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Shorebird Breeding Biology in Wetlands of the Playa Lakes, Texas, USA

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Abstract.—Wetlands in the Playa Lakes Region of Texas are important habitats for North American wintering waterfowl and migrant shorebirds. However, shorebird breeding biology has been overlooked in characterizing the region's ecological importance. In 1998 and 1999, American Avocet (*Recurvirostra americana*), Black-necked Stilt (*Himantopus mexicanus*), Killdeer (*Charadrius vociferous*), and Snowy Plover (*C. alexandrinus*) breeding ecology were studied in playas, saline lakes, and riparian wetlands in the Playa Lakes Region of Texas. Chronology of nest initiation, clutch sizes, and hatching success for 298 Snowy Plover, 111 American Avocet, 43 Killdeer, and 26 Black-necked Stilt clutches were measured. All four species nested in saline lakes, American Avocet and Killdeer also nested in playas, and Snowy Plover nested on riparian wetlands. American Avocet had higher hatching success in 1999 (52%) than 1998 (8%), because of more suitable hydrological conditions and lower predation. Hatching success was higher in 1998 than 1999 for Killdeer (1998, 63%; 1999, 21%) and Snowy Plover (1998, 47%; 1999, 33%) due to failures caused by flooding and hail in 1999. In other regions, clutch predation limits shorebird productivity, but hatching success in the Playa Lakes Region appears to be limited by unpredictable precipitation patterns and wetland hydroperiod. As such, breeding shorebird conservation and management should focus upon maintaining wetland hydrological integrity. *Received 20 May 2003, accepted 19 September 2004.*

Key words.—American Avocet, Black-necked Stilt, Breeding Biology, Killdeer, Playas, Playa Lakes Region of Texas, Saline Lakes, Snowy Plover.

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Wetlands in the Southern Great Plains (SGP) and Playa Lakes Region (PLR) of Texas provide important habitat for migrant shorebirds as stopover sites between the Gulf coast and Cheyenne Bottoms, Kansas (Davis and Smith 1998; Brown *et al.* 2001; Fellows *et al.* 2001). Using both freshwater and saline wetlands, migrant shorebird occurrence is transient and dependent upon suitable wetland habitat availability in the PLR (Davis and Smith 1998; Brown *et al.* 2001). Shorebird research in the SGP and the PLR has focused on migration ecology (Hands *et al.* 1991; Skagen and Knopf 1994; Davis and Smith 1998), but other SGP wetlands (i.e., saline wetlands in Oklahoma) are important for breeding American Avocet (*Recurvirostra americana*), Black-necked Stilt (*Himantopus mexicanus*), and Snowy Plover (*Charadrius alexandrinus*) (Hill 1985; Winton and Leslie 1997; Winton *et al.* 2000). These studies were conducted outside the PLR of Texas. Consequently, the relative importance of PLR wetlands to breeding shorebirds, at regional and continental scales, remains poorly understood (Davis and Smith 1998; Seyffert 2001).

With both abundant and diverse wetlands, the PLR is an important site for breeding shorebirds. However, regional wetland suitability for breeding shorebirds may be compromised by interactions between unpredictable precipitation patterns and human induced pressures. PLR wetland hydroperiods are dependent upon hydrological input from precipitation runoff and water losses via high evapotranspiration rates, particularly during the summer. Hydroperiod reductions may also be exacerbated from agriculturally related sedimentation and ground water pumping for irrigation during summer (Bolen *et al.* 1989; Haukos and Smith 1994; Luo *et al.* 1997; Fellows *et al.* 2001; Smith and Haukos 2002). Therefore, suitability and importance of PLR wetlands for breeding shorebirds will be directly influenced by wetland hydroperiod modification and anthropogenically driven wetland disturbances (Conway *et al.* 2005).

Throughout North America, shorebird numbers have experienced declines (in some cases >70%) since 1970 (Howe *et al.* 1989; Page and Gill 1994). Wetland destruction, alteration, and degradation from agricultural activities and urbanization, as well as unpredictable precipitation patterns and exotic plant invasions, have all been cited as potential causes of observed declines (Hill 1985; Bowen and Kruse 1993; Koenen *et al.* 1996; Espie *et al.* 1988; Powell and Collier 2000). Impacts of wetland perturbations on shorebirds may also be compounded by high nest predation rates (Page *et al.* 1983; Paton 1995; Yogev *et al.* 1996), whereby natural and anthropogenic forces may combine to compromise shorebird numbers at regional and continental scales.

