USE OF MAN-MADE PONDS BY MIGRATING AND WINTERING WATERFOWL IN THE BLACKLAND PRAIRIE OF CENTRAL TEXAS

THESIS

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By

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ABSTRACT

Texas provides winter habitat for millions of migratory waterfowl every year. Most ducks winter on the playas or Gulf Coast, and research regarding waterfowl use and restoration of these areas is abundant. Waterfowl use of habitats elsewhere in Texas has been sparsely studied. However, evidence suggests that ducks use numerous interior ponds and lakes throughout Texas. Blackland Prairie habitat in central Texas extends east-northeast of the city of San Marcos and contains many small ponds, dugouts and drainage basins. This area is well suited for agricultural land use and pasture grasses, and lies between the playas and Gulf Coast.

I counted ducks on 18 ponds during the fall and winter of 2002 and 2003 to identify the species using central Texas Blackland Prairie habitat during migration and winter. Surface area, distance from each pond to nearest aquatic habitat, distance from each pond to nearest study pond, species richness and visual estimates of human disturbance were measured or estimated for each pond and analyzed against waterfowl abundance in a multiple regression analysis.

I counted 14,632 ducks of 16 species. American wigeons (*Anas americana*, 36%), gadwalls (*Anas strepera*, 29%), ring-necked ducks (*Aythya collaris*, 11%), northern shovelers (*Anas clypeata*, 9%) and lesser scaup (*Aythya affinis*, 7%) accounted for the majority of observed ducks. Puddle ducks (78%) were more abundant than diving ducks (19%) throughout the study.

Ducks used all 18 ponds at some time during the study. Four ponds accounted for 73% of total ducks. Pond surface area ranged from 0.01 – 12.55 ha and positively correlated with waterfowl abundance ($r^2 = 0.357$, $P < 0.05$). Surface area correlated negatively with waterfowl density ($r^2 = -0.285$, $P < 0.05$).

The multiple regression model was significant ($R^2 = 0.873$, $P < 0.0001$). Species richness, distance to nearest aquatic habitat and disturbance scores were significant predictors of waterfowl abundance. Distance to nearest aquatic habitat and disturbance scores entered the model negatively, indicating that fewer ducks used isolated, highly disturbed ponds.

Small lakes and ponds in central Texas Blackland Prairie habitat provide adequate habitat for numerous species of ducks during the fall and winter. These ponds are ecologically important to migrating and wintering ducks, and their management potential to benefit waterfowl is substantial.

INTRODUCTION

Each year Texas provides wintering habitat for millions of migratory waterfowl. Two major areas in the state support the majority of these birds: the Gulf Coast bays and marshes and playas on the southern High Plains. The Gulf Coast attracts about 78% of the North American wintering redhead (*Aythya americana*) population and the majority of wintering pintails (*Anas acuta*) in the state (Weller 1964). The playas may support about a million ducks, mostly mallards (*Anas platyrhynchos*), when adequate moisture is present (Simpson et al. 1981). With the increase of agriculture, urbanization, reservoir development, deforestation and industrial land-use over the past 40 years, these habitats have been reduced in size and quality. Accordingly, the majority of research addressing wintering waterfowl in Texas has been directed toward habitat restoration and preservation in these areas. It has been suggested that waterfowl may be expanding their winter range in an effort to escape intensive hunting pressure and landscape deterioration and to exploit food resources in other areas (Baldassarre and Bolen 1994).

Waterfowl use of ponds elsewhere in Texas has been sparsely studied. Hoy (1987) and Johnson and Swank (1981) documented waterfowl use of reservoirs in north-central and south Texas, respectively. McAdams (1987) classified waterfowl use of ponds in south Texas. Evidence from these studies suggests that waterfowl use areas outside of the playas and Gulf Coast prairies during fall and winter. This is not surprising considering the large number of waterfowl that congregate and winter at the Gulf Coast. Waterfowl are undoubtedly attracted to many interior ponds and lakes that provide important wintering habitat. Their abundance in these areas is appreciable and warrants further research.

Winter habitat must provide cover and food resources to sustain birds during activities such as pair-bonding, initiation of migration, and daily maintenance. Diving ducks (Aythyini) tend to congregate along coastal areas, but have been known to winter as far north as the Great Lakes (Bellrose 1978). Dabbling ducks exhibit more variation when selecting winter habitat, both between and within species (Cooperrider et al. 1986). Heitmeyer and Vohs (1984) reported all dabbling ducks in Oklahoma preferred natural wetlands to farm ponds, likely because of an absence of a littoral zone on steep-sided farm ponds. In Texas, Hobaugh and Teer (1981) concluded that the most important wetland characteristics influencing waterfowl use were lake surface area and abundance of aquatic vegetation. Additionally, Evrard (1975) found a significant positive correlation existed between waterfowl use and pond size on newly created dugouts in Wisconsin. Mallards, blue-winged teal (*Anas discors*) and green-winged teal (*Anas crecca*) used ponds as small as 0.01 ha. Hopper (1972) and Lokeman (1972) reported similar findings.

Murphy et al. (1984) found pond surface area had the greatest influence on species richness among numerous limnological variables. However, he reported that waterfowl density was greatest on smaller ponds. Hudson (1983) described similar trends between waterfowl use and pond size in Montana. In addition to pond area, Elmberg et al. (1994) found a positive correlation between length of shoreline and species richness. On the contrary, Weller and Weller (2000) described positive correlations between species richness, abundance and pond size in south Texas.

During waterfowl pair-bonding in late winter, territorial pressure on the most abundant species may force individuals or pairs of waterfowl onto smaller, less desirable wetlands for space and isolation from competitors. Evans and Black (1956) reported this behavior in mallards and blue-winged teal. The result is a dispersal of individuals and pairs from areas of high density to areas of lower density. Heitmeyer and Vohs (1984) documented a late-winter shift in waterfowl abundance from reservoirs to small wetlands in Oklahoma. Despite the pressures of competition and pair-bonding on wintering grounds, ducks that successfully over-winter show some degree of winter philopatry. Robertson and Cook (1999) reported high homing rates and return rates of up to 10% for dabbling ducks on large study areas. Waterfowl that display winter philopatry may gain local knowledge of the wintering area and exploit food resources and avoid predators, thereby increasing winter survival.

As land-use changes continue to modify the wintering habitat of waterfowl, some species have adapted by modifying their food habits to include upland food sources such as agricultural crops. American wigeons (*Anas americana*), mallards, pintails, blue winged teal and green-winged teal are regular field feeders on wintering areas further south in the United States (Baldassarre and Bolen 1994).

Little research has examined waterfowl habitat selection, species richness, and species abundance in areas of Texas outside the playas and Gulf Coast. The Blackland Prairie habitat in Texas is typified by low-lying, gently sloping terrain containing Houston Black series soils. These soils consist of deep, moderately well drained uniform dark-colored alkaline clays, often referred to as "black gumbo," interspersed with some gray acid sandy loams (Batte 1984). Blackland Prairie habitat in Texas extends as a narrow corridor from south-central Texas north and northeast to the Red River. These soils are suited for improved pasture grasses and field crops, such as King Ranch (K-R) bluestem (*Bothriochloa ischaemum*), coastal bermudagrass (*Cynodon dactylon*), grain sorghum (*Sorghum spp.*), cotton (*Gossypium spp.*), corn (*Zea spp.*), and wheat (*Triticum spp.*). The majority of wetlands or moist soil environments in this area are man-made farm ponds, drainage basins, and small lakes. Waterfowl use of these wetlands varies. Many ducks use them as temporary stopovers during migration while others over-winter in the area. Waterfowl were abundant in this area many years ago, but the intensive agricultural development has severely diminished available wetland habitat (Hobaugh and Teer 1981). With continued wetland drainage in critical waterfowl habitat, small ponds and dugouts are becoming increasingly important to wintering waterfowl. Suggestions to increase waterfowl use of stock ponds have been made (Lokemoen 1973), but little information exists for some areas on the relationship between pond characteristics and waterfowl use.

In northeast Texas, current research is addressing the use of stock ponds by mallards as a result of a tremendous increase in the number of wintering ducks in the area (Kraai 2003). Northeast Texas has an estimated 400,000 ponds less than 1 ha in size located in the Oak Woods / Blackland Prairie region. A study similar to the current study in northeast Texas could provide comparative information for the Southern Blackland Prairie segment. With this in mind, I began this study 3 years ago. The objectives of my study were: (1) to identify waterfowl use of central Texas Blackland Prairie ponds during fall and winter, (2) to identify which species utilize the study area throughout fall and winter, and (3) to examine the relationships between waterfowl abundance, species richness, waterfowl density and wetland parameters including surface area, distance to nearest aquatic habitat and adjacent habitat use/human disturbance factors.

