J. Field Ornithol., 61(3):310–319

EFFECTS OF CAPTURE, HANDLING, BANDING, AND RADIO-MARKING ON BREEDING LEAST TERNS AND SNOWY PLOVERS

LAURA A. HILL[1]
Oklahoma Cooperative Fish and Wildlife Research Unit
Zoology Department, Oklahoma State University
Stillwater, Oklahoma 74078 USA

LARRY G. TALENT
Zoology Department
Oklahoma State University
Stillwater, Oklahoma 74078 USA

Abstract.—We evaluated a technique to minimize adverse effects of capture, handling, banding, and radio-marking on breeding Interior Least Terns (*Sterna antillarum athalassos*) and Western Snowy Plovers (*Charadrius alexandrinus nivosus*). We used T-shaped spring traps to capture 116 birds on nests and minimized disturbances by trapping less than 15% of the breeding population each year, confining most human activity to the edge of colonies, aborting trapping attempts during inclement weather, masking birds during handling, and freeing them from release boxes. Radio backpacks were glued to birds over their center of gravity. Total interruption was about 30 min and decreased during the heat of midday when 80% of 79 birds returned to their nests within 10 min of trap activation. Trapping, banding, and equipping birds with radio backpacks did not significantly affect reproduction. Neither species showed obvious behavioral changes associated with radio backpacks; however, most Snowy Plovers tugged at their leg bands in an apparent attempt to remove them.

EFECTO DE LA CAPTURA, MANEJO, ANILLAMIENTO, Y COLOCACIÓN DE RADIOTRANSMISORES EN LA REPRODUCCIÓN DE *STERNA ANTILLARUM ATHALASSOS* Y *CHARADRIUS ALEXANDRINUS*

Sinopsis.—Evaluamos una técnica para minimizar los efectos adversos de la captura, manejo, anillamiento y colocación de radiotransmisores, en la reproducción de *Sterna antillarum athalassos* y *Charadrius alexandrinus*. Utilizamos trampas de resorte en forma de T para la captura de 116 aves en sus nidos. Minimizamos el disturbio, atrapando (en un periodo anual) a menos del 15% de las aves reproduciéndose, limitando las actividades humanas a los márgenes de las colonias, suspendiendo las capturas durante periódos de mal tiempo, anillando aves mientras se manipulaban, y liberándolas desde cajas después que éstas se habían calmado. Los radiotransmisores fueron encolados en el centro de gravedad de las aves. El tiempo total de perturbación fue de cerca de 30 min y reducido durante las horas más calientes del día cuando el 80% de las aves (de un total de 79) regresaban a sus nidos dentro de un periodo de 10 min luego de la activación de las trampas. El atrapar, anillar y colocar radiotransmisores en las aves no afectó significativamente su reproducción. Ninguna de las especies mostró cambios marcados en su conducta relacionados a la colocación de radiotransmisores. Sin embargo, los playeros trataron de quitarse sus anillas.

We evaluated a technique to minimize adverse effects of trapping, handling, banding, and radio-marking on breeding Interior Least Terns (*Sterna antillarum athalassos*) and Western Snowy Plovers (*Charadrius*

[1] *Current address: Ecological Services, U.S. Fish and Wildlife Service, 222 South Houston Avenue, Suite A, Tulsa, Oklahoma 74127 USA.*

alexandrinus nivosus). Both species are listed as threatened, endangered, or of special status throughout their ranges, and are sensitive to human disturbance, including field research (Brubeck et al. 1981, Massey et al. 1988, Rodgers and Burger 1981).

STUDY AREA

Our study area was a 4050 ha salt flat bordering Great Salt Plains Reservoir at Salt Plains National Wildlife Refuge (NWR) in northwest Oklahoma. Both species nest where the Salt Fork of the Arkansas River, Cottonwood Creek, and Clay Creek cross the flat. During summer, strong winds and temperatures commonly above 32 C create a highly evaporative environment. A 1–3 mm salt crust forms on the floodplain as water evaporates from brine drawn to the surface by capillary action (Johnson 1972). The salt flat is barren except for occasional flood debris, grassy hummocks, and patches of inland salt grass (*Distichlis spicata*), sea purslane (*Sesuvium verrucosum*), and tamarisk (*Tamarix gallica*), an exotic species.

METHODS

We plotted nest locations on maps during searches of the salt flat from May to August 1983 and 1984. We marked individual nests with wooden tongue depressors placed about 60 cm from scrapes and buried so that only 3-cm tabs remained exposed. Incubation stage of each nest was estimated by egg flotation (Hays and LeCroy 1971 as modified by Hill 1985), and every 1–3 d, nests were checked from a distance to determine egg and nest survival. To further minimize disturbances, we trapped and marked less than 15% of the breeding Least Terns and Snowy Plovers on our study area each year.