Therefore, shorebird breeding ecology and reproductive success in the PLR of Texas is likely to be directly related to wetland functional stability, whereby regional importance of the PLR to continental shorebird numbers may be assessed. During 1998 and 1999, American Avocet, Black-necked Stilt, Killdeer (*Charadrius vociferous*), and Snowy Plover breeding biology was examined in playas, saline lakes, and riparian wetlands in the PLR of Texas. The primary objective of this study was to estimate the relative importance of the PLR to continental populations of these four species. Specifically, the objectives of this study were to (1) estimate chronology of arrival and nest initiation, (2) quantify apparent and adjusted hatching success, (3) document causes of clutch failure, and (4) examine influence of wetland type and year on the aforementioned demographic parameters.

STUDY AREA AND METHODS

Study area. The PLR of Texas encompasses approximately 82,000 km^2, stretching from the Canadian River to the Edwards Plateau (Bolen *et al.* 1989; Haukos and Smith 1994). The semi-arid PLR is intensively farmed (Bolen *et al.* 1989), where PLR wetlands provide refugia of biological diversity (Haukos and Smith 1994). More than 22,000 playas (Haukos and Smith 1994), approximately 40 saline lakes (Brune 1981), and branches of the Canadian, Red, and Brazos Rivers exist in the region.

Available study site wetlands were located by ground surveys in March, April, and May 1998 and 1999, and by aerial surveys from a fixed-wing plane on 10 April 1998 and 17 April 1999. Ground surveys were performed by driving in counties that received rain during winter and identifying available wetlands. During ground surveys, available wetlands identified during aerial surveys were located. Available wetlands were defined as those that contained surface water during aerial or ground surveys. Study site wetlands were selected randomly from the pool of available wetlands, where use of specific wetlands was dependent upon landowner permission. A total of 76% of available playas and 71% of available saline lakes were used as study sites during 1998 and 1999. All available riparian wetlands (N = 12) were selected as study sites.

In 1998, 54 playas in Floyd, Briscoe, Randall, Armstrong, Gray, and Carson counties, and ten saline lakes in Lynn, Terry, and Bailey counties were randomly selected as study site wetlands. Also, 8.5 km of the Prairie Dog Town Fork of the Red River in Hall and Childress counties, 4 km of the North Fork of the Red River in Wheeler County, 4 km of the Salt Fork of the Red River in Donley County, 4 km of the Canadian River in Potter County, and 6.25 km of the North Fork of the Pease River in Motley County were used as study sites. In 1999, 52 playas in Floyd, Briscoe, Randall, Armstrong, Gray, Carson, and Swisher counties, and twelve saline lakes in Lynn, Terry, Cochran, and Bailey counties were randomly selected as study site wetlands. Also, 2.5 km of the Prairie Dog Town Fork of the Red River in Hall County, 4 km of the North Fork of the Red River in Wheeler County, 4 km of the Salt Fork of the Red River in Donley County, 2 km of the Canadian River in Potter County, and 2.5 km of the North Fork of the Pease River in Motley County were used as study sites.

Bird surveys and nest discovery. Each wetland was surveyed to detect the presence or absence of breeding shorebirds at least every ten days from 24 April-18 August 1998 and 22 February-19 August 1999. In 1999, surveys were initiated in saline lakes during February to include the arrival of Snowy Plover. When shorebirds were observed, nest searches were made. Nests were located by watching adults flush from or return to nests, searching in appropriate habitat(s), scanning for incubating adults with binoculars or a spotting scope, and accidental discovery. Behavioral cues (i.e., distraction displays) were also used to locate nests. American Avocet, Black-necked Stilt, and Killdeer nests were checked every 7-12 days until the fate of nest contents was determined. Snowy Plover nests were checked every 1-2 days as part of another study.