STUDY AREA

Hays County occupies an area of about 180,000 ha in south-central Texas, approximately 38 km southwest of Austin. The Balcones Escarpment divides the county into 2 distinct regions. The Edwards Plateau in the northwest is hilly, covered in trees, and used primarily as ranchland. This area includes about 75% of the county. The Blackland Prairie in the southeast quarter is comprised of grassy, agricultural plains. At one time, the Blackland Prairies wintered many waterfowl, but the change in land use to agriculture has left little natural wetland habitat. Man-made structures such as flood-prevention lakes, farm ponds and dugouts now dominate the landscape.

The mean annual rainfall in Hays County is 86.5 cm, and the average temperature is 35.5° C in July and 4.4° C in January. Hays County has a growing season of 254 days per year. In 2001, 6,802 ha of land were planted in crops. The majority of this cropland was located in the Blackland Prairie. Farm ponds, dugouts and small lakes in this low-lying area far outnumber those located in the Edwards Plateau portion of the county.

My study sites were located entirely in Blackland Prairie habitat of southeastern Hays County and northwestern Guadalupe County. This area is located between the cities of San Marcos and Seguin along Highway 123 (Fig. 1). Each pond was unique in terms of surface area, human disturbance, and attractiveness to ducks. The borders of some ponds received heavy grazing pressure by livestock and contained little or no emergent vegetation and upland vegetative cover. In the absence of grazing, other ponds contained

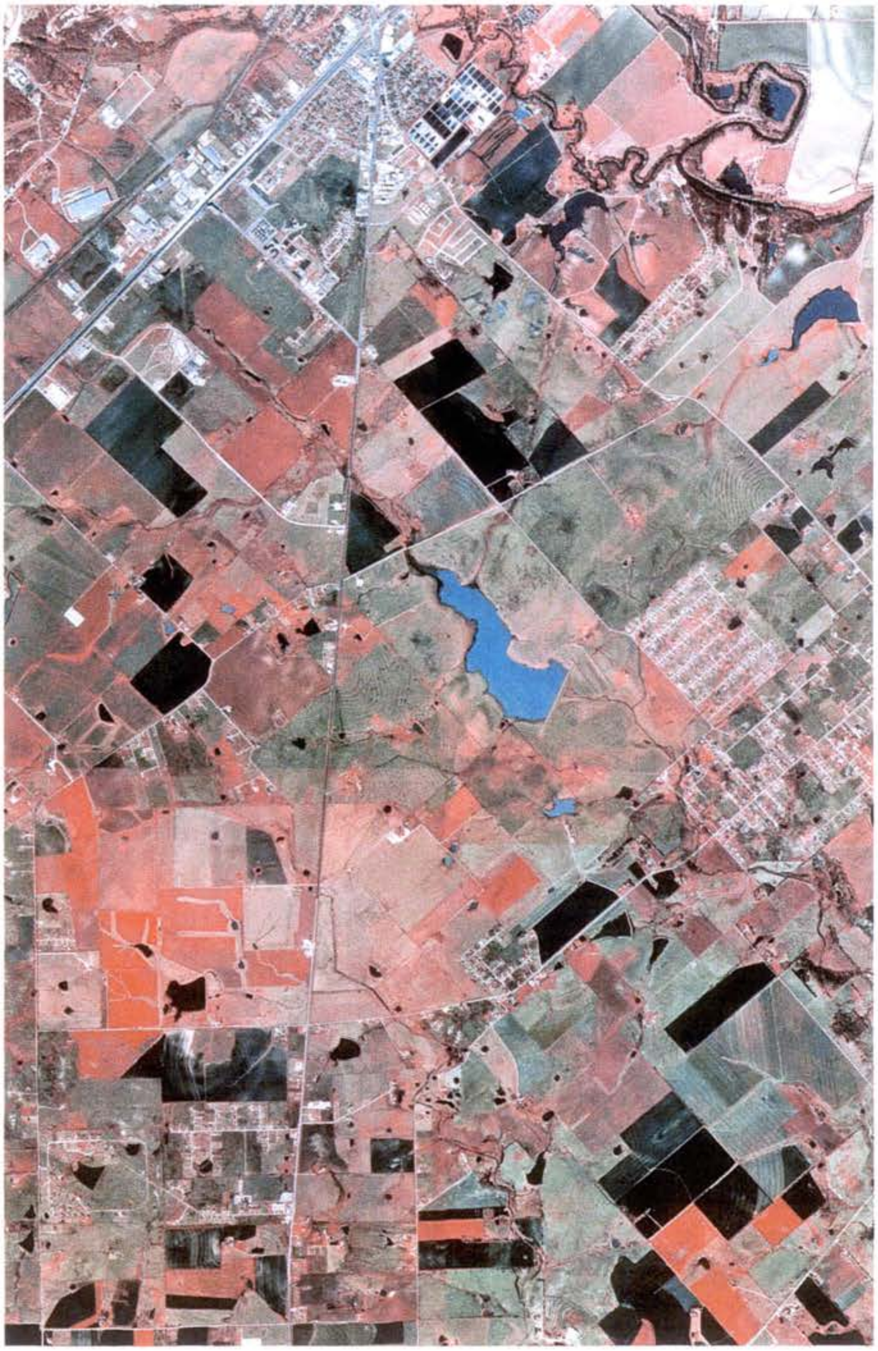

Figure 1. Aerial photograph of the study area, including 18 ponds in central Texas Blackland Prairie habitat. This area is located southeast of the city of San Marcos, along Highway 123.

stands of cattails and/or rushes and had dense upland vegetative cover. Other ponds with light grazing had intermediate levels of vegetative cover. Most ponds were small farm ponds or dugouts built primarily for cattle. Larger ponds were built for other purposes such as flood-retention or agricultural activities.

METHODS

Bird Counts

I conducted bird counts on 18 ponds located throughout the study area. While conducting a bird count, all ducks on a pond were counted one time. I made 17 counts from 24 January 2002 to 8 April 2002. I conducted an additional 24 counts from 14 October 2002 to 8 April 2003. I made 2-3 counts per week from various vantage points surrounding each pond. The time of day for counts varied between morning, noon, and afternoon. I used a Bausch and Lomb 70X spotting scope for species identification. The time required to complete a bird count averaged about 3 hours.

My bird count data was used to identify species richness, waterfowl density (ducks/ha), frequency (%), and relative abundance (%) of each duck species encountered. I defined species richness as the total number of species observed on a particular pond throughout the study. I defined frequency as the total number of counts in which a species was present. I defined relative abundance as the total number of individuals of one species compared to the total number of ducks counted. I used temporal analysis to provide a time line for when species first/last arrived/departed the study area. I used correlation and multiple regression analyses to examine relationships between waterfowl abundance, surface area, adjacent habitat use/disturbance, species richness, distance to nearest aquatic habitat, distance to nearest study pond and waterfowl density. The purpose of this analysis was to identify which parameter or set of parameters accounted for waterfowl use of ponds. All data were analyzed with SPSS statistical software. I used a stepwise regression procedure to identify the predictors that significantly contributed to the final regression model. Abundance data were transformed (log + 1) to account for the large number of ducks observed on 3 ponds.

Surface Area / Distance Measurements

I used ESRI ARCVIEW GIS 3.2 software and USGS DOQQ aerial photographs to estimate the surface area of each pond. Distances between ponds and from each pond to the nearest aquatic habitat were estimated in the same manner. In some cases, distance to nearest aquatic habitat and distance to nearest study pond were the same. Some ponds were either too small to be calculated in this manner or were created after aerial photos were taken. I calculated the surface areas of these ponds using a Bushnell Sports Optics Yardage Pro 400 laser range finder and a Lenntech surface/area calculator. I measured the length of each shoreline to compute the total surface area.

