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ARTICLE

Coastal Pond Use by Redheads Wintering in the Laguna Madre, Texas

Bart M. Ballard · J. Dale James · Ralph L. Bingham · Mark J. Petrie · Barry C. Wilson

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Abstract The distribution of North American redheads (*Aythya americana*) during winter is highly concentrated in the Laguna Madre of Texas and Tamaulipas, Mexico. Redheads forage almost exclusively in the lagoon and primarily on shoalgrass (*Halodule wrightii*) rhizomes; however, they make frequent flights to adjacent coastal ponds to dilute salt loads ingested while foraging. We conducted 63 weekly aerial surveys during October–March 2000–2003 to record use of coastal ponds by redheads. We collected information from used and unused coastal ponds to better understand factors selected by redheads for their dietary fresh water requirements. Coastal ponds used by redheads had greater surface area, percent open water, average depth, and turbidity than unused coastal ponds. Similarly, redheads used coastal ponds with lower salinity and ammonia concentrations than unused ponds. Redheads were observed on coastal ponds >6 km from foraging areas on 95% of surveys during dry conditions in 2000–01, compared to 43% of surveys during moderately wet conditions in 2001–02 and 5% during very wet conditions in 2002–03. Finally, our data suggests that redheads rely on dietary freshwater sources throughout winter and do not reduce visitation to these coastal ponds as winter progresses.

Keywords *Aythya americana* · Coastal ponds · Redhead · Laguna Madre · Texas · Winter

B. M. Ballard (✉) · J. Dale James · R. L. Bingham
Caesar Kleberg Wildlife Research Institute,
Texas A&M University-Kingsville,
MSC 218, 700 University Boulevard,
Kingsville, TX 78363, USA
e-mail: bart.ballard@tamuk.edu

M. J. Petrie
Ducks Unlimited, Inc., Pacific Northwest Office,
1101 SE Tech Center Drive, Suite 115,
Vancouver, WA 98683, USA

B. C. Wilson
Gulf Coast Joint Venture, Ducks Unlimited, Inc.,
700 Cajundome Boulevard,
Lafayette, LA 70506, USA

Present Address:
J. Dale James
Ducks Unlimited, Inc., Southern Regional Office,
193 Business Park Drive, Suite E,
Ridgeland, MS 39157, USA

Introduction

The Laguna Madre of Texas is a large, shallow lagoon that comprises about 80% of the seagrass distribution along the Texas Coast (Texas Parks and Wildlife Department 1999). This seagrass community has been historically dominated by shoalgrass (*Halodule wrightii*), which is 1 of 5 species of seagrass growing in this lagoon, and the only species with significant distribution that occurs in the diets of waterfowl. The large expanses of seagrasses in the Laguna Madre provide abundant food and foraging habitat for several species of waterfowl that are common during winter, including redhead (*Aythya americana*), lesser scaup (*A. affinis*), northern pintail (*Anas acuta*), and American wigeon (*Anas americana*) (U.S. Fish and Wildlife Service 2004). In particular, the Laguna Madre is the primary wintering area for about 80% of the continental redhead population (Weller 1964; Michot 2000). This large concentration of redheads spends much of the nonbreeding season along the lower Texas coast, usually arriving in mid-October and remaining until early March (Kiel 1957; Custer et al. 1997; James 2006) where they forage primarily on shoalgrass rhizomes (Michot et al. 2008; D. James, unpublished data).

Limited freshwater inflows and high evaporation rates in the Laguna Madre result in water salinities reaching >50 ppt

(Cornelius 1982; Quammen and Onuf 1993). Hence, to maintain osmotic equilibrium from ingestion of high salt loads while foraging in the Laguna Madre, redheads make daily flights to adjacent freshwater sources (Kiel 1957; Mitchell et al. 1992; Woodin 1994; Adair et al. 1996; Michot et al. 2006). However, the semi-arid climate and unpredictable precipitation events in this region result in great annual variability in the proportion and distribution of inundated basins (Brown et al. 1977).

Our objectives were to identify attributes of coastal ponds used by wintering redheads adjacent to the Laguna Madre of Texas and to assess the location and attributes of these used ponds relative to unused ponds. This information can then be used by managers for coastal pond enhancement to provide freshwater drinking sites for redheads and other lagoon feeding waterfowl.