Clutch fate. Clutches were considered successful if at least one egg hatched (Mayfield 1975). Conversely, clutches were considered to have failed if (1) eggs were absent prior to the estimated hatching date, (2) obvious signs of predation or trampling (i.e., tracks, broken shells present, crushed eggs, etc.) were visible, (3) nests and clutches were flooded or destroyed by hail, or (4) eggs were present one week beyond the estimated hatching date (abandoned). If nest-scrapes were located prior to laying, hatching dates were estimated from when the eggs were laid, where American Avocet, Black-necked Stilt, and Killdeer eggs were floated to estimate hatching dates when nests were located during incubation (Ehrlich *et al.* 1988). As Snowy Plover nests were visited frequently eggs were not floated. The fate could not be accurately determined for < 5% of all clutches. Such clutches may have been successful or failed, but no evidence was available and they were classified as "unknown" (Manolis *et al.* 2000). Hatching success was calculated for each species using a standard proportion (i.e., number of successful clutches divided by the total number of clutches) and a modified Mayfield estimate corrected for exposure (Mayfield 1975; Johnson 1979). Incubation periods used for Mayfield estimates followed Ehrlich *et al.* (1988). Confidence intervals (95%) for Mayfield estimates were calculated following Murphy *et al.* (1999). Biased estimates may occur when clutches with unknown fates are excluded (Manolis *et al.* 2000). To prevent incorporating downward bias in Mayfield estimates, days of exposure were calculated for each species by terminating exposure with the last observed active date for clutches with unknown fates and with the midpoint between the last observed active and first observed inactive date for clutches with known fates (Murphy *et al.* 1999; Manolis *et al.* 2000). The use of the Mayfield method assumes a constant risk of failure throughout incubation.

Data analysis. A Fisher's exact test comparing two proportions was used to compare hatching success estimates within each species (1) between years (i.e., 1998 and 1999), (2) between years within a wetland type (i.e., playa or saline lake), and (3) between wetland types within a year (Zar 1999). Chi-squared tests were used to examine differences in clutch size and number(s) of eggs hatched per nest for Snowy Plover between years (Zar 1999). Similar Chi-squared tests examining differences in clutch sizes and numbers of eggs hatched per nest were not performed for American Avocet, Black-necked Stilt, and Killdeer due to sample size violations for individual clutch size categories (Zar 1999).

RESULTS

Chronology of arrival and nest initiation. All four species were present on study wetlands when surveys began in 1998 (24 April) and some remained until after surveys were terminated (18 August), although most had departed by early-mid July. Only 6% of the total number of American Avocet, 8% of Black-necked Stilt, 7% of Killdeer, and 4% of Snowy Plover observed in 1998 were observed during July and August (Fig. 1). In 1999, Killdeer were present when surveys were initiated (22 February). By mid-late March, American Avocet and Snowy Plover were present, and Black-necked Stilt arrived approximately two weeks later, in early April (Fig. 1). All species were present when surveys were terminated (19 August) (Fig. 1). By this time, nesting activities had ceased, and individuals during this period were likely to be migrants.

Most American Avocet nests were discovered during the first two weeks of June, with the earliest found on 11 May (1998) and the latest on 12 July (1999) ($\bar{x}$ = 4 June; SD ± 13 days). The earliest hatch date was 16 June (1998), and the latest clutch hatched on 20 July (1999) ($\bar{x}$ = 24 June; SD ± 9 days). Black-necked Stilt clutches were found between 15 May and 9 July ($\bar{x}$ = 18 June; SD ± 14 days), with the earliest hatching on 22 June (1998) and latest on 15 July (1999) ($\bar{x}$ = 3 July; SD ± 7 days). Killdeer clutches were found as early as 31 March (1998) and as late as 11 July (1999) ($\bar{x}$ = 5 June; SD ± 24 days), with the earliest hatching on 1 May (1999) and the latest on 25 July (1999) ($\bar{x}$ = 25 June; SD ± 20 days). Most Snowy Plover nests with eggs were found during June, but were found as early as 7 April (1999) and as late as 12 August (1999) ($\bar{x}$ = 8 June; SD ± 22 days. The earliest clutch hatched on 12 May (1999) and the latest on 8 August (1999) ($\bar{x}$ = 5 July; SD ± 20 days) (Fig. 2).