Adjacent Land Use / Disturbance

Each pond and the surrounding land were unique with respect to land-use practices and encroachment of human activity. I used visual estimates of the following: 1) presence and extent of adjacent cropland, 2) extent of cattle grazing in and adjacent to the pond, 3) presence/absence of emergent aquatic vegetation, 4) presence/absence of upland vegetative cover, 5) proximity of residential/industrial buildings, and 6) proximity and extent of vehicular traffic on adjacent roads to categorize the extent of disturbance associated with each pond. I used a 9-point system of subjective estimates for these variables, and combined all variables to obtain an average disturbance score for each pond. Table 1 provides a general characterization for each disturbance score.

Table 1. Characterization of disturbance scores ranging from 1 (undisturbed) to 9 (highly disturbed). Study site characteristics were produced from visual estimates of adjacent cropland use, cattle grazing, aquatic vegetation, upland vegetative cover, adjacent buildings and adjacent vehicular road use.

Disturbance Score	Site Characteristics
1	No adjacent cropland use or cattle grazing; robust stands of aquatic vegetation and upland vegetative cover; lack of adjacent buildings and roads
2	< 20% adjacent cropland use and little or no cattle grazing; high levels of aquatic vegetation and upland vegetative cover; no adjacent buildings or major roads nearby
3	< 30% adjacent cropland use and light grazing; moderate-high levels of aquatic vegetation and upland vegetative cover; small homes and lightly traveled roads nearby
4	< 40% adjacent cropland use and light-moderate cattle grazing; moderate-high levels of aquatic vegetation and upland vegetative cover; buildings, homes and lightly traveled roads nearby
5	< 50% adjacent cropland use and light-moderate cattle grazing; moderate levels of aquatic vegetation and upland vegetative cover; buildings and homes nearby; moderate-heavy adjacent road use
6	< 60% adjacent cropland use; moderate cattle grazing; moderate-light patches of aquatic vegetation and upland vegetative cover; buildings nearby; moderate-heavy adjacent road use
7	< 70% adjacent cropland use; moderate-heavy cattle grazing; light aquatic vegetation; light-moderate upland vegetative cover; buildings nearby; moderate-heavy adjacent road use
8	< 80% adjacent cropland use; high level of grazing; little or no aquatic vegetation and upland vegetative cover; buildings and busy roads nearby.
9	> 80% adjacent cropland use; high level of cattle grazing; no aquatic vegetation or upland vegetative cover; buildings and busy roads within 50 m

For example, pond 13 was surrounded by tall grass and thick stands of shrubs and trees (Fig. 2). There was no evidence of cattle grazing near this pond and the closest road was small and sparingly traveled. The pond contained large amounts of emergent vegetation and was well sheltered from the nearest homestead. This pond received a score of 2, indicating few signs of disturbance.

Pond 7 contained shoreline vegetation of moderate height and was located in a field that showed signs of little or no grazing (Fig. 3). A dense stand of cattails existed in one corner of the pond. The presence of two adjacent roads (1 heavily traveled) and a nearby machine shop resulted in a score of 5, moderately disturbed.

Pond 2 contained no emergent vegetation, had a trampled shoreline with little vegetative upland cover, and was heavily grazed (Fig. 4). A busy road was within 50 m of the pond and surrounding lands were in pasture. This highly disturbed pond received a score of 9. The resulting score for each pond was used as a predictor in a multiple regression analysis to identify any relationship between waterfowl abundance and the degree of disturbance associated with each pond.

Figure 2. Pond 13 was surrounded by tall grass and thick stands of shrubs and trees. This pond contained large amounts of aquatic vegetation and was sheltered from dwellings. The relatively undisturbed site was assigned a score of 2.

Figure 3. Pond 7 contained moderate shoreline vegetation in a field that was lightly grazed. It contained a few stands of cattails and was located near 2 roads and a machine shop. This sight was assigned a score of 5, moderately disturbed.

Figure 4. Pond 2 was heavily grazed, contained no upland cover and emergent vegetation, and was located within 50 m of a busy road. This highly disturbed site was assigned a score 9.

RESULTS

Waterfowl Abundance

A total of 14,632 ducks of 16 species used the 18 study ponds in 2002 and 2003 (Table 2). American wigeons were the most common species throughout the study (Table 3), accounting for 36% of ducks counted (n = 5,338). I counted an average of 130 wigeons during each of 41 duck counts with a peak of 268 individuals. Gadwalls (*Anas strepera*) also contributed substantially to waterfowl abundance (n = 4,232) with an average of 103 birds per count. Gadwalls accounted for 29% of all individuals observed (Fig. 5). Both wigeons and gadwalls were observed on ponds with a frequency of 100%. These 2 species represented the majority (69%) of all waterfowl species counted. This trend occurred in both seasons.

Ring-necked ducks (*Aythya collaris*, 11%), northern shovelers (*Anas clypeata*, 9%), and lesser scaup (*Aythya affinis*, 7%) had secondary importance on ponds with an average of 37, 32, and 24 ducks per count, respectively. Each species had a frequency of 88% or more. Ring-necked ducks were most prevalent in late December 2003, when a high of 154 individuals was counted. Both ring-necked ducks and northern shovelers exhibited considerable variation in abundance between years. Ring-necked ducks increased from 6% to 13% while northern shovelers decreased from 16% to 4% between years (Figs. 6, 7). The level of lesser scaup remained relatively constant between years, with a total count of 977 individuals. On 6 February 2003, I counted 78 lesser scaup with most using one pond.

Table 2. Pond-specific waterfowl abundance measurements (N_t) for 41 counts during the fall/winter of 2001-2002 (N_1) and 2002-2003 (N_2). Mean number of waterfowl per pond, surface area (ha), waterfowl density (# ducks/ha), disturbance score and total number of species observed are included.

Pond	N_1	N_2	N_t	MEAN	SA	Density	Disturbance	# Species
1	217	109	326	7.95	9.71	0.82	5	7
2	122	207	329	8.02	0.37	21.57	9	11
3	1	5	6	0.15	0.13	1.09	8	3
4	20	2	22	0.54	0.13	4.00	8	3
5	259	226	485	11.83	0.22	53.05	9	7
6	82	112	194	4.73	12.55	0.38	6	4
7	193	109	302	7.37	0.89	8.28	5	7
8	44	23	67	1.63	0.22	7.33	3	5
9	1823	3305	5128	125.07	7.28	17.17	9	13
10	91	62	153	3.73	0.32	11.81	7	5
11	322	684	1006	24.54	3.24	7.58	8	10
12	134	145	279	6.80	0.61	11.21	3	5
13	71	430	501	12.22	0.81	15.10	2	6
14	117	59	176	4.29	0.45	9.65	5	5
15	6	1	7	0.17	0.01	21.34	7	3
16	73	18	91	2.22	0.02	110.98	7	5
17	1873	1849	3722	90.78	3.24	28.04	4	11
18	525	1313	1838	44.83	2.27	19.78	8	9
Total	5973	8659	14632	19.40	-	-	-	-

Table 3. Species-specific waterfowl abundance measurements (N_t) for 41 counts on 18 ponds during the fall/winter 2001-2002 (N_1) and 2002-2003 (N_2). Mean number of ducks per count, standard error and frequency of occurrence are reported. Range is the fewest/most birds counted during any one event.

Species	**N_1**	**N_2**	**N_t**	**MEAN**	**SE**	**Frequency**	**Range**
American Wigeon	2030	3308	5338	130.20	11.04	1.00	11-268
Blue-winged Teal	84	20	104	2.54	0.66	0.37	0-13
Bufflehead	55	114	169	4.12	0.62	0.73	0-20
Canvasback	61	99	160	3.90	0.87	0.59	0-28
Cinnamon Teal	3	1	4	0.10	0.08	0.05	0-3
Gadwall	1510	2722	4232	103.22	8.98	1.00	6-199
Green-winged Teal	166	15	181	4.41	0.93	0.51	0-25
Hooded Merganser	0	1	1	0.02	0.02	0.02	0-1
Lesser Scaup	321	656	977	23.83	3.28	0.88	0-78
Mallard	8	4	12	0.29	0.13	0.15	0-4
Northern Pintail	132	58	190	4.63	1.07	0.59	0-27
Northern Shoveler	967	377	1344	32.78	4.75	0.90	0-98
Redhead	58	34	92	2.24	0.81	0.24	0-20
Ring-necked Duck	382	1157	1539	37.54	5.36	0.95	0-154
Ruddy Duck	195	93	288	7.02	0.96	0.93	0-29
Wood Duck	1	0	1	0.02	0.02	0.02	0-1
Total	5973	8659	14632	356.07	7.00	-	0-268

