# Nest Sites and Conservation of Endangered Interior Least Terns Sterna antillarum athalassos on an Alkaline Flat in the South-Central Great Plains (USA)

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# Nest sites and conservation of endangered Interior Least Terns *Sterna antillarum athalassos* on an alkaline flat in the south-central Great Plains (USA)

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**Abstract.** We monitored nest sites of endangered Interior Least Terns on a 5 095 ha alkaline flat in north-central Oklahoma, USA. After nest loss, Least Terns commonly renested and experienced 30% apparent nest success in 1995–1996 (n = 233 nests). Nest success and predation differed by location on the alkaline flat in 1995 and overall, but nest success and flooding did not differ by microhabitat type. Predation was highest at nests ≤ 5 cm from debris (driftwood/hay) in 1995. No differences in nesting success, flooding, or predation were observed on comparing nests inside and outside electrified enclosures. Coyotes and Striped Skunks were confirmed nest predators, and Ring-billed Gulls were suspected nest predators. We identified one location on the alkaline flat of about 1 000 ha with consistently lower nest losses attributable to flooding and predation and the highest hatching success compared with other parts of the alkaline flat; it was typified by open ground and bisected by several creeks. Management activities that minimize flooding and predation in this area could further enhance nest success and theoretically increase overall productivity of this population of Least Terns. However, the efficacy of electrified enclosures and nest-site enhancements, as currently undertaken, is questionable because of considerable annual variation in use by and protection of Least Terns.

**Key words:** Interior Least Terns, *Sterna antillarum athalassos*, apparent nest success, flooding, nest losses, predator exclosures, Oklahoma

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## INTRODUCTION

General guidelines for conservation of colonial avian species exist, but they often are hampered by a lack of specific information on individual species (Burger 1989, Hoffmann et al. 1996). The Interior Least Tern of the central United States was listed as endangered in 1985 (United States Fish & Wildlife Service 1985). Least Terns nest in a variety of habitats throughout the United States, such as coastal beaches (Burger 1984, 1989), interior riverine sandbars (Leslie et al. 1997, 2000), human-made islands from dredging activities (Kirsch 1996), and expansive alkaline flats with little or no ground-hugging vegetation (Koenen et al. 1996b, Schweitzer & Leslie 1996, 1999). Although Interior Least Terns have been reasonably well studied (e.g. Kirsch 1996, Thompson et al. 1997, Kirsch & Sidle 1999), specific insight on nest-site selection and efficacy of recovery and management approaches (e.g. vegetation manipulations, elevated nesting structures, predator-free enclosures) frequently is not available to guide conservation. For any Least Tern nesting habitat, unique characteristics and perils necessitate detailed spatial and temporal assessments to permit adequate protection.

One of the largest inland populations of Interior Least Terns nests annually on an expansive alkaline flat in the south-central Great Plains, USA (United

States Fish & Wildlife Service 1990, Kirsch & Sidle 1999). Because of the rarity of Interior Least Terns and the unique nature of the alkaline flat (Schweitzer & Leslie 1999) relative to more typical breeding habitat (Kirsch 1996, Leslie et al. 1997, 2000), breeding colonies have been monitored intermittently since the early 1980s (Grover & Knopf 1982, Boyd 1990, Hill 1985, 1993, Schweitzer 1994, Koenen et al. 1996b, Schweitzer & Leslie 1996, 1999). Because Least Terns demonstrate various degrees of nest-site selection for particular features on the alkaline flat (Schweitzer & Leslie 1999), we and others have used various habitat improvements to reduce nest losses from natural factors such as flooding and predation (Boyd 1990, Utych 1993, Koenen et al. 1996b, Winton 1997) and to enhance recovery objectives for the metapopulation of Interior Least Terns (United States Fish & Wildlife Service 1990).

Our objectives were to assess nest success of Interior Least Terns by location and microhabitat type on this unique alkaline flat and compare nest success inside electrified enclosures with nest-site enhancements versus nests outside of the enclosures. We predicted that Least Tern nests in certain locations and associated with particular microhabitat types on the alkaline flat would experience lower predation and loss to flooding, and thereby higher success, than generally occurred elsewhere. We also discuss the efficacy of conservation strategies that have been used on the alkaline flat to enhance breeding success of Least Terns.

