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Abstract.—The reproductive ecology of the Least Tern (*Sterna antillarum*) was examined at four nesting colonies along the Lower Mississippi River during the 1995-1997 breeding seasons. Nest success, hatching success, and reproductive success were calculated in order to estimate productivity and evaluate reproductive status. Nesting colonies varied in size from 172 to 550 nests, with average clutch sizes ranging from 1.9-2.7 eggs/nest. Both nest success, the proportion of nests from which at minimum one egg hatched, and hatching success, the proportion of eggs that hatched, were significantly higher in 1995 (97% and 94% respectively) as compared to 1996 and 1997 (~40%). Reproductive success averaged between 0.28-1.27 fledglings/clutch. Predation and untimely flooding were the largest negative impacts upon successful tern reproduction. *Received 2 March 2002, accepted 5 September 2002.*

Key words.—Clutch initiation, hatching success, Least Tern, Mississippi River, nest success, productivity, reproductive success, *Sterna antillarum.*

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The Least Tern (*Sterna antillarum*), which breeds in the interior of North America, has been listed as endangered by the U.S. Fish and Wildlife Service since 1985 (USFWS 1985). The riverine habitat, which Least Terns depend upon, had been vastly altered due to impoundment, channelization, and stabilization projects designed to achieve flood control and navigation objectives. As a result of the federal listing, surveys were conducted by the U.S. Army Corps of Engineers (Jones 2001) and the Missouri Department of Conservation (Smith and Stucky 1988; Smith and Renken 1990). According to these surveys and work by Kirsch and Sidle (1999), approximately 52-79% of Least Terns nest along the Lower Mississippi River between Cairo, Illinois and Vicksburg, Mississippi. However, productivity data for the Lower Mississippi River are only available from work along the Missouri stretch (Smith and Stucky 1988; Smith and Renken 1990, 1991, 1993; Renken and Smith 1995a, 1995b). Therefore, a need existed to determine the reproductive success of terns south of Memphis, Tennessee, to provide a more complete picture of the range-wide status of the Least Tern.

Generally, Least Terns begin nesting from early May to early June (Youngworth 1930; Hardy 1957; Whitman 1988). However, timing of nesting of Least Terns along the Lower Mississippi River is affected by spring floods, which may persist until late June and postpone egg laying until sandbars used for nesting become exposed (Bacon and Rotella 1998). The floods are influenced by spring rains within the Ohio River and Illinois River drainage areas, and the melting of the snow pack of the north-central states (Boyd, pers. comm. 1997; Sparks *et al.* 1998). Incubation period averages 21 days (Hays 1980), followed by an 18-20 day period of development before the chick can fly (Hardy 1957; Whitman 1988).

The objective of this study was to examine several aspects of the reproductive ecology of Least Terns nesting on the Lower Mississippi River, including clutch size, clutch initiation, nest success, hatching success, and reproductive success. These data are important for making informed decisions about the conservation and management of the species.

STUDY AREA

Four nesting colonies were studied between Memphis, Tennessee and Friars Point, Mississippi. The terns nested on sandbars located within diked reaches of the Mississippi River at Cow Island Bend (Desoto Co., River Mile 715; 35°00'N, 90°18'W), Porter Lake Dikes (Crittenden Co., River Mile 700; 34°51'N, 90°22'W), St. Francis Dikes (Tunica Co., River Mile 672; 34°37'N, 90°35'W), and Kangaroo Point (Phillips Co., River Mile 647; 34°22'N, 90°43'W). These colonies were selected based on aerial surveys conducted by the U.S. Army Corps of Engineers (Rumancik 1994), which previously indicated large numbers of nesting terns.

Flow regimes along the Lower Mississippi River are relatively dynamic (Renken and Smith 1995b) and influence the physical characteristics of a sandbar. Depending upon river flows, the four sandbars varied from one to three square kilometers over the course of the nesting season. Each sandbar was characterized as an open expanse of sandy substrate mostly devoid of vegetative cover. Patches of Sandbar Willow (*Salix interior*) and small clumps of herbaceous vegetation could be found in wetter areas.

