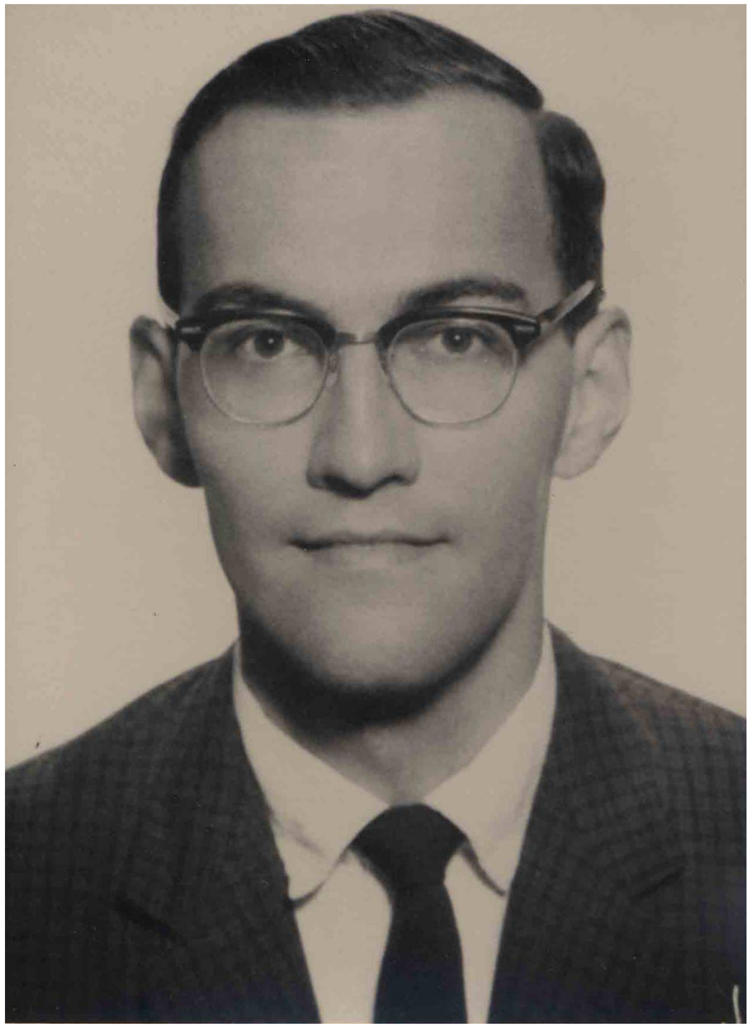
Half a Century of Ornithology in Texas:
the Legacy of Dr. Keith Arnold



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Community ecology of ducks wintering along a southeast Texas urban gradient

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Abstract – Visual surveys of four lakes in southeast Texas were conducted to examine the relationships between lake morphometry and human presence to habitat selection of wintering ducks. Lake area and human disturbance have the most influence on habitat selection, with the latter having the most significant effect. The Theory of Island Biogeography was also applied to the data to explore the potential for using biogeographical approaches to understanding wintering habitat selection and future conservation implications. This study provides a baseline for future studies designed to understand factors affecting winter distribution of ducks in southeast Texas.

Migration is a fascinating phenomenon seen across the animal kingdom on small and large scales. The physiological, ecological and behavioral forces that drive duck migration have been the focus of many studies (e.g., Bellrose 1963, Johnsgard 1965, Able 1974, Robinson et al 2010, Arzel et al 2014, Shipes et al 2015, Takekawa et al 2015, Lonsdorf et al 2016). Habitat selection by migratory species and its relationship to the success of an individual and the community is an important paradigm in ecology (review in Arzel et al. 2006, Kaminski and Elmberg 2014). How and what information ducks gather of a potential habitat is a multidimensional process which can be influenced by lake area, inter-/intraspecific competition, morphology, previous experience, age/sex of the individuals and other factors (Reed et al 1999, Beatty et al 2014a,b).