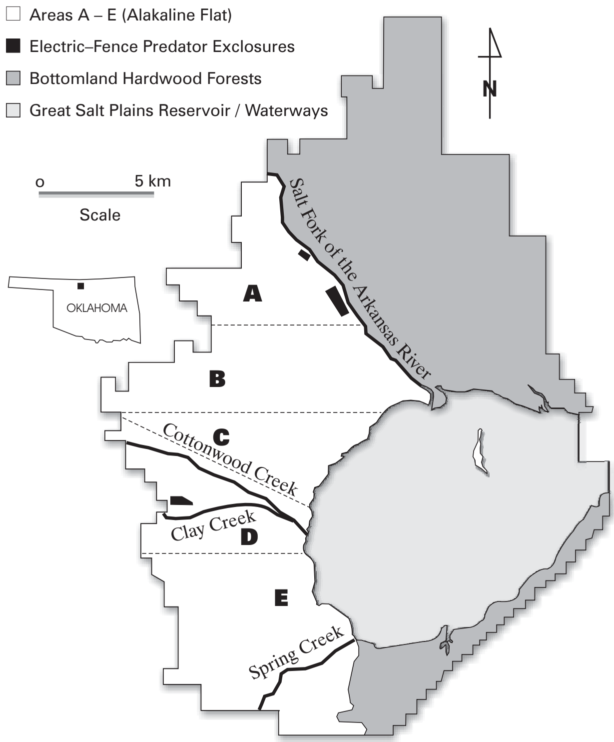

Fig. 1. The alkaline flat at Salt Plains National Wildlife Refuge with strata A–E, electric-fence predator exclosures, and ephemeral watercourses that bisect the flat.

## STUDY AREA

Our study was conducted at Salt Plains National Wildlife Refuge (NWR) in north-central Oklahoma, USA (Alfalfa County, 36°45′N, 98°15′W). The 5 095 ha, alkaline-encrusted flat is sparsely covered by ground-hugging vegetation, driftwood, and other debris and has little change in elevation. The flat drains into the Great Salt Plains Reservoir (Fig. 1), which constitutes an important stop-over site for migrating shorebirds and waterfowl in the Central Flyway in North America and is included in the Western Hemisphere Shorebird Reserve Network (www.manomet.org/srn/). Spring, Cottonwood, and Clay creeks and the Salt Fork of the Arkansas River are ephemeral water sources that cross the alkaline flat (Fig. 1) and are used for foraging by Least Terns (Schweitzer & Leslie 1996).

Rains in excess of several centimeters cause sheet-flooding of the alkaline flat and considerable nest loss. Rainfall from 1 May through 31 July was 50.6 cm in 1995 (wet year) and 28.5 cm in 1996 (dry year). During the nesting season of Least Terns, rainfall totals in May, June, and July were 16.7 cm, 24.2 cm, and 9.7 cm in 1995 and 4.7 cm, 13.5 cm, and 10.3 cm in 1996, respectively. Precipitation, resulting sheet-flooding, and fluctuating levels of the Great Salt Plains Reservoir (343.0–344.8 m above mean sea level in 1995, 342.9–344.2 m in 1996) inundated varying parts of the alkaline flat in both years.

From April through October, visitors to Salt Plains NWR are allowed to enter only one of six adjacent 10 ha units on the alkaline flat per year to dig selenite crystals. Each unit varies in its proximity to known nesting locations of Least Terns (Utych 1993, Koenen 1995, Winton 1997). Invasion of exotic Salt Cedar *Tamarix* spp. has occurred along water courses on the alkaline flat, which has reduced availability of nesting habitat for Least Terns and provided concealment for mammalian predators on the near-featureless alkaline flat (Hill 1993, Koenen et al. 1996a).

# METHODS

## Nest and habitat assessments

Least Tern nests were located by systematically traversing the alkaline flat from May to August in 1995 and 1996. Nest sites were marked with 30 cm wooden dowels placed about 10 m from the nest cup following protocol of Koenen et al. (1996b). We used an all-terrain vehicle and binoculars to monitor nest sites during morning and evening, timed to reduce disturbance and heat stress to adults and eggs (Blanco et al. 1999, Carney and Sydeman 1999, Wendeln & Becker 1999). We used nest success as an index of productivity (Powell & Collier 2000) because fledgling success was not determined. To evaluate area-specific nest success, we divided the alkaline flat into five strata of about 1 000 ha each (Fig. 1) based on fluvial patterns and general nest-site distribution (Hill 1985). All strata were largely featureless with little change in elevation, but relative to one another, strata A and B had more driftwood debris than strata C and D, and strata E was unique with a sparse cover of large wind-driven logs. Sheet-flooding after rainfall tended to be less problematic from north to south. Strata A, B, and D were more influenced by fluvial processes and their substrates typically were wetter than in strata C and E. All five strata were searched equally for nests.