Nest Totals by Wetland Type. In 1998 and 1999, 478 nests were monitored in playas (N = 94), saline lakes (N = 372), and riparian wetlands (N = 12). All four species were found nesting in saline lakes, and only Snowy Plover nested in riparian wetlands. American Avocet nests were found in both playas (N = 84) and saline lakes (N = 27), as were Killdeer (playas, N = 10; saline lakes, N = 33), but all Black-necked Stilt nests (N = 26) were in saline lakes. Over 95% of all Snowy Plover nests were in saline lakes (N = 286) with the remainder in riparian wetlands (N = 12) (Table 1).

Hatching success and clutch size. Hatching success varied significantly between 1998 and 1999 for American Avocet (Z = 4.37; P <

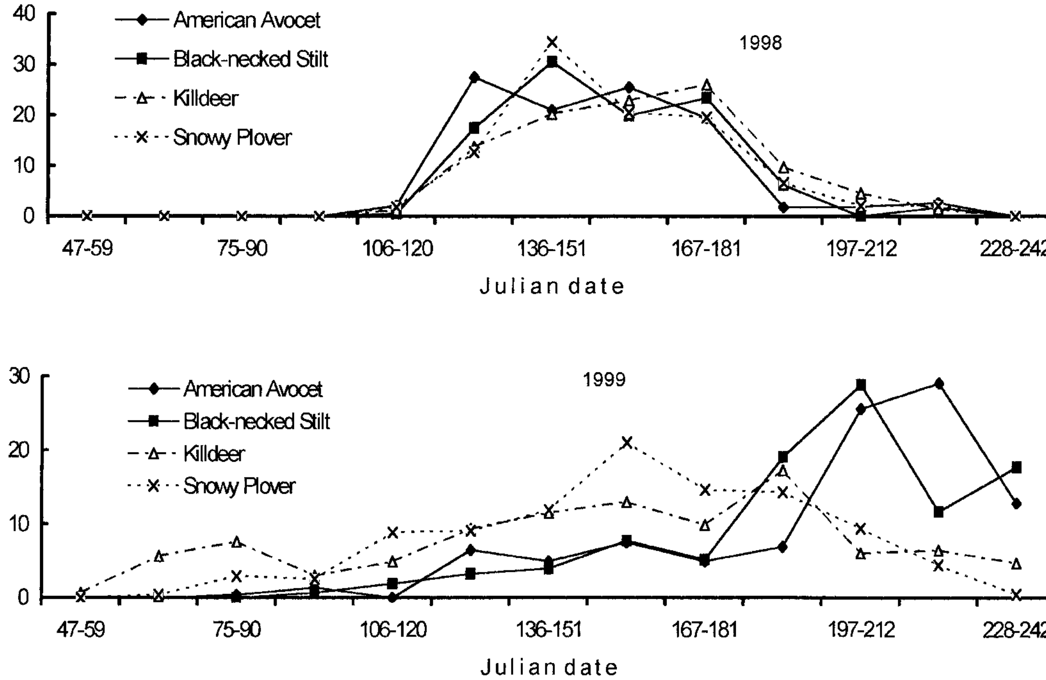

Figure 1. Chronology of occurrence for American Avocet, Black-necked Stilt, Killdeer, and Snowy Plover (% of total number of each species counted on study site wetlands) observed in playa, riparian, and saline lake wetlands in the Playa Lakes Region of Texas, 1998 and 1999.

0.001), Killdeer ($Z = 2.41$; $P < 0.01$) and Snowy Plover ($Z = 2.27$; $P < 0.02$), but not for Black-necked Stilt ($Z = 0.04$; n.s.) (Table 1). Killdeer and Snowy Plover experienced significantly higher hatching success rates in 1998 than 1999, whereas the converse was true for American Avocet (Table 1). Clutch size was greater ($\chi^2_3 = 7.65$; $P < 0.03$) in 1998 than 1999 for Snowy Plover and more eggs were hatched per Snowy Plover nest in 1998 than 1999 (Table 1).

In 1998, Snowy Plover hatching success was similar between saline lakes and riparian wetlands ($Z = 1.75$; n.s.), and hatching success was similar between saline lakes and playas for American Avocet ($Z = 1.20$; ns) and Killdeer ($Z = 0.01$; n.s.) in 1998. In 1999, American Avocet hatching success was higher ($Z = 1.99$; $P < 0.03$) in playas (57%) than saline lakes (13%). In 1999, only two Killdeer nests were found in playas and Snowy Plover were only found nesting in saline lakes, so no hatching success comparisons were made between wetland types for these species.