Study Area

We conducted research along the lower Texas coast inclusive of the Laguna Madre, barrier island, and adjacent mainland. The Texas Laguna Madre is a coastal lagoon that extends approximately 208 km from Corpus Christi Bay to Port Isabel, is approximately 11,125 km^2 in size, and averages <1 m in depth (Tunnel 2002). The Laguna Madre receives little freshwater inflow from mainland drainages and annual evaporation typically exceeds precipitation, sometimes resulting in hypersaline conditions (McMahan 1968; Tunnel 2002). Salinities in the Laguna Madre averaged 34.5 ppt from 1975–2005, but vary seasonally and can reach >50 ppt (Texas Parks and Wildlife, unpublished data).

The lower Texas Coast has a semi-arid to subtropical climate with mild winter temperatures averaging 14.2 C and annual rainfall averaging 68 cm (Fulbright et al. 1990; Tunnel 2002). April and September typically coincide with periods of greatest precipitation; however, tropical storms and hurricanes can have large impacts on precipitation patterns and wetland habitat conditions. During the 3 years of our study, this area experienced markedly different freshwater habitat conditions. During the winter of 2000–01 and first half of 2001–02, the Palmer drought Severity Index (PDSI) for most or all of the study area ranged from moderate to severe drought; 2000–01 was classified as experiencing more severe drought conditions both spatially and temporally. In contrast, PDSI characterized October 2002 to March 2003 as moderately wet to very wet (www.drought.unl.edu/dm/archive.htm).

The mainland adjacent to the Laguna Madre is dominated by unimproved rangeland used for cattle ranching. The landscape contains a relatively high density of coastal pond basins, averaging 2.2/km^2 throughout most of the region, but reaching 4.8 basins/km^2 near the coast (McAdams 1987). Coastal ponds in this region are primarily seasonal due to the semi-arid climate and can become limited and spatially concentrated during dry years. Because of the unreliability of surface water, impoundments have been constructed in some areas to provide drinking water for cattle. These impoundments are typically kept inundated by windmills and can be important sources of dietary fresh water for waterfowl.

Methods

Aerial Surveys

We conducted aerial surveys to monitor coastal pond use by redheads each week from mid-October through mid-March during 2000 to 2003. Surveys typically took 6 hours of flight time and were initiated during mid-morning. Our survey timing was based on previous findings that redheads were actively foraging during early morning and use of coastal ponds increased during mid- and late morning and remained relatively stable through early afternoon (Mitchell et al. 1992). The area within 10 km of the shoreline was delineated as our sampling area based on distances of ponds used by redheads reported by Adair et al. (1996). Thus during each survey, we systematically surveyed up to 10-km inland on the mainland side of the Laguna Madre and all of Padre Island to the east. Surveys were flown in a 152 Cessna at an altitude of 100 m and a flight speed of 160 km/h. During each survey, we recorded location and number of redheads for each pond where we observed redheads. We systematically altered the start of each survey among 4 locations along the Laguna Madre to reduce confounding of ponds and time of day.

Coastal Pond Parameters

For each pond used by redheads we identified a paired "non-used" pond where we never observed redhead use during aerial surveys. To reduce any confounding effects with distance to foraging habitat, an adjacent non-used pond was defined as the nearest pond with no observed use by redheads and that was positioned no further from potential foraging areas than its used pair.

We attempted to initiate a monthly schedule for site visits of coastal ponds during the mid-point of each month. However, because of complicated coordination protocol (i.e., corporate hunting leases on large ranches) for access to some sites, as well as unimproved roads limiting access after precipitation events, ≥ 80% of coastal ponds were sampled during each month. We recorded physical and water chemistry data from pairs of used and non-used ponds. The area of inundation was determined in the field by mapping the boundary of inundation with a hand-held