Lake area is a widely studied environmental factor along with correlates of habitat selection (Elmberg et al 1994, Kosiński 1999). The size of the lake can affect habitat diversity, which in turn can lure various ecomorphological groups to the area, affecting intra-/interspecific relationships. This follows the spatial heterogeneity hypothesis, that greater environmental complexity in diverse habitats provides more diverse resources that can support more species (Nudds 1992). Individuals may also rely upon prior knowledge of an area to determine the benefit of a particular habitat (Nichols et al 1983). Distribution of species by age groups or sex has also been shown to affect habitat selection (Hepp and Hines 1991). These mechanisms that underlie habitat selection have been tested mostly during breeding season (Beatty et al 2014a,b).

Migratory ducks need to balance the cost of locating/selecting a specific habitat and the benefit that habitat can provide (Paulus 1988, Reed et al 1999, review in Kaminski and Elmberg 2014, Austin 2017). This cost:benefit ratio differs between breeding (high somatic/energetic cost) and non-breeding (low cost) sites due to food availability and quality more than other lake characteristics (Suter 1994, Kosiński et al, 2006). Therefore we would expect to see a difference in habitat selection between breeding and non-breeding locations.

Disturbances from human presence/activity also can have an effect on habitat selection/avoidance. Many duck species will avoid disturbance, if the cost of selecting alternative sites nearby is comparatively low (Gill 1996, 2001).

Biogeography has its foundation in species distribution based on ecological drivers, among other factors (e.g., history, climate, geology). The Theory of Island Biogeography focuses on the spatio-temporal patterns of species colonization. Traditionally used to describe island colonization, the theory has been expanded to movement studies and preserve design for a variety of habitats and species (Miller 1976, Samson 1980, Wu and Vankat 1995, Cumming et al 2012). Integrating such concepts can provide additional information on species movements in relation to environmental influences. This can be used to assess whether environmental factors influence the dynamic equilibrium of habitat selection (i.e., immigration and extinction rates) by migratory ducks.

Southeast Texas is one of many areas utilized by migratory North American ducks during winter. This study was designed to evaluate the influence lake morphology has on migrant duck habitat selection along an urban gradient of lakes. Specifically, we explore patterns between species richness and abundance with lake size and human presence to examine the following questions:

1. Are there observed patterns in habitat selection measured as species richness and abundance in relation to lake size (i.e., surface area)?
2. Do human population density and proximity (distance from city) affect migratory duck habitat selection?
3. Can Island Biogeography Theory be applied to migratory duck populations in southeast Texas?

Data collected will provide a baseline index for migratory duck habitat selection in southeast Texas, which we hope will catalyze future studies.

METHODS

Four different lakes harboring migratory ducks were selected for sampling which offered an array of variation in size, distance to the city and human population density (Fig. 1). The largest lake was Mary Manor (N = 16 samples) at 992,008 m^2, a semi-private lake in rural Katy (Waller Co.) with some seasonal hunting. The second largest was at White Lake at Cullinan Park in Sugarland (Harris Co.; N = 18) at 145,620 m^2. Two much smaller lakes in Harris County included a private lake off the Bauer Rd frontage road on Highway 290 (herein referred to Bauer/290 Lake; N = 14) at 40,923 m^2, and McGovern Lake in Herman Park (N = 20) at 26,492 m^2 (Fig. 2).

Sampling took place during the duck migration/wintering season (November 2010 – March 2011). Species and number of individuals were documented. Most lakes were sampled weekly or slightly less frequently. Mary Manor Lake, White Lake, and Bauer/290 Lake were sampled with binoculars from a single vantage point that permitted full view of all ducks on the lake. Walking the perimeter was necessary at McGovern Lake, which contained two large islands which ducks could hide behind.

