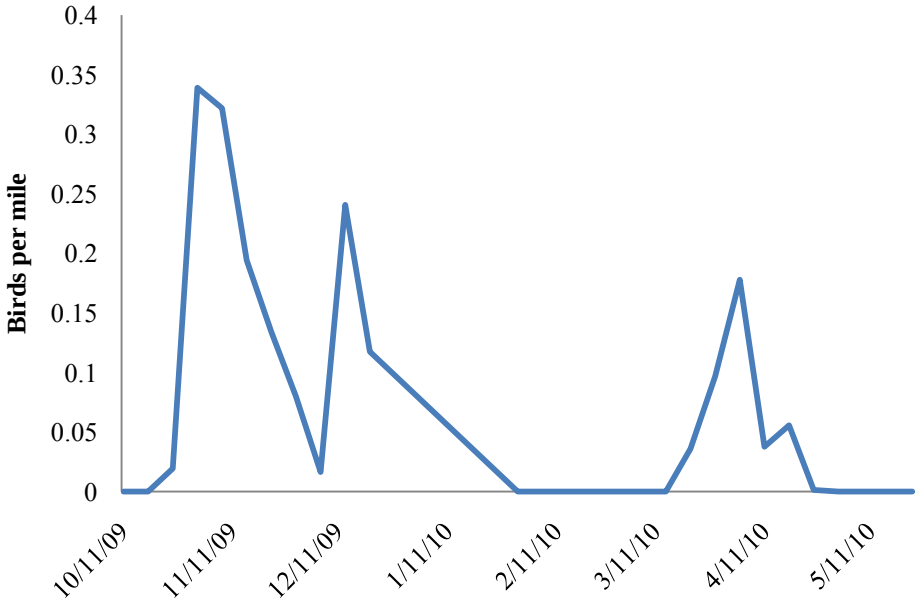
Green heron

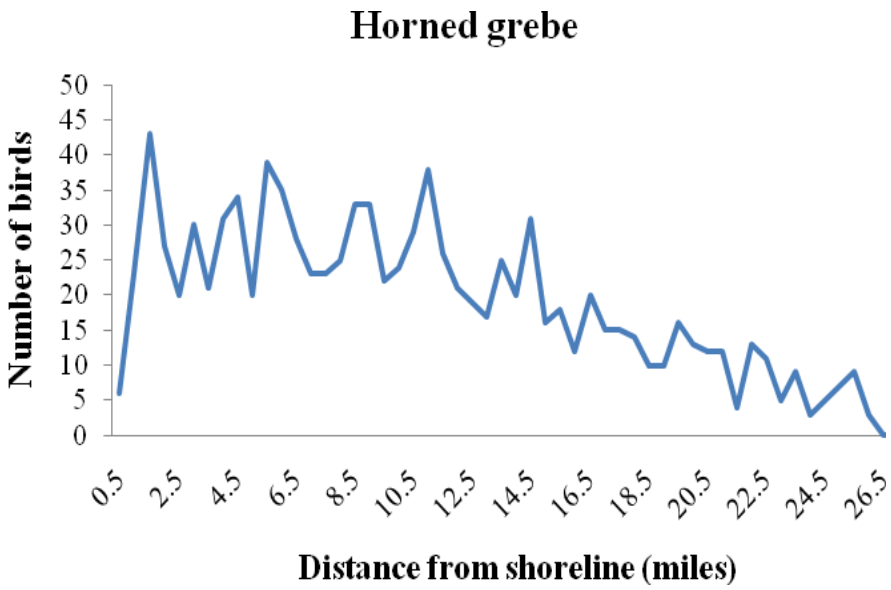

N
W
E
S
Green heron
1
0
30
60
120 Miles

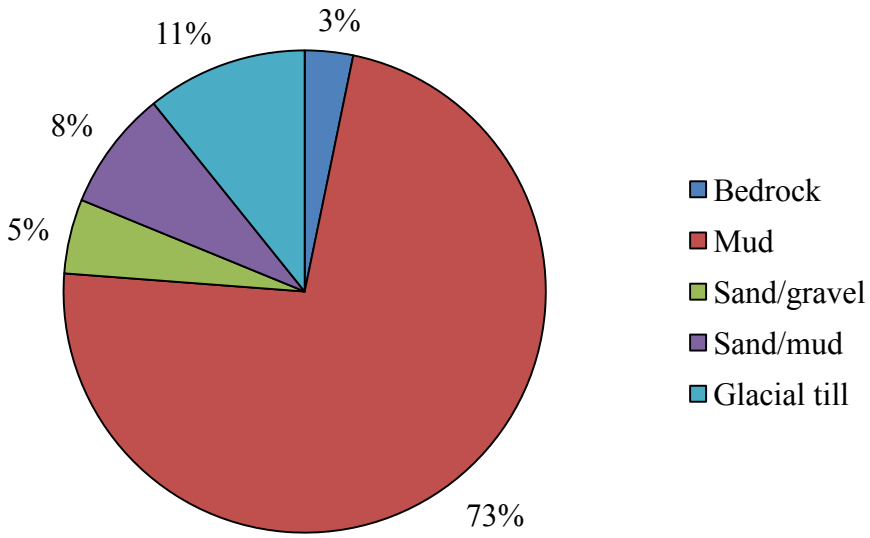

Birds per mile
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

Horned grebe

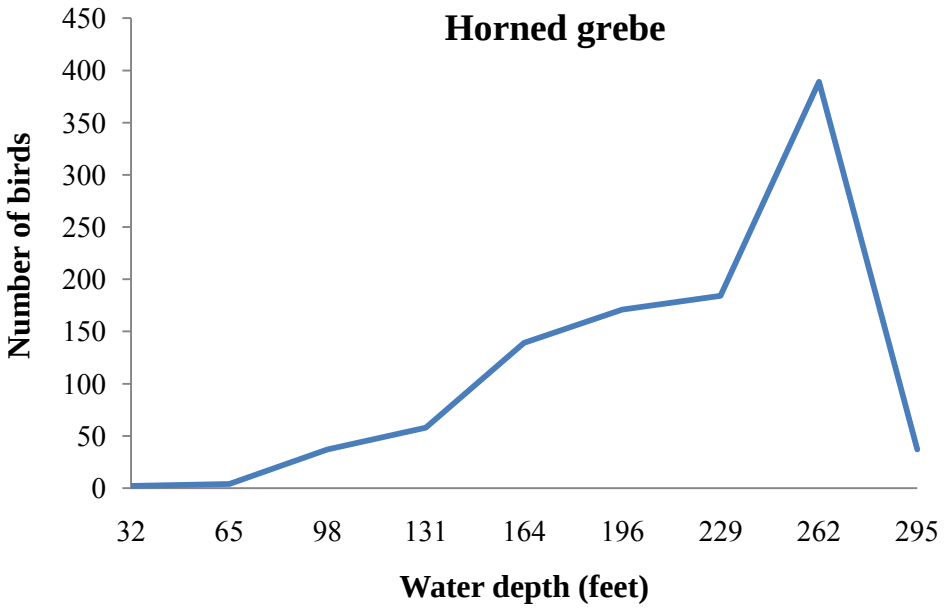




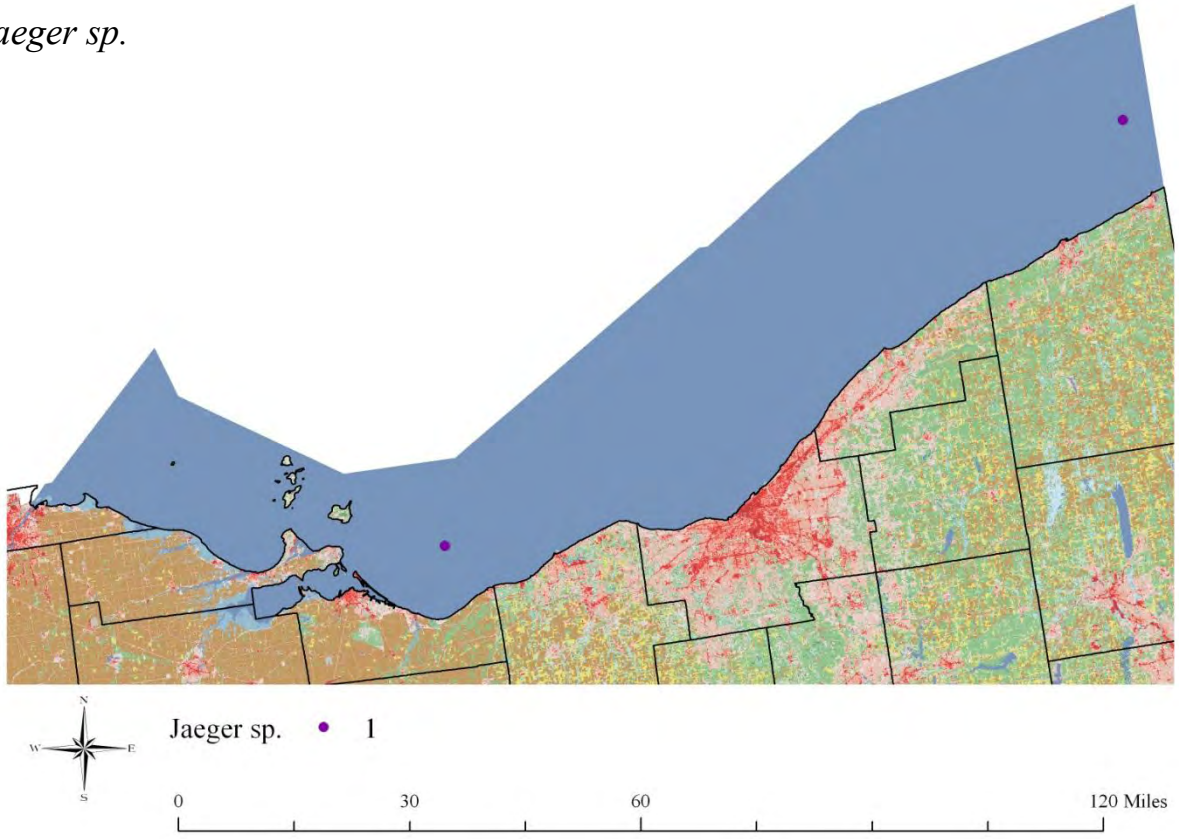


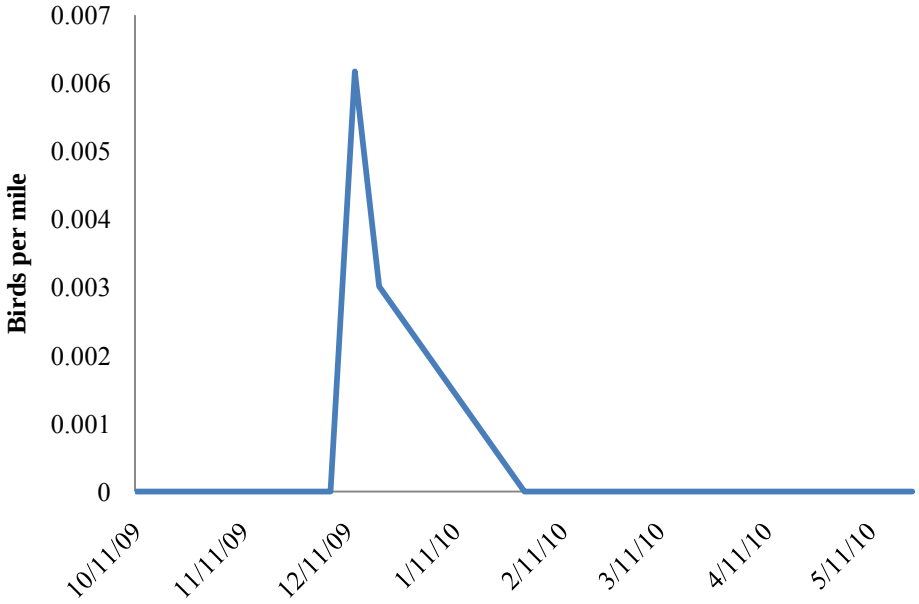


Number of horned grebe observations by substrate type

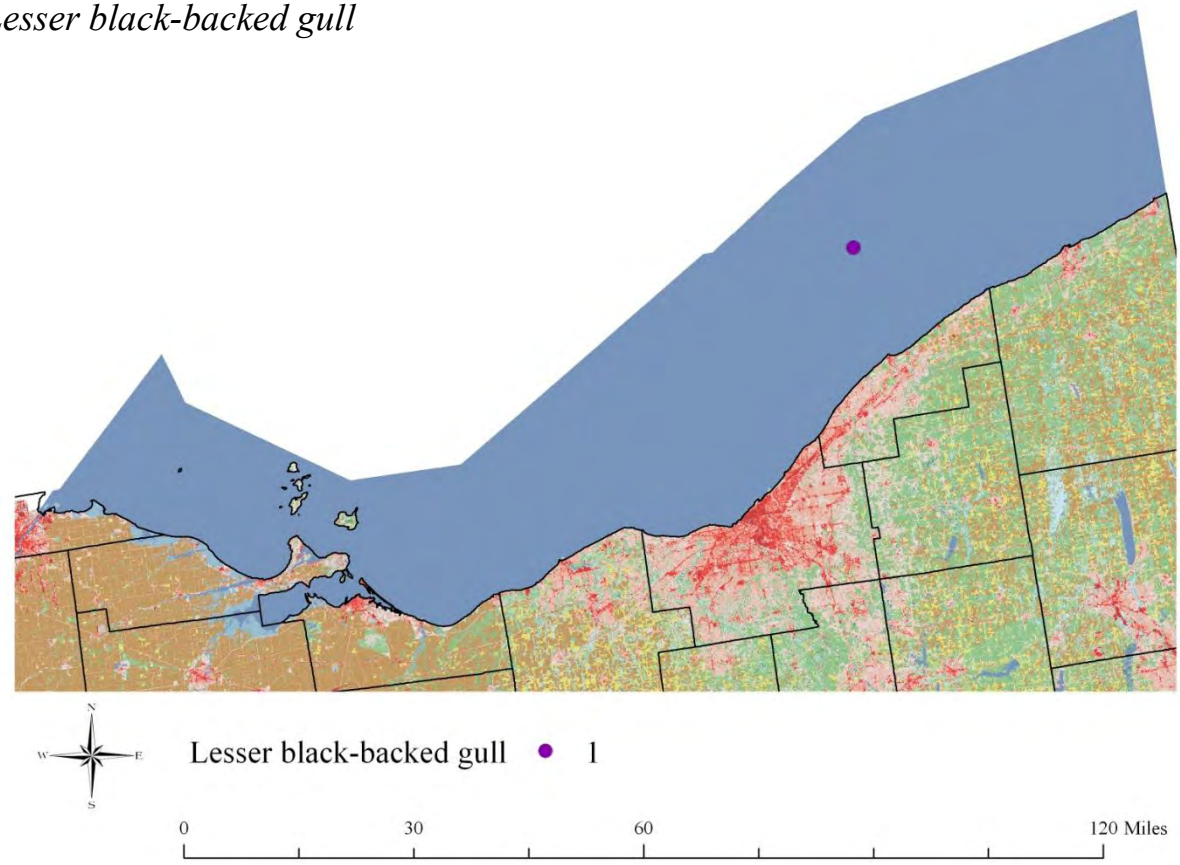

Horned grebe
Number of birds
450
400
350
300
250
200
150
100
50
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

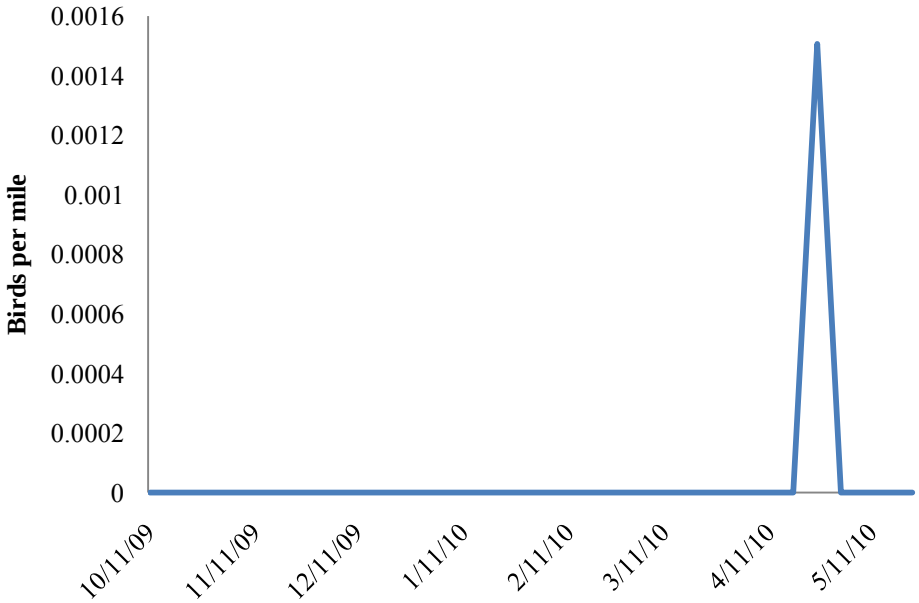
Jaeger sp.