Five microhabitats associated with individual nests were recorded: 1) ≤ 5 cm from driftwood debris, 2) ≤ 5 cm from other debris (hay, dead vegetation, metal, bone, glass), 3) in the open (no adjacent features), 4) on man-made habitat improvements (i.e. plowed ridges, gravel mounds, Koenen et al. 1996b, Winton 1997), and 5) ≤ 5 cm from other features (i.e. live vegetation, selenite crystal outcroppings) designed to attract Least Terns to elevated sites safe from flooding and placed inside electrified enclosures designed to exclude terrestrial medium-sized predators.

Two electrified enclosures (4.5 ha and 24 ha) were constructed in 1991 (Koenen et al. 1996a), and another 20 ha electrified enclosure was constructed in 1995 (Winton 1997) to reduce canid predation (Fig. 1). Each fenced enclosure was electrified by a solar-powered 12 volt battery and had 5 wires spaced 14, 28, 42, 62, and 86 cm from the ground on metal posts at 6 m intervals (Lohemoen et al. 1982, Utych 1993). Fence locations and sizes were determined based on high-density nesting areas used by Least Terns in previous years (Hill 1985) and placed near ephemeral watercourses crossing the flat (Fig. 1).

## Statistical analyses

We used the Mayfield method to estimate annual nest success (Mayfield 1961, 1975, Johnson 1979) to permit comparisons with previous published work on Least Terns on the alkaline flat (e.g. Koenen et al. 1996b). However, we used apparent nest success (% of nests hatched relative to the total number of monitored nests; Miller & Johnson 1978, Johnson & Shaffer 1990) to compare success among areas of the alkaline flat and relative to microhabitats associated with individual nests. Apparent nest success is the most appropriate index for high-visibility species such as Least Terns that tend to nest colonially and experience temporally uneven mortality events — both conditions can bias estimates of nest success from the Mayfield method (Klett & Johnson 1982, Johnson & Shaffer 1990). We used $\chi^2$ analyses to ascertain differences in nest outcomes among areas and by microhabitat type. We used $p = 0.10$ because often the urgency of recovery objectives makes it reasonable to accept a higher risk of a Type 1 error (Schefler 1969) to attain conservation goals for sensitive species (Winton et al. 2000).

# RESULTS

Peak nesting occurred in June during both years, and breeding Least Terns generally were concentrated near seasonally ephemeral streams (Fig. 1). We located and monitored 117 Least Tern nests in 1995 and 116 nests in 1996 ($n = 233$, Table 1); renesting after loss was common. We checked the status of nests every 2.6 days ± 0.9 SD in 1995 and every 2.7 days ± 0.9 SD in 1996, until one or more eggs hatched or outcome was determined. Only 53% of all nests in 1995 and 59% of all nests in 1996 were re-sighted after our initial discovery. Least Terns experienced 29–37% nest success using the Mayfield method and 30% apparent nest success in 1995–1996 (Table 1). Mean clutch size in 1995–1996 was 2.1 eggs ± 0.7 SD, and hatching success was 0.6 chicks/pair in 1995 (64 hatchlings) and 1996 (67 hatchlings).

Apparent nest success differed by strata in 1995 ($\chi^2 = 10.83$, df = 4, $p < 0.05$) and cumulatively ($\chi^2 = 7.57$, df = 4, $p < 0.10$). Generally, more nests were successful in strata C and D (Fig. 1) in both years than expected (Table 1). Number of nests lost to predation differed by strata in 1995 ($\chi^2 = 16.91$, df = 4, $p < 0.005$) and cumulatively ($\chi^2 = 6.05$, df = 4, $p < 0.10$). Number of flooded nests differed by strata in 1996 ($\chi^2 = 7.05$, df = 4, $p < 0.10$, Table 1).