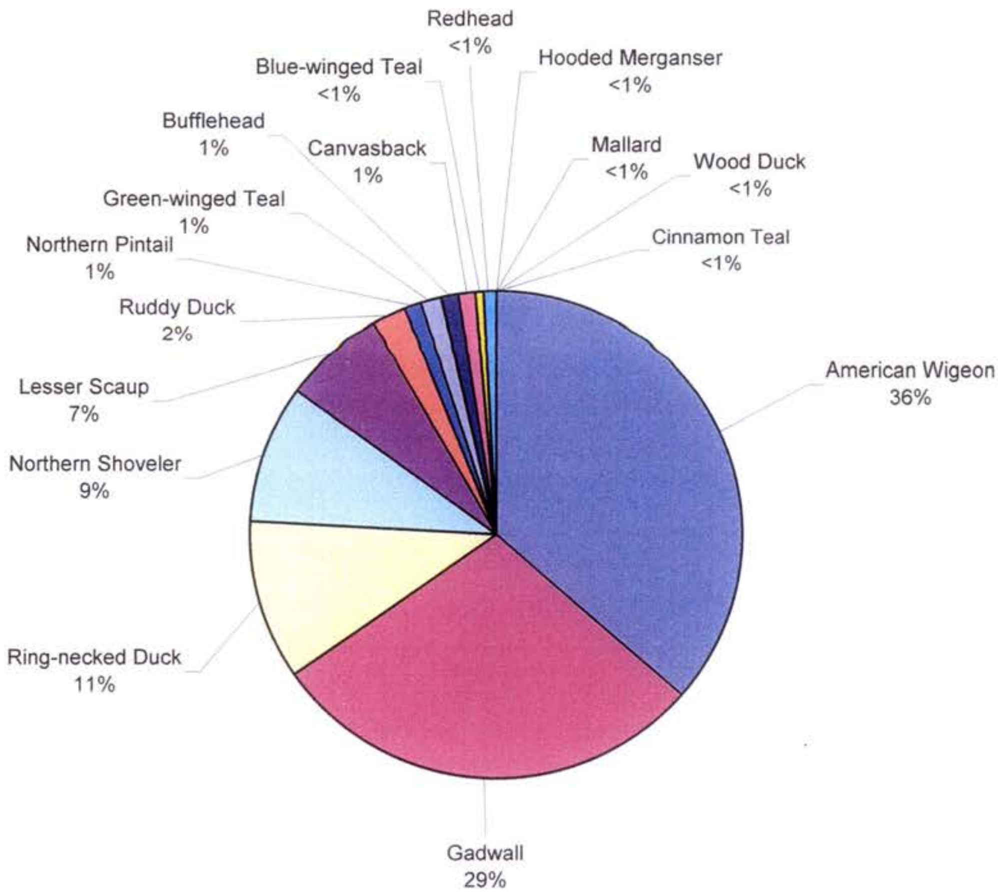

Figure 5. Species-specific percent use by waterfowl of 18 study ponds in 2001-2002 and 2002-2003. Number of species = 16. A total of 41 counts were conducted. Use is expressed as relative abundance. Total number of birds observed = 14,632.

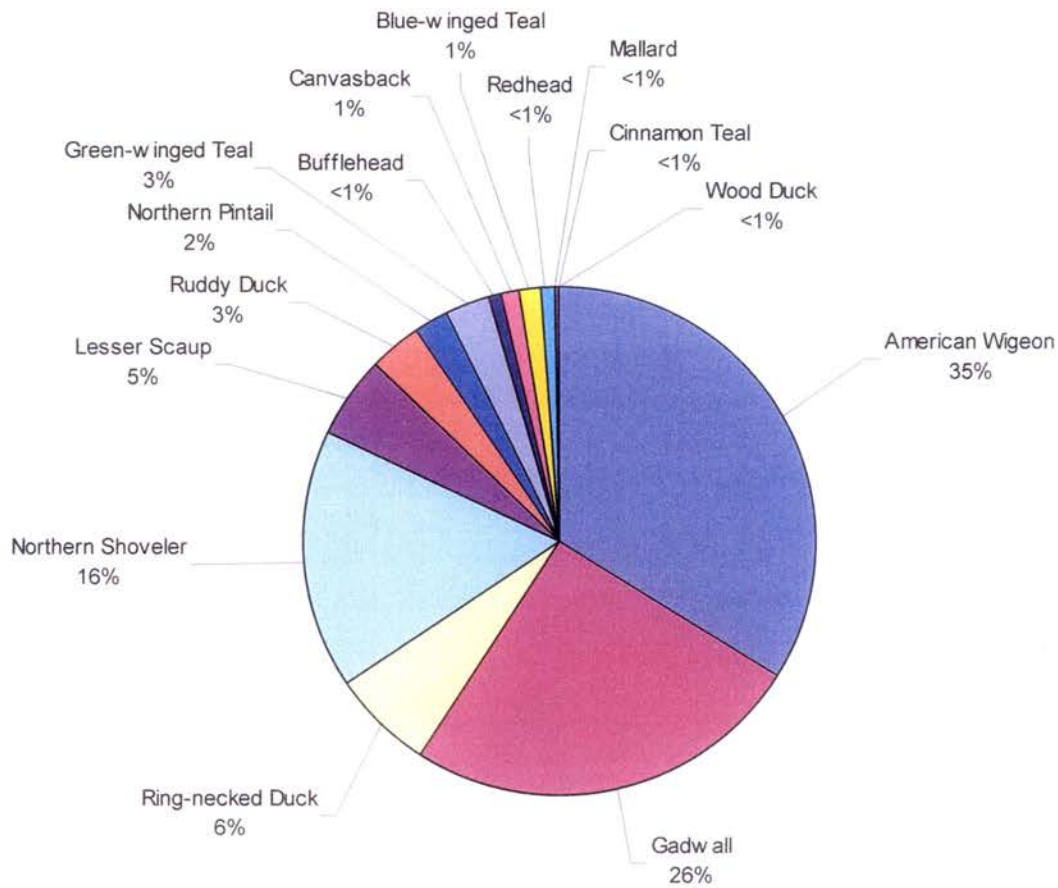

Figure 6. Species-specific percent use by waterfowl of 18 study ponds from 24 January 2002 to 8 April 2002. Number of species = 15. A total of 17 counts were conducted. Use is expressed as relative abundance. Total number of birds observed = 5,973.