N
W
E
S
Jaeger sp.
1
0
30
60
120 Miles

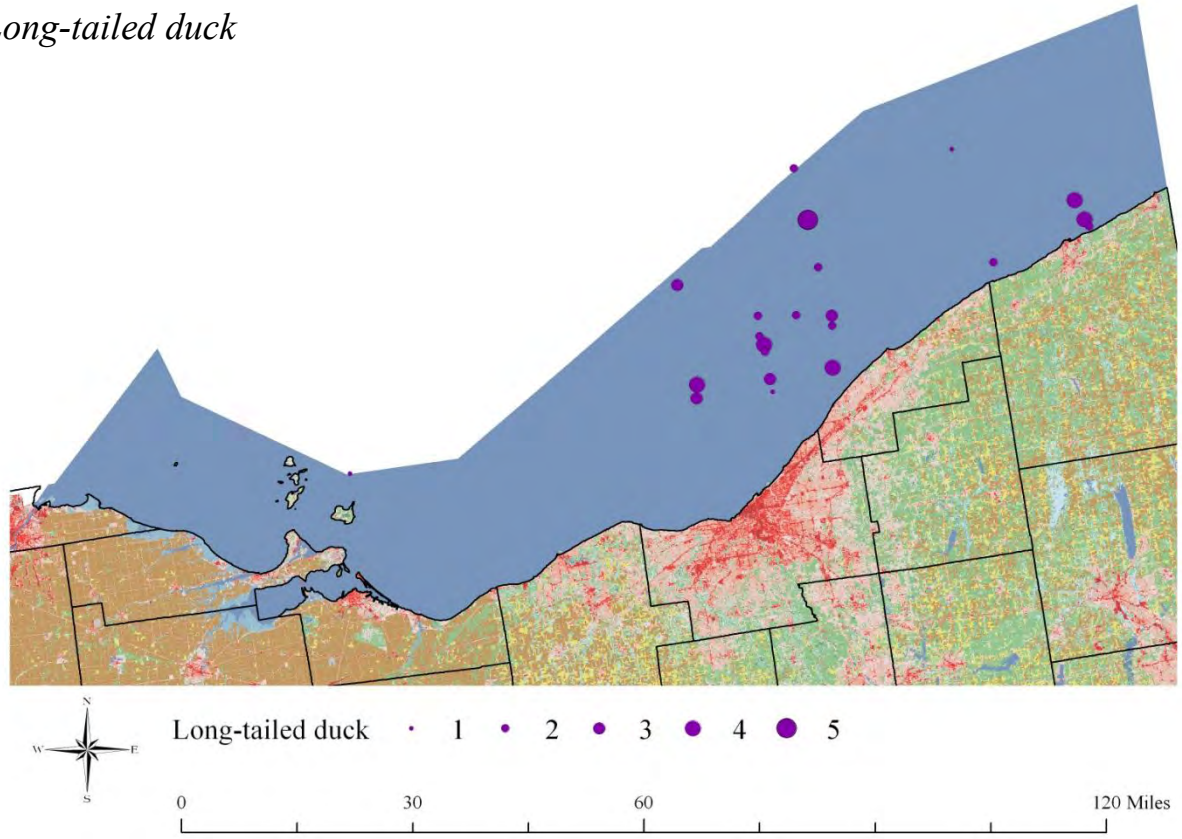

Birds per mile
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

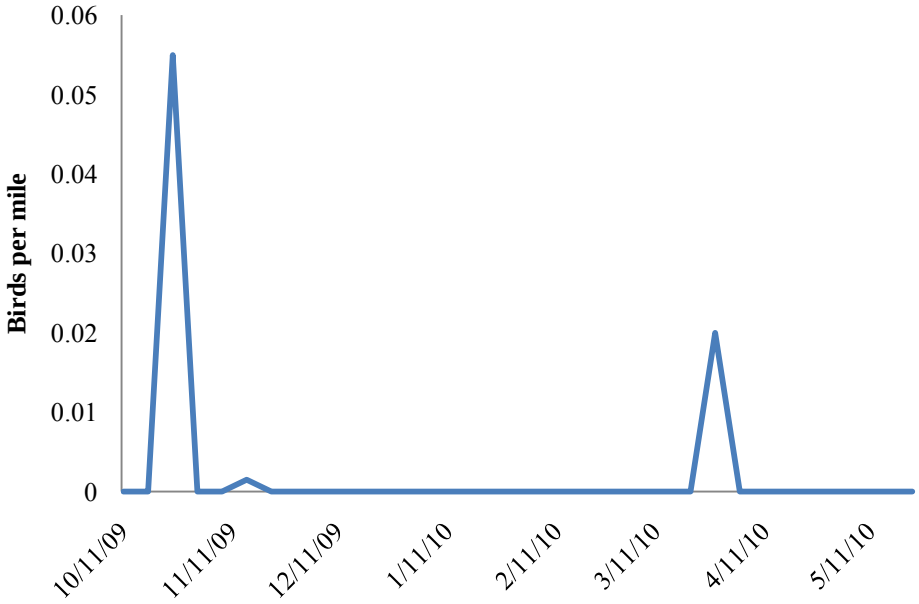
Lesser black-backed gull

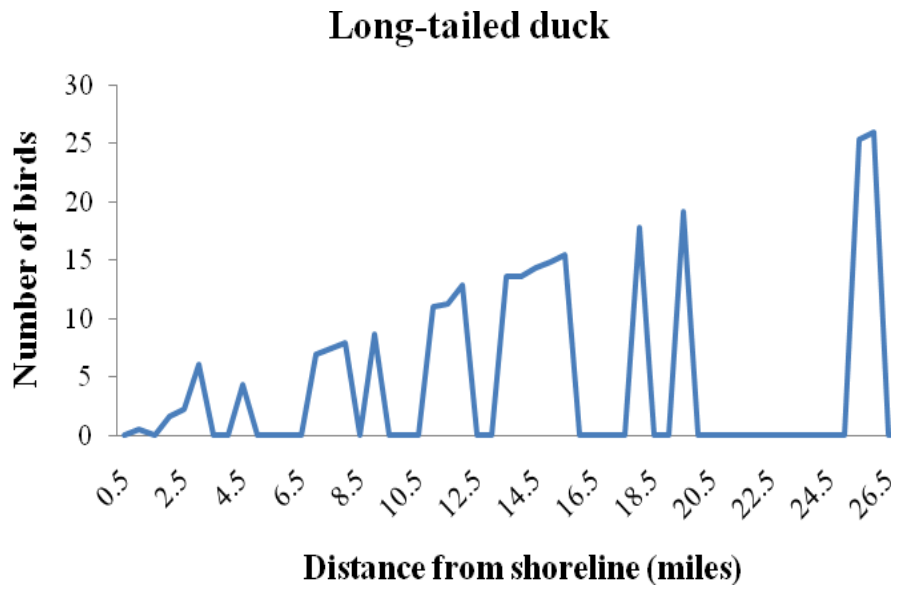


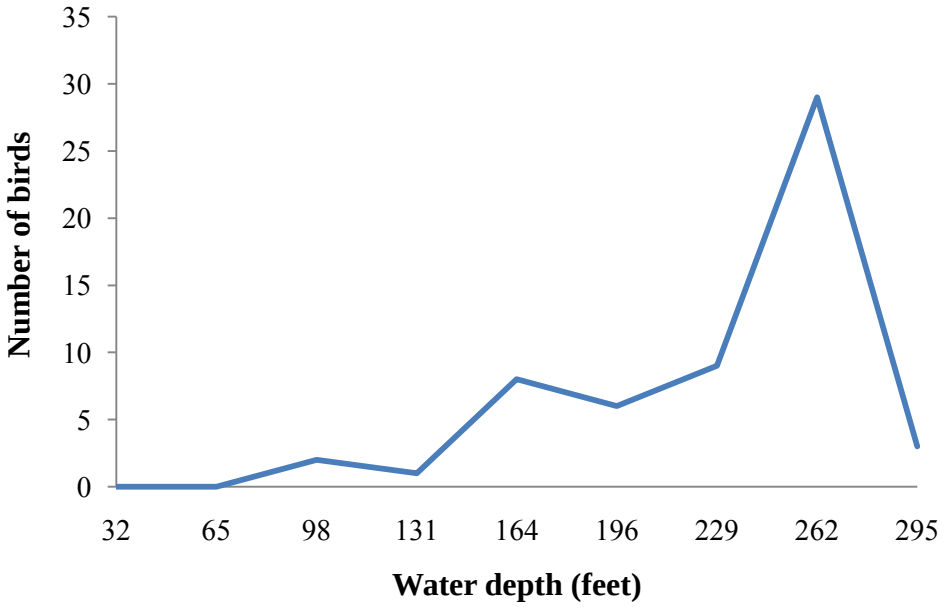


Long-tailed duck

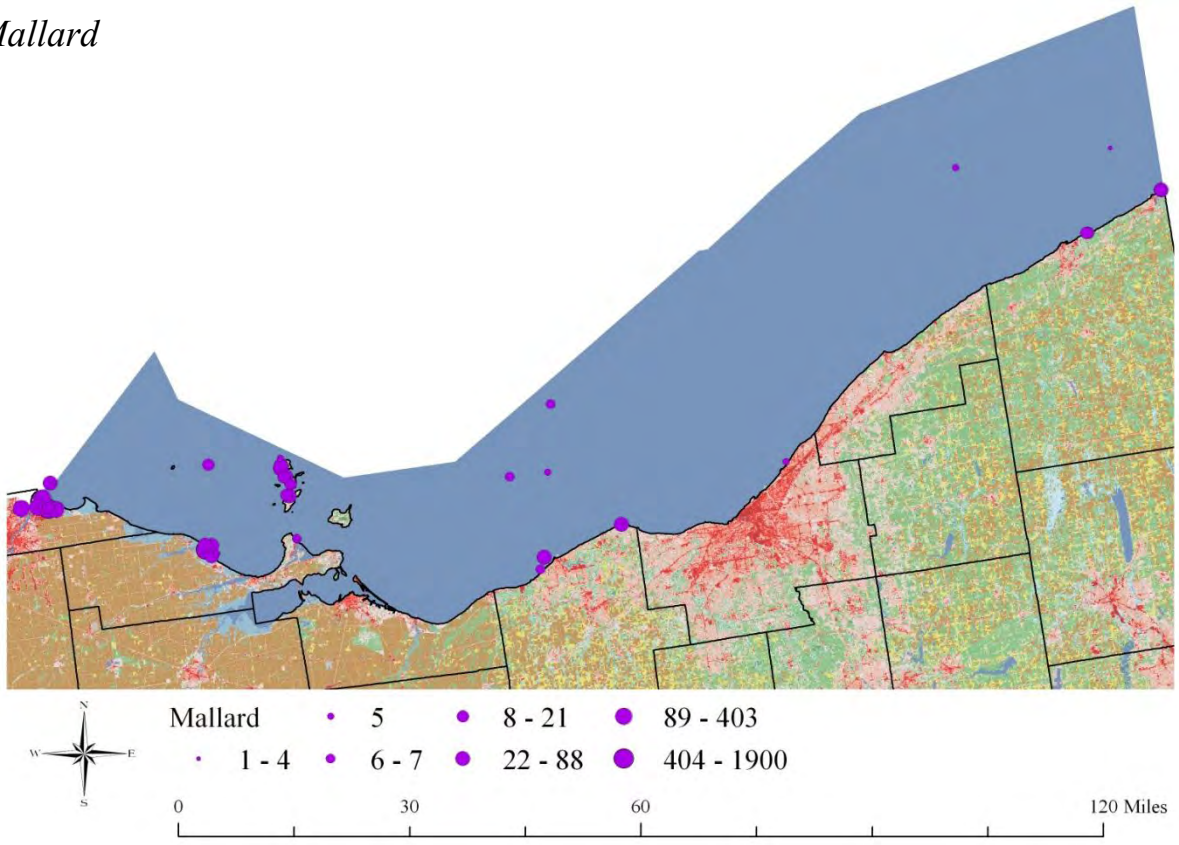


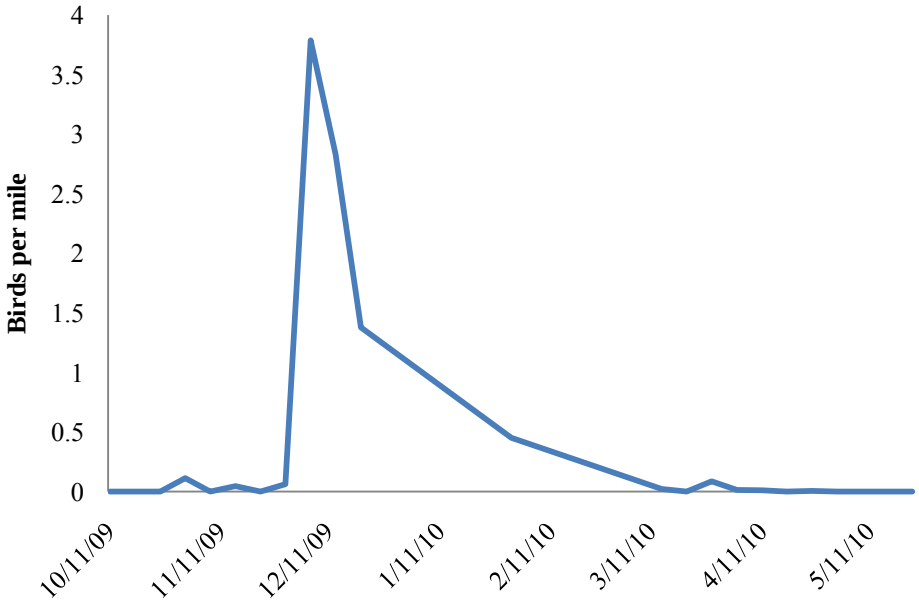


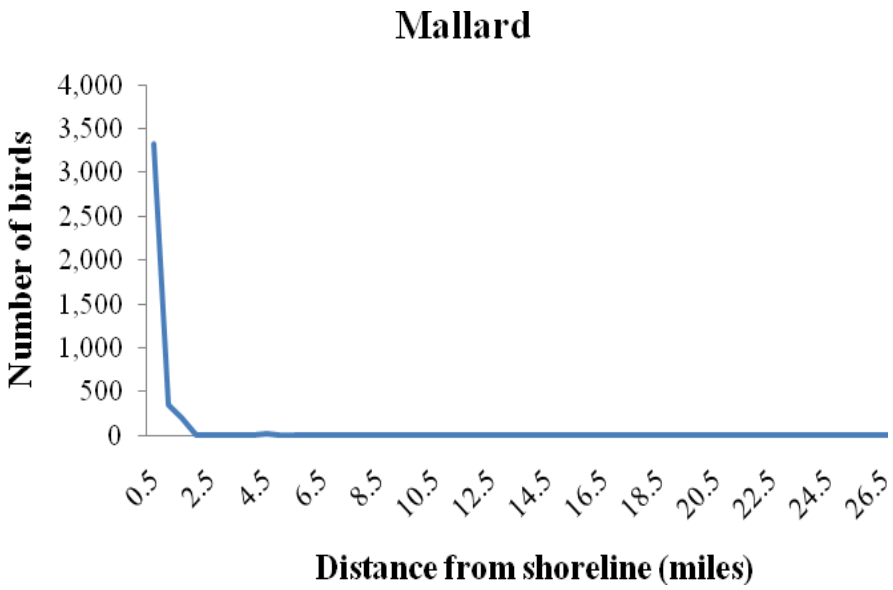

Long-tailed duck
Number of birds
30
25
20
15
10
5
0
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
18.5
20.5
22.5
24.5
26.5
Distance from shoreline (miles)

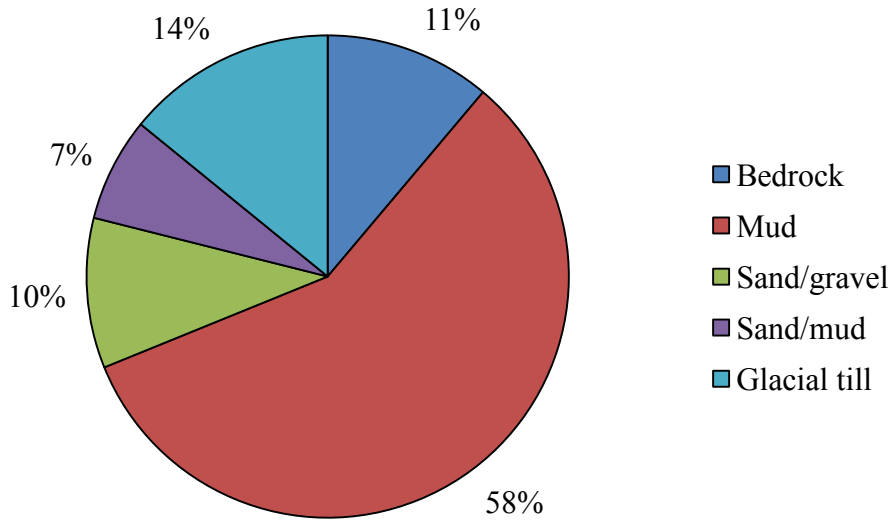

Number of birds
35
30
25
20
15
10
5
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

Mallard

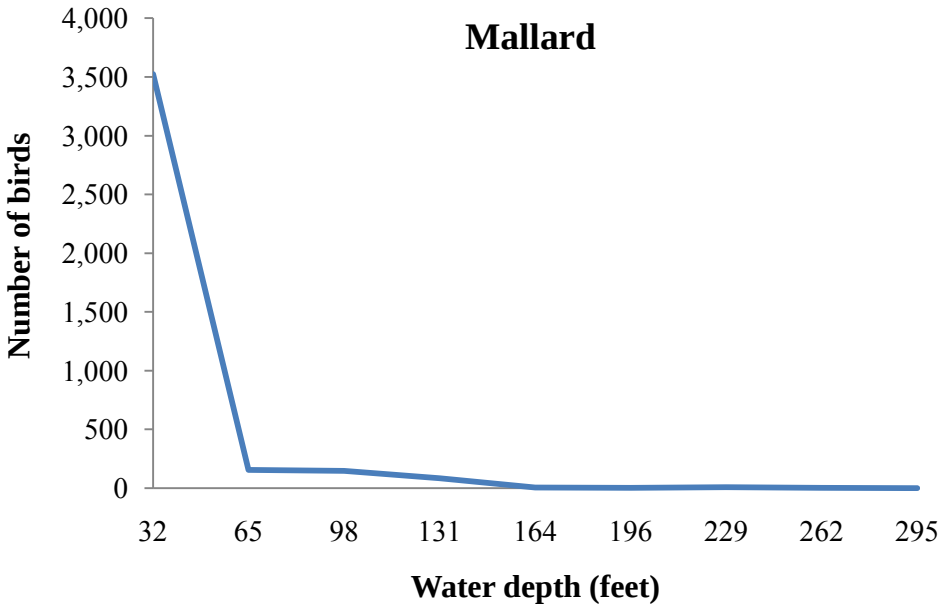

Mallard
1 - 4
5
6 - 7
8 - 21
22 - 88
89 - 403
404 - 1900
0
30
60
120 Miles


Birds per mile
4
3.5
3
2.5
2
1.5
1
0.5
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