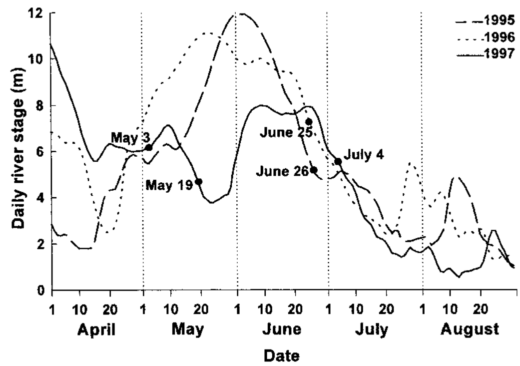

Figure 1. Daily river stages for the Mississippi River at Memphis, Tennessee for 1995-1997. Data provided by the U.S. Army Corps of Engineers, Memphis District.

METHODS

Since the timing of spring floods influences the availability of nesting substrate, river levels were monitored by consulting daily river stage data recorded at Memphis, Tennessee and provided by the Memphis District, U.S. Army Corps of Engineers. Studies were conducted from 26 June to 8 August in 1995; 25 June to 8 August in 1996; and from 28 May to 24 August in 1997. Visits to each colony were delayed until late June (June 25-26) in both 1995 and 1996 because of unusually long spring flood seasons (May-June; Fig. 1), which prevented nesting. Lower river levels, and possibly higher sandbars, provided nesting habitat earlier in 1997. Nesting habitat was available at Kangaroo Point by 3 May 1997, while at both Porter Lake Dikes and St. Francis Dikes nesting substrate was available by 19 May 1997 (Fig. 1). Spring floods in early June 1997 destroyed all previous nesting at Porter Lake Dikes and St. Francis Dikes, postponing the season's major nesting until the river levels dropped below 6.1 m after 4 July (Fig. 1).

Colonies were visited every four days after the discovery of the first nest scrape. Nest scrapes containing eggs were marked with a wooden tongue depressor placed in the ground 40-60 cm from the nest, while walking a systematic course through the colony. Each tongue depressor was marked with a number that uniquely identified each nest, and allowed the progression of a nest to be followed throughout the nesting cycle until eggs either hatched or the eggs in the nest failed. Early nesting failures occurred during 1996 and 1997, and some colony sites may have included terns attempting a second nesting. Since marked adults were not available, second nesting attempts could not be identified.

Nest number, clutch size, and egg status (i.e., egg intact, damaged, missing, predated, pipped or hatched) were recorded during each visit to a colony. Evidence of nest activity (i.e. presence or absence of tern tracks) and possible causes of nest failure (e.g., signs of predation) were also noted. The total number of nests, frequency of clutch sizes, and nest outcome (i.e., successful, failed, or unknown) were subsequently determined. Chi-square analysis was used to examine the frequencies of clutch sizes in relation to colony and year and only nests where clutches were known to be completed were included in estimates of clutch size.

Because seasonal river levels determined available nesting substrate and egg laying began as soon as nesting substrate was available, most nests were found early. Subsequently, clutch initiation, defined as the laying date of the first egg, was determined by assuming that eggs were laid on consecutive days (Hardy 1957; Thompson *et al.* 1997) and back dating from the day the clutch was found. The peak period of clutch initiation was determined as the first 75% of clutches laid at any one colony, which provided a reasonable estimate which could be used to determine when most eggs would hatch. The median clutch initiation date was estimated and statistically analyzed using the Median test (Zar 1996). The null hypothesis, that all colonies had the same median date, was tested by calculating a grand median. If rejected, the proportions of data distributed to each side of the grand median would differ among samples and the individual medians for the whole colony would differ (Sokal and Rohlf 1995). Differences among years and among colonies within years were examined using multiple comparison testing among medians (Zar 1996). Early clutches inundated by spring floods were not used to determine the peak period of clutch initiation, but were used to determine the median date of initiation, as excluding these early clutches would provide a false median date for the nesting season as a whole.