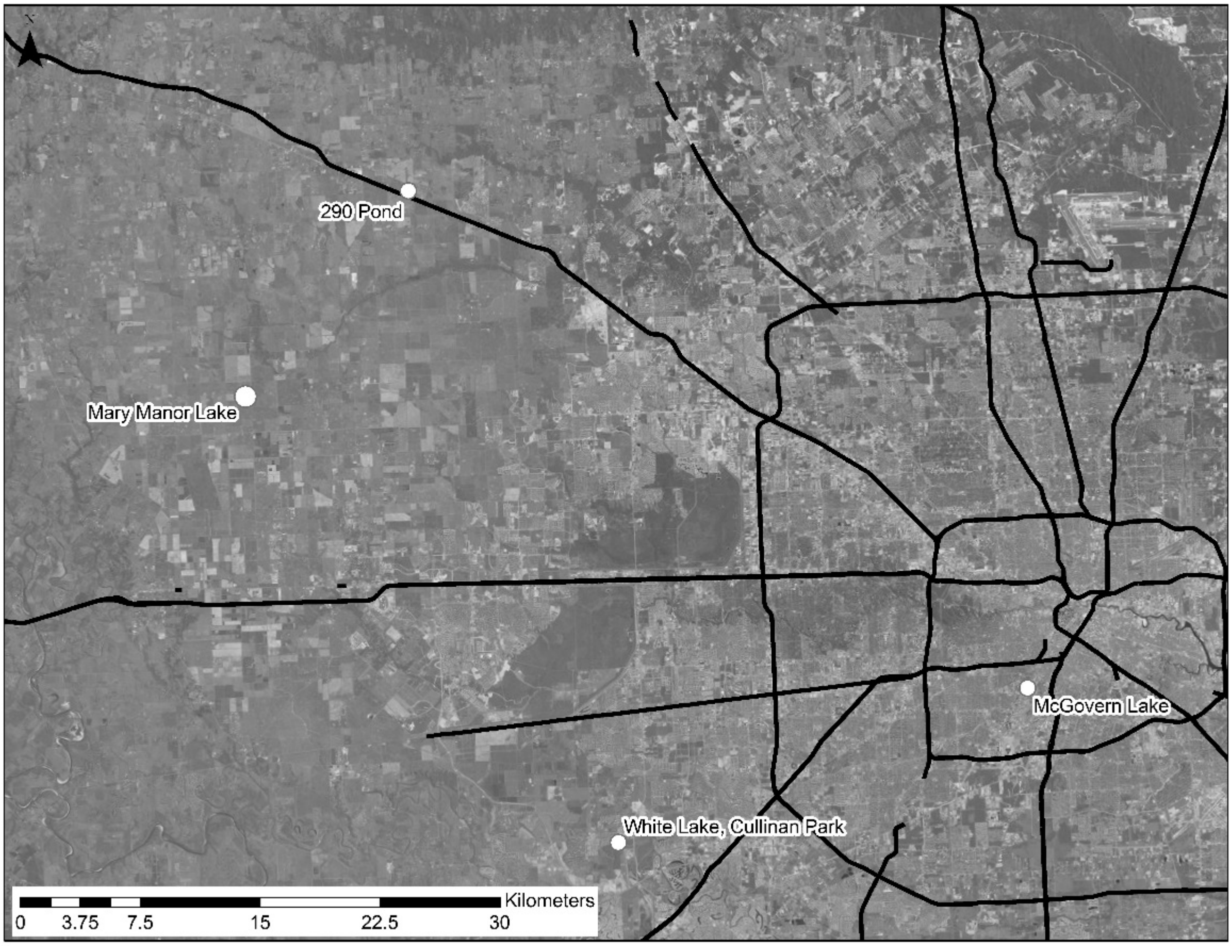


Figure 1 - Locations of Mary Manor, White, Bauer/290 and McGovern Lakes.

To analyze the spatial dispersal behavior of migratory ducks, several parameters were measured and calculated. Species richness, abundance and Simpson's index of diversity of ducks at each site were computed. Additionally, the surface area of each lake, km from city and human population density were obtained using U.S. Census Bureau (2010) data, and processed using ESRI (2010) with ArcGIS Desktop (2010). Distance to the nearest shoreline was measured as the shortest direct distance, and was invariably Galveston Bay. Distance from the nearest city was obtained by measuring the linear distance from each lake to city hall in downtown Houston.

Human population density was measured within a 1 km radius of each lake buffer. Site specific differences in species richness, abundance, index of diversity, species richness and abundance/m^2 of lake area among sampling sites were tested with a non-parametric Kruskal-Wallis Test. Pearson's product-moment correlations were calculated to test the relationship between environmental variables (lake area, km from city, population density) and species richness, abundance, index of diversity, species richness and abundance/m^2 of lake area. GraphPad InStat (version 3.06) was used for all statistical analysis.