We captured nesting birds with T-shaped spring traps (modified from Doty and Lee 1974) (Fig. 1) which minimized visual and physical obstruction of nests. Each trap consisted of a white wooden frame, U-shaped 4-mm-diameter galvanized-wire bail, two hinges (springs from Victor rat traps), and white 8-mm-mesh stretch netting.

Each trap was set with the stem pointing downwind and the crossbar 10–12 cm from the nest center. Traps were secured with two 30-cm wires driven into the ground. To acclimate birds, we set traps about 2 h before attaching a trip line extending to the colony edge (usually 40–50 m). Once the trip line was in place, trappers watched the nest site with a 20× telescope. If a nesting bird did not return within 5–10 min, trappers donned white sheets for camouflage. When a bird returned to its nest, the trip line was pulled, flipping the net over the bird. We recorded time from attachment of the trip line until a bird returned to its nest (capture time). To reduce stress to eggs at unattended nests, trapping was discontinued during inclement weather, which was defined as rain or exposure for 30 min to cool (below 21 C) or hot (above 31 C) temperatures. We took these precautions because potentially lethal thermal extremes are

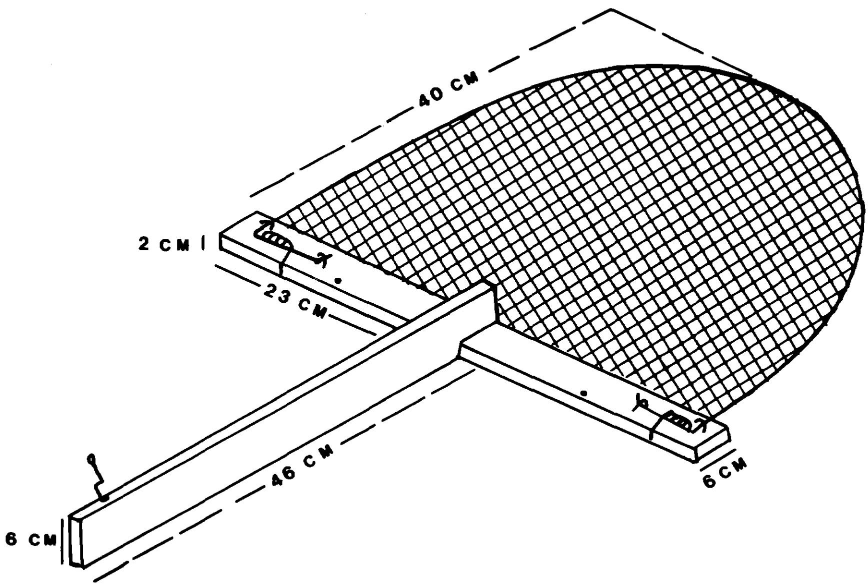

FIGURE 1. Spring-loaded trap for capturing incubating Least Terns and Snowy Plovers. The trap was set by placing the crossbar 10–12 cm from the nest center, staking the frame to the ground, swinging and latching the bail over the stem of the T, and attaching a trip line to the latch.

moderated by Least Tern and Snowy Plover nest attentiveness (Hill, pers. obs.; Purdue 1976).

Trapped terns and plovers were divided into two experimental groups based on incubation stage and type of marker applied. Birds from both groups were removed from traps immediately after capture and a black drawstring bag, designed to mask the eyes but expose the beak for respiration, was placed over the head of each bird (adopted from Poole 1981). Terns sometimes screamed and frequently tried to bite while being removed from traps; however, defensive behavior subsided after masking. Plovers rarely vocalized or bit when removed from traps and were docile while wearing masks. Masked birds were taken to the colony edge for weighing, measuring, and marking, thereby allowing other birds to resume incubation.

Some terns and plovers (hereafter called banded) were captured throughout all stages of incubation and were marked with a size-1B, U.S. Fish and Wildlife Service band above the joint. Additionally, most plovers in this group received a 1B, plastic, color-band above or below each joint on the remaining unmarked tarsi.

Other nesting terns and plovers (hereafter called radio-marked) were captured within 5 d of hatch and were marked with a 1B Service band above the joint and a radio backpack. Radios, constructed by personnel at the Denver Wildlife Research Center, resembled kidney beans (encased in stycast 1090 epoxy, with 12–15 cm antennas) and weighed 2.0–2.6 g (6–7% of bird weight). We painted the entire surface of each radio with gray or tan enamel paint to blend with dorsal feathers of terns and plovers, respectively. Painted radios were glued to birds over their center of gravity, near the mid-dorsal apterium (Mewaldt 1958) where the lower back and upper tail meet.