global positioning system (GPS) unit. We determined percent open water through visual estimation and estimated average water depth from 6 depth measurements taken equidistant apart along transects across the long and short diameter of the wetland. We recorded the primary water source (e.g., windmill, artesian well, runoff, etc.) and whether the wetland was created or natural. We averaged water chemistry parameters (temperature, salinity, conductivity, and pH) from 3 measurements taken within the wetland at random points using a YSI multiprobe. We collected 8, 25-mL water samples from each pond, placed them in clean, polyethylene bottles, and preserved them at 4 C. We used a Hach DR200 spectrophotometer to determine turbidity, ammonia, and nitrate concentrations of water samples from coastal ponds (USEPA 1983). We assessed turbidity by homogenizing a 50-mL water sample and analyzed ammonia concentrations using 3, 25-mL water samples by the salycilate reaction method (USEPA 1983). If analysis was not possible within 8 hr, we acidified samples for storage with hydrochloric acid before refrigeration and subsequently neutralized them before analysis with sodium hydroxide. We analyzed the remaining 3, 25-mL water samples for nitrate concentrations using the cadmium reduction method (USEPA 1983).

Statistical Analyses We used a stepwise approach to model combinations of 11 explanatory variables (i.e., wetland area, percent open water, temperature, average depth, deepest depth, salinity, conductivity, turbidity, pH, ammonia, and nitrate) in SAS PROC LOGISTIC with the SELECTION=SCORE option to obtain the 5 models with the largest score Chi-square values for sets of models with 1 to 11 variables. AIC values were then computed for all of the 51 resulting models. Wetland sites were experimental units, some of which were sampled more than once. Because of the repeated sampling, we used the method of generalized estimating equations in SAS PROC GENMOD (Diggle et al. 1994; Allison 1999) to estimate coefficients and standard errors of the clustered data for the top 3 models based on AIC values from the logistic regression analysis. We used regression analysis (PROC REG; SAS Institute, Inc. 2001) to compare aerial survey estimates of redhead abundance to number of coastal ponds used.

Results

We conducted 63 weekly aerial surveys during winters 2000–01, 2001–02, and 2002–03 to record use of coastal ponds adjacent to the Laguna Madre by redheads. Redheads used 54 different coastal ponds throughout the study, ranging from 23 during the dry conditions in 2000–01, to 40 during 2001–02. The number of coastal ponds used by redheads was strongly related to the number of redheads counted on surveys in the Laguna Madre (James 2006) during dry conditions in 2000–01 (r=0.67, n=23, P<8 0.001), but less related in 2001–02 (r=0.45, n=22, P=0.031) and 2002–03 (r=0.49, n=18, P=0.067) (Fig. 1). Also, the average (± SE) distance from freshwater drinking sites to nearest potential foraging areas in the Laguna Madre was greater (t≥5.46, P<0.001) in 2000–01 (3.8±0.20 km) than in 2001–02 (2.6±0.11 km) or 2002–03 (2.2±0.14 km). Redheads were observed on coastal ponds >6 km from foraging areas on 95% of surveys in 2000–01, compared to 43% of surveys in 2001–02 and 5% in 2002–03.

Of the 51 candidate models evaluating parameters of coastal ponds, only 3 had AIC values <60, and each had nonsignificant lack of fit (P≥0.702) using the Hosmer and