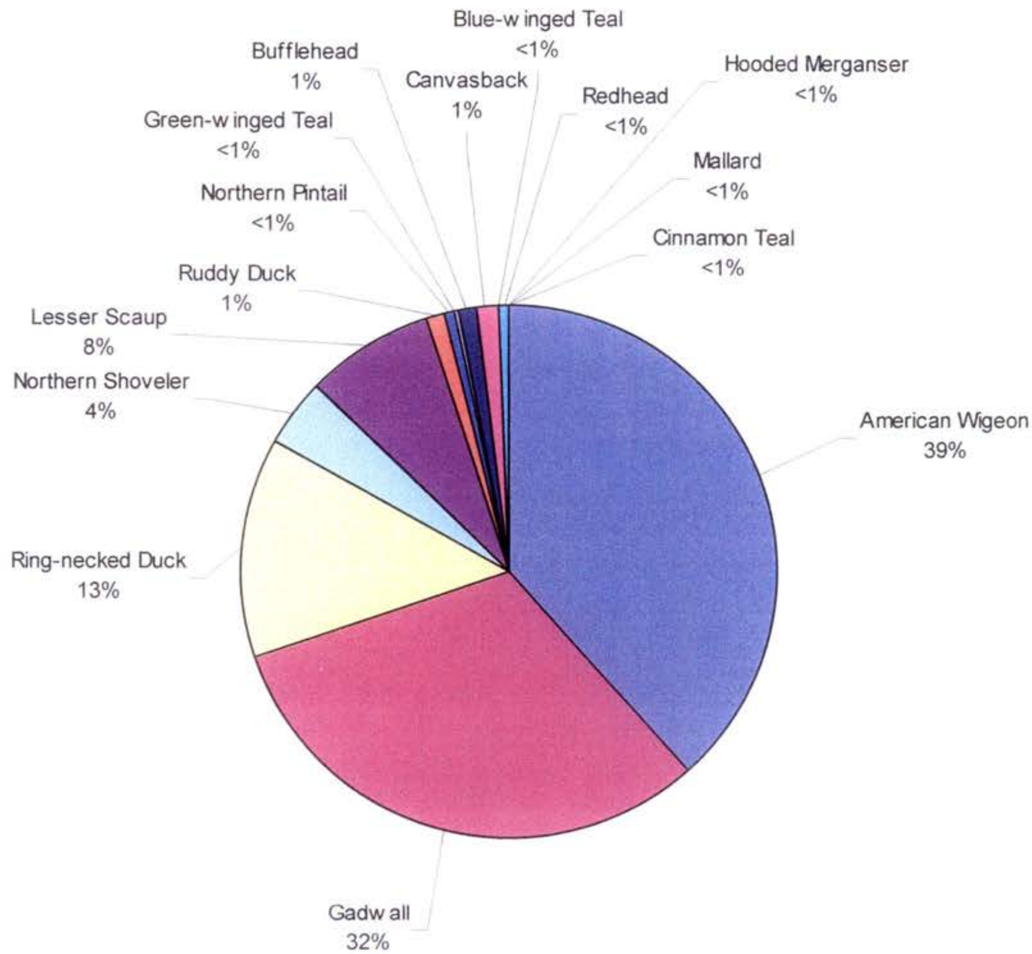

Figure 7. Species-specific percent use by waterfowl of 18 study ponds from 14 October 2002 to 9 April 2003. Number of species = 15. A total of 24 counts were conducted. Use is expressed as relative abundance. Total number of birds observed = 8,659.

Ruddy ducks (*Oxyura jamaicensis*), northern pintails, green-winged teal, buffleheads (*Bucephala albeola*) and canvasbacks (*Aythya valisineria*) comprised between 1% and 2% of the total waterfowl abundance. Despite their relatively low numbers, ruddy ducks maintained a frequency of 93%. Northern pintails and canvasbacks occurred with approximately the same frequency (59%). I counted a total of 190 pintails and 160 canvasbacks. Counts of green-winged teal and buffleheads averaged 4 birds per count, but buffleheads occurred more frequently (73% and 51%, respectively).

I counted 84 blue-winged teal in year 1 but only 20 in year 2. I observed the same trend for redheads (year 1 = 58, year 2 = 34). Each species contributed less than 1% to waterfowl abundance on ponds. The largest number of redheads seen on any one count was 20 on 6 March 2002, late in the season.

Four species were extremely rare and averaged less than one bird per count. I counted only 12 mallards and saw them with a frequency of 15%. I observed four cinnamon teal (*Anas cyanoptera*) during two counts. I observed one hooded merganser (*Lophodytes cucullatus*) and one wood duck (*Aix sponsa*) over the course of the study. These four species accounted for a combined 0.13% of total individuals counted.

Overall, puddle ducks (n = 11,405, 78%) and diving ducks (n = 2,768, 19%) composed 97% of all ducks counted. The other 3% included ruddy ducks, wood ducks, mergansers and buffleheads. Ring-necked ducks and lesser scaup were the most abundant diving ducks.

2002-2003 Season

Waterfowl arrived on the ponds and increased dramatically during mid-October (Fig. 8). The peak of the 2002-2003 season occurred on 21 November 2002, when I saw

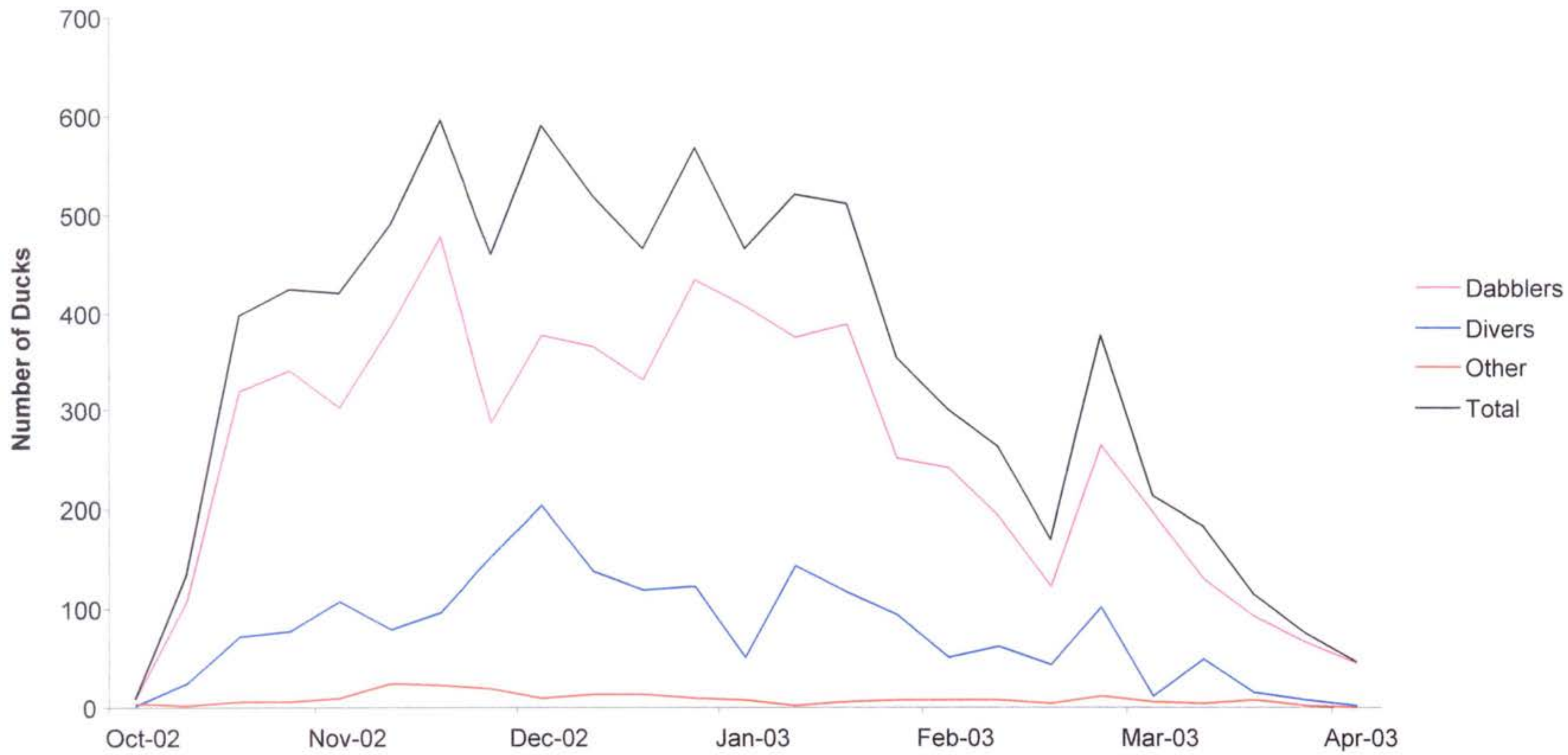

Figure 8. Total number (n = 8,659) of ducks including dabblers, divers, and other species counted on the study ponds during the fall/winter of 2002-2003. A total of 24 counts were made from October 2002-April 2003.

596 ducks. I observed the largest number of puddle ducks (n = 477) on this date. I observed the largest number of diving ducks (n = 205) on 20 December 2002. Waterfowl abundance declined throughout February but increased sharply on 11 March 2003. Both puddle ducks and divers increased at this time. The increase in waterfowl abundance was followed by a steady decline in numbers until all ducks had left the area by mid-April.

The five most common species appeared on ponds within a few days of each other in early winter (Fig. 9). American wigeons and ring-necked ducks reached their peak abundance in late December. Gadwalls, northern shovelers and lesser scaup were most abundant in late January/early February. By the beginning of April, ring-necked ducks, northern shovelers and lesser scaup had left the area. The two most common species, American wigeons and gadwalls were the last to leave.

Study Ponds

Ducks used all 18 study ponds at some time during the study. The cumulative total number of ducks observed per pond ranged from 6-5,128 (Table 2). Four ponds accounted for 73% (n = 11,694) of total ducks. In contrast, four other ponds had < 1% of total ducks. Diving duck use was concentrated on three ponds (86%). One pond accounted for 56% (n = 1,538) of all diving duck observations.