Estimates of nest success and hatching success were analyzed by chi-square. Nest success was defined as the proportion of nests of known outcome (i.e. successful or failed) that were successful (Kirsch 1990). A successful nest was defined as one from which at least one egg hatched (Miller and Johnson 1978; Hill 1985; Kirsch 1990; Smith and Renken 1993). Hatching success was defined as the proportion of eggs that hatch from nests of known outcome (Kirsch 1990; Brunton 1997).

Reproductive success, defined as the number of fledglings produced per nest, is a difficult parameter to estimate for terns (Massey and Atwood 1981; Erwin and Custer 1982; Smith and Renken 1993) because the young are mobile, leaving the nest within two to three days of hatching. In addition, their cryptic coloration and behavior make direct estimates of fledgling success often impossible. A mark-recapture methodology was used to estimate fledgling numbers (Hardy 1957; USFWS 1992; Renken and Smith 1993; Brunton 1997). A drift fence, 45 cm high, was placed in a shallow "V" configuration. The fence extended outward 91-183 m from the apex of the "V" set up and young terns, approximately 14 days old (still too young to fly), were herded into the drift fence between 07.00 h and 10.00 h. Upon capture, terns were banded on the right tarsus with aluminum U.S. Fish and Wildlife Service bands. Young terns were herded for a second time on the same day between 17.00 h to 19.00 h and the numbers of banded vs. unbanded birds were recorded. The number of Least Tern chicks surviving to the fledgling stage was determined using the Bailey-modified version of the Lincoln-Peterson index (Bailey 1951; Seber 1982). The Bailey-modified version is a more conservative estimate and is used when the number of recaptures is small (less than ten) (Bailey 1951; Begon 1979; Seber 1982). The method also allows the calculation of a standard error.

RESULTS

Clutch Size—The frequency of clutch sizes varied significantly with year ($\chi^2_4 = 546$, $P < 0.001$) and among colonies within a given year (1995, $\chi^2_6 = 63$, $P < 0.001$; 1996, $\chi^2_6 = 45$, $P < 0.001$; 1997, $\chi^2_6 = 44$, $P < 0.001$). Average clutch size declined progressively from 1995 - 1997 (Table 1). A modal clutch size of three was found in 1995 and 1996, but was two in 1997 (Table 1). Although Least Terns normally lay 1-3 eggs per clutch (Thompson *et al.* 1997), five clutches of four eggs were found during both 1995 and 1996, four clutches of four eggs during 1997, and one clutch of five eggs was found at Porter Lake Dikes in 1995. However, these clutches represented less than 0.5% of the total nests each year.

Clutch Initiation—The number of nests reported include those of known and unknown outcome for which an estimate of the clutch initiation date could be determined. The range of initiation dates was similar for 1995 (24 June to 25 July) and 1996 (25 June to 23 July) whereas clutch initiation began a month earlier (23 May) and ended almost a week later (29 July) in 1997 (Table 2). Median clutch initiation varied significantly among years ($\chi^2_2 = 47$, $P < 0.001$) and among colonies within years (1995: $\chi^2_3 = 92$, $P < 0.001$; 1996: $\chi^2_3 = 138$, $P < 0.001$; 1997: $\chi^2_3 = 592$, $P < 0.001$). Fifty three percent of nests were initiated prior to the median date in 1995, while 43% and 49% of nests were initiated prior to the median date in 1996 and 1997 respectively. During 1997, the first 75% of clutches (peak clutch initiation) were laid

Table 1. Clutch size at four Least Tern colonies along the Lower Mississippi River. Egg columns represent the percentage frequency of clutch sizes.