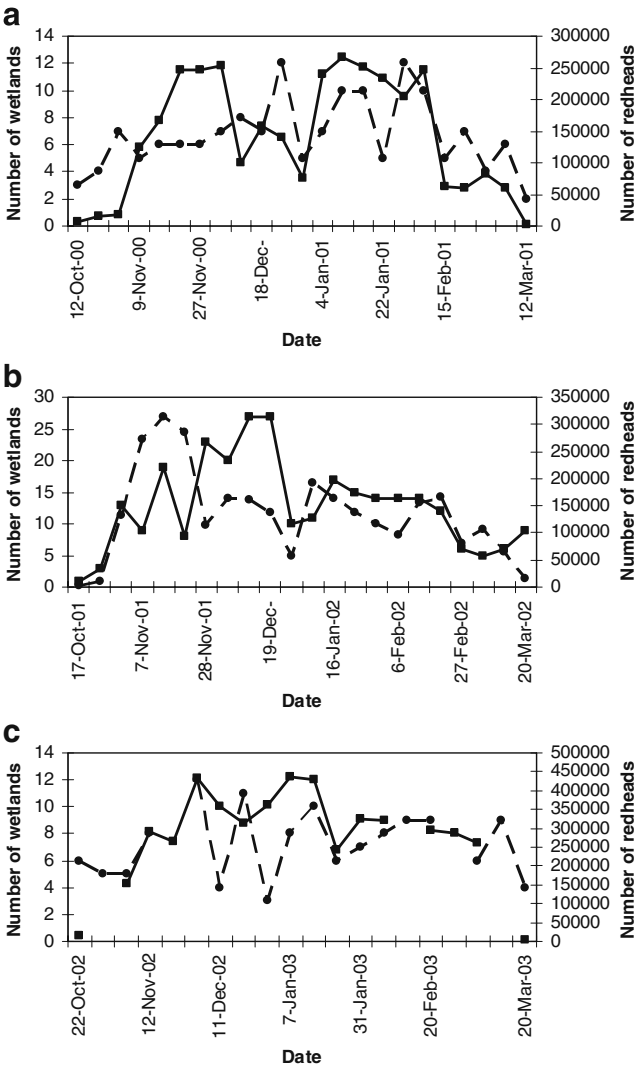

Fig. 1 Numbers of redheads (solid line) and coastal ponds used by redheads (dashed line) observed during weekly aerial surveys of the lower Texas coast during Oct–Mar 2000–01 (**a**), 2001–02 (**b**), and 2002–03 (**c**)

Lemeshow goodness-of-fit test (SAS Institute, Inc., 2001). All 3 models exhibit positive coefficients for surface area, percent open water, average depth, turbidity, and nitrate, suggesting that with increasing values of these variables, redheads exhibited increased use (Table 1). The 3 top models also exhibited negative coefficients for deepest water depth and ammonia, suggesting that with increasing values of these variables, redheads exhibit decreased use. The best model included these 7 variables as well as salinity with a negative coefficient (Table 1). Thus, salinity was lower in ponds used by redheads than in those with no use.

About 45% of the wetlands used by redheads had a relatively continuous source of water provided by artesian wells, windmills, or pumps, which also appeared to have a large influence on salinity. On average, wetlands with no continuous water source had salinities over 4-times greater than wetlands with a continuous water source (t=3.74, df=39.1, P<0.001). Only 20% of the nonused wetlands sampled had a continuous water source.

Discussion

We found a strong relationship between the number of coastal ponds used by redheads and numbers of redheads along the lower Texas coast during the dry winter of 2000–01. During 2001–02 and 2002–03 when more coastal ponds held water compared to the dry winter, redheads were consistently dispersed across many ponds even when redhead abundance was low along the lower Texas Coast. Greater availability of coastal ponds during wet conditions allowed birds to be more widely dispersed along the coast. Thus, the number of coastal ponds used by redheads remained relatively high as redhead abundance fluctuated during winter of wetter years, and thus a weaker correlation between the 2 parameters occurred.

We found that during the wetter years redheads used ponds closer to the coast as more ponds became available. Although our aerial surveys sampled areas further inland from the Laguna Madre, we never observed redheads using coastal ponds that were positioned >5.7 km from the shoreline or >8.1 km from the nearest foraging area. Adair et al. (1996) also found that proximity to foraging areas was an important selection characteristic for coastal ponds by redheads and lesser scaup (*A. affinis*). Also, data collected in 2000–03 (James 2006:35–37) indicates that redhead distribution in the Laguna Madre was concentrated in areas closer to coastal ponds in 2000–01 when conditions were dry, and use was more dispersed in 2002–03 when conditions were wet.