Table 1. Nest distribution and outcome (N) by strata (A–E) and inside/outside electrified enclosures (In, Out): apparent nest success is the percentage of nests hatched relative to the total number of monitored nests (1995 and 1996).

| Outcome | A | | B | | C | | D | | E | | N | | % | | In | | Out | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 |
| Nests | 44 | 12 | 18 | 22 | 11 | 39 | 27 | 19 | 17 | 24 | 117 | 116 | | | 41 | 8 | 76 | 108 |
| Success | 8 | 2 | 2 | 8 | 3 | 15 | 15 | 6 | 7 | 4 | 35 | 35 | 30 | 30 | 7 | 3 | 28 | 32 |
| Predation | 12 | 2 | 0 | 4 | 3 | 7 | 0 | 7 | 0 | 3 | 15 | 23 | 13 | 20 | 8 | 1 | 7 | 22 |
| Flood | 20 | 7 | 12 | 6 | 3 | 10 | 11 | 3 | 6 | 12 | 52 | 38 | 44 | 33 | 19 | 3 | 33 | 35 |
| Other | 4 | 1 | 4 | 4 | 2 | 7 | 1 | 3 | 4 | 5 | 15 | 20 | 13 | 17 | 7 | 1 | 8 | 19 |

Number of successful nests did not differ by microhabitat type in 1995, 1996, or cumulatively, although nest success in the open was consistently higher than expected in both years (Table 2). Nests near driftwood debris had lower nest success than expected in 1995 and higher nest success than expected in 1996. In general, nests near adjacent features had lower success than expected in both years (Table 2). Number of flooded nests did not differ by microhabitat type in 1995, 1996, or cumulatively, but number of nests lost to predation differed by microhabitat type in 1995 ($\chi^2$ = 9.07, df = 4, p < 0.10).

Table 2. Distribution of nests (%) by microhabitat type relative to outcome: H — hatched, F — flooded, P — predation, U — unknown (214 of the 233 nest in Table 1 were evaluated for microhabitat association).

| Microhabitats | H | F | P | U |
|---|---|---|---|---|
| Driftwood debris (N = 97) | 25 | 34 | 14 | 27 |
| Other debris (N = 63) | 24 | 37 | 13 | 27 |
| In the open (N = 37) | 43 | 35 | 11 | 11 |
| Man-made improvements (N = 14) | 21 | 29 | 36 | 14 |
| Other (N = 3) | 33 | 33 | 0 | 33 |

Least Terns nested most often near driftwood debris in 1995 (56% of all nests) and hay debris in 1996 (47% of all nests). Hay bales used to stabilize banks on Ralston Island in the reservoir eroded during an August 1995 flood creating a new microhabitat type for Least Terns in 1996. Seventy-five percent of all nests observed in both years were found near driftwood and hay debris (Table 2) with 24% apparent nest success. Seventeen percent of all monitored Least Tern nests were in the open with 43% apparent nest success.

Least Terns nested inside electrified enclosures in both years, but more so in 1995 (Table 1). Apparent nesting success for Least Terns was 20% lower inside fences in 1995 and 8% higher inside fences in 1996 than for nests located outside fences (Table 1). Number of nests lost to predation or flooding did not differ inside versus outside electric fences in 1995, 1996, or cumulatively, although the overall number of flooded nests inside enclosures exceeded expected values in both years (Table 1). Flooding accounted for 46% of nests lost inside electric fences in 1995 and 38% in 1996, and only three of 31 nests hatched inside the 24 ha electric fence in stratum A (Fig. 1) in 1995.

Coyotes *Canis latrans* were responsible for 19 of 38 (50%) nest losses; four were inside electrified enclosures. A Striped Skunk *Mephitis mephitis* preyed on the eggs of one Least Tern nest in the open in 1996 (3% of nest losses). Evidence of tracks and yolk stains near destroyed Least Tern nests suggested that avian predators, likely Ring-billed Gulls *Larus delawarensis*, were responsible for 13 of 38 (34%) nest losses; five were inside electrified enclosures.

## DISCUSSION

Generally, our estimates of nest success for Least Terns at Salt Plains NWR using the Mayfield method were on the low end of the range observed during previous research from 29% in our study to 75% reported by Koenen et al. (1996b). Hill (1985) monitored 222 Least Tern nests on the alkaline flat in 1982–1984 with 52%–56% nest success. Utych (1993) monitored 31 Least Tern nests while evaluating compatibility of the dig site near Clay Creek (Fig. 1) in 1990–1991 and found that 39% were successful, similar to the 29–37% observed during our study. Koenen et al. (1996b) recorded nest success of 52–75% outside electrified enclosures in 1993–1994. Elsewhere, Least Terns experience variable nest success due to predation, human disturbance, weather, etc. (Burger 1984, Kirsch 1996, Thompson et al. 1997).