	1995						1996						1997					
Colony	N[1]	Mean	Range	1 egg	2 egg	3 egg	N[1]	Mean	Range	1 egg	2 egg	3 egg	N[1]	Mean	Range	1 egg	2 egg	3 egg
Cow Island	550	2.7	1 - 4	1.8	28.9	69.1	265	2.3	1-4	15.5	35.1	47.9	172	2.0	1-3	14.0	69.2	16.9
Porter Lake	201	2.6	1 - 5	1.5	39.3	58.7	392	2.3	1-3	11.7	44.1	44.1	361	1.9	1-4	29.1	56.2	14.4
St. Franics	245	2.4	1 - 4	2.9	49.8	46.1	183	2.6	1-3	0.5	35.0	64.5	374	1.9	1-4	28.6	54.0	16.8
Kangaroo Pt.	219	2.4	1 - 4	2.7	54.3	42.5	159	2.5	1-4	5.7	39.6	54.1	346	2.1	1-4	18.2	53.8	27.7
Totals	1215	2.6	1 - 5	2.1	39.4	57.9	999	2.4	1-4	9.7	39.3	50.5	1253	2.0	1-4	23.9	56.7	19.2

[1]Number of nests used to calculate clutch size.

over a 43-day period, whereas the same proportion of clutches were laid within 13 days during 1995 and 1996. Clutch initiation reported for all years probably included renesting birds, which was particularly likely at Porter Lake Dikes and St. Francis Dikes in 1997, when early nests were inundated by late spring floods (Table 2).

Nest Success—Estimates of proportionate nest success ranged between 0.03 to 0.99 with the lowest estimates indicating instances of catastrophic nest losses due to flooding or predation (Table 3). Chi-square analysis indicated significant differences among years ($\chi^2_2 = 1024$, $P < 0.001$) and among colonies within years (1995: $\chi^2_3 = 52$, $P < 0.001$; 1996: $\chi^2_3 = 419$, $P < 0.001$; 1997: $\chi^2_3 = 396$, $P < 0.001$). Significant variation among years was due to high success (97%) during 1995, as nest success was not significantly different between 1996 and 1997 ($\chi^2_1 = 0.96$, n.s) when 1995 values were excluded. Differences in nest success were due to a larger percentage of nests impacted by flooding and predation during 1996 and 1997, which subsequently affected hatching success (Table 3).

Hatching Success—Hatching success estimates closely followed the trends noted for nest success. The proportion of eggs hatched in 1995 (94%) was higher than subsequent years with estimates varying significantly with year ($\chi^2_2 = 2216$, $P < 0.001$) (Table 4). Within a given year, hatching success also varied significantly among colonies (1995: $\chi^2_3 = 69$, $P < 0.001$; 1996: $\chi^2_3 = 977$, $P < 0.001$; 1997: $\chi^2_3 = 768$, $P < 0.001$).

Reproductive Success—In 1995, 260 Least Tern chicks were banded; 114 were banded in 1996; and 325 in 1997 (Table 5). According to the Bailey-modified estimate of the number of fledglings produced within a year, most fledglings were produced in 1995 and the fewest produced in 1996 (Table 5). The greatest number of fledglings (823 ± 162) was recorded on Cow Island Bend in 1995. Overall, reproductive success averaged 0.28-1.27 for the three years ranging between zero for heavily predated colonies to 1.79 per clutch (Table 5). The highest rate of reproductive success was noted at St. Francis Dikes (1.79 and 1.23 fledglings/clutch) during 1995 and 1996, and at Cow Island Bend in 1997 (0.87 fledglings/clutch).

Table 2. Clutch initiation dates at four Least Tern colonies along the Lower Mississippi River. Data presented in Julian date.