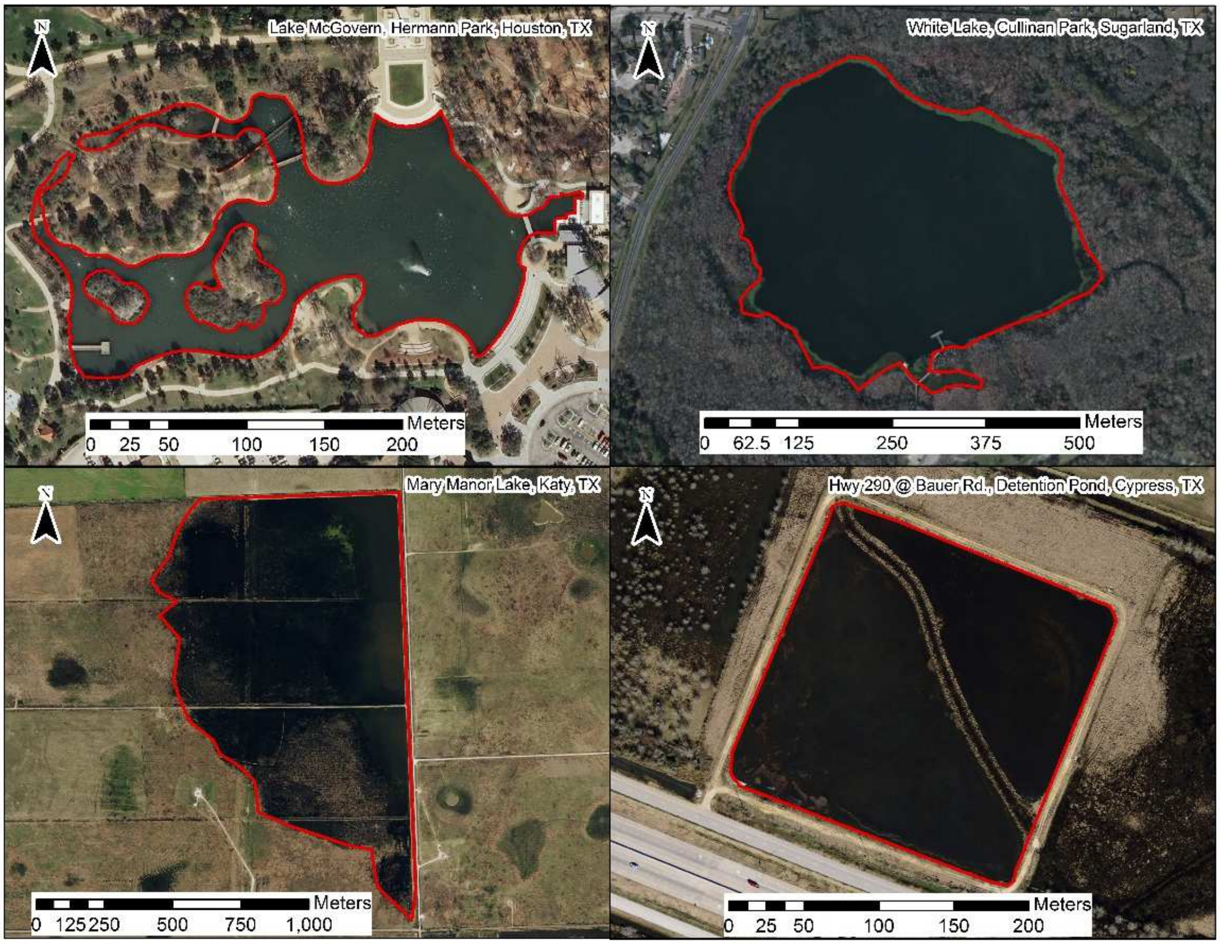


Figure 2 - Sizes and shapes of the four lakes in this study: McGovern (top left), White (top right), Mary Manor (bottom left), Bauer/290 (bottom right).