In playas, American Avocet hatching success ($Z = 3.31$; $P < 0.001$) was higher in 1999 than 1998 (Table 2). Hatching success did not vary ($Z = 0.80$; n.s.) between years for Killdeer nesting in playas (Table 2). In saline lakes, Killdeer hatching success was higher in 1998 than 1999 ($Z = 2.91$; $P < 0.02$), but American Avocet hatching success was similar between years ($Z = 0.80$; n.s.) (Table 3). Hatching success was similar ($Z = 1.59$; n.s.) between years for Snowy Plover in saline lakes (Table 3). Neither clutch size nor number of eggs hatched per nest varied significantly between years for Snowy Plover in saline lakes (Table 3).

DISCUSSION

Breeding Season Duration

Breeding shorebird use of PLR wetlands depends upon hydroperiod, particularly in playas where surface water presence depends upon a combination of precipitation, evaporation, and pressures from agricultural

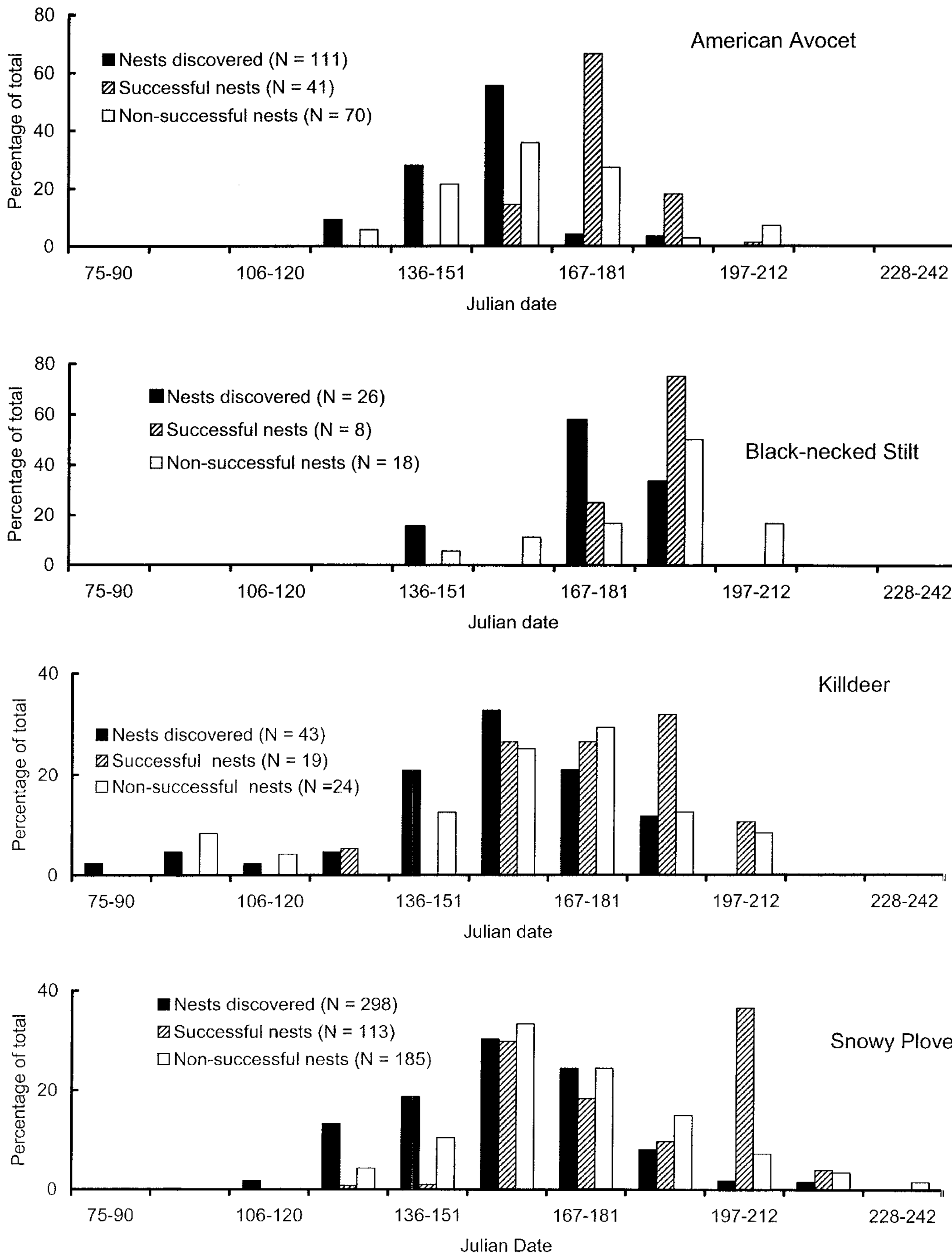

Figure 2. Chronology of nest discovery, successful nest termination, and non-successful nest termination (% of total number of nests monitored for each category) for American Avocet, Black-necked Stilt, Killdeer, and Snowy Plover nesting in playas, riparian wetlands, and saline lakes in the Playa Lakes Region of Texas, 1998 and 1999.

activities (Bolen *et al.* 1989). For example, American Avocet nests were not initiated in playas after mid June 1998, as surface water was absent by early June due to a regional drought (Conway 2001). Conversely, Killdeer continued to incubate eggs into July

Table 1. Nest fates, hatching success, and productivity estimates for American Avocet, Black-necked Stilt, Killdeer, and Snowy Plover nesting in playas, saline lakes, and riparian wetlands in the Playa Lakes Region of Texas, 1998 and 1999.

	American Avocet		Black-necked Stilt	Killdeer		Snowy Plover	
	1998	1999	1998, 1999	1998	1999	1998	1999
Total number of nests	38	73	26	24	19	104	194
Successful	3	38	8	15	4	49	64
Predated	30	20	13	5	6	29	22
Hailed	0	0	0	0	2	2	13
Flooded	0	9	0	0	7	0	66
Trampled	2	0	0	3	0	3	0
Abandoned	0	5	3	1	0	13	22
Unknown fate[a]	3	1	2	0	0	8	7
Apparent hatching success (%)	8 b[d]	52 a	31	63 a	21 b	47 a	33 b