The surface area of the 18 ponds varied greatly. Measurements ranged from 0.01 to 12.55 ha. Twelve ponds measured < 1 ha. Three ponds measured between 1 and 5 ha and three ponds had a surface area > 5 ha. The average pond size was 2.36 ha. Surface area positively correlated with waterfowl abundance ($r^2 = 0.357$, $P < 0.05$). Waterfowl abundance increased with surface area to a critical point, then the relationship became

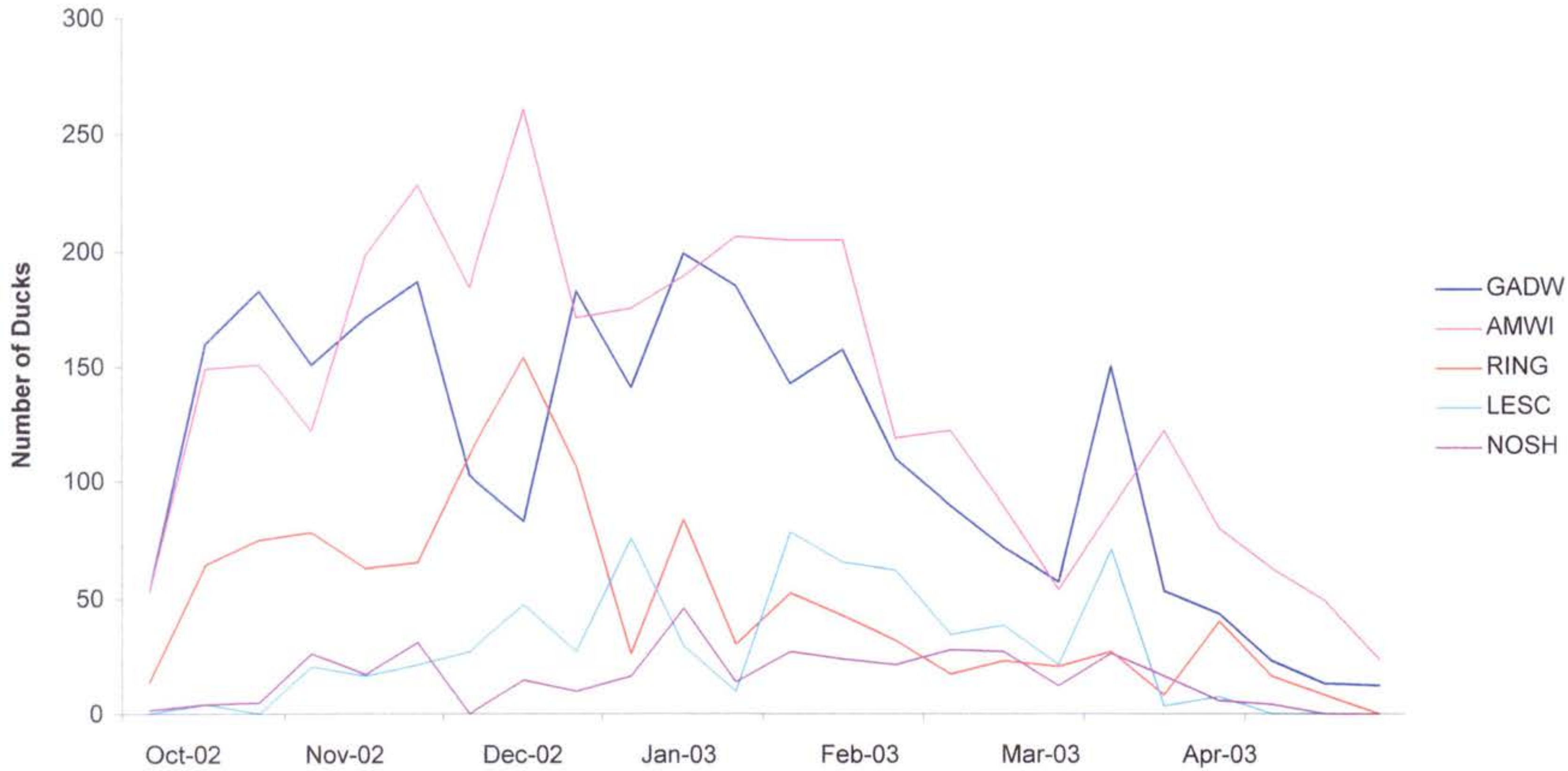

Figure 9. A comparison of the five most abundant duck species counted (n = 8,220) on the study ponds during the fall/winter of 2002-2003. Gadwall (GADW), American Wigeon (AMWI), Ring-necked Duck (RING), Lesser Scaup (LESC) and Northern Shoveler (NOSH). A total of 24 counts were made from October 2002-April 2003.

negative (Fig. 10). When I eliminated the 3 ponds > 5 ha from the correlation analysis, the relationship strengthened to the $P < 0.01$ level ($r^2 = 0.812$).

Species richness ranged from 3-13 species per pond (Mean = 6.61, SE = 0.52). Ten or more species occurred on three ponds, with pond 9 having the most ($n = 13$). The fewest species ($n = 3$) occurred on ponds 3, 4, and 15. Each of these ponds had a surface area less than 0.15 ha. Species richness positively correlated with waterfowl abundance ($r^2 = 0.909$, $P < 0.01$).

Waterfowl density on ponds ranged from 0.38-110.98 ducks/ha. Density negatively associated with surface area ($r^2 = -0.285$, $P < 0.05$) and distance to nearest aquatic habitat ($r^2 = -0.002$, $P > 0.05$). This indicated that larger, more isolated ponds had a lower waterfowl density than small ponds with water nearby. The pond with the highest waterfowl density had a surface area of only 0.02 ha. To the contrary, the pond with the lowest density had a surface area of 12.55 ha. The average waterfowl density for all 18 ponds was 19.82 ducks/ha.

Factors Affecting Waterfowl Use

I used surface area, distance to nearest aquatic habitat, distance to nearest study pond, disturbance score, and species richness as predictors with waterfowl abundance in a step-wise multiple regression. The resulting model was significant ($P < 0.0001$, $R^2 = 0.873$) (Table 4). Distance to nearest study pond was the only predictor omitted from the final model. This supported the assumption that the study ponds were independent and did not influence each other with regard to waterfowl use. Despite a positive relationship between surface area and waterfowl abundance, surface area was the only insignificant