RESULTS

A total of 14 species of migratory ducks were identified during the sampling period across all four sites (Table 1). Species and abundance data were used to calculate species richness and diversity (Table 2, Fig. 3) for statistical comparisons of relationships among these variables to lake morphometry and human parameters (Table 3).

Lake morphometry

When considering all lakes, area had a positive relationship with index of diversity ($p<0.01$), species richness ($p<0.05$) and abundance ($p<0.05$; Fig. 4 A, B, C). However there were no significant differences in index of diversity, species richness or abundance for each of the four individual lakes ($p>0.05$), except for McGovern Lake which had a significantly lower index of diversity ($p<0.01$) and species richness ($p<0.05$; Fig. 3).

Table 1 - Average species composition at each of the four lakes over the survey period					
Common Name	**Latin Name**	**McGovern**	**White**	**Bauer/290**	**Mary Manor**
Black-bellied Whistling-Duck	*Dendrocygna autumnalis*	70			
Wood Duck	*Aix sponsa*	2	2		
Gadwall	*Anas strepera*		47	23	23
American Wigeon	*Anas americana*		18	10	1
Mallard	*Anas platyrhynchos*				14
Mottled Duck	*Anas fulvigula*			5	15
Blue-winged Teal	*Anas discors*		13	20	73
Northern Shoveler	*Anas clypeata*		7	15	41
Northern Pintail	*Anas acuta*		3	5	10
Green-winged Teal	*Anas crecca*				40
Redhead	*Aythya americana*	2		1	1
Ring-necked Duck	*Aythya collaris*	34	31	31	
Lesser Scaup	*Aythya affinis*	2	4	4	
Ruddy Duck	*Oxyura jamaicensis*		5	4	1

Table 2 - Mean species richness, abundance and index of diversity for all lakes					
Lake	**Mean Species Richness**	**Mean Species Richness/m^2**	**Mean Abundance**	**Mean Abundance/m^2**	**Mean Index of Diversity**
McGovern	3.29	0.00012	112.08	0.0041	0.38
Bauer/290	3.65	0.058453	56.73	0.00152	0.50
Mary Manor	4.53	0.000005	142.95	0.0001	0.64
White	4.32	0.000030	103.57	0.0007	0.59

Table 3 - Lake morphometric and human parameters measurements				
Lake	**Surface Area (m^2)**	**Km to Nearest Shore**	**Km from City**	**Population Density**
McGovern	26,492	37	5	6911
Bauer/290	40,923	85	49	38
Mary Manor	992,008	89	52	28
White	145,620	63	31	5645