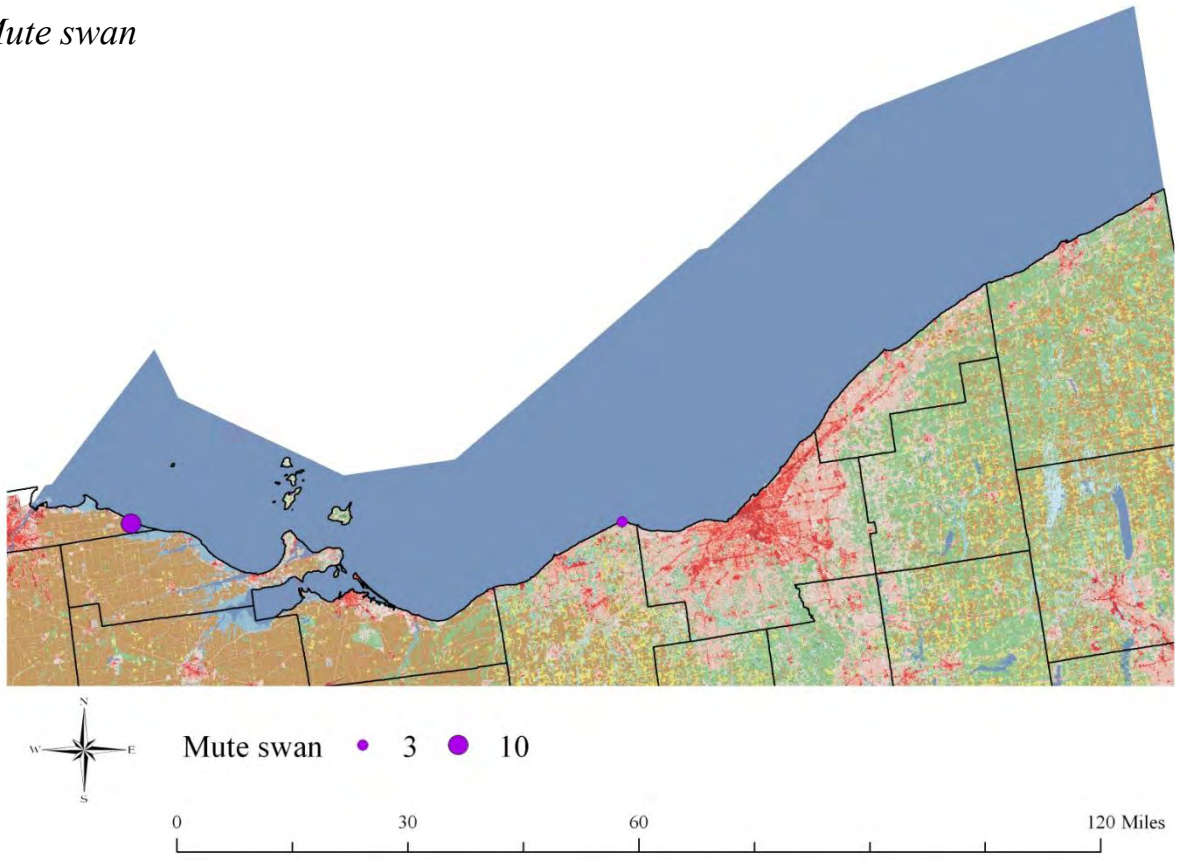


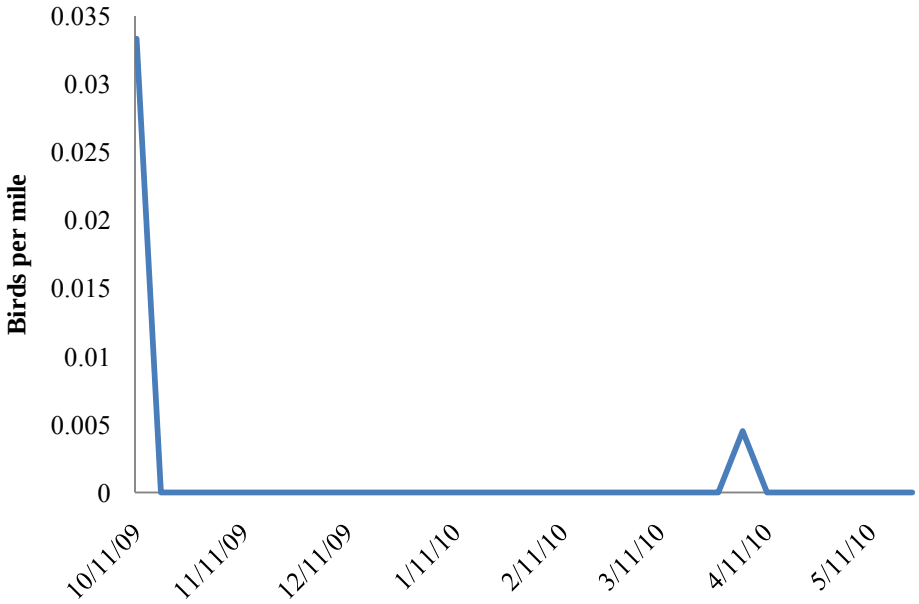


Number of mallard observations by substrate type

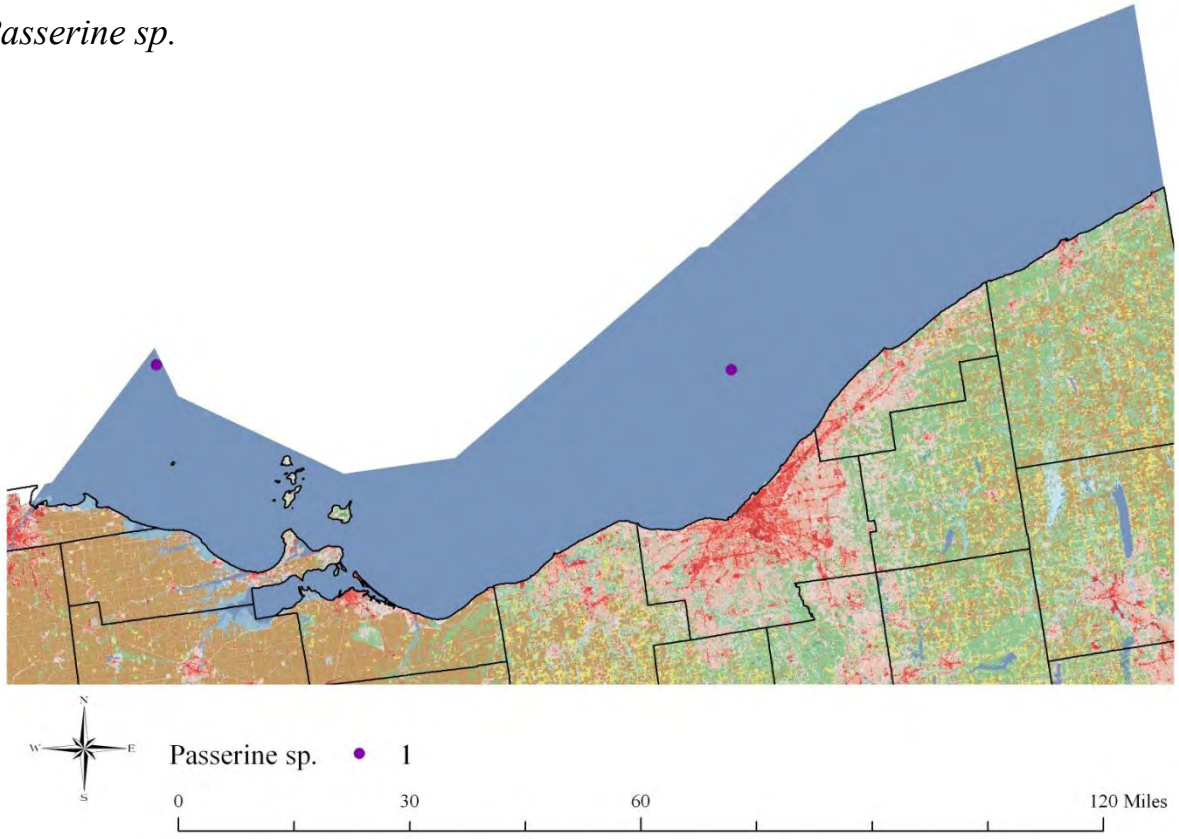

Mallard
Number of birds
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

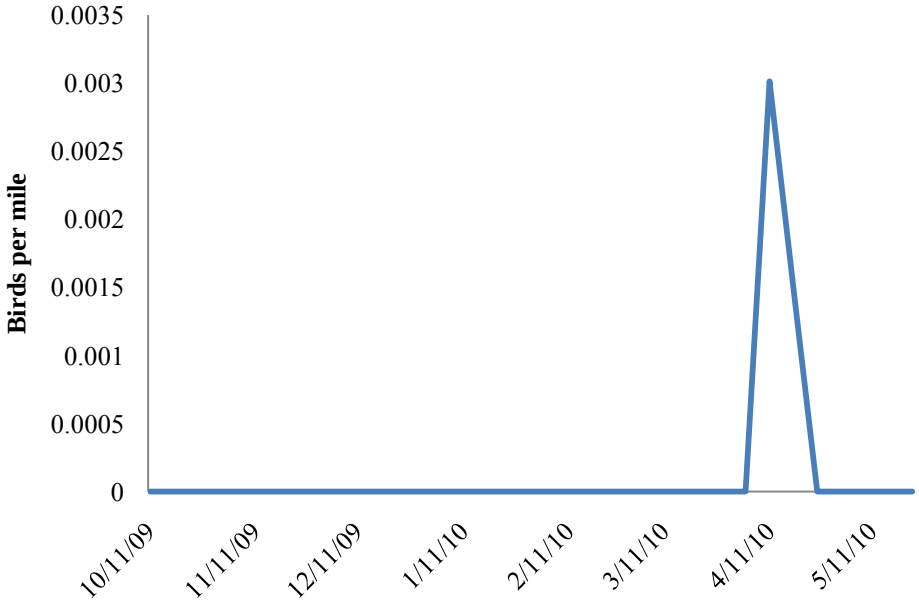
Mute swan


N
W
E
S
Mute swan
3
10
0
30
60
120 Miles

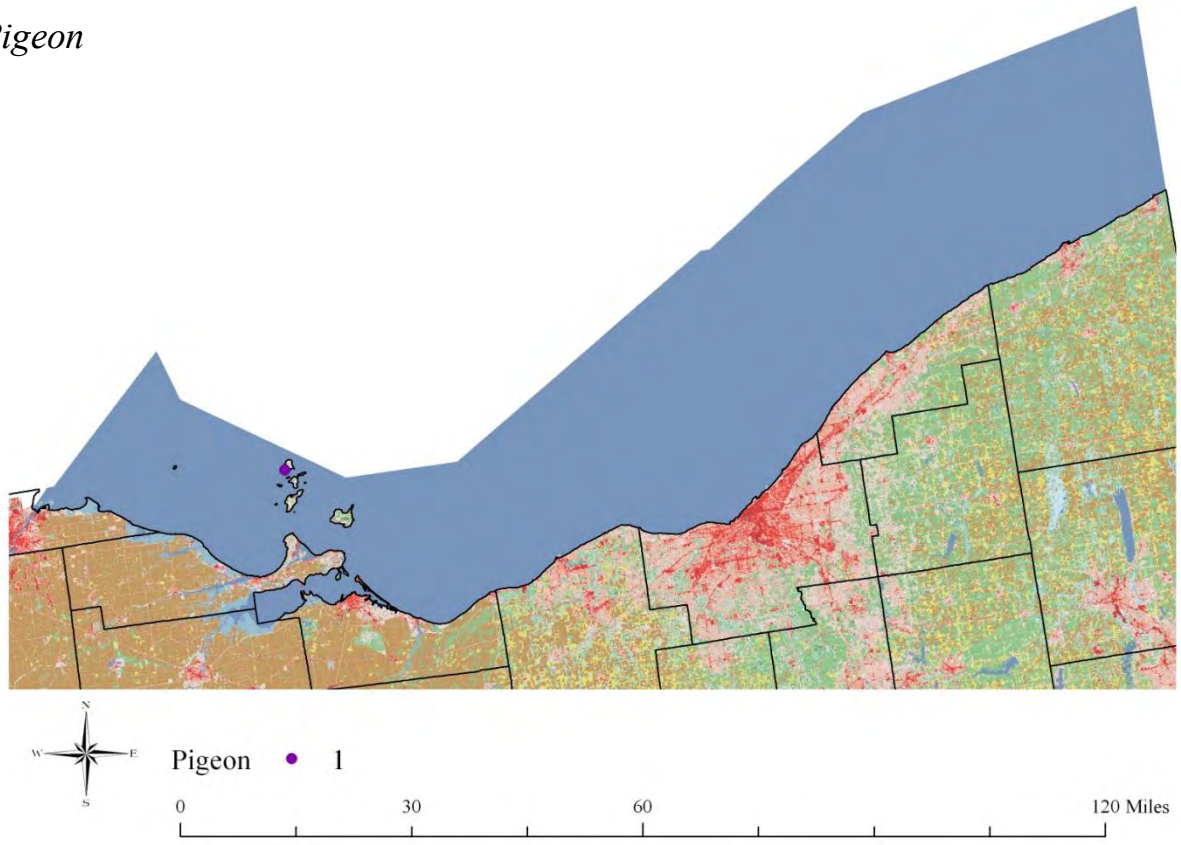

Birds per mile
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

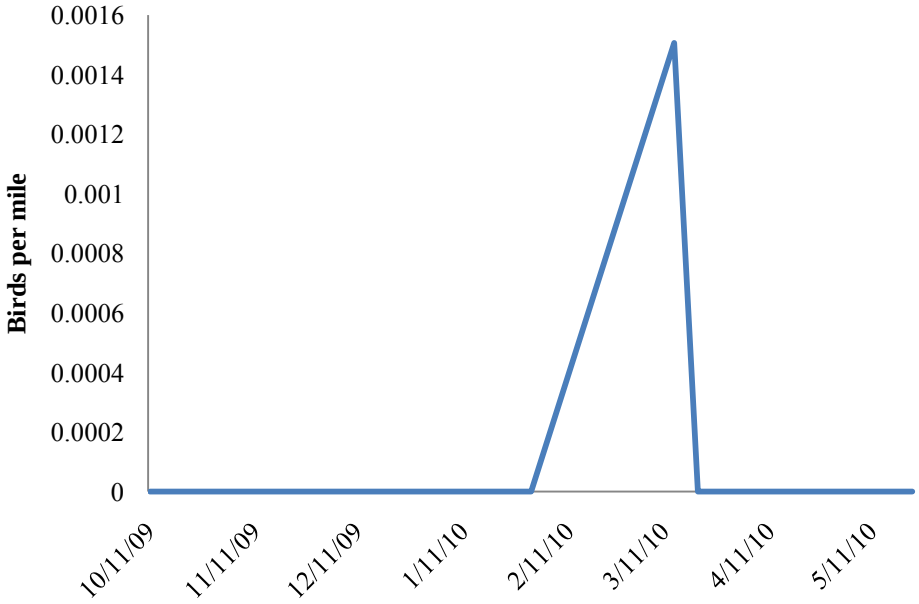
Passerine sp.