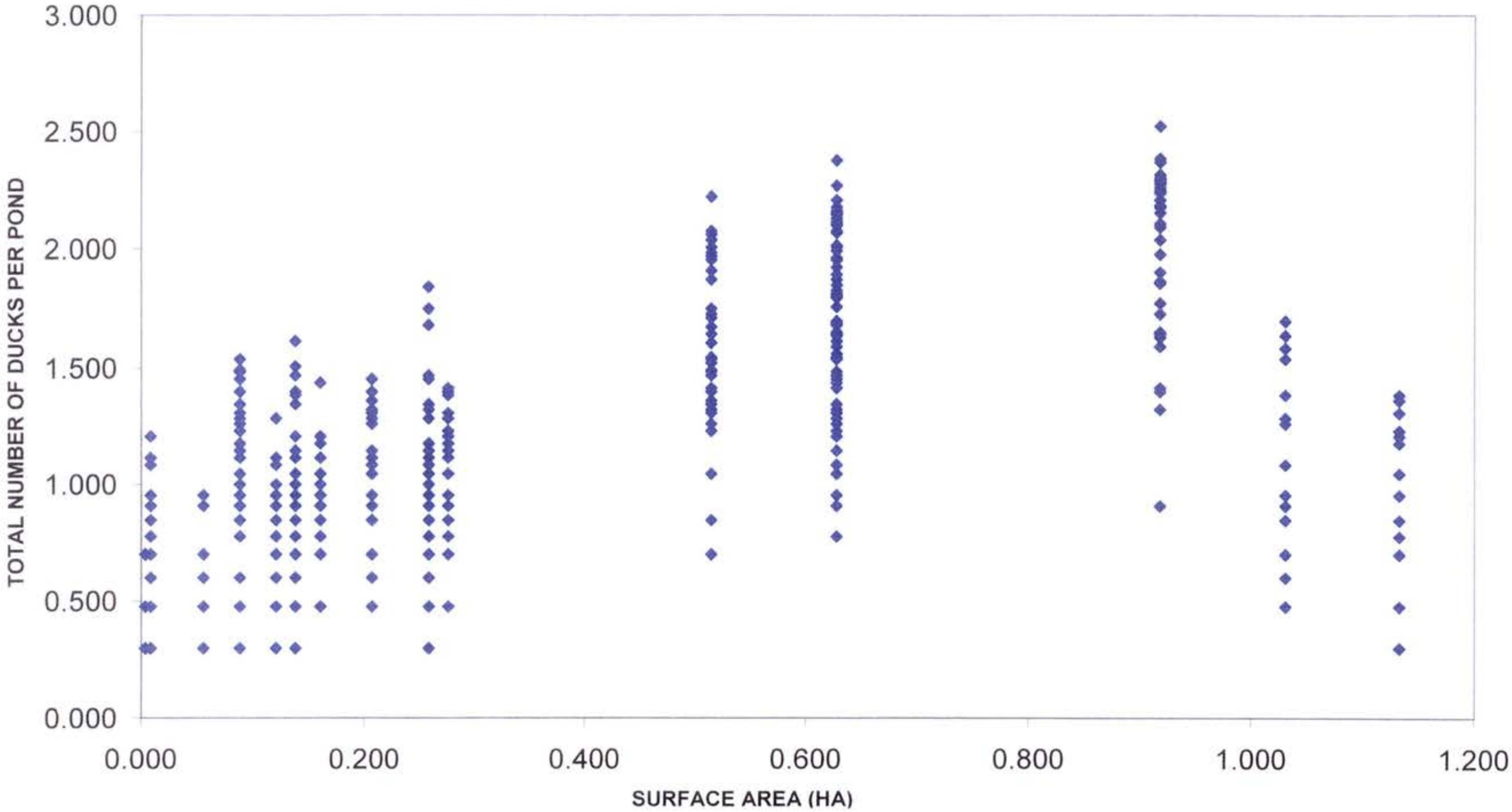

Figure 10. Log-Log plot of waterfowl abundance vs. pond surface area of 18 study ponds throughout the study. Total number of counts = 41.

Table 4. (a) Multiple regression equation and (b) ANOVA table showing the relative importance of each variable in predicting waterfowl abundance on central Texas Blackland Prairie ponds. Significance of the coefficients are provided (c). The dependant variable waterfowl abundance was transformed log + 1 and regressed against the independent variables surface area (SA), disturbance (DISTURB), species richness (RICHNESS) and distance to nearest water (DISTWAT).

(a) Waterfowl abundance = 0.310 + 0.018 area – 0.039 disturbance + 0.169 richness – 0.000984 nearest water

Adjusted $R^2 = 0.873$ N = 36

(b) ANOVA

Model		Sum of Squares	DF	Mean Square	F	Sig.
1	Regression	10.874	4	2.719	61.207	0.000
	Residual	1.377	31	0.044		
	Total	12.251	35			

Predictors: (Constant), DISTWAT, DISTURB, SA, RICHNESS
Dependent Variable: WATERFOWL ABUNDANCE

(c)

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	0.310	0.130	-	2.385	0.023
	SA	1.812E-02	0.010	0.112	1.781	0.085
	DISTURB	-3.882E-02	0.017	-0.145	-2.345	0.026
	RICHNESS	0.169	0.012	0.895	13.942	0.000
	DISTWAT	-9.837E-04	0.000	-0.151	-2.461	0.020

predictor ($P = 0.085$). However, when the three ponds > 5 ha were omitted from the regression model (Ponds 1, 6, and 9), surface area became significant ($P < 0.05$).

Species richness positively associated with waterfowl abundance and was responsible for the majority of the observed variation ($P < 0.01$). As expected, this was a strong relationship. Ponds that attracted many species of waterfowl also attracted many individuals. Surface area did not significantly influence this relationship, but positively correlated with species richness. Large ponds tended to attract more duck species than small ponds. Distance to nearest aquatic habitat and disturbance scores affected the model negatively, indicating that fewer ducks used isolated, highly disturbed ponds.

DISCUSSION

Waterfowl Abundance

My results indicate that a substantial number of ducks used ponds in the Blackland Prairie in central Texas throughout the fall and winter. I observed 16 species (Table 3). American wigeons and gadwalls accounted for 69% of all ducks counted (n = 9,570). After 41 counts, both species maintained an average over 100 individuals per count and occurred with a frequency of 100%. It is apparent that American wigeons and gadwalls have developed strong traditions of wintering in the area. Heitmeyer and Vohs (1984) found these two species spent early winter in Oklahoma but left the state by late winter. Factors such as temperature, food availability and habitat suitability probably accounted for the move from Oklahoma to areas farther south. This pattern of movement is consistent with my findings. American wigeons were most abundant during late December (n = 261) and gadwalls reached their peak abundance in late January (n = 199) (Fig. 9). Both species were among the first to arrive and last to depart. Considering their abundance and length of stay, American wigeons and gadwalls should be considered the dominant winter waterfowl residents on Blackland Prairie ponds in central Texas.

Northern shovelers were the third most prevalent dabbling duck on ponds during my study. I counted 1,344 individuals with a frequency of 90%. However, I only counted 377 in the second season. Despite having lower abundance than American wigeons and gadwalls, shovelers accounted for almost 10% of total waterfowl abundance and should also be considered an important winter resident in the area (Fig. 5). Like gadwalls, shovelers reached their peak abundance in late January (n = 46). Northern shovelers arrived later and left the study site earlier than wigeons and gadwalls. Despite a considerable winter range, only a small population of shovelers winter in Texas, particularly along the Gulf Coast. Thus, it appears that this species was less-dependant on central Texas for wintering habitat, or environmental conditions favored wintering habitats elsewhere in 2002-2003.

Blue-winged teal, green-winged teal, cinnamon teal, northern pintails and mallards comprised the remaining species of the dabbling duck cohort observed on ponds. Cinnamon teal and mallards were extremely rare during duck counts (n = 4 and 12, respectively). The majority of cinnamon teal winter in central Mexico, and most mallards in Texas winter in the northern and eastern parts of the state (Bellrose 1978). Observations of these two species were unique and worth mentioning.

Blue-winged teal occurred on ponds with a frequency of 37%. These ducks appeared to use ponds as stop-over sites during migration. I observed the majority of these ducks during late March to early April, probably on their migration to nest in the prairie pothole region of the northern United States. Blue-winged teal might have used ponds during fall migration in September, but duck counts did not begin until October.

Green-winged teal outnumbered all other teal species on ponds and occurred with a frequency of 51%. My study ponds were located between two major wintering sites for this species: the panhandle and Gulf Coast. Because of the relatively low frequency, I thought most green-winged teal used ponds as stop-over sites during migration. Most were likely headed farther south. Green-winged teal are known to winter as far south as South America (Bellrose 1978).

Northern pintail abundance almost mirrored that of green-winged teal during the study. I observed pintails in 59% of duck counts, but the species contributed only 1% to total waterfowl abundance on ponds. Known for wandering and pioneering new areas, pintails either used ponds as stop-over sites during migration to the coast or found ponds suitable for habitation during winter (Bellrose 1978).

Four species (ring-necked, lesser scaup, canvasback and redhead) of diving ducks used ponds. Ring-necked ducks were the third most abundant species throughout the study. With an average of 37 birds per count and a frequency of 95%, ring-necked ducks accounted for 11% of total waterfowl abundance. This species was most abundant in late December, and its numbers slowly decreased thereafter. Primarily an east-coast resident, ring-necked ducks have large wintering grounds in Florida and Louisiana. However, a small population of ring-necked ducks winters on the Texas Gulf Coast. The ring-necked ducks I found on ponds were probably part of this Texas population. The ponds provided adequate food and cover for large congregations of these birds during winter.

The lesser scaup was the fifth most abundant species during the study. I most frequently observed this species in groups of 10 or more. Primarily a resident of the Mississippi flyway, some lesser scaup populations migrate through Texas on their way to the Gulf Coast of Texas or Mexico. I saw lesser scaup at a frequency of 88% on ponds. The lesser scaup certainly used ponds as a wintering ground. Several ponds must have been rich with animal life, affording nutrients and energy for this omnivorous duck.

Canvasbacks and redheads did not contribute substantially to waterfowl abundance, but both species used ponds during the study. I observed only 160 canvasbacks, however, a frequency of 59% suggested some individuals might winter in the area. On the contrary, I observed redheads at a much lower frequency (24%), and the species used ponds only briefly on their way to the Gulf Coast. Redheads are attracted to shallow, brackish waters and prefer plant foods, while canvasbacks prefer freshwater and readily eat animals if plant foods diminish (Bellrose 1978). This could explain why I saw canvasbacks more frequently and in greater numbers than redheads. Both species migrate to Texas from Manitoba and primarily winter on or near the coast.