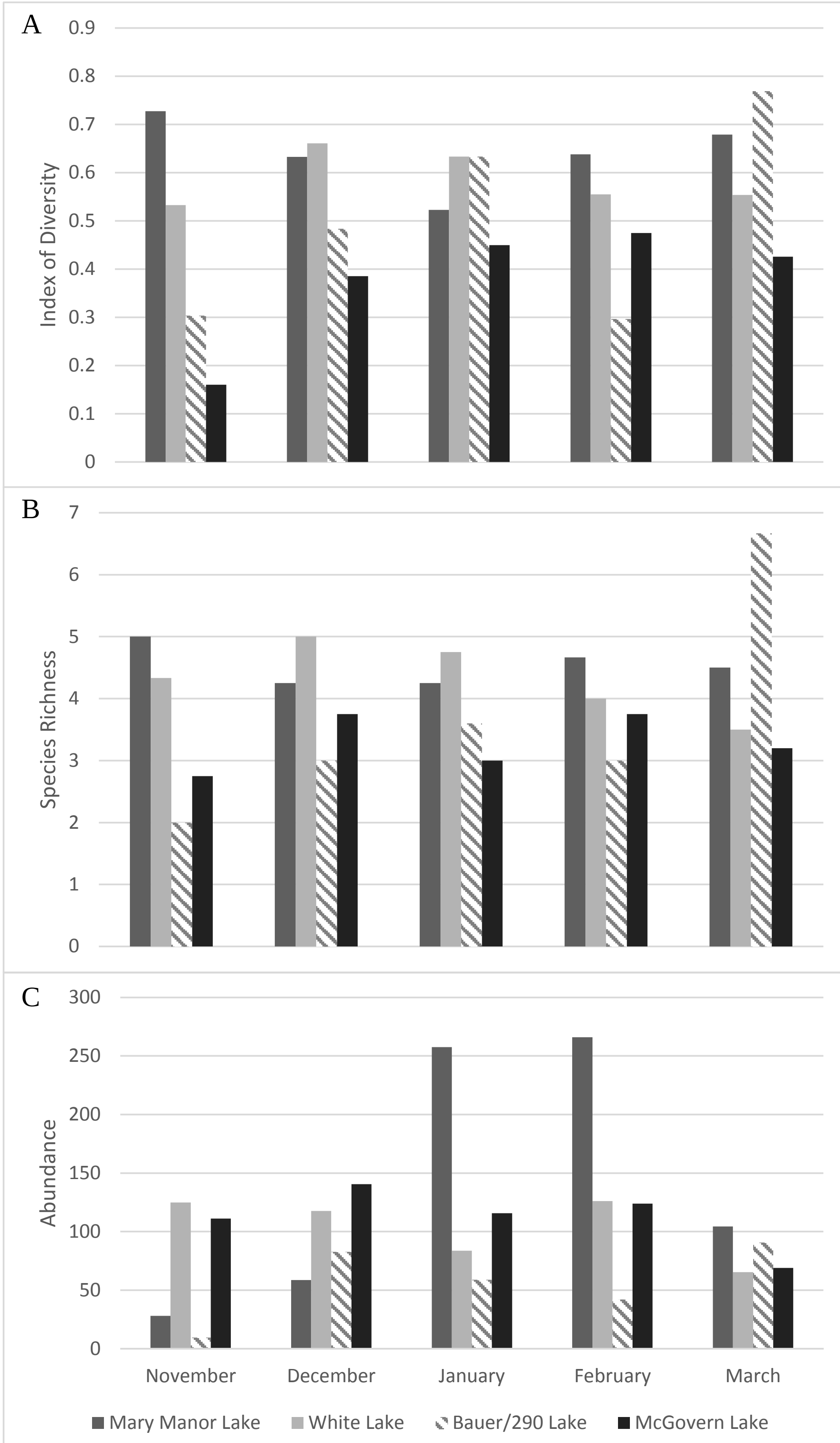


Figure 3 - Monthly index of diversity, species richness and abundance averages of all four lakes over the survey period.

For pair-wise comparisons of individual lakes, species richness/m^2 was significantly lower at Mary Manor Lake than Bauer/290 Lake ($p<0.001$) and McGovern Lake ($p<0.001$). White Lake had significantly lower species richness/m^2 than Bauer/290 Lake ($p<0.05$) but higher than McGovern Lake ($p<0.001$).

Mary Manor Lake had significantly lower abundance/m^2 than all other lakes ($p<0.05$), and White Lake had significantly lower abundance/m^2 than McGovern Lake ($p<0.001$).