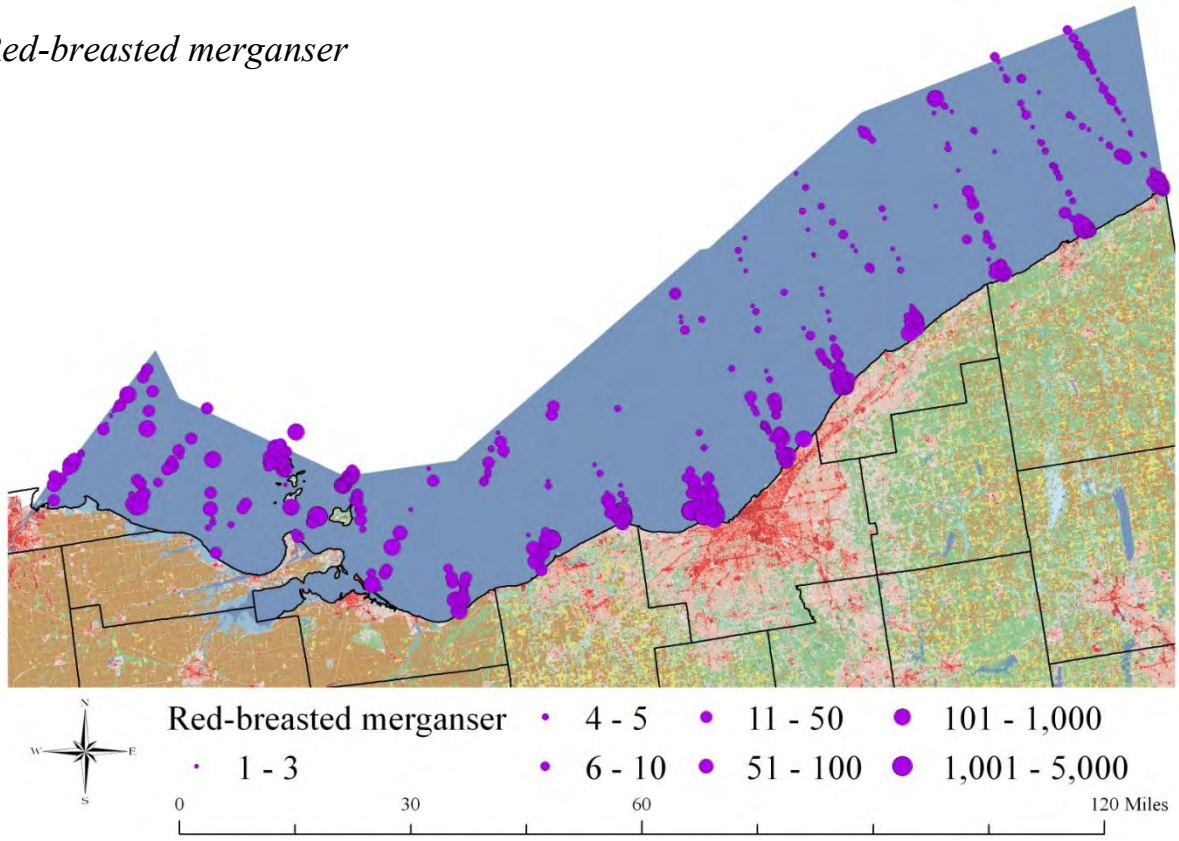


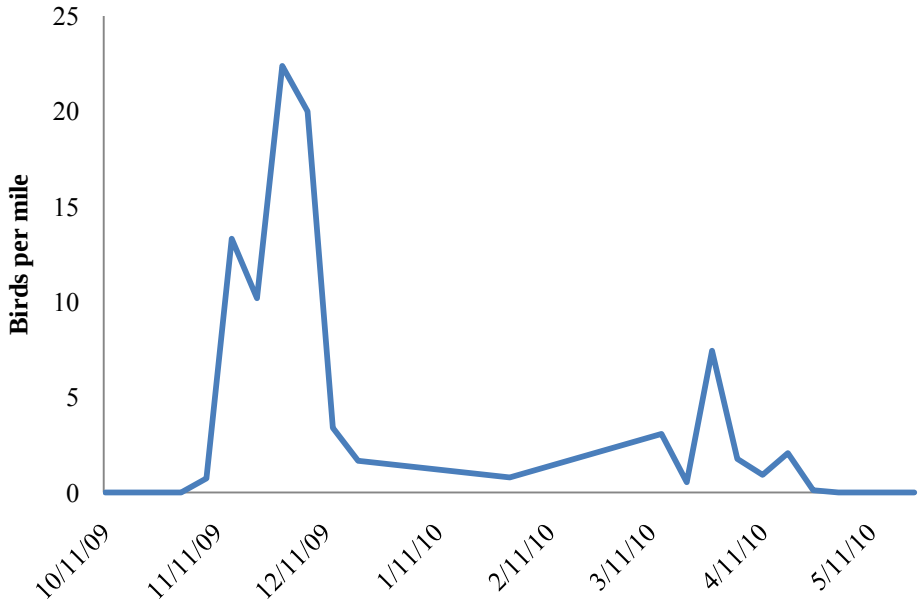
Pigeon

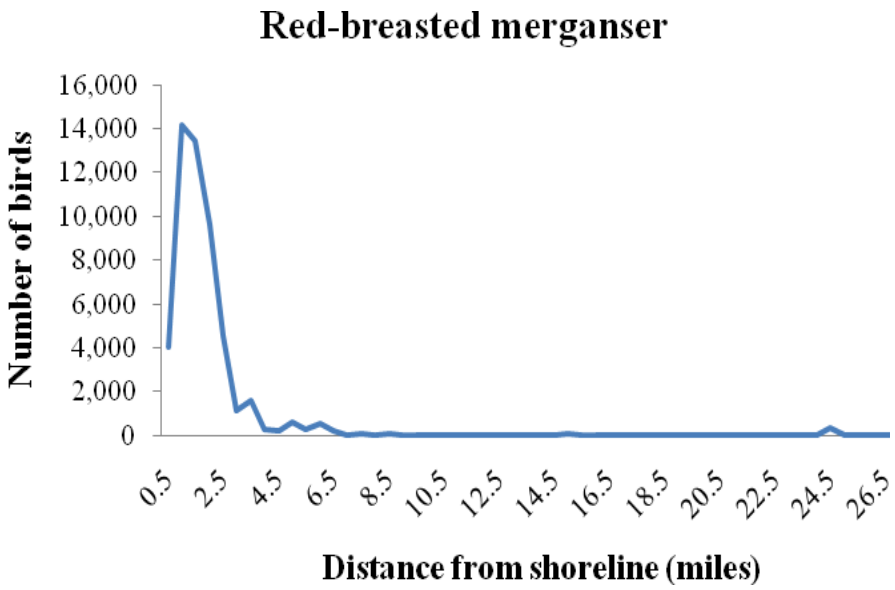

N
W
E
S
Pigeon
1
0
30
60
120 Miles

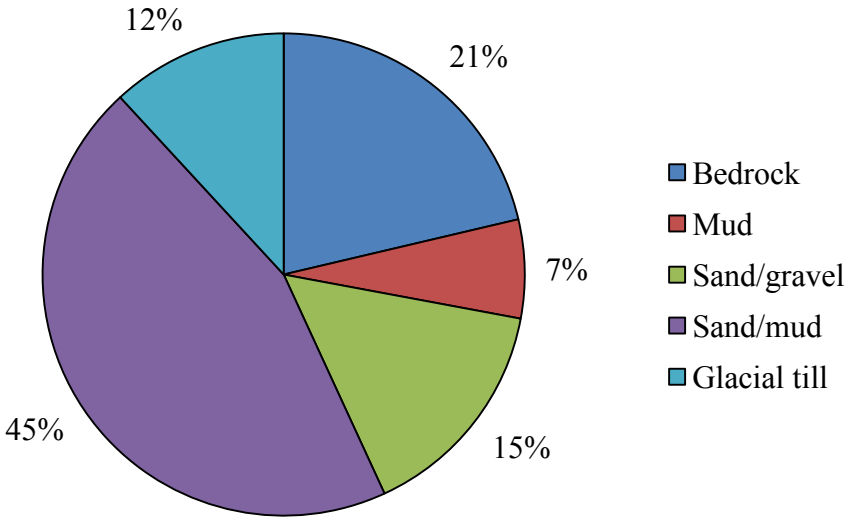

Birds per mile
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

Red-breasted merganser

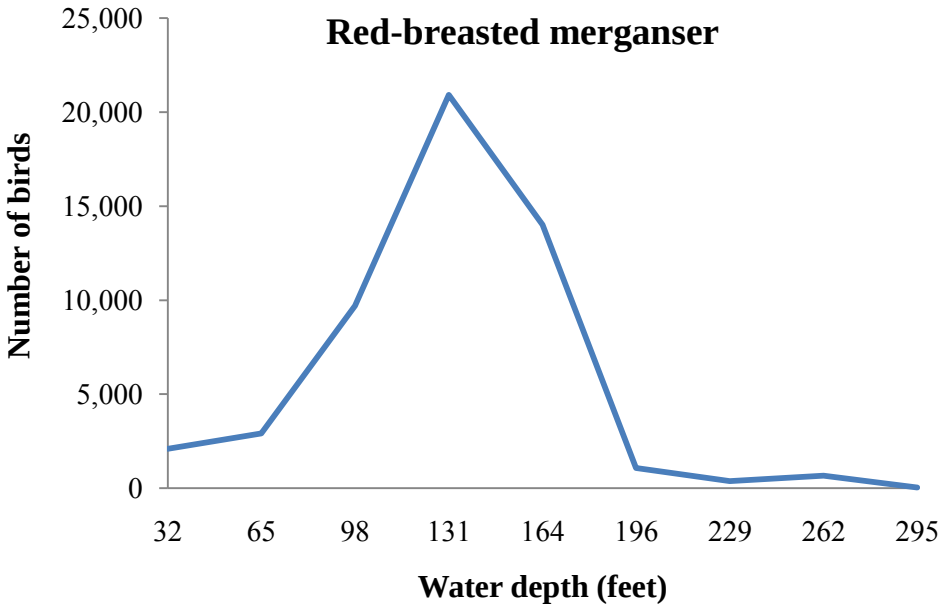




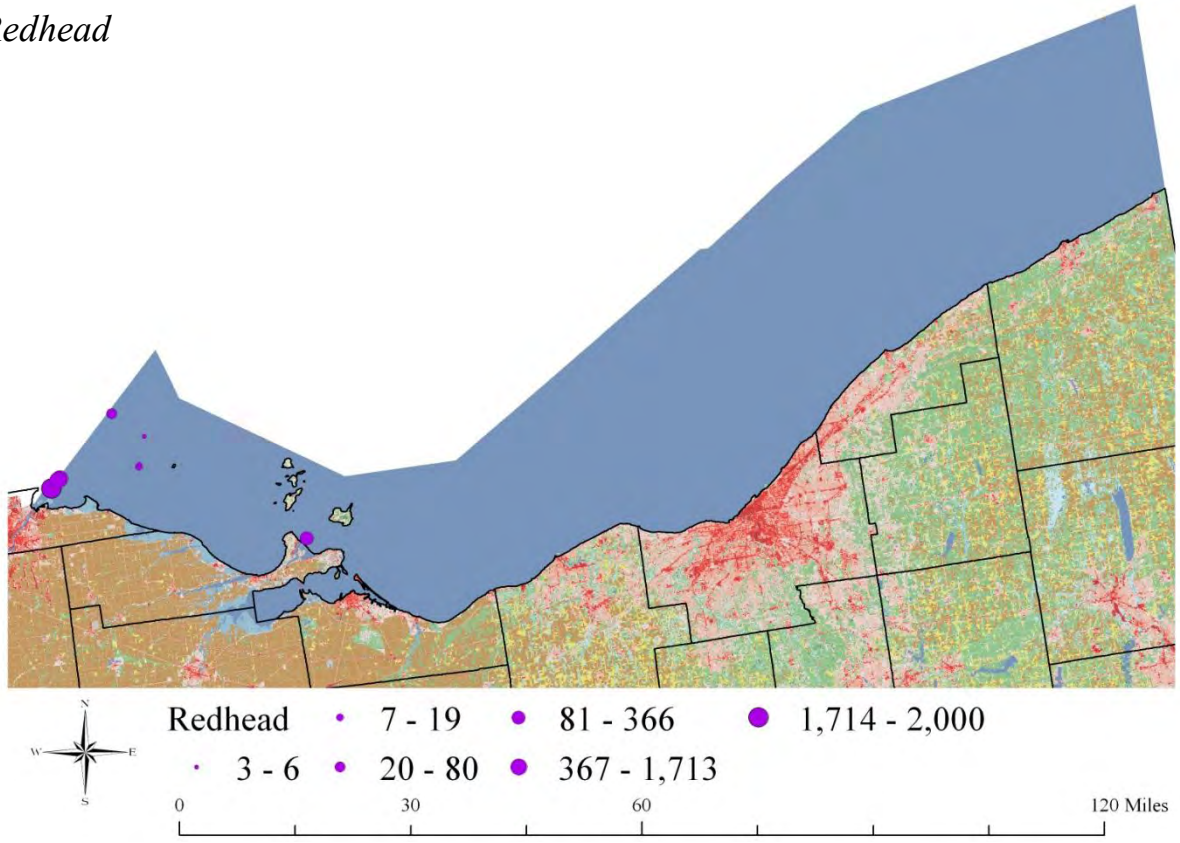


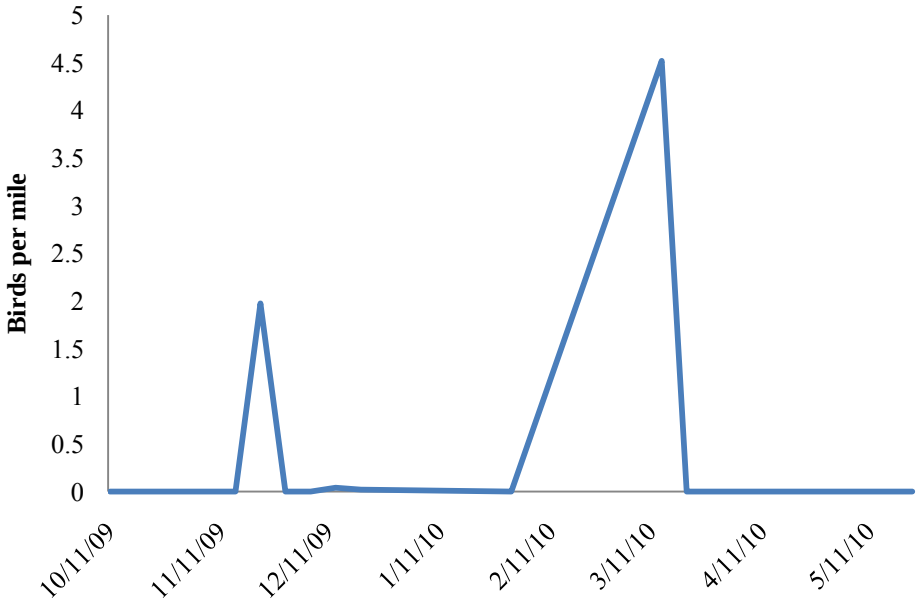


Number of red-breasted merganser observations by substrate type

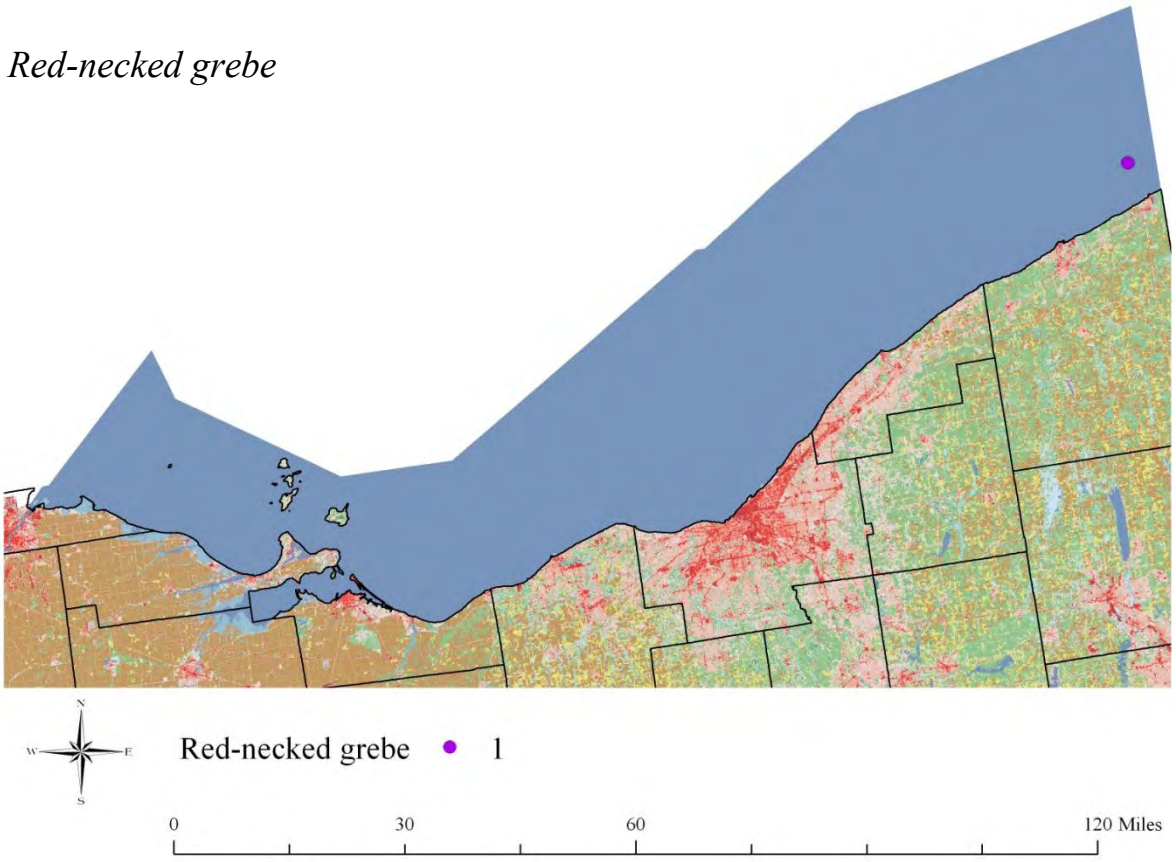

Red-breasted merganser
Number of birds
25,000
20,000
15,000
10,000
5,000
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

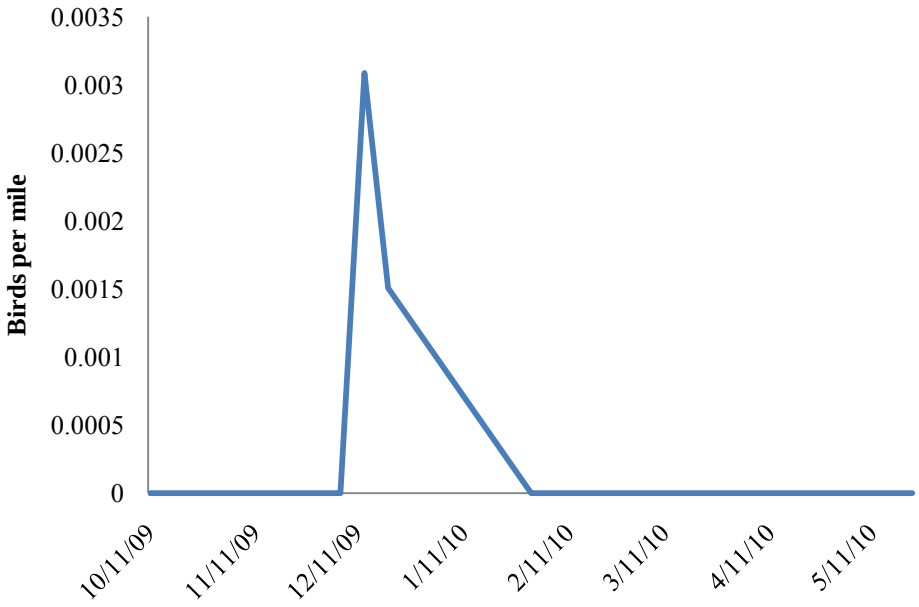
Redhead


Redhead
3 - 6
7 - 19
20 - 80
81 - 366
367 - 1,713
1,714 - 2,000
0
30
60
120 Miles