Cyanoacrylate-based glue (Superglue) was applied to the base of the radio and to the bird's skin, and the radio was held in place until the glue hardened. This initial bond was strengthened by gluing surrounding feathers atop the radio.

Prior to release, each bird was unmasked and retained inside a dark box (21 × 18 × 18 cm) with a vertically sliding door attached to a pull line (Hill 1985:31). Handling time (elapsed time from capture until the bird was placed in the box) and box time were recorded.

We kept birds boxed for a minimum of 4 min or until they quieted. Terns were calm inside the release box; plovers tended to be active the first 10–90 s, but then became quiet. The purposes of the box were to allow birds time to stabilize from such trauma as fright or temperature disturbance (Smith et al. 1983) and to allow trappers to hide so birds could be released and observed from the colony edge with little additional disturbance. Upon release, terns usually stepped out and immediately flew, whereas plovers ran out and stopped to preen or tug at their leg bands. A few birds (1 banded and 2 radio-marked plovers, and 2 radio-marked terns) immediately resumed incubation. For others, we returned the next day to determine if they had resumed incubation.

We averaged the sum of capture, handling, and box times as a measure of total interruption, and we analyzed capture times by incubation stage, time of day, and weather to determine if trappers could use bird behavior to reduce total interruption. We assessed effects of trapping and radio-marking by comparing nest depredation, nest desertion, nest survival, and egg survival of experimental groups with controls. Because nest and egg fate can vary with stage of the nesting cycle (Burtt and Tuttle 1983), control nests were selected for statistical comparisons by stratified random sampling of nontrapped birds nesting concurrently with experimental birds. All statistical tests were two-tailed: unpaired t-test, chi-square test for independence, and Z-test (Bart and Robson 1982).

RESULTS

We captured and marked 32 terns on 25 nests and 84 plovers on 81 nests. The banded group contained 12 terns (7 males, 5 females; 10 nests) and 66 plovers (24 males, 42 females; 66 nests). The radio-marked group contained 20 terns (7 males, 13 females; 15 nests) and 18 plovers (7 males, 11 females; 15 nests). Additionally, we monitored breeding success of 104 Least Tern and 252 Snowy Plover nests as controls.

Trapping success of terns (91% of 33 attempts) was higher than of plovers (79% of 106 attempts) primarily because we aborted more attempts

TABLE 1. Effect of incubation stage and time of day[a] on mean capture time (min) of Least Terns and Snowy Plovers at Salt Plains NWR, Oklahoma.[b]

	Least Terns			Snowy Plovers		
	n	x̄	SE	n	x̄	SE
Incubation stage:						
Early (≤7 d)	0			20	15.6	2.9
Mid (8–14 d)	13	8.1	2.1	34	15.4	2.9
Late (≥15 d)	19	16.4	5.4	30	11.9	2.3
Time of day:						
Morning (0601–1100)	7	40.6	7.6	20	29.4	4.0
Midday (1101–1600)	19	7.1	1.9	49	8.9	1.4
Evening (1601–2100)	6	8.5	3.0	15	16.2	4.2

	Least Terns	Snowy Plovers
Early vs. mid.		0.04 (52), $P > 0.80$
Mid vs. late	1.43 (18, 12), $P > 0.15$	0.93 (62), $P > 0.30$
Early vs. late		1.01 (48), $P > 0.30$
Morn. vs. mid.	4.27 (6, 18), $P < 0.01$	4.88 (19, 48), $P < 0.002$
Mid. vs. even.	0.36 (23), $P > 0.60$	1.66 (14, 48), $P < 0.12$
Morn. vs. even.	3.93 (6, 5), $P < 0.01$	2.36 (14, 19), $P < 0.05$

[a] Generally, morning temperatures were below 21 C, midday above 31 C, and evening 21–31 C.

[b] Unpaired t-tests for equal means: t (df), P-level.

to capture plovers due to inclement weather. We attempted to capture most plovers (80% of all attempts) in May and June, and most terns (75%) in July and August. During 1983 and 1984, 76% of the days in May were rainy or cool, compared with 40% in June, and 10% in July and August. Mean high temperatures increased in 1983 and 1984 from 24 C in May, to 31 C in June, 36 C in July, and 37 C in August. Generally, after early June, morning (0601–1100) temperatures were cool, midday (1101–1600) hot, and evenings (1601–2100) moderate (21–31 C).

Length of interruption.—Total interruption was about 30 min (x̄ ± SE: terns, 26.0 ± 3.7 min; plovers, 30.1 ± 1.9 min). Because all birds were boxed for a minimum of 4 min, variation in mean box time (terns: 4.4 ± 0.5 min; plovers: 5.0 ± 0.3 min) was low. Mean handling time (terns: 8.8 ± 0.4 min; plovers: 11.0 ± 0.5 min) was affected by the number of trappers and their experience. Mean capture time (terns, 12.8 ± 3.3 min; plovers, 14.1 ± 1.6 min) contributed the greatest variability (58%) to total interruption, and was influenced more by time of day and associated weather than by incubation stage (Table 1).