	1995			1996			1997		
Colony	Range (N)[1]	Median	Peak[2]	Range (N)[1]	Median	Peak[2]	Range (N)[1]	Median	Peak[2]
Cow Island	176 - 201 (546)	181[a]	176 - 185	181 - 198 (272)	184[a]	181 - 186	192 - 210 (182)	199[a]	192 - 203
Porter Lake	178 - 202 (195)	183[b]	178 - 189	182 - 199 (371)	187[b]	182 - 191	149 - 208 (372[3])	187[ab]	184 - 191
St. Francis	177 - 205 (255)	187[c]	177 - 193	183 - 205 (196)	192[c]	183 - 192	150 - 206 (382[4])	187[b]	185 - 200
Kangaroo Pt.	175 - 206 (240)	179[d]	175 - 184	177 - 199 (161)	182[d]	177 - 185	143 - 187 (418)	161[c]	148 - 172
Totals	175 - 206 (1236)	182[e]	175 - 188	177 - 205 (1000)	185[e]	181 - 192	143 - 210 (1354)	185[f]	161 - 204

[1]Number of nests for which clutch initiation could be determined includes nests of known and unknown outcome.

[2]Peak clutch initiation period represents the first 75% of active clutches laid (see text).

[3]N includes 95 clutches laid 29 May 1997 which became inundated 2 June 1997. These clutches are not included in the calculation of peak initiation.

[4]N includes 136 clutches laid 30 May 1997 which became inundated 2 Jun 1997. These clutches are not included in the calculation of peak initiation.

[abcd]Median clutch initiation date varied significantly among colonies within a given year (see text).

[ef]Median clutch initiation date varied significantly among years (see text).

Table 3. Nest success and the percentage of nests affected by flooding (F) or predation (P) at four Least Tern colonies along the Lower Mississippi River.

	1995				1996				1997			
Colony	Number of nest	Nest Success[1]	%F	%P	Number of nest	Nest Success[1]	%F	%P	Number of nest	Nest Success[1]	%F	%P
Cow Island	550	0.99	0	0.2	265	0.03	0	95.5	172	0.94	0	1.7
Porter Lake	201	0.97	0	1.5	392	0.30	25.3	44.4	361	0.07	26.3	59.3
St. Francis	245	0.98	0	0	183	0.93	5.5	0	374	0.55	36.4	3.7
Kangaroo Pt.	219	0.89	0	5.0	159	0.64	0	25.8	346	0.38	15.0	4.6
Totals	1215	0.97[a]	0	1.2	999	0.40[b]	10.9	46.8	1253	0.42[b]	22.6	19.7

[1]Calculated as the number of successful nests divided by the total number of nests of known outcome.
[a,b]Nest success varied significantly among years (see text).

DISCUSSION

Reproductive Parameters

Estimates of clutch size, hatching success, nest success, and reproductive success reported in this study fall within reported values for the Least Tern (Smith and Renken 1993; Kirsch 1996; Thompson *et al.* 1997; Bacon and Rotella 1998; Kirsch and Sidle 1999). This study is the first to estimate reproductive success of the Least Tern nesting south of Memphis, Tennessee in the Lower Mississippi River Valley. Although data on tern numbers has been gathered each year since 1985 by the U.S. Army Corps of Engineers (Jones 2001), it is also necessary to evaluate the reproductive effort needed to maintain population levels. To date, efforts to model population trends of Least Terns are limited (Kirsch 1996; Kirsch and Sidle 1999) because information pertaining to adult and post-fledgling survival are poorly known (Massey *et al.* 1992; Renken and Smith 1995a; Kirsch and Sidle 1999). A conservative estimate of 0.51 fledglings/pair has been considered necessary for population maintenance (Kirsch 1996), although models proposed by Kirsch and Sidle (1999) increase this estimate to 0.6 - 1.12 fledglings/pair. Yearly estimates obtained in the present study indicated that recruitment south of Memphis, Tennessee during 1996-97 was below required limits. However, long-lived spe-

Table 4. Hatching success at four Least Tern colonies along the Lower Mississippi River. Number of eggs laid are represented in parentheses.