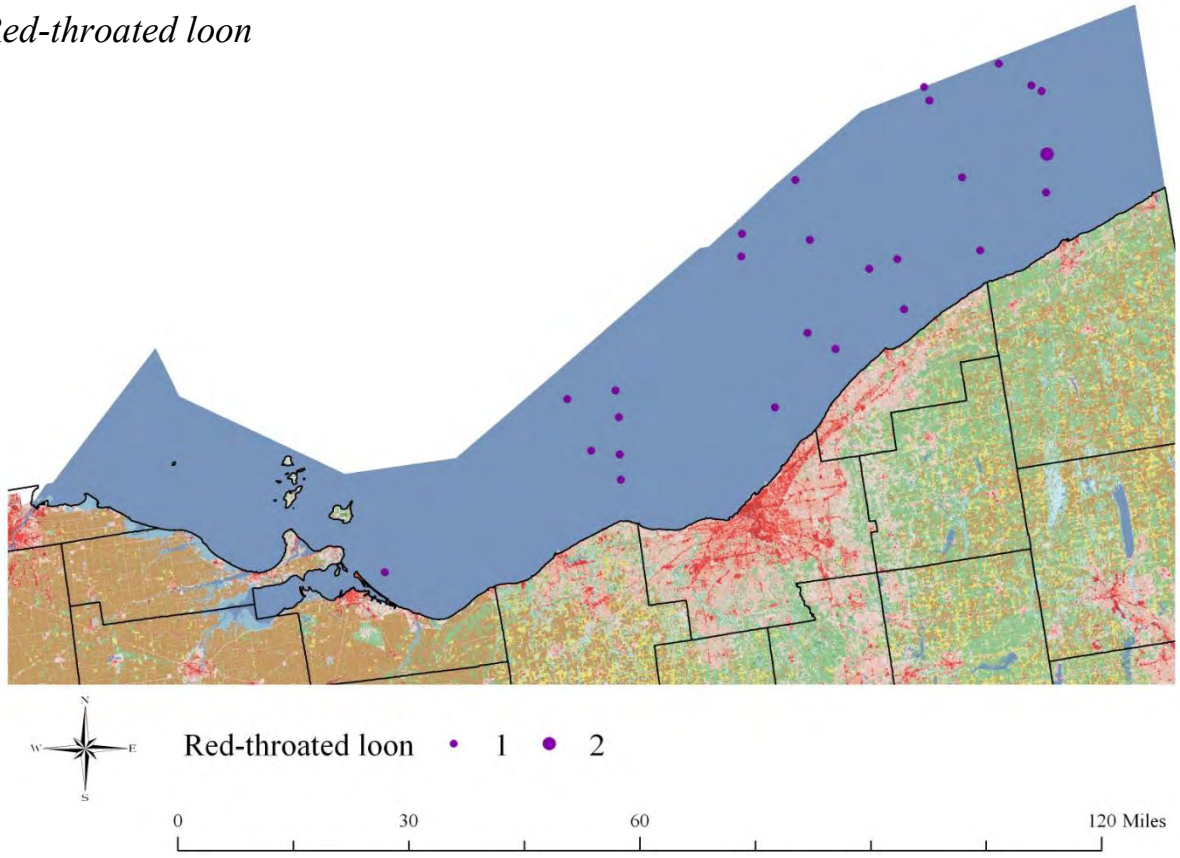

Birds per mile
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

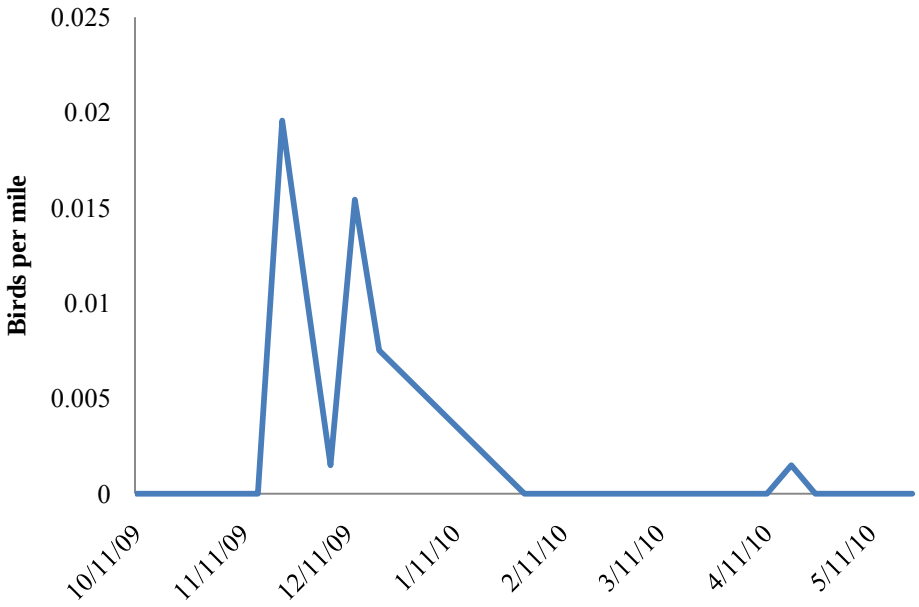
Red-necked grebe



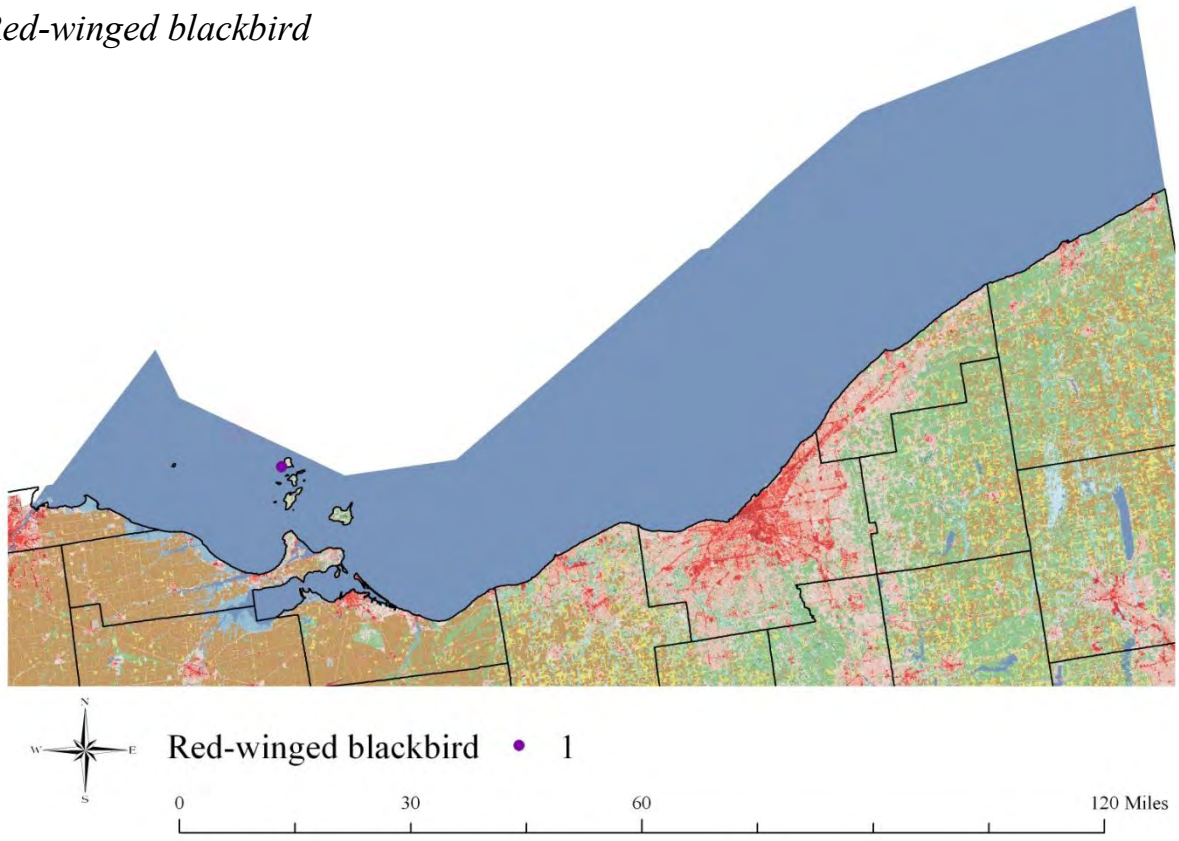


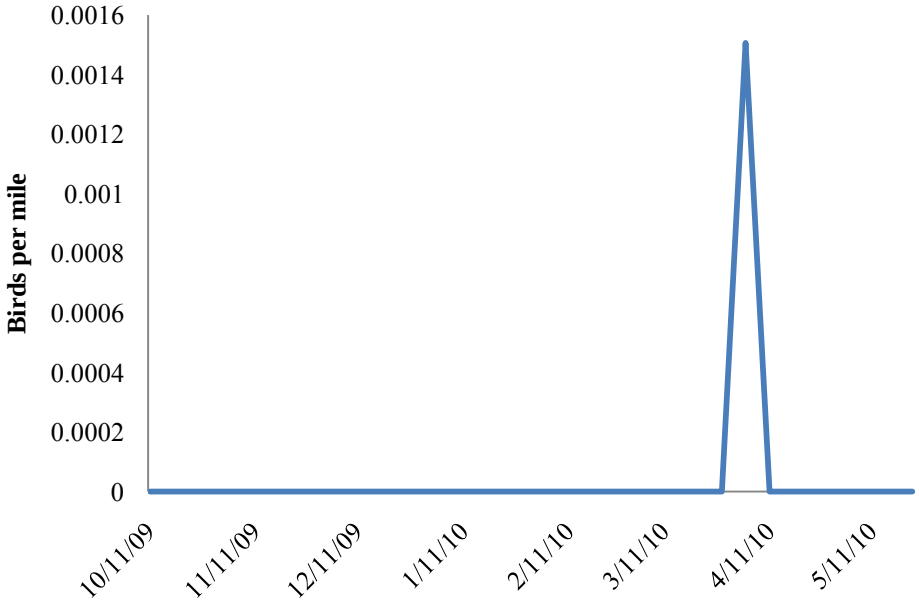
Red-throated loon



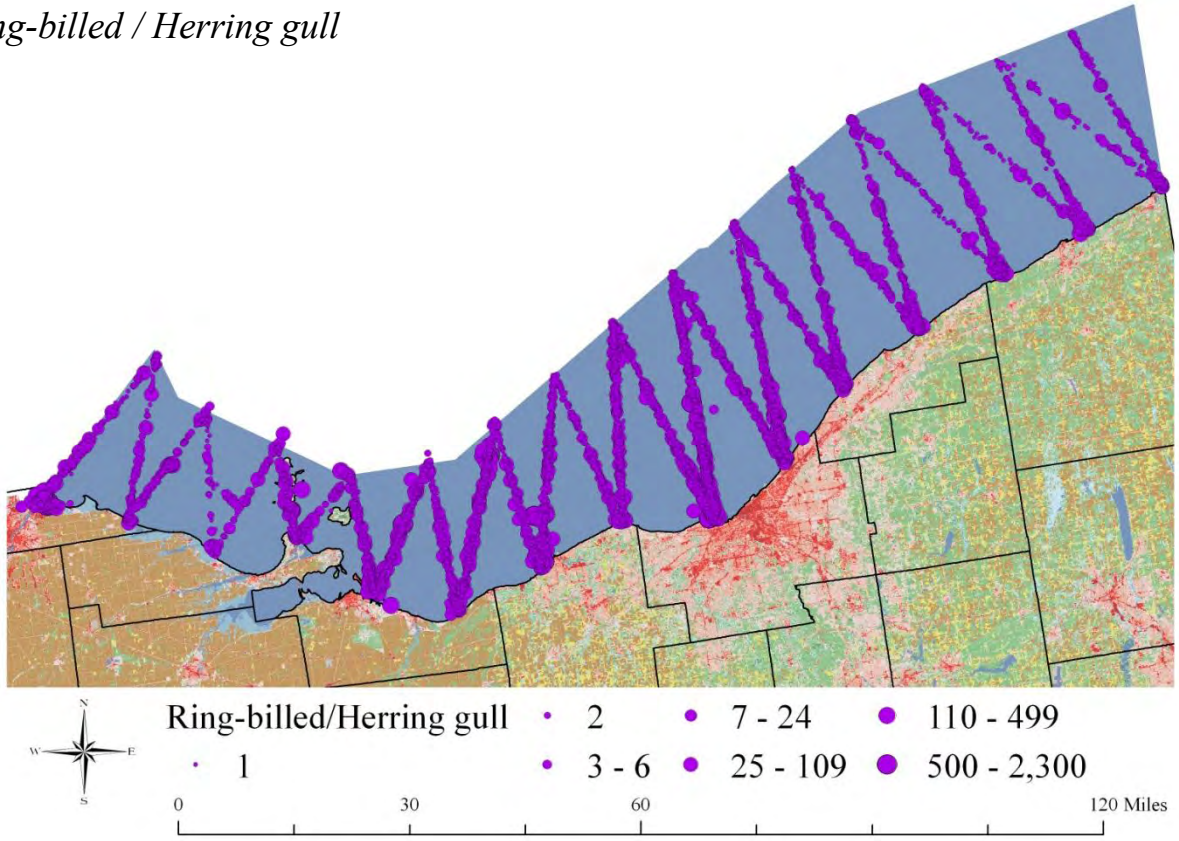


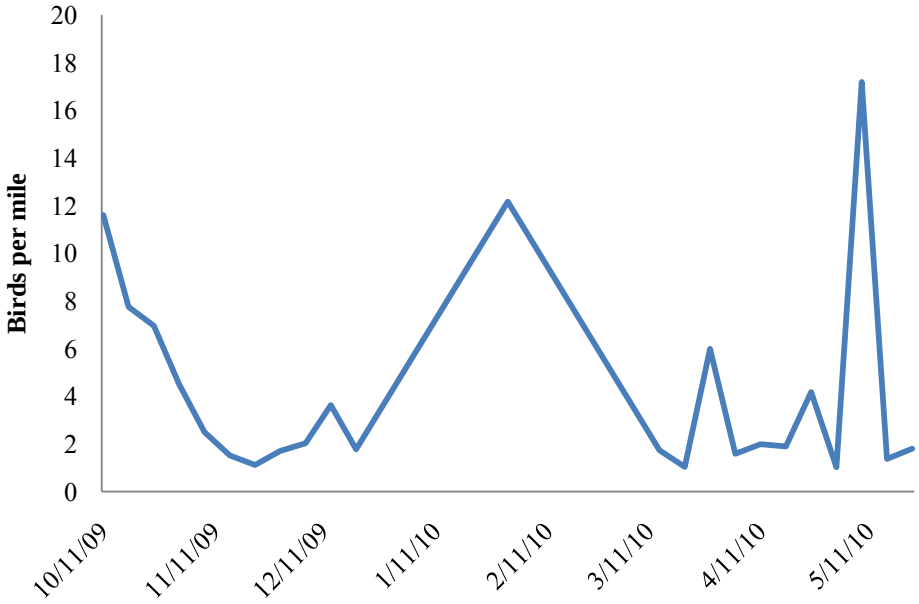
Red-winged blackbird

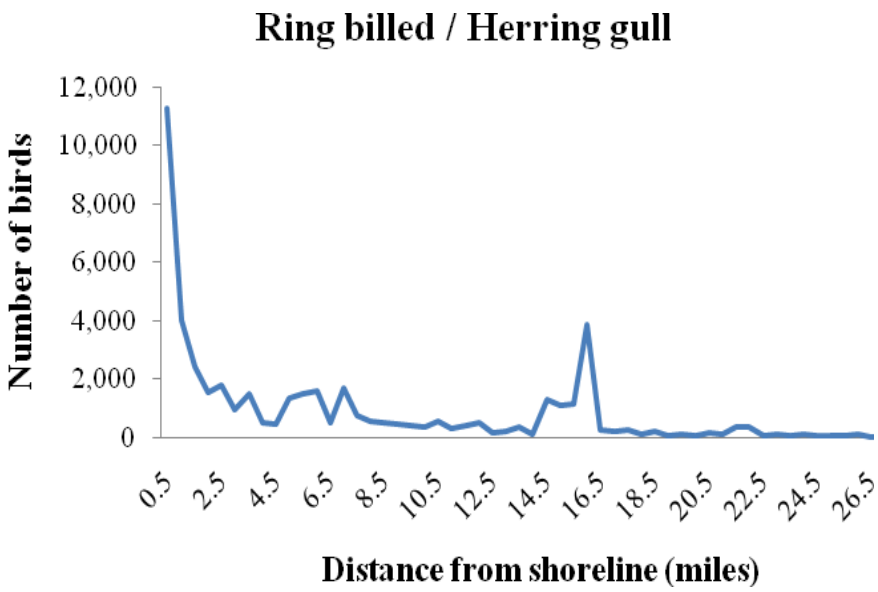




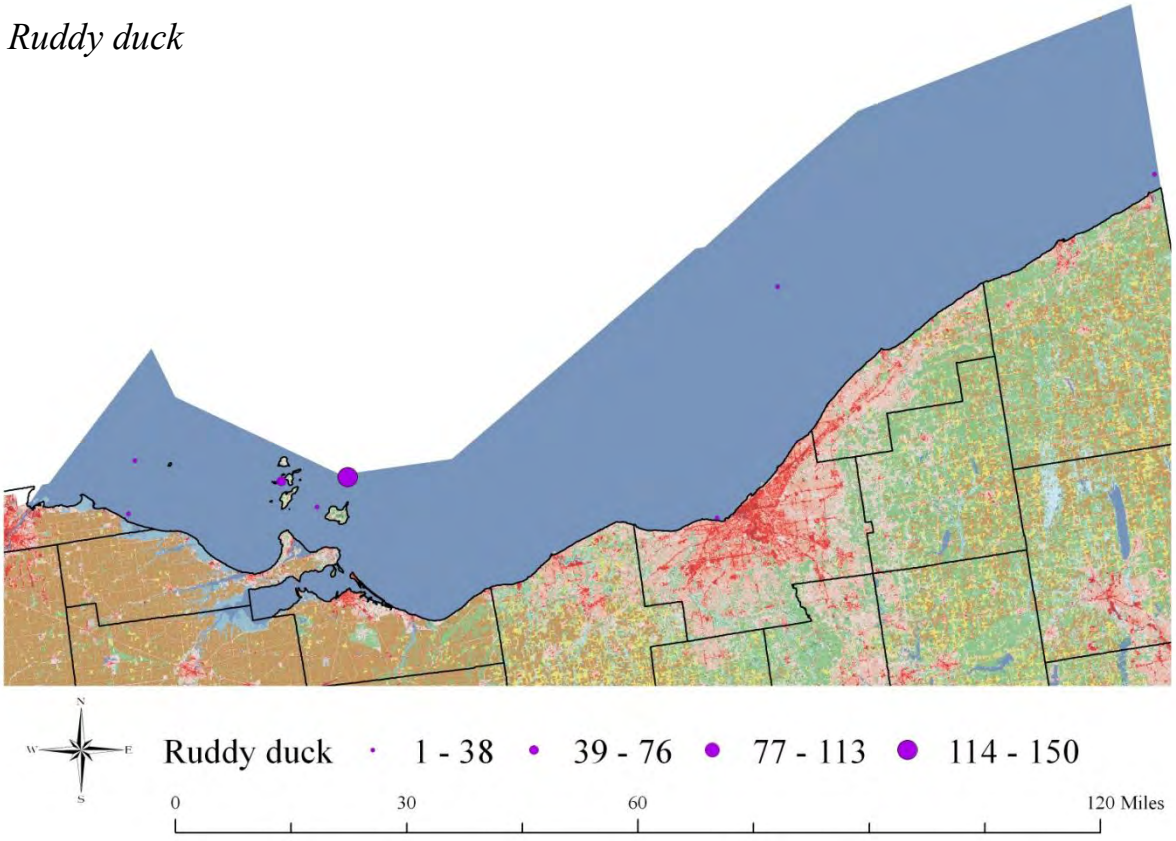
Ring-billed / Herring gull

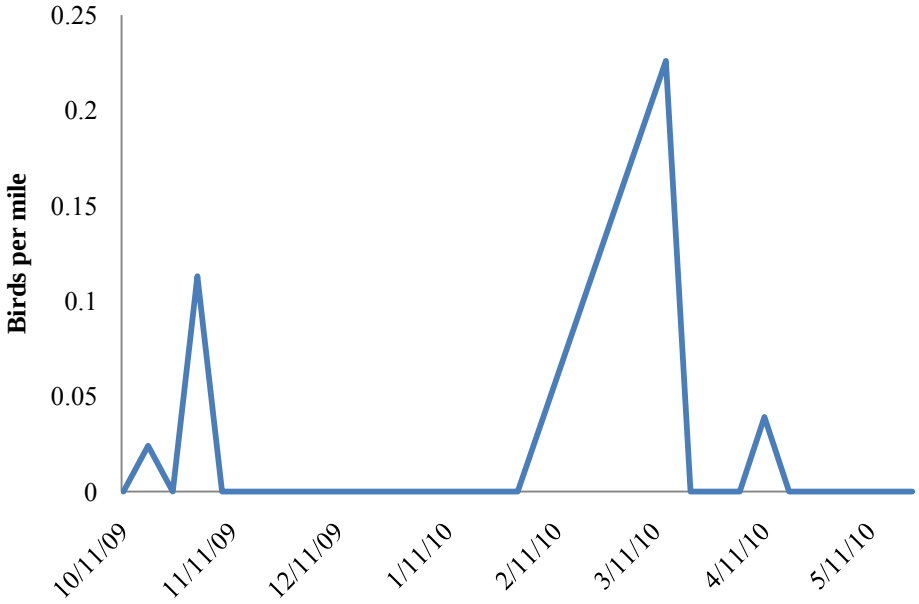


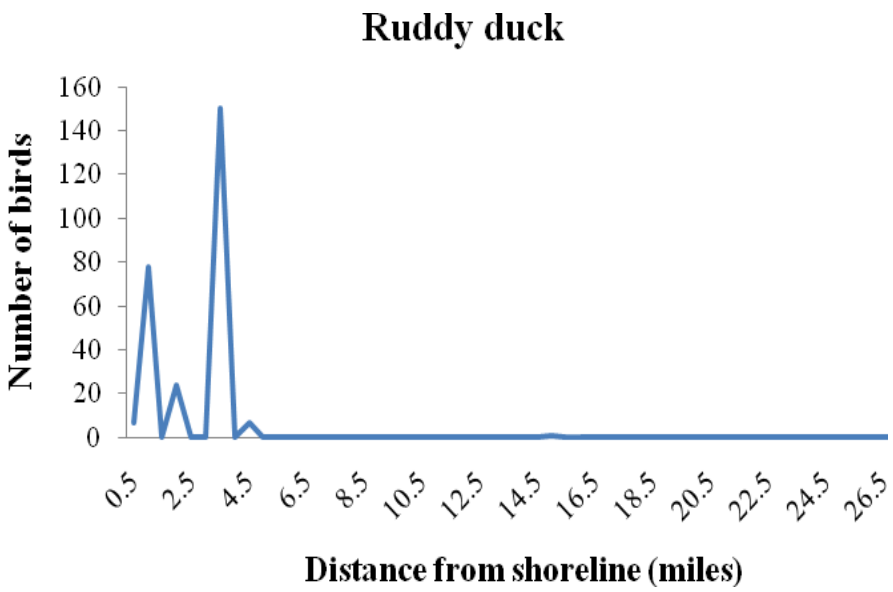



Ring billed / Herring gull
Number of birds
12,000
10,000
8,000
6,000
4,000
2,000
0
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
18.5
20.5
22.5
24.5
26.5
Distance from shoreline (miles)