Mayfield (%, 95% CI)[b]	12 (6-24)	39 (28-54)	21 (10-44)	45 (26-76)	13 (5-37)	37 (29-49)	30 (24-37)
Total eggs laid	130	257	91	83	61	280	482
Total eggs hatched	12	116	24	51	15	130	175
Eggs hatched/nest[c] ($\bar{x}$, SE)	0.32 (0.17)	1.59 (0.20)	0.92 (0.30)	2.13 (0.37)	0.79 (0.36)	1.25 (0.14) a	0.90 (0.09) b
Clutch size ($\bar{x}$)	3.42	3.52	3.50	3.46	3.21	2.71 a	2.48 b
Single egg clutches	3	4	2	2	3	6	26
Two egg clutches	1	4	1	2	2	18	48
Three egg clutches	11	15	5	3	2	80	120
Four egg clutches	23	50	18	17	12	0	0
Total exposure days	494	1098	310	316	214	1593	3094

[a]Unknown clutches may have been successful or failed. For success estimates they were classified as failed.
[b]Confidence intervals (95%) calculated following Murphy *et al.* (1999).
[c]Mean number of eggs hatched per clutch.
[d]Values followed by the same letter in the same row for the same species are not statistically different.

after American Avocet nesting activities had ceased in playas. In saline lakes, hydroperiod duration is extended because of spring connections to underground water (Brune 1981; Reeves and Temple 1986). For example, all four species were incubating clutches in saline lakes after nesting activities had ceased in playas in 1998.

American Avocet (11 May-12 July) and Black-necked Stilt (15 May-9 July) experienced an eight-week breeding season, longer than in Oklahoma (17 May-5 June; Winton and Leslie 1997). Snowy Plover had an extended breeding season, where clutches were monitored for 17-weeks (7 April to 12 August). Most hatching (54%) occurred during June, but ranged between early May and into early August. This is longer than reported in California (23 March-13 July; Warriner *et al.* 1986), (18 April-15 July; Page *et al.* 1983), Utah (second week of April-18 July; Paton 1995), Oklahoma (24 May-20 July; Grover and Knopf 1982), Oregon and Nevada (26 April-first week of July; Herman *et al.* 1988), or Kansas (15 May-30 June; Boyd 1972). Use of saline lakes with springs enables Snowy Plover to rear multiple broods. For example, six individuals (5 males and 1 female) hatched two clutches (Conway 2001), a previously undocumented phenomenon east of the Rocky Mountains (Page *et al.* 1995).