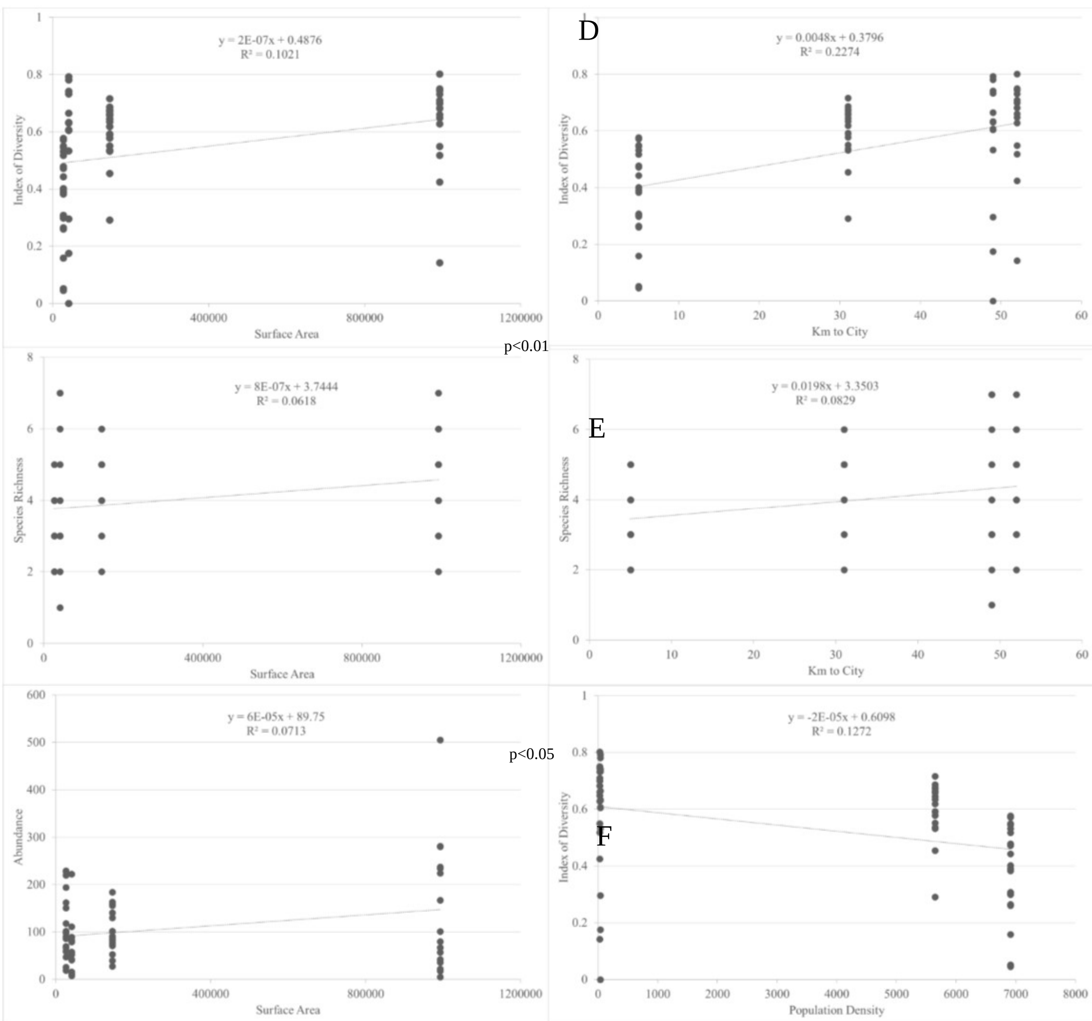
Human parameters
Index of diversity ($p<0.0001$) and species richness ($p<0.05$) showed significantly positive relationships with distance from the city (Fig. 4 D, E).

Index of diversity significantly decreased ($p<0.01$) with increasing human population density (Fig. 4 F). Population density did not influence species richness or abundance statistically ($p>0.05$).

A

B

C



p<0.01

p<0.0001

p<0.05

p<0.05

Figure 4 - Correlation analysis of index of diversity, species richness and abundance versus lake surface area, km from the city and population density.

p<0.01

DISCUSSION

Previous studies of migratory duck habitat selection have presented significant differences in distribution patterns (Hepp and Hines 1991, Elmberg et al 1994, Kosiński 1999, Reed et al 1999, Beatty et al 2014a,b). The majority of these results are based on breeding ground selection (Beatty et al 2014a,b). Here, we have collected data on non-breeding habitat selection to examine the effects that lake morphometry and human parameters have on migratory ducks settling in southeast Texas.

Historically, lake area has influenced distribution patterns of ducks more so than any other lake parameter (Elmberg et al 1994, Kosiński 1999). A similar trend is seen along the four lakes investigated in this study. As expected, these relationships suggest that as lake area increases, more species/individuals are found.

The basic systems of the lakes surveyed differ among one-another. Although not quantified, shoreline length and vegetation varies between each lake. These observations suggest that although a positive trend is seen in lake area, other measurements of lake morphometry do not seem to be a driver for habitat selection in migratory ducks.