	1995		1996		1997	
Colony	Number of nests	Hatching success[1]	Number of nests	Hatching success[1]	Number of nests	Hatching success[1]
Cow Island	550	0.97 (1472)	265	0.03 (624)	172	0.93 (349)
Porter Lake	201	0.93 (520)	392	0.30 (911)	361	0.08 (671)
St. Francis	245	0.95 (602)	183	0.90 (483)	374	0.59 (708)
Kangaroo Pt.	219	0.87 (527)	159	0.63 (397)	346	0.40 (727)
Totals	1215	0.94[a] (3121)	999	0.4[b] (2415)	1253	0.44[c] (2455)

[1]Calculated as the number of eggs that hatched divided by the number of eggs laid in nests of known outcome.
[a,b,c]Hatching success varied significantly among years (see text).

Table 5. Fledgling estimates and reproductive success at four Least Tern colonies along the Lower Mississippi River based on mark-recapture methodology.

	1995			1996			1997		
Colony	N[1]	Bailey-modified ± SE	Reproductive success[2] (N)[3]	N	Bailey-modified ± SE	Reproductive success[2] (N)[3]	N	Bailey-modified ± SE	Reproductive success[2] (N)[3]
Cow Island	154	824 ± 162	1.50 (550)	0	0	0.00 (265)	96	150 ± 11	0.87 (172)
Porter Lake	15	155 ± 74	0.77 (201)	12	50 ± 18	0.13 (392)	0	0	0.00 (266)[4]
St. Francis	81	438 ± 69	1.79 (245)	101	226 ± 22	1.23 (183)	150	198 ± 10	0.83 (238)[4]
Kangaroo Pt.	10	65 ± 35	0.30 (219)	1	0	0.00 (159)	79	134 ± 13	0.45 (299)[4]
Totals	260	1546 ± 190	1.27 (1215)	114	276 ± 27	0.28 (999)	325	483 ± 20	0.50 (975)

[1]Number of fledglings banded during initial capture (see text).
[2]Reproductive success is estimated as the number of fledglings produced per nest based on the Bailey modified estimate of the number of fledglings.
[3]Number of nests of known outcome used to estimate reproductive success.
[4]Reproductive success does not include the nests that were inundated early in the nesting season (see text).

cies may decline slowly over long periods only to recover during short and infrequent periods of high productivity (Kirsch 1996). Whether success during 1995 was sufficiently high to compensate for the lower productive years needs to be addressed.

Major Factors Influencing Reproductive Success

Annual hydrological patterns in combination with predation pressures posed the greatest negative effects on the breeding success of Least Terns in this study. Coastal breeding Least Terns initiate nesting as early as late April to mid-May (Jackson 1976; Hays 1980; Massey and Atwood 1981; Thompson 1982; Burger and Gochfeld 1990; Brunton 1997). However, the exact timing of yearly spring flooding events varies unpredictably along the Lower Mississippi River, influencing the timing of nesting (Bacon and Rotella 1998; this study). Although terns arrived at breeding areas as early as 19 May, they may wait up to one month (late June) for the nesting habitat to become available (i.e., when river levels drop) and even then sandbar habitat may or may not remain above water consistently for the minimum requisite breeding period of 50 days (Smith and Renken 1991; this study). Other studies have shown Least Terns begin nesting late May through mid-June (Smith and Renken 1993; Kirsch 1996; Dugger *et al.* 2000; this study). During 1995-96 spring floods were prolonged until late June, but during 1997 the early exposure of nesting habitat by May was suddenly flooded in early June, destroying the first nesting attempt on both Porter Lake Dikes and St. Francis Dikes. The unexpected rise in river levels postponed the season's major nesting event and explains the longer clutch initiation period for 1997. This early flooding and subsequent renesting may also have led to lower average clutch sizes for the year (Massey and Atwood 1981).