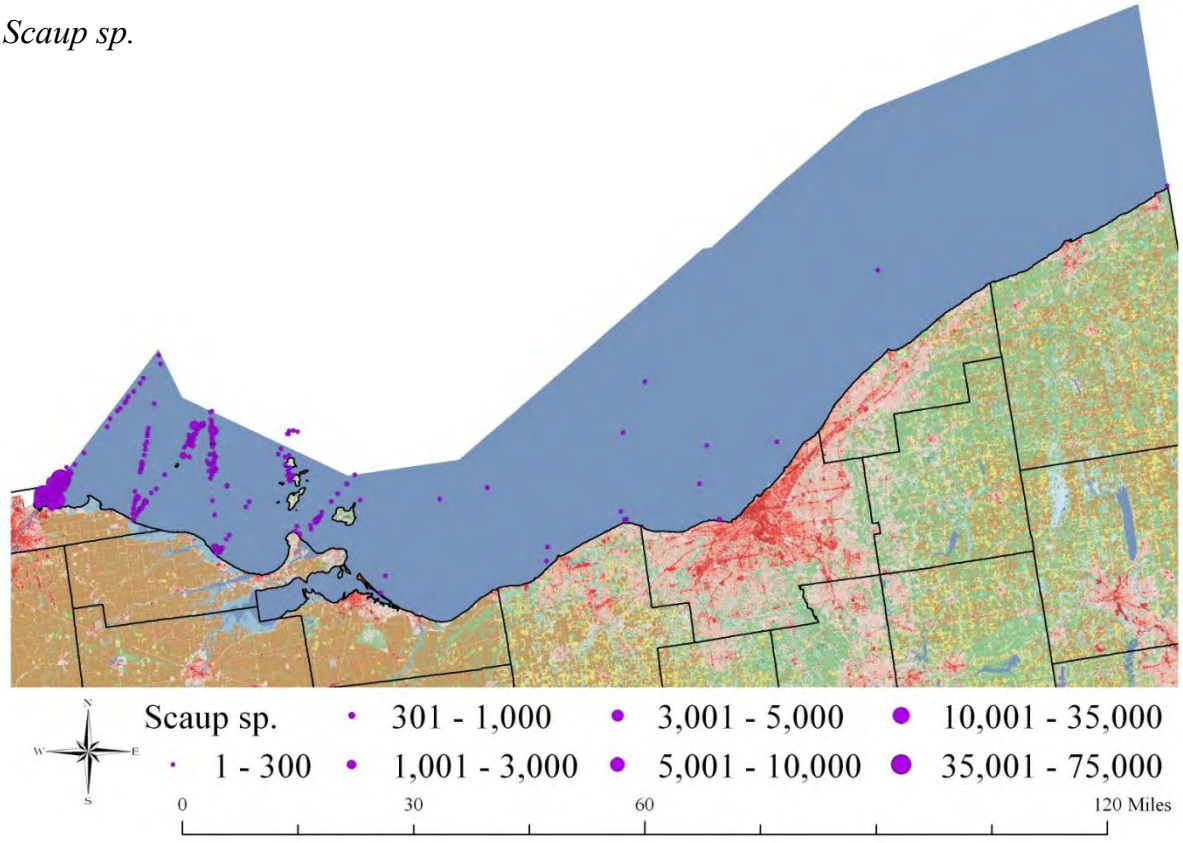
Ruddy duck

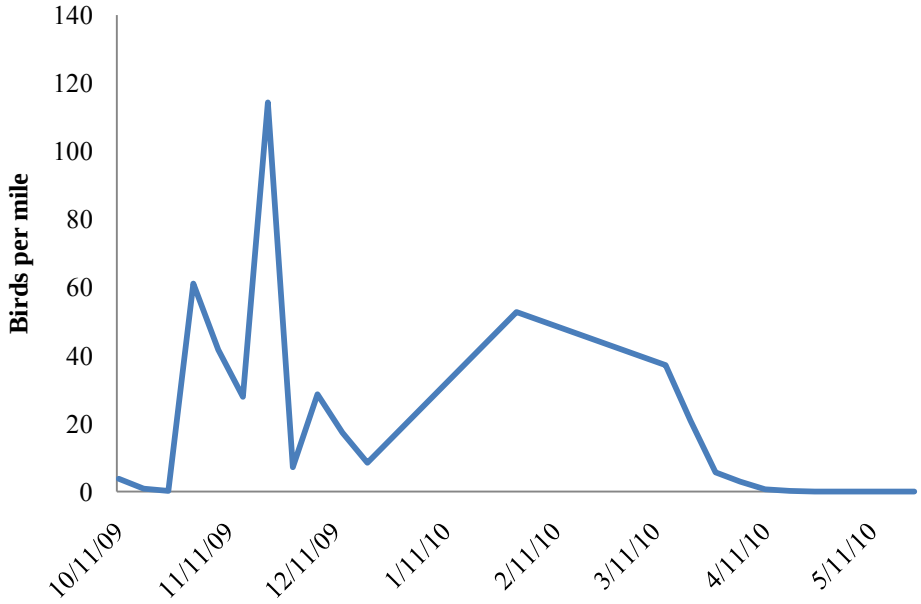

N
W
E
S
Ruddy duck
1 - 38
39 - 76
77 - 113
114 - 150
0
30
60
120 Miles

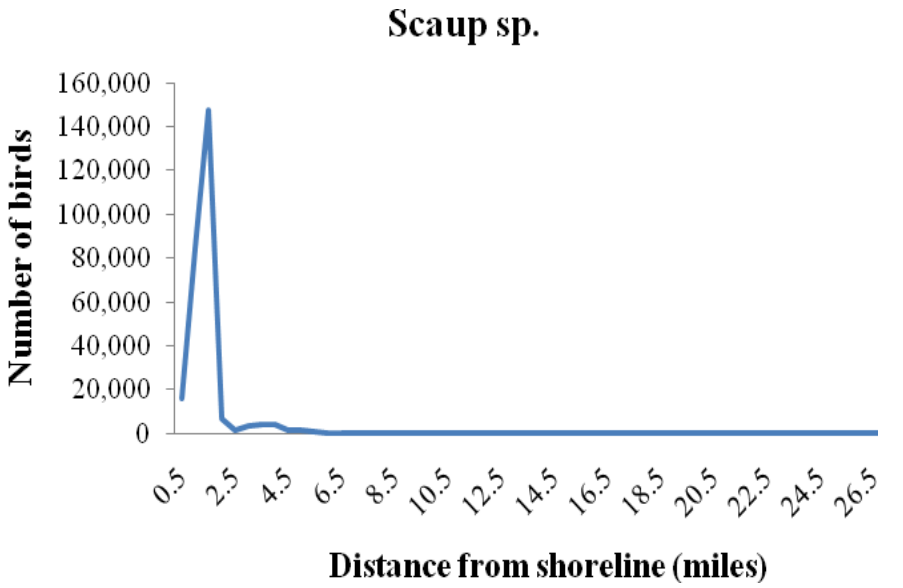

Birds per mile
0.25
0.2
0.15
0.1
0.05
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

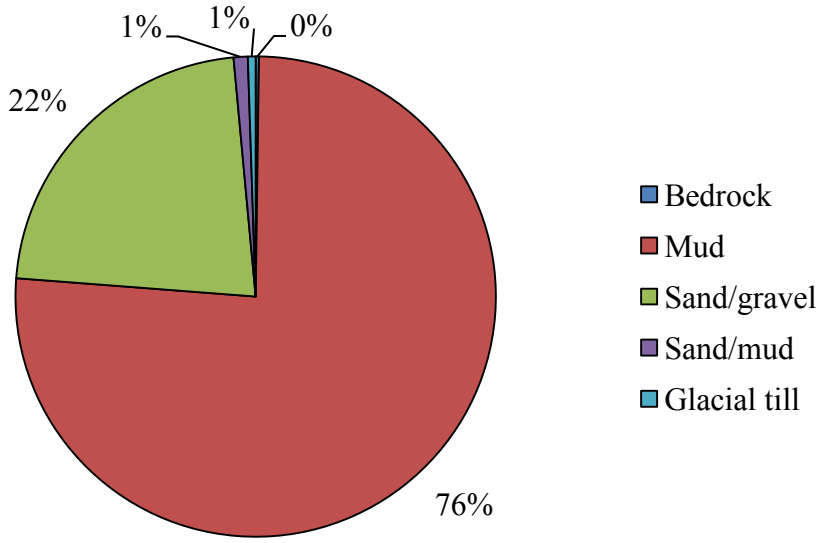

Ruddy duck
Number of birds
160
140
120
100
80
60
40
20
0
0.5
2.5
4.5
6.5
8.5
10.5
12.5
14.5
16.5
18.5
20.5
22.5
24.5
26.5
Distance from shoreline (miles)

Scaup sp.

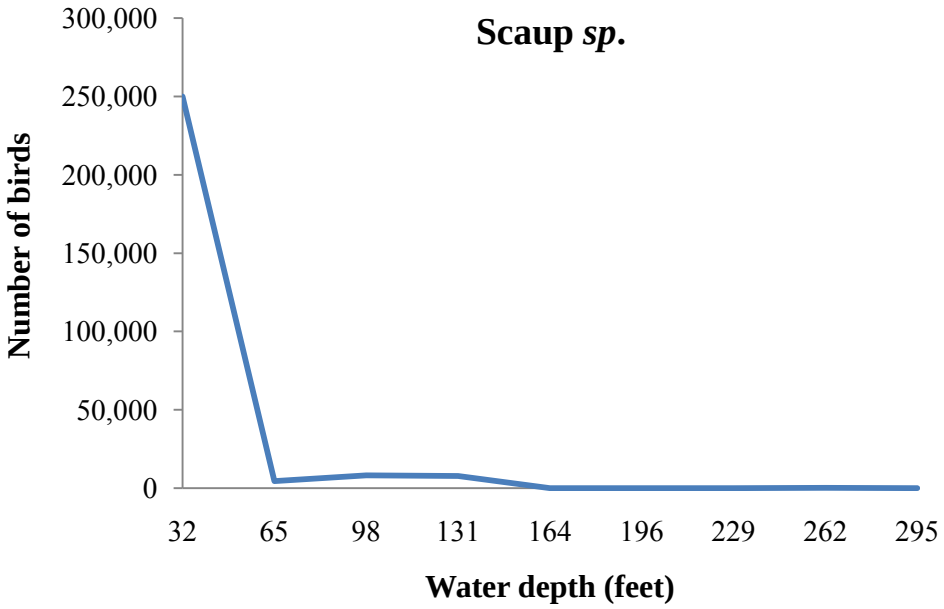

Scaup sp.
1 - 300
301 - 1,000
1,001 - 3,000
3,001 - 5,000
5,001 - 10,000
10,001 - 35,000
35,001 - 75,000
0
30
60
120 Miles


Birds per mile
140
120
100
80
60
40
20
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