We found that 9 variables influenced redhead use of coastal ponds. Redheads tended to use larger wetlands with a greater average depth and proportion of open water. This is consistent with previous research showing that redheads spend most of their time in these coastal ponds drinking and not foraging (Adair 1990; Mitchell et al. 1992; Adair et al. 1996). Adair et al. (1996) also found that redheads appeared to select deeper ponds. However, our modeling did suggest a somewhat contradictory result as although redhead use increased as average depth increased, it decreased as greatest depth increased. This finding is not

Table 1 Coefficient estimates, standard errors, and p-values for 9 variables considered to influence redhead use of coastal ponds adjacent to the Laguna Madre, Texas during winters 2000–03

	Model 1			Model 2			Model 3		
	Coefficient	SE	p-value	Coefficient	SE	p-value	Coefficient	SE	p-value
Intercept	−7.15	1.96	<0.001	−7.00	1.86	<0.001	−7.68	1.91	<0.001
Wetland area (ha)	0.59	0.26	0.021	0.58	0.25	0.019	0.54	0.27	0.046
% open water	0.06	0.02	0.005	0.05	0.02	0.006	0.05	0.02	0.013
Average depth (cm)	8.09	3.17	0.011	7.70	3.00	0.010	8.60	3.99	0.031
Deepest depth (cm)	−5.85	2.26	0.010	−5.56	2.13	0.009	−5.86	3.09	0.058
Salinity (ppt)	−0.10	0.05	0.034						
Conductivity				−0.07	0.04	0.070			
Turbidity	0.02	0.01	0.011	0.02	0.01	0.011	0.02	0.01	0.005
Ammonia	−1.12	0.40	0.006	−1.11	0.39	0.005	−1.21	0.42	0.005
Nitrate	1.66	0.93	0.075	1.63	0.89	0.067	1.86	0.99	0.060
Goodness of Fit	4.05			6.37			5.06		
Score Chi-Square	23.52			23.46			22.68		
R-Square	0.623			0.620			0.586		
AIC	58.1			58.3			58.8		

fully understood, but is likely the result of small, created wetlands that have very deep areas next to levees and proportionally more shallow water away from the levee. Many of these ponds were quite small and supported emergent vegetation in shallow areas, both characteristics that we found to be negatively related to redhead use.

The models also indicate that increased use of coastal ponds by redheads was related to increased turbidity and nitrate. Decreased water quality in coastal ponds may be a result of use by large concentrations of redheads. Adair (1990) and Skoruppa and Woodin (2000) found that heavy use of coastal ponds by redheads can impact water quality. These studies suggested that fecal deposition by high densities of waterfowl elevated nitrate, ammonium, chlorophyll, and total phosphorus concentrations. Salinity has also been shown to be an important variable in selection of coastal ponds by redheads (Adair 1990; Adair et al. 1996). Our best model supports this by indicating use of ponds with lower salinities. A continuous water source appeared to be an important attribute that may help keep salinities tolerable to redheads in some ponds.

Historically, salinities in the Laguna Madre were much higher than current readings, commonly reaching >100 ppt (Quammen and Onuf 1993). In 1949, the Gulf Intracoastal Waterway was completed allowing interchange between the upper and lower segments of the Laguna Madre as well as a more direct connection with the Gulf of Mexico. As a result, salinities have been moderated in the lagoon and seldom reach 60 ppt (Quammen and Onuf 1993; Texas Parks and Wildlife Department, unpublished data). Since 1975, the long-term average salinity has closely approximated seawater at 34.5 ppt (Texas Parks and Wildlife Department, unpublished data). During our study, October–March salinities averaged 43.2 ppt in 2000–01, 42.0 ppt in 2001–02, and 31.8 240 ppt in 2002–03 and were inversely related to the PDSI.

The supraorbital nasal gland (salt gland) of redheads and other waterfowl can acclimate (i.e., become more efficient at excreting salts) to concentrated salt ingestion after the birds move from fresh water to saline habitats (Schmidt-Nielsen and Kim 1964; Cornelius 1982; Bennett and Hughes 2003). Thus, it has been speculated that the reliance on coastal ponds by redhead decreases over the course of winter (Mitchell et al. 1992). Consistent with Adair et al. (1996), we found no indication that reliance on coastal ponds by redheads declined from arrival in mid-October through their departure in March. The small number of ponds sampled by Mitchell et al. (1992) comprised only 11% of the ponds on which we observed redheads over the entire Laguna Madre. Their observed reductions in use of coastal ponds by redheads could have been related to birds moving to ponds off their study site to obtain dietary fresh water rather than a decline in fresh water use (Adair et al 1996). We suggest that the availability of dietary freshwater sources is important to redheads throughout winter along the lower Texas coast.

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