McGovern Lake was the only lake significantly different with regards to index of diversity and species richness. McGovern Lake did have significantly higher abundance/m^2 compared to White Lake, however, this is based on mainly a single species identified only on McGovern Lake, the Black-bellied Whistling-Duck (*Dendrocygna autumnalis*). This whistling-duck does well around human development and can be found in large numbers in close contact with humans. McGovern Lake experiences heavy human disturbance (e.g., outdoor recreation) daily compared to the other lakes which are more sequestered from human activities. This, in addition to the negative trends seen in the index of diversity versus human population, suggests that human disturbance is an important factor affecting duck habitat selection across these four urban lakes.

Results suggest the perceived habitat does not appear to influence migratory ducks overwintering on the surveyed lakes. This agrees with previous studies that suggest foraging is the main driving force in habitat selection for non-breeding ducks (Paulus 1988, Suter 1994, Kuczyñski et al. 2006). The recorded distribution suggests that all four lakes sustain enough resources to support basic dietary needs. There appears to be no inter-/intraspecific competition with similar assemblages of species recorded among the lakes surveyed. This suggests the food resource capacity threshold of the habitat has not been reached, and species may be using the presence of conspecifics as a cue for habitat quality (Nichols et al 1983, Reed et al 1999, Kuczyñski et al. 2006, Austin 2017). Further studies investigating additional parameters are needed to confirm these results. For example, an aereographic characteristic that all of these sites share when viewing the lakes at a landscape scale, is aquatic vegetation and water that is clear enough to see the bottom. Water that is turbid and brown at a landscape scale are not selected by the ducks (F. Collins pers. obs.).

Although there are some identified trends, the species surveyed appear to exhibit flexibility in environmental variables (Hepp and Hines 1991) based on equal winter distribution across habitats. This evenness in habitat selection may be influenced by migratory ducks having minimal time to survey and select an area (Paulus 1988, Reed et al 1999). Conserving energy would reduce their cost and balance out any difference in benefits provided by each habitat.

With regards to direct human interaction, there is a trend towards a non-random colonization of the lakes surveyed. The significantly lower index of diversity and species richness seen at McGovern lake may be a negative response in habitat selection due to disturbance (review in Arzel et al 2006, Kuczyñski et al. 2006, Beatty et al 2014b). This can be compared to White Lake which has a population of alligators that actively predate the ducks. The lack of behavioral response to a risk of predation versus avoidance of human interaction suggests human disturbance is considered a substantial risk to be avoided, whereas predation may occur in a habitat with compensating advantages (review in Arzel et al 2006, Austin 2017). Hunting (e.g., at Mary Manor) is another major human disturbance experienced by the species surveyed but was not analyzed in this study. Further surveys of known hunting grounds versus population dynamics (Brooks 1999) and the subsequent effect on habitat selection would broaden our understanding of overwintering habitat selection in migrating ducks. Annual data over a broad range would provide beneficial information on spatiotemporal variation and how this influences habitat selection.

If we view the data from a biogeographical standpoint, the distribution of migratory ducks in this study appears to be influenced by ‘island size’ (i.e., lake area) and agrees with predictions of equilibrium in island biogeography (Miller 1976, Wu and Vankat 1995). The effect of lake area follows the tenet of island biogeography that larger islands will support more species than smaller islands (Samson 1980, Wu and Vankat 1995). Further investigations are needed to detail this trend, to identify if there is a significant effect of lake area over a wider variety of lake sizes, and whether the trend is a response to only water surface area or habitat heterogeneity. Species richness/abundance parameters did not differ significantly across surveyed months within each site. An equilibrium appears to be achieved during the survey period with regard to species and abundance of individuals migrating to each lake (i.e., immigration/extinction rates). Additional year-long surveys could expand the equilibrium tenet to examine how migratory species affect lake communities.

The outcome of habitat selection is based on a number of related influences (Reed et al 1999, Beatty et al 2014a,b). Although the environmental carrying capacity appears to be equal across the surveyed lakes, there is a correlation between species richness/abundance parameters and lake area, suggesting size may be a factor in determining habitat selection (c.f., Brooks 2003) of ducks over-wintering in southeast Texas. Further research is needed to broaden the understanding of the mechanisms driving habitat selection. This information could broaden investigations to explore conservation and management efforts, as well as movement patterns in terms of island biogeography and habitat preservation.

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