Nest Predation and Hatching Success

Predation is an important source of shorebird clutch failure, and is partially responsible for variable yearly hatching success. For example, predation caused variation in American Avocet clutch failure in both Oklahoma (19-83%; Grover and Knopf 1982), (8-17%; Hill 1985), (50-58%; Winton and Leslie 1997) and Utah (34-36%; Sordahl 1996). In California, Black-necked Stilt hatching success also varied (8-74%), due to predation

Table 2. Nest fates, hatching success, and productivity estimates for American Avocet and Killdeer nesting in playas in the Playa Lakes Region of Texas, 1998 and 1999.

	American Avocet		Killdeer
	1998	1999	1998 and 1999
Total number of nests	19	65	10
Successful	2	37	5
Predated	13	18	5
Hailed	0	0	0
Flooded	0	7	0
Trampled	2	0	0
Abandoned	0	2	0
Unknown fate[a]	2	1	0
Hatching success (%)	11 b[d]	57 a	50
Mayfield (%, 95% CI)[b]	10 (3-30)	43 (31-59)	30 (10-86)
Total eggs laid	75	229	32
Total eggs hatched	8	112	19
Eggs hatched/nest[c] ($\bar{x}$, SE)	0.42 (0.29) b	1.75 (0.22) a	1.9 (0.64)
Clutch size ($\bar{x}$, SE)	3.95 (0.05)	3.58 (0.09)	3.20 (0.36)
Clutch range	3-4	1-4	1-4
Single egg clutches	0	1	1
Two egg clutches	0	4	2
Three egg clutches	1	13	1
Four egg clutches	18	47	6
Exposure days	224	977	118

[a]Unknown clutches may have been successful or failed. For success estimates they were classified as failed.
[b]Confidence intervals (95%) calculated following Murphy *et al.* (1999).
[c]Mean number of eggs hatched per clutch.
[d]Values followed by the same letter in the same row for the same species are not statistically different.

pressures (Ohlendorf *et al.* 1989). Indeed, yearly hatching success variation was observed for both American Avocet (8%, 1998; 52%, 1999) and Black-necked Stilt (33%, 1998; 25% 1999) during this study. Of the 26 Black-necked Stilt clutches monitored, 50% were predated by Feral Pigs (*Sus scrofa*), and 71% (N = 50) of failed American Avocet clutches were predated by Coyotes (*Canis latrans*) in playas and Feral Pigs in saline lakes.

Although Killdeer and Snowy Plover experienced clutch predation, hail and flooding caused nearly as many Killdeer clutch failures (N = 9) as predation (N = 11). Of 185 failed Snowy Plover nests, 43% were flooded or destroyed by hail and 28% were predated. Precipitation was also an important source of clutch failure in Oklahoma (Grover and Knopf 1982; Winton *et al.* 2000), but not in California (4%; Warriner *et al.* 1986) or Utah (14%; Paton 1995). Although avian predators, such as the Raven (*Corvus corax*), American Crow (*C. brachyrhynchos*), and gulls (*Larus* spp.) were important egg and chick predators in California and Oklahoma (Page *et al.* 1983; Warriner *et al.* 1986; Powell and Collier 2000; Winton *et al.* 2000), none were observed during this study.

Yearly variation in Snowy Plover hatching success has been observed in other regions. During this study, Snowy Plover hatching success was higher in 1998 (47%) than 1999 (33%). These estimates are lower than in California (50%, Warriner *et al.* 1986; 59%, Page *et al.* 1985) and Kansas (55-60%; Boyd 1972), within the range of estimates in Utah (11-49%; Paton 1995), and in Oklahoma (21-71%; Winton *et al.* 2000; 38-73%; Grover and Knopf 1982), and higher than estimates from the Texas coast (25%, Elliot and Zonick 1998). In the PLR, use of saline lakes and hatching success is variable; regulated by unpredictable precipitation events and hydroperiod.