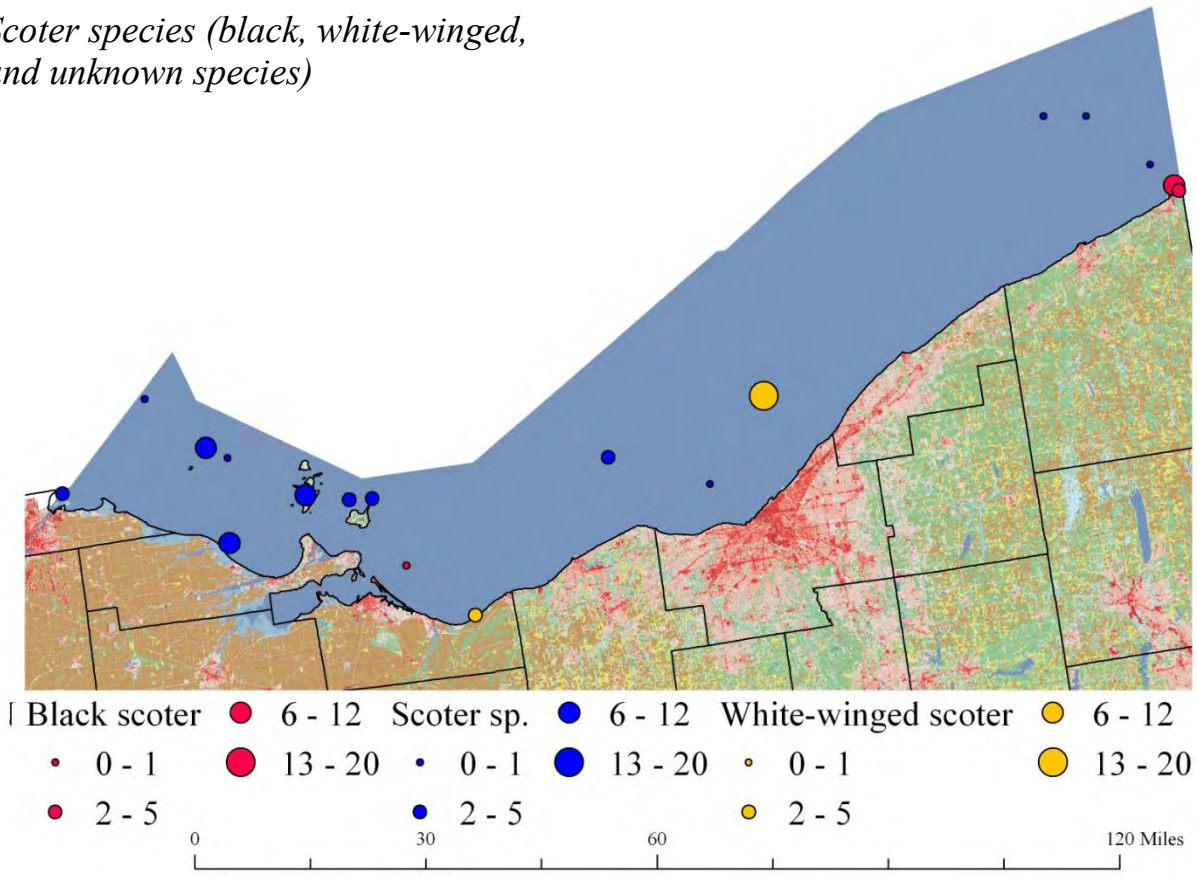


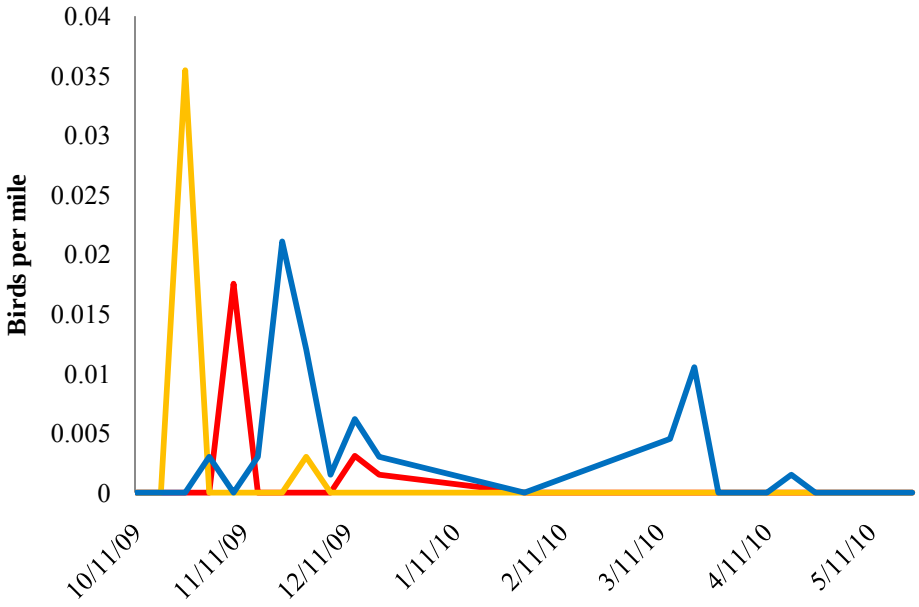


Number of scaup *sp*. observations by substrate type

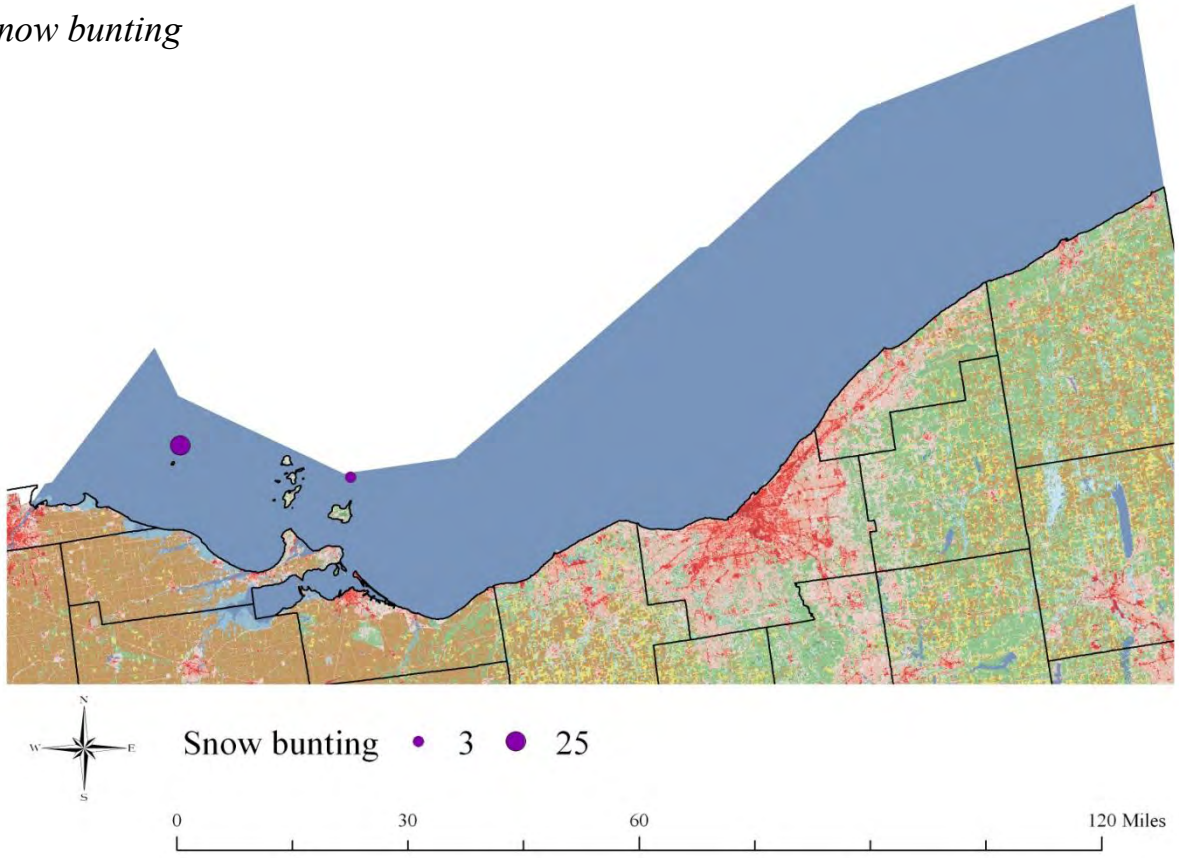

Scaup sp.
Number of birds
300,000
250,000
200,000
150,000
100,000
50,000
0
32
65
98
131
164
196
229
262
295
Water depth (feet)

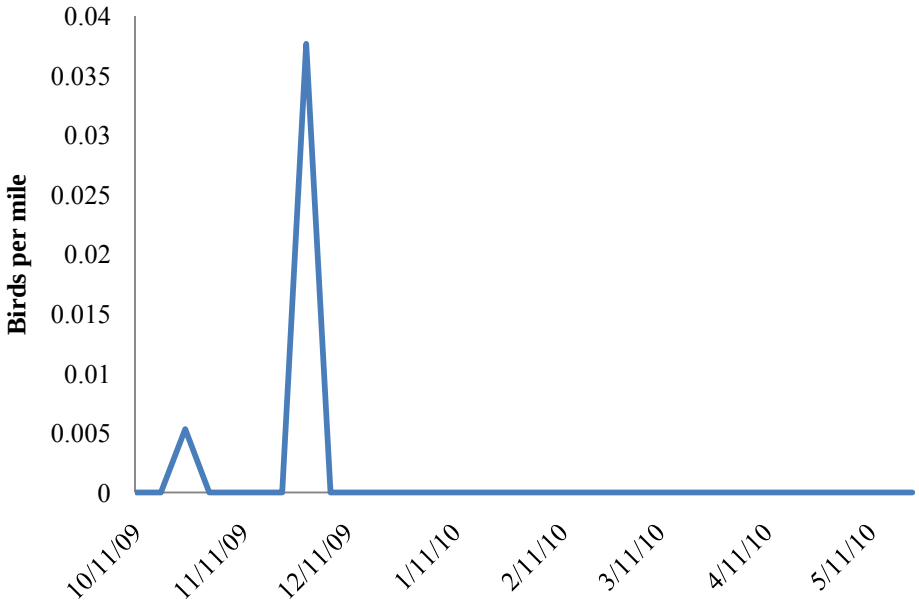
Scoter species (black, white-winged, and unknown species)



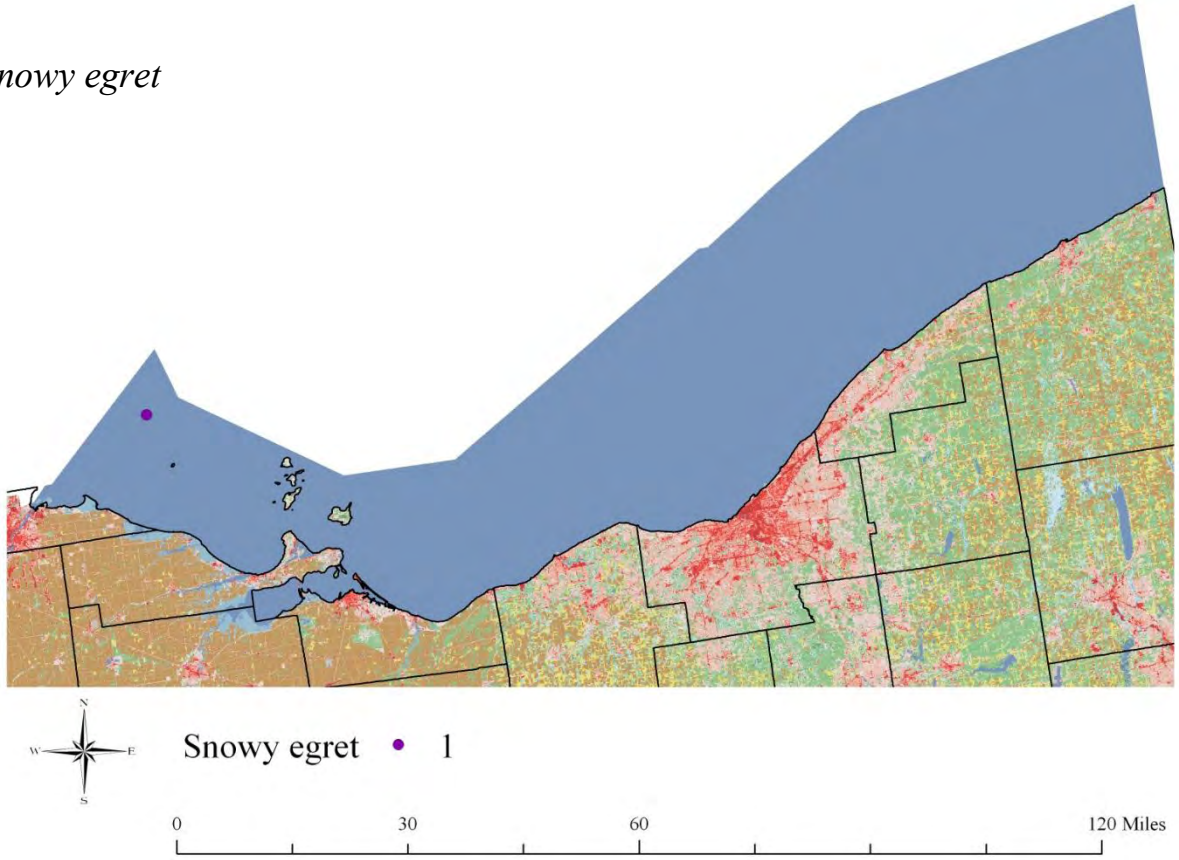


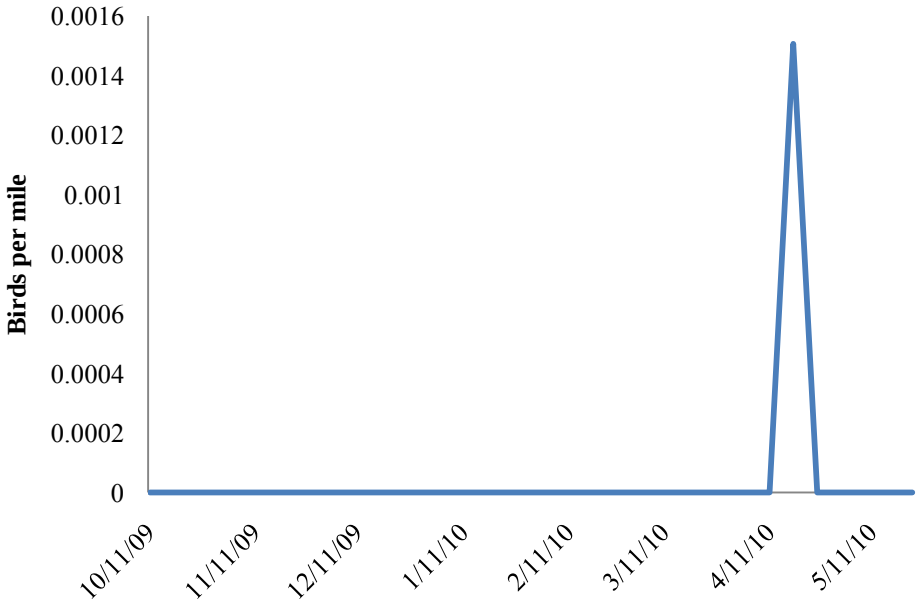
Snow bunting



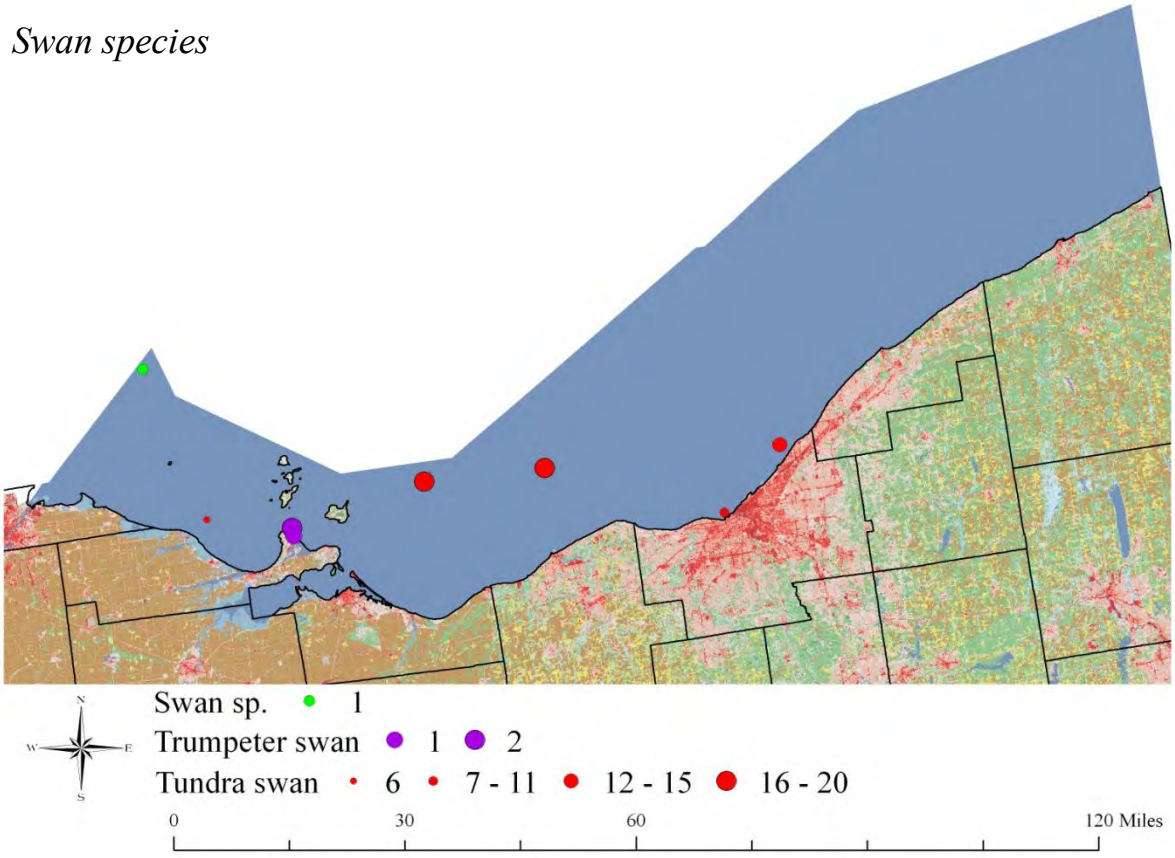


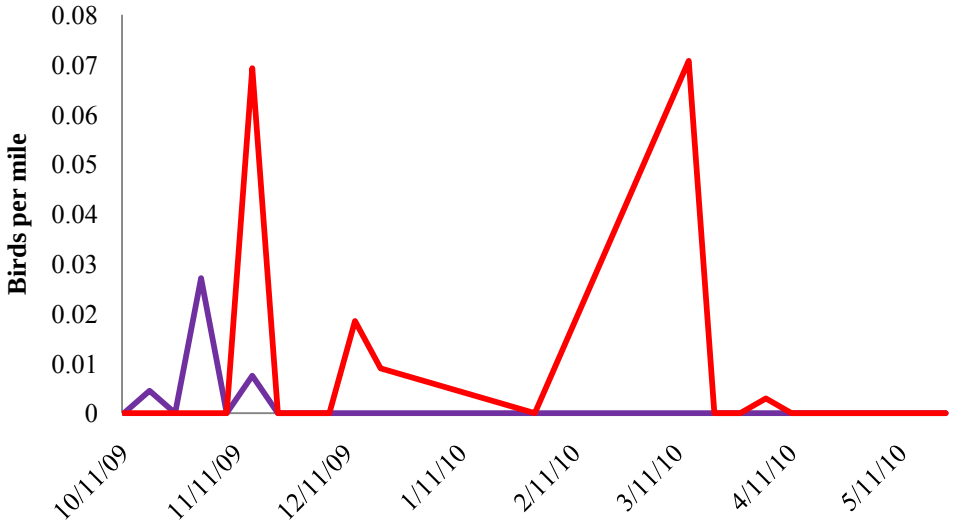
Snowy egret


N
W
E
S
Snowy egret
1
0
30
60
120 Miles

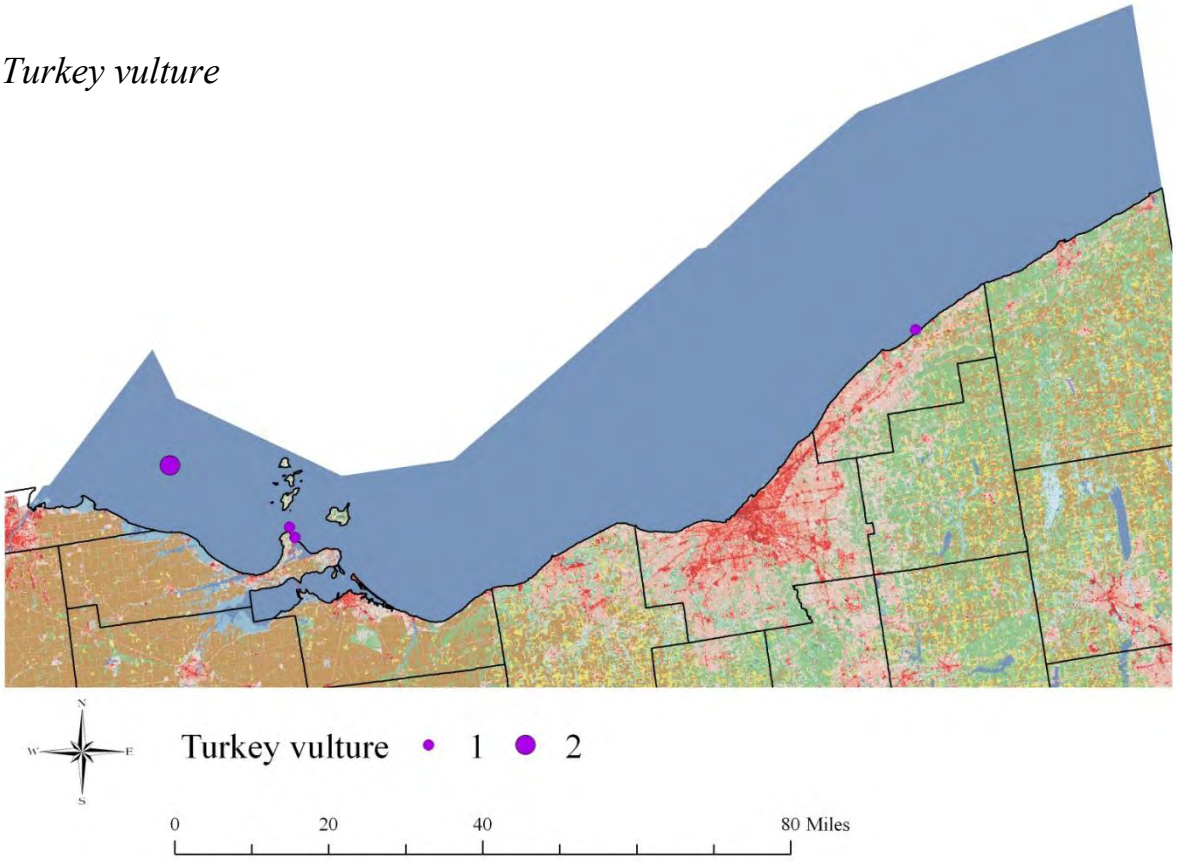

Birds per mile
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
10/11/09
11/11/09
12/11/09
1/11/10
2/11/10
3/11/10
4/11/10
5/11/10