Given the size of the alkaline flat and the uniformity of its physical character, it is apparent that nesting habitat for Least Terns is not limited. Least Terns nest in a diffuse pattern that varies from uniform to random, with inter-nest distances of about 21 m to > 100 m and 5–25 nests/colony (Schweitzer & Leslie 1999). Such a nesting pattern may be advantageous by reducing predator knowledge of a colony's location and minimizing benefits of visiting a colony to a predator. Burger (1984) noted that Least Tern colonies on the east coast of the United States with < 80 birds experienced less predation than colonies with > 80 birds, and even larger colonies (~ 500 pairs) can be very susceptible to catastrophic predation (Brunton 1997). Additionally, we found that Least Terns nesting in a particular area on the alkaline flat (Stratum D, Fig. 1), which was mostly open (no debris or natural attractions), had fewer nests lost to natural factors (flooding and predation) and higher hatching success than elsewhere on the alkaline flat.

Flooding and predation were the dominant causes of failure of Least Tern nests on the alkaline flat, and both were markedly affected by rainfall quantity and timing, which differed between years. Pernicious effects to nesting Least Terns, as determined by the Mayfield method, were most pronounced in the wet year of 1995. Conversely, nest success was higher in the dry year of 1996. The alkaline flat varied from bright white when dry to dark brown after rainfall (Schweitzer & Leslie 1999). The latter conditions made Least Tern nests less cryptic and, in addition to increased loss from flooding, appeared to expose nests to greater loss to predators in the wet year of 1995.

Microhabitat types associated with Least Tern nests differed between years; hay debris was only available in 1996. Clearly, Least Terns preferred to nest in association with driftwood or some type of debris, but that behavior seemed to increase the chance of predation. We believe that Coyotes, the primary terrestrial predator of Least Tern nests, associate lines of driftwood debris on the alkaline flat with reliable food sources (i.e. nesting birds, chicks, eggs). Hill (1985) found 160 nests (72%) near objects (debris) with 56% nesting success and 52 nests (23%) in the open with 52% nesting success. In contrast, we found that nests in the open, although fewer in number, generally experienced greater success than nests associated with debris.

Electrified enclosures to protect Least Tern nests from terrestrial predators have had mixed results at Salt Plains NWR (Utych 1993, Koenen et al. 1996b). Nest-site selection by Least Terns in electrified enclosures may be influenced more by availability and proximity of water during nest initiation than habitat improvements inside or outside enclosures (i.e. gravel mounds, plowed ridges, and platforms, Koenen et al. 1996b, Winton 1997), use of decoys (Kotliar & Burger 1984, Winton 1997), or proximity of human activity (i.e. crystal-digging area, Utych 1993, Koenen 1995). For example, abundant rainfall in 1995 juxtaposed the electrified enclosures and the Salt Fork of the Arkansas River (Stratum A, Fig. 1), and 41 nests occurred inside the enclosures. Nest success was low that year because of a single rainfall event that flooded initial nesting attempts of Least Terns. In contrast, during the dry year of 1996, the Salt Fork was low and > 350 m from the enclosure, and only 4 nests occurred within the enclosure. Hill (1985) also noted that with few exceptions, Least Terns tended to nest near the ephemeral watercourses that traversed the alkaline flats at Salt Plains NWR.

Electrified enclosures will not provide protection to nesting Least Terns from avian predators such as gulls and may even attract such predators by concentrating nesting terns in a small area and providing a visual attraction on the near-featureless alkaline flat. Avian predators were not implicated as nest predators of Least Terns at Salt Plains NWR from 1977 to 1992 (Grover & Knopf 1982, Hill 1985, Utych 1993). Koenen et al. (1996a) first observed Ring-billed Gulls preying on Japanese Quail *Coturnix coturnix* eggs in artificial nests on the alkaline flat in 1993–1994. Numbers of Ring-billed Gulls spending the summer at Salt Plains NWR have increased since then (R. Krey, pers. comm.). We observed gulls taking eggs and chicks of Snowy Plovers *Charadrius alexandrinus* in 1995–1996 (Winton et al. 2000) and assumed that gulls also preyed on Least Tern eggs because of yolk stains we observed at destroyed nests.