Buffleheads typically winter in coastal areas throughout North America. Each year in Texas, more than 4,000 wintering buffleheads occupy the Texas Gulf Coast and its interior reservoirs and lakes (Bellrose 1978). Although comparatively small in numbers (n = 169), I observed buffleheads at a frequency of 73% on study ponds. Abundance was greatest in mid-November, followed by a slow decline throughout winter. Buffleheads primarily eat animal foods including aquatic insects and crustaceans, but also readily consume seeds of pondweeds and bulrushes when available. Because of the high frequency and an average of more than 4 birds per count, I concluded that a small number of buffleheads used the ponds throughout winter. Other buffleheads probably used them as resting and feeding sites during migration to areas further south.

Ruddy ducks, like buffleheads, were not abundant (n = 288) but had a frequency of 93% on ponds throughout the study. Most wintering ruddy ducks in Texas are found along the coast and in the panhandle. Others occupy inland lakes, ponds and reservoirs. Primarily vegetarians, a small number of ruddy ducks secured food sources and used some of the ponds as winter habitat during the study.

I sighted only one hooded merganser and one wood duck on ponds. The study area lies on the western border of major wintering grounds for both species, and I considered the species as rare on ponds.

Study Ponds and Factors Affecting Waterfowl Use

Waterfowl use of the 18 ponds varied. Habitats in the central Texas Blackland Prairie were apparently suitable for both dabblers and divers. Although diving ducks concentrated their use on 3 ponds, dabbling ducks used every pond and composed the majority of duck observations (78%). Of the 18 ponds, three averaged less than one duck per count (Table 2). The largest of these ponds was 0.13 ha. It appears that very small ponds did not attract many waterfowl. Ducks regularly used 10 ponds and these ponds averaged more than five ducks per count. Pond 9 had the highest use and averaged over 125 ducks per count! The three most heavily used ponds had an average surface area of 4.26 ha.

Surface area has been reported as a strong positive predictor of waterfowl abundance on ponds and lakes (Flake et al. 1977, Hobaugh and Teer 1981). However, surface area was not a significant predictor in my regression model. Waterfowl abundance increased with surface area up to about 8 ha (Fig. 10). Two larger ponds showed significant declines in waterfowl use. Removal of these ponds from the regression model resulted in a strong positive relationship between surface area and waterfowl abundance ($P < 0.05$). Copelin (1961) reported that small flood-control impoundments attracted more ducks than any large reservoirs in western Oklahoma. Chabrack (1979) suggested large, open-water lakes prone to wind and wave action had less attractiveness to waterfowl, especially dabblers. The two largest ponds were indeed more exposed to wind and wave action. Based on my results, ponds larger than 8 ha were less attractive to waterfowl wintering in the area. Numerous limnological, ecological and physical variables including depth, slope, presence of food sources, duck distribution on ponds, and competition between duck species should be considered before size of pond is determined to be a limiting factor.

There was a significant positive correlation between species richness and waterfowl abundance ($P < 0.01$) in my model that explained the majority of the observed variation. Elmberg et al. (1994) reported a strong positive correlation between species richness and surface area on lakes between 2-48 ha in size. Species richness positively correlated with surface area and negatively correlated with distance to nearest water, but neither relationship was significant ($P > 0.05$). Ponds with several species of ducks tended to be large, contained many individuals, and had ponds nearby. This reinforces the idea that waterfowl are social birds and that the lack of interspecific competition allowed multiple species to exploit resources in the same areas.

The disturbance score for each pond was derived from ocular estimates of several variables including: presence and extent of adjacent cropland, cattle grazing, presence/absence of upland vegetative cover, proximity to buildings/houses and proximity to roads/traffic. Disturbance was a significant predictor and entered the model negatively (Table 4). Highly disturbed sites attracted fewer waterfowl. The disturbance variable was measured by estimation and its significance could have resulted from a single factor or any combination of factors that were pooled together to provide a disturbance score.

Cropland nearby the ponds could result in more waterfowl if stubble and grain are present as food sources during migration. On the other hand, if no grain is left behind and crops are planted up to the pond margin, then waterfowl may be deterred from the area. Cattle grazing was common in areas surrounding most ponds. Heavy grazing can result in a loss of emergent vegetation, as cattle will readily eat cattails (*Typha spp.*) and bulrushes (*Scirpus spp.*). Grazing can also cause a loss of emergent vegetation and upland vegetative cover by trampling (Logan 1975). Proximity to buildings and roads might also deter waterfowl as they approach ponds. Aquatic vegetation undoubtedly plays a vital role with respect to waterfowl abundance and habitat selection. Hobaugh (1977) found aquatic vegetation was the most important factor affecting waterfowl use of floodwater retarding structures in north-central Texas. On the contrary, Flake et al. (1977) concluded that pond size was the most important variable explaining the number of paired ducks on stock ponds in North Dakota. It was outside the scope of this study to analyze each of the disturbance variables individually. Any further research should address how each type of disturbance affects waterfowl abundance in order to obtain a better understanding of habitat selection in the area.

As noted before, distance to nearest aquatic habitat was a significant predictor that entered the model negatively. Isolated ponds attracted fewer ducks during the study. This result is only applicable to the conditions of this study area with respect to pond density and the spatial scale at which the study took place. It is possible that when choosing ponds in an area, ducks prefer areas high in pond density to those areas with larger, more isolated ponds. Presence of nearby ponds may provide additional security, escape cover and food resources to visiting ducks. Of course, this relationship would not apply to semi-arid areas that provide fewer, larger lakes and reservoirs to wintering or migrating waterfowl. Large west Texas reservoirs may be the only option for visiting waterfowl during dry spells.

The model produced by the multiple regression analysis was significant ($R^2 = 0.873$, $p < 0.05$) (Table 4). It should be noted that the variation was attributed only to the parameters measured, and that there are numerous other factors that could influence waterfowl abundance and use of wetlands. Parameters such as weather, invertebrate abundance, pond distribution, length of shoreline and numerous other limnological and ecological parameters can all influence waterfowl habitat selection.

Waterfowl in Oklahoma generally avoided farm ponds during winter, favoring natural wetlands (Heitmeyer and Vohs 1984). Farm ponds typically do not support much aquatic vegetation because of the steep sides and lack of water fluctuations. However, central Texas Blackland Prairie habitat contains few natural wetlands. The majority of water in the area is in the form of small water-retaining lakes and farm ponds used by cattle. It is clear that these small lakes and ponds provide adequate habitat for numerous species of waterfowl throughout the fall and winter. Therefore, I concluded that small lakes and farm ponds in the central Texas Blackland Prairie are ecologically important and their management potential to benefit wintering waterfowl is worthy of future research.

At least some of the large numbers of waterfowl that used the ponds might have used “local knowledge” of the area from previous successful winters in the area. Winter philopatry is most prevalent among female waterfowl and provides benefits to returning individuals (Roberston and Cooke 1999). These individuals use their knowledge of the area to avoid predators, secure food or find a mate. Such individuals enjoy a higher over-winter survival rate and better overall health. I observed pair-bonding behaviors during the study, especially head-bobbing and chase flight displays.

MANAGEMENT IMPLICATIONS

The numerous small lakes, ponds and dugouts in central Texas Blackland Prairie habitat have been built primarily for agricultural purposes. These bodies of water provide water to livestock and help prevent flooding and runoff in areas prone to such activity. Secondary benefits such as stocking fish and attracting waterfowl can be achieved with little effort. Physical features of a pond can play an important role when evaluating the potential benefit to waterfowl. Potential sites should be larger than 0.2 ha and no larger than 8.0 ha. Smaller or larger ponds attracted fewer ducks. Large ponds are prone to wind and wave action, which can deter waterfowl. In general, large ponds tend to attract more waterfowl species but maintain lower densities than smaller ponds. Small ponds attract fewer birds but realize larger densities. Distance to the nearest aquatic habitat also appears to influence waterfowl use. Isolated ponds do not attract as many ducks as ponds situated close to other ponds or rivers. Highly disturbed areas also attract fewer ducks.

Expected benefits from this research are to inform the public about the diversity and abundance of waterfowl in the area and to strengthen our understanding of waterfowl habitat selection. It is our hope that this study may emphasize the importance of Blackland Prairie habitat to migrating and wintering waterfowl in central Texas, and to contribute to a foundation of future research upon which others can expand, culminating with informed management decisions that sustain or increase the health of the landscape.

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VITA

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