Distribution of short (≤30 min) and long (>30 min) capture times varied among morning, midday, and evening periods (terns: $\chi^2 = 9.07$, df = 2, $P < 0.025$; plovers: $\chi^2 = 22.23$, df = 2, $P < 0.001$). Capture times generally were shortest during the heat of midday: 80% of 79 birds trapped during midday temperatures above 31 C returned to their nests within 10 min of trap activation. Capture times longer than 30 min were most common in May and early June, and during cool morning (68% of 37 birds) and moderate evening (68% of 15 birds) temperatures when birds tended to be less broody.

Mean capture time of terns was twice as long in late as in mid incubation, but sample size was small, variance was high, and the difference was not significant (Table 1). Mean capture times were similar for plovers throughout all stages of incubation (Table 1).

Effect on reproduction.—Daily nest and egg survival of banded and radio-marked birds did not differ from controls (Table 2). Moreover, nest depredation and desertion as a result of trapping, banding, and attaching radios was similar to controls (Table 3).

Only 1 of 25 tern and 3 of 81 plover nests were depredated or deserted within 2 d after trapping and marking adults. One pair of radio-marked terns returned to their nest the day of trapping (late in the nesting season) but abandoned it 2 d later; the eggs were addled. Two plover nests were depredated, and one nest surrounded by flood water was deserted within 1 d after trapping.

Behavioral responses.—Terns did not pull at their leg bands; however, 80% of plovers did so immediately after release and occasionally throughout the breeding season. Neither species showed obvious adverse reaction to transmitters. Although we did not monitor nest exchange duties before and after radio attachment, all but one nest of radio-marked birds successfully hatched. We did not quantify effects of radios on the terns' fishing abilities, but radio-marked terns did hover and dive successfully. No birds lost radios and 48% were transmitting when birds migrated 1–2 mo later.

DISCUSSION

To facilitate trapping of shorebirds in mixed colonies, one trap should be able to capture different species. A trap that does not allow birds to run directly to their nests may not be the best design for capturing plovers; a trap that does not allow birds to alight directly on their nests may not be ideal for terns. Our trap was effective for capturing both species and allowed selective trapping of one sex or successive members of a pair. With our trapping procedure, birds were safely trapped during the heat of midday when short capture times reduced total interruption.

Our trapping method had little effect on Least Tern and Snowy Plover reproduction. Trapping-induced desertion has been documented for coast-nesting Least Terns (Brubeck et al. 1981, Massey and Atwood 1981). Smith (1987) used our trapping methods and reported no significant effect on reproduction of 24 Interior Least Terns captured and banded on the lower Mississippi River. J. G. Sidle and G. R. Lingle (pers. comm.) also followed our procedures and had no desertion or hatch loss among four Piping Plovers (*C. melodus*) trapped and radio-marked at sand pits near the Platte River, Nebraska.

In our study, plover nest desertion and depredation after trapping was either as "high" as 4.5% or as low as 0%. We use this either/or dichotomy

TABLE 2. Daily nest and egg survival rates[a] of experimental and control[b] groups of Least Terns and Snowy Plovers at Salt Plains NWR, 1983 and 1984.

	Least Tern						Snowy Plover					
	n	Nest survival rate	SE	n	Egg survival rate	SE	n	Nest survival rate	SE	n	Egg survival rate	SE
Banded	10	0.9735	0.0131	24	0.9654	0.0098	43	0.9730	0.0063	126	0.9581	0.0046
Control	10	0.9503	0.0242	21	0.9529	0.0242	43	0.9655	0.0078	118	0.9668	0.0046
Radio-marked[c]	15	0.9543	0.0223	39	0.9442	0.9801	15	1.0	0	45	0.9873	0.0073
Control	15	0.9912	0.0088	34	0.9801	0.0088	15	0.9874	0.0125	41	0.9815	0.0092

	Least Tern		Snowy Plover	
	Nest	Egg	Nest	Egg
Banded vs. control	0.123, $P > 0.89$	0.082, $P > 0.94$	0.064, $P > 0.94$	0.092, $P > 0.92$
Radio-marked vs. control	0.213, $P > 0.82$	0.036, $P > 0.81$	0.013, $P > 0.90$	0.045, $P > 0.96$

[a] Z-test (Bart and Robson 1982) for equal daily survival rates: Z, P-level.
[b] Control nests were selected by stratified random sampling of nontrapped birds nesting concurrently with