In addition to the direct flooding of nests, river level fluctuations also influence the degree of predation a colony site experiences. Sandbars remained isolated from the main shoreline for a greater portion of the incubation period during 1995 because river levels remained high. High river levels decrease the potential for mammalian predators gaining access to the colony sites via dikes or accreted shoreline. Such a concern is important, given many sandbars are found within diked reaches of the river, including those in this study on which colonies were established. During the incubation phase at Cow Island Bend in 1996, eggs and nests were predated by Raccoons (*Procyon lotor*) as indicated by tracks around the nests. Raccoons gained access to the sandbar early in the season when river levels dropped sufficiently causing the sandbar's attachment to the riverbank shoreline. The loss of 154 nests (41%) on Porter Lake Dikes in 1997 was also due to shoreline accretion and subsequent Coyote (*Canis latrans*) predation. St. Francis Dikes was the only colony site that had consistently high nest and reproductive success across years. Such success may be attributed to the sandbar's "isolation" throughout the nesting season (water flowing around it throughout the summer), thus reducing the likelihood of mammalian predation (Brunton 1997).

Low estimates of reproductive success at Kangaroo Point were attributed to Barred Owls (*Strix varia*). Barred Owls attacked incubating Least Tern adults during the evening, taking both adults and juveniles as indicated by foot tracks often leading to a pile of tern feathers and mandibles. Foot tracks were also found leading from one nest to another. Such "foot-hunting" behavior has been noted in this and other owl species (McMillian 1998). Because Barred Owls are considered opportunistic predators and are known to nest typically from March through April (Mazur and James 2000), it is likely that juvenile Barred Owls would be fed Least Tern chicks.

Management Recommendations

The breeding biology of the Least Tern is closely tied to the flow dynamics of the river (Bacon and Rotella 1998; Tibbs and Galat 1998; this study). Ensuring that habitat is available from May through August should increase levels of productivity (Smith and Renken 1991). The sandbar habitat that exists must be preserved, with emphasis placed upon those that are exposed for the duration of the breeding season (May-August) (Smith and Renken 1991). Increasing the availability of nesting habitat so that Least Terns would be dispersed among more sites would reduce vulnerability of the population to flooding events and isolated instances of predation (Smith and Renken 1993; Kirsch and Sidle 1999).

Attempts to ensure flood control and address navigation priorities along the Mississippi River have spanned a period of 200 years (Smith and Winkley 1996), consequently most sandbars today are located within dike fields (Smith and Renken 1993). Dike fields are designed to trap sediment, increasing the likelihood that the sandbar will accrete to the shoreline, eventually becoming vegetated and unsuitable for Least Tern nesting (Smith and Stucky 1988). Appropriate management and understanding of sedimentation rates and accretion patterns of diked reaches could prevent sandbar accretion and maintain Least Tern nesting habitat while achieving navigation objectives (Smith *et al.* 1982; Beckett and Pennington 1986). Dikes should be modified to ensure river flows between the sandbar and shore, particularly throughout the Least Tern breeding season (Renken and Smith 1993). This would remove travel corridors for mammalian predators and provide slack-water areas rich in fish prey (Tibbs and Galat 1998).

As public use of sandbar habitat along the Mississippi River increases, education will play an increasingly important role in minimizing human disturbance on nesting Least Terns. Posting signs along sandbars with nesting colonies is not effective, given the large size of the sandbars and the work needed to maintain them during a single year (C. S. and M. W. pers. obs.). Rather, signs that educate the public about the importance of sandbars and minimizing disturbance during the nesting season would likely be more effective if placed at public boat ramps. Finally, more effort needs to be dedicated to banding and resighting or recapturing Least Terns to determine post-fledgling survival and annual adult survival rates (Kirsch 1996). Understanding breeding success and yearly recruitment will allow for better population modeling and management decisions.

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