Various means of providing elevated nest sites (e.g. gravel mounds and plowed ridges) to protect nests from flooding have been tried inside and outside enclosures (Koenen et al. 1996b, Winton et al. 2000). Unfortunately, the efficacy of these nest-site enhancements is in question. Koenen et al. (1996b) found that Least Tern nests on gravel mounds and plowed ridges were not more protected from flooding than nests on the unmodified alkaline flat. In our study, we found that Least Tern nests near habitat enhancements experienced 21% success, while other nests had higher success (i.e., 25% near driftwood, 24% near other debris, 33% near live vegetation, and 43% in the open). As with electrified fences, it also is unclear if such habitat modifications provide a visual attraction for terrestrial and aerial predators (Winton et al. 2000).

## CONCLUDING REMARKS

Because Least Tern nests in the open tend to be most successful, we recommend caution when considering supplementing barren nesting habitats of Least Terns with driftwood or other habitat improvements (United States Fish & Wildlife Service 1990), particularly in areas with viable nest-predator populations. Such enhancement of barren nesting habitat used by Least Terns may attract predators such as Coyotes.

Among the six conditions that diminish the efficacy of electrified enclosures described by Koenen et al. (1996b), we consider two to be particularly problematic for increasing productivity of Least Terns at Salt Plains NWR and in similar nesting habitat. 1) Electrified enclosures can protect only a small part of the alkaline flat and their placement relative to watercourses is critical to increase the probability that terns will nest within them. 2) Avian predators such as Ring-billed Gulls are not deterred by such enclosures and may even be attracted to them.

Despite the challenges, continued efforts to minimize the impact of natural factors (i.e. flooding and predation) that reduce nest success of Least Terns at Salt Plains NWR and elsewhere should be undertaken to enhance recovery and conservation efforts. It is quite likely that such techniques will have to be designed to deal with vagaries of each individual nesting location or nesting habitat type (e.g. alkaline flat versus riverine sandbar).

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## STRESZCZENIE

**[Miejsca lęgowe i ochrona rybitwy małej (ssp. *athalassos*) na alkalicznej równinie w stanie Oklahoma, USA]**

Podgatunek ten został zaliczony do zagrożonych na centralnym obszarze USA. Dane o preferencjac w stosunku do miejsc lęgowych potrzebne są dla działań ochronnych. Praca zajmuje się mikrosieliskami gniazdowania oraz porównuje sukces gniazdowy w miejscach chronionych elektrycznym ogrodzeniem w porównaniu do nie ogrodzonych.

Badania wykonano na obszarze 5.1 tys. ha alkalicznej równiny w rezerwacie Salt Plains (Fig. 1). Jest to jedno z największych skupisk lęgowych śródlądowej populacji rybitwy małej.

W okresie lęgowym lat 1995 i 1996 badano sukces gniazdowy (% gniazd z których wyszło potomstwo) 233 gniazd, w których znaczną część stanowiły lęgi powtarzane. Głównymi przyczynami start były zalania powodziowe i drapieżnictwo (kojoty, skunksy, prawdopodobnie mewy). Sukces gniazdowy w miejscach chronionych elektrycznym ogrodzeniem był w pierwszym roku niższy o 20%, a następnym wyższy o 8% w stosunku do wyników z miejsc nieogrodzonych (Tab. 1). Straty gniazd z powodu drapieżnictwa były zróżnicowane w pięciu wyróżnionych typach mikrosiedlisk (Tab. 2). Najbardziej preferowane były (75% gniazd) miejsca wśród naniesionych przez wodę szczątków drzewnych i roślinnych (Tab. 2), ale sukces gniazdowy był tam niski (24%). Natomiast mniej liczne gniazda (17%), które znajdowały się w miejscach odkrytych miały sukces znacznie wyższy (43%).

Wyniki pracy sugerują ostrożność w stwarzaniu rybitwom małym sztucznych siedlisk gniazdowych z preferowanymi przez te ptaki szczątkami powodziowymi. Nasuwają też zastrzeżenia co do stosowania sztucznych ogrodzeń. Istotne znaczenie ma kontrolowanie czynnika powodziowego i drapieżnictwa.