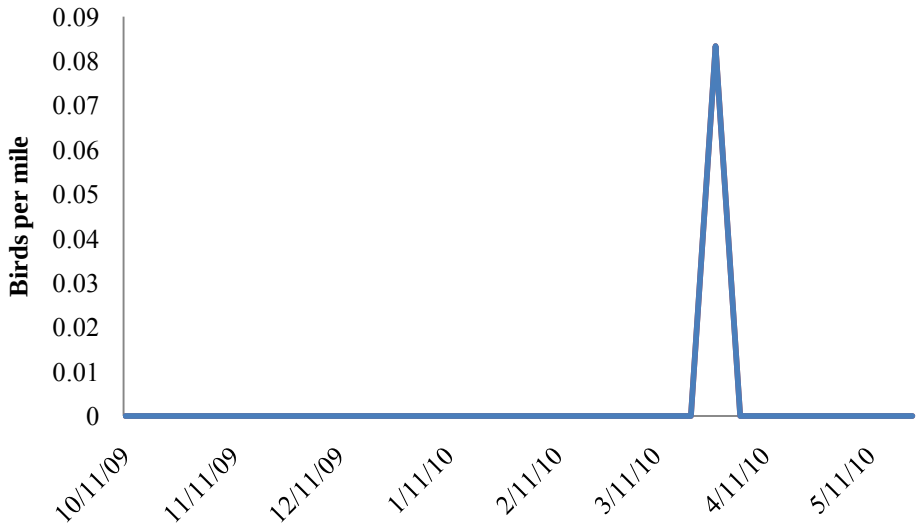
Swan species



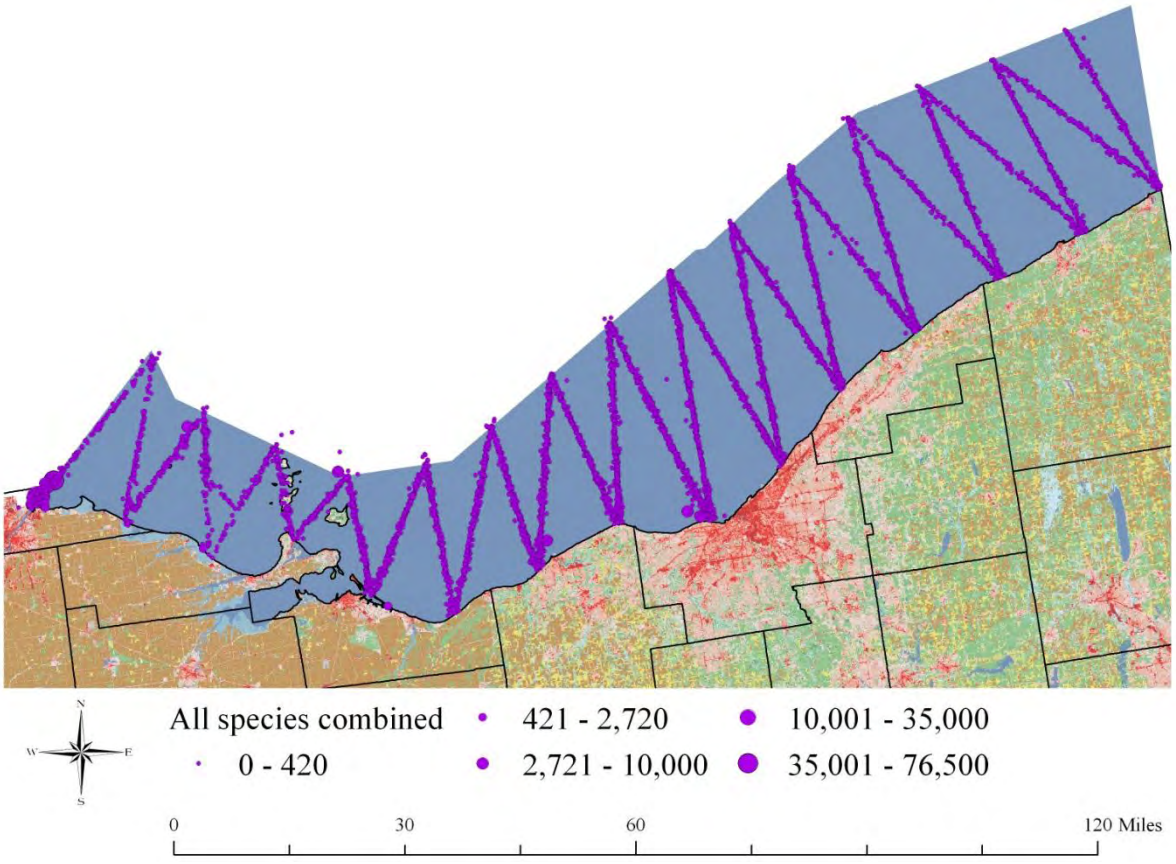


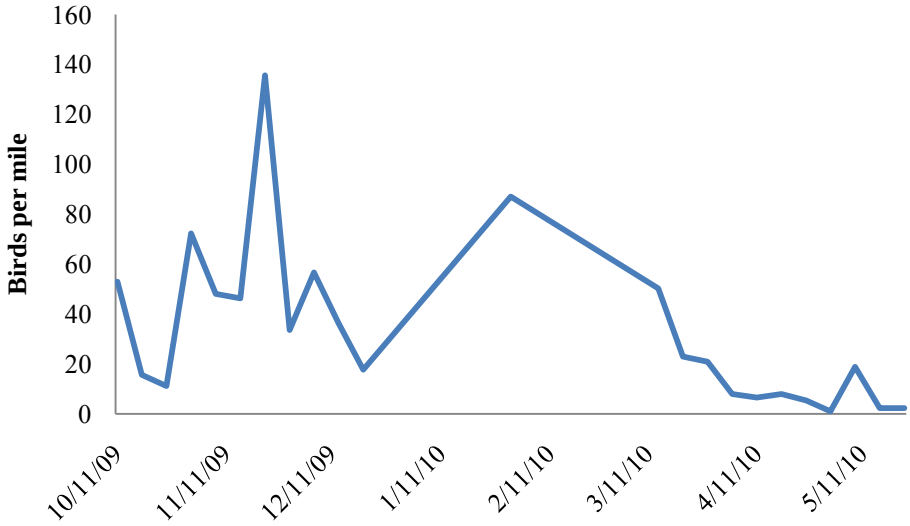
Turkey vulture



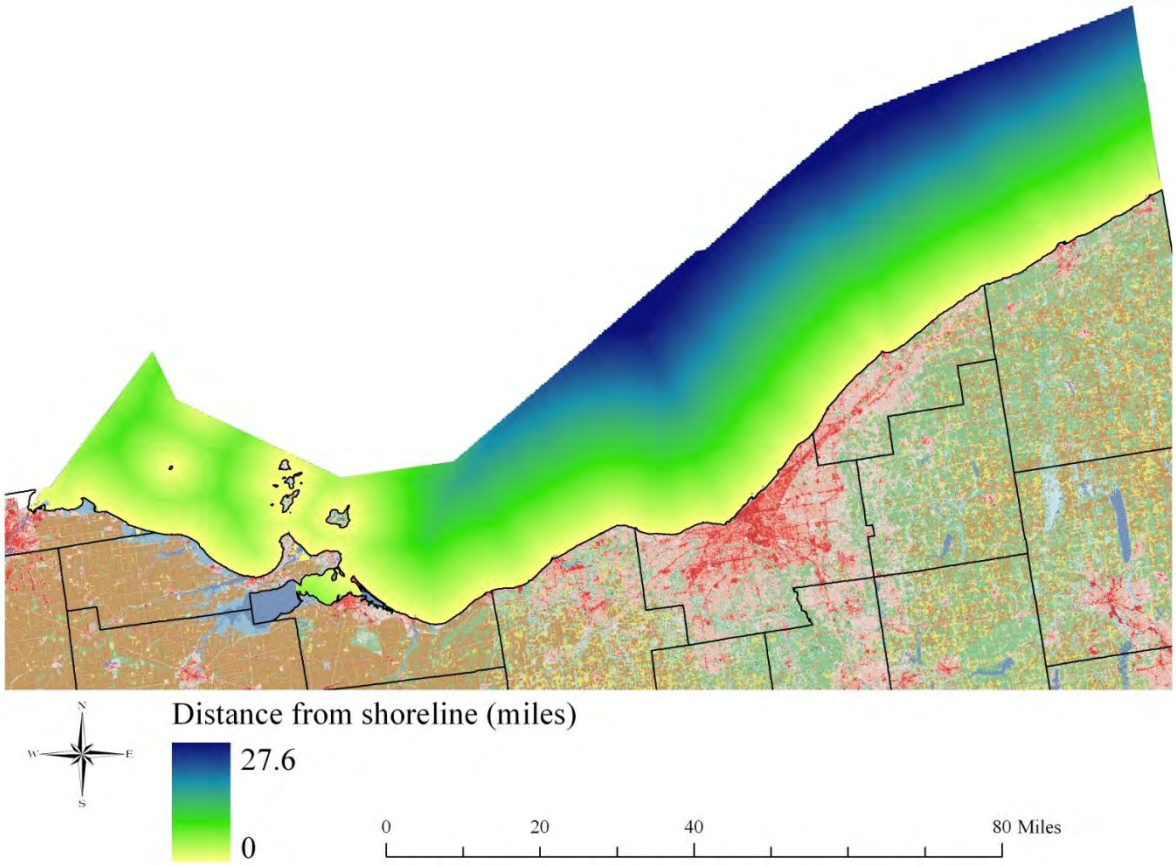


All species combined

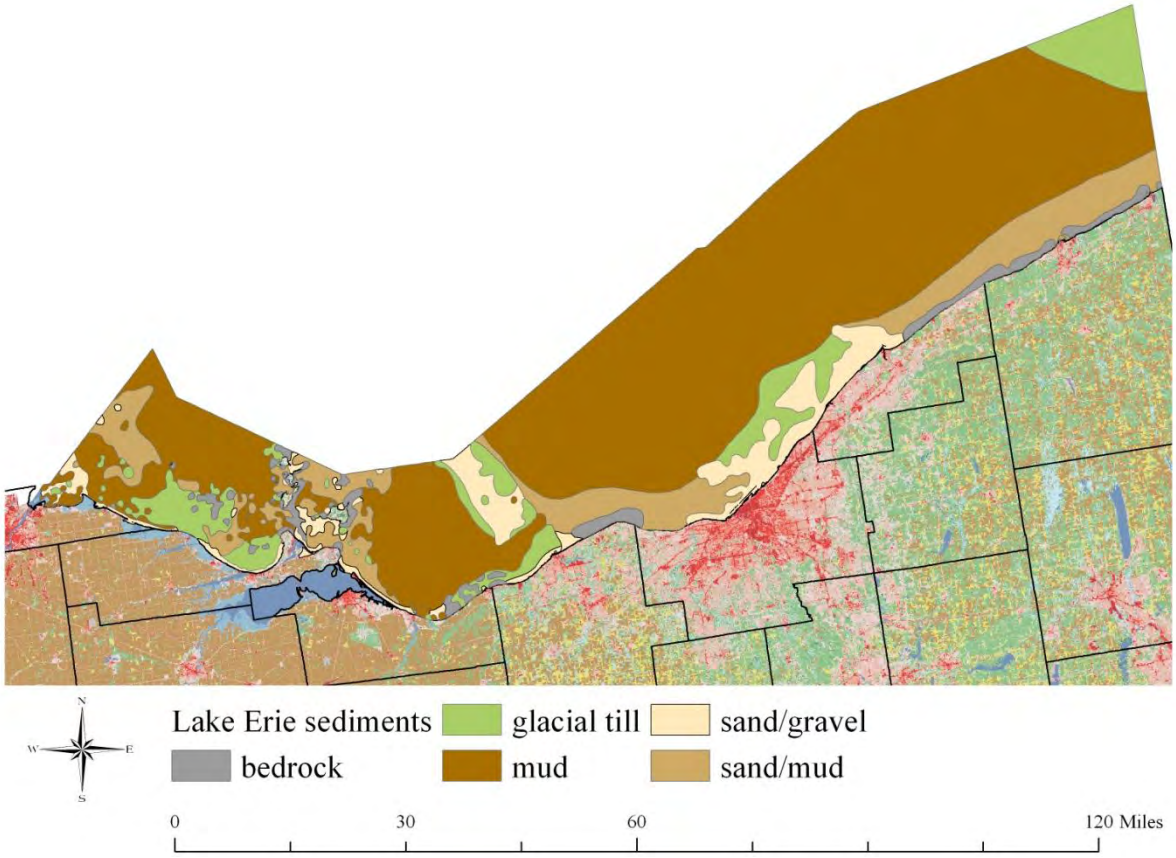
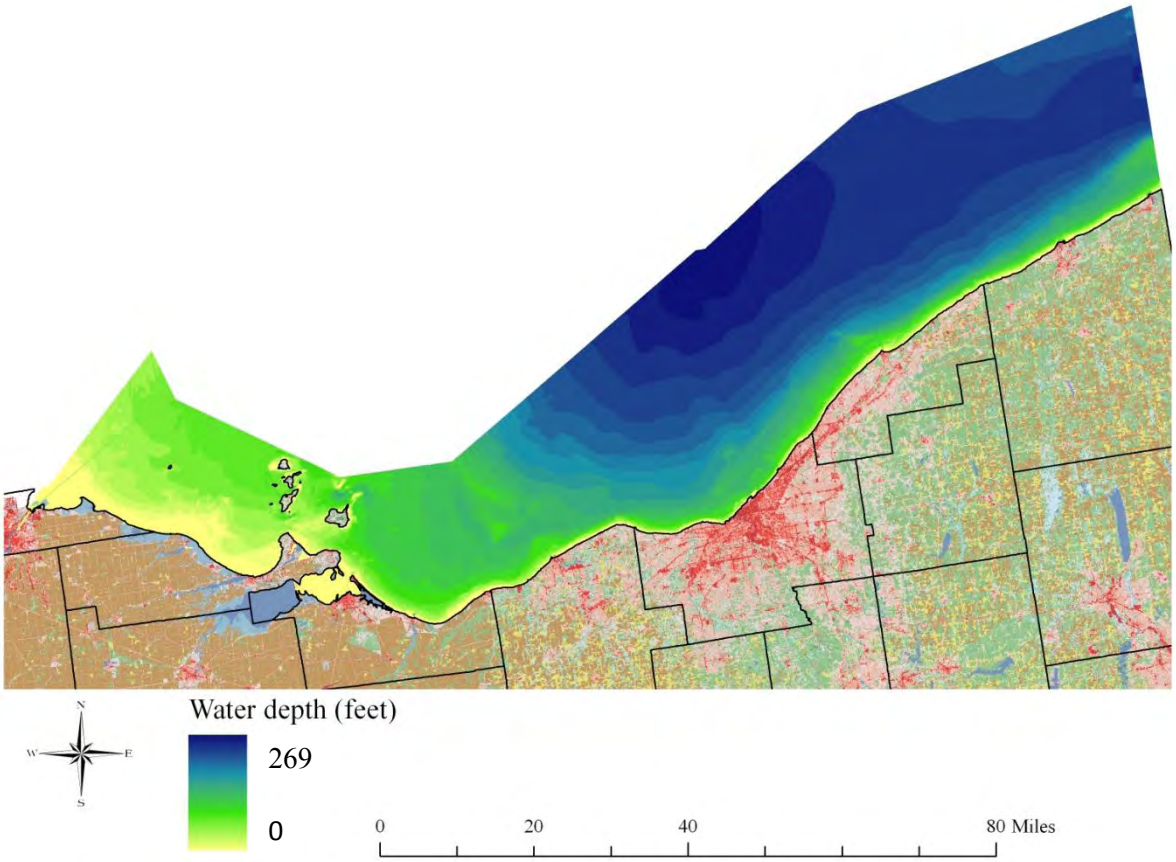




Distance from shoreline



Substrate map



Water depth