Conservation Implications

Saline lakes and riparian wetlands of the PLR of Texas are critical habitat for regionally

Table 3. Nest fates, hatching success, and productivity estimates for American Avocet, Killdeer, and Snowy Plover nesting in saline lakes in the Playa Lakes Region of Texas, 1998 and 1999.

	American Avocet		Killdeer		Snowy Plover	
	1998	1999	1998	1999	1998	1999
Total number of nests	19	8	16	17	92	194
Successful	1	1	9	4	40	64
Predated	17	2	5	4	27	22
Hailed	0	0	0	2	2	13
Flooded	0	2	0	7	0	66
Trampled	0	0	0	0	3	0
Abandoned	0	3	1	0	13	22
Unknown fate[a]	1	0	1	0	7	7
Apparent hatching success (%)	5 a[d]	13 a	56 a	24 b	43 a	33 a
Mayfield (%, 95% CI)[b]	14 (5-34)	18 (5-64)	44 (23-81)	11 (3-37)	34 (25-46)	30 (24-37)
Total eggs laid (N)	55	24	55	57	246	482
Total eggs hatched	19	8	32	15	106	175
Eggs hatched/nest[c] ($\bar{x}$, SE)	0.21 (0.21)	0.5 (0.5)	2.0 (0.44)	0.88 (0.40)	1.12 (0.14) a	0.90 (0.09) a
Clutch size ($\bar{x}$, SE)	2.89 (0.23)	3.00 (0.46)	3.44 (0.24)	3.35 (0.28)	2.67 (0.06)	2.48 (0.05)
Clutch range	1-4	1-4	1-4	1-4	1-3	1-3
Single egg clutches	3	2	1	3	6	26
Two egg clutches	1	0	2	0	18	48
Three egg clutches	10	2	2	2	68	120
Four egg clutches	5	4	11	12	0	0
Exposure days	270	121	240	172	1367	3094

[a]Unknown clutches may have been successful or failed. For success estimates they were classified as failed.
[b]Confidence intervals (95%) calculated following Murphy *et al.* (1999).
[c]Mean number of eggs hatched per clutch.
[d]Values followed by the same letter in the same row for the same species are not statistically different.

breeding Snowy Plover. Western North American Snowy Plovers are designated as endangered (Page *et al.* 1995) and number only around 2,000 individuals (Morrison *et al.* 2001), but Great Plains Snowy Plover are more abundant (≈13,000 individuals; Morrison *et al.* 2001). Conservation concerns for western and Great Plains populations may vary locally, but are generally similar, where anthropogenic disturbances, predation, habitat loss, and exotic species invasion pose threats to stability (Page *et al.* 1995). Where predation and human disturbances are limiting factors for western Snowy Plover (Page *et al.* 1995), alteration of wetland hydroperiod and untimely precipitation events may limit Snowy Plover reproductive success in the PLR.

Saline lakes are, or were, connected to the Ogallala aquifer and contain springs that may persist through the nesting season (Brune 1981; Reeves and Temple 1986). However, when aquifer pumping for irrigation occurs during the breeding season (Bolen *et al.* 1989), spring integrity is compromised and volume decreases (personal observation). When combined with high evaporation, springs cease to flow. As these springs may be the only water source for nesting shorebirds, it is critical that conservation efforts focus upon maintaining spring integrity, particularly as saline lakes supported 96% of all Snowy Plover nests and was the only wetland in which all four species nested. Riparian wetlands supported small numbers of breeding Snowy Plover and a colony of Interior Least Tern (*Sterna antillarum athalassos*; Conway *et al.* 2003), these habitats are also being degraded which compromises their structure and function (Magill 1998; Bonner and Wilde 2000).

Although playas were not used by breeding shorebirds as frequently as saline lakes, their abundance underscores their importance (Conway *et al.* 2005). The lack of nesting in man-made wetlands highlights the need for conservation and management of playas, as man-made wetlands cannot compensate for natural wetland losses in the PLR

(Conway *et al.* 2005). Playa hydrology is threatened by sedimentation from agriculture and is cited as a major cause of reduced playa hydroperiod (Luo *et al.* 1997; Smith and Haukos 2002). Preventing sedimentation in playas would enhance suitability for nesting shorebirds, by extending playa hydroperiod. Landowners should be encouraged not to remove water from playas for irrigation during the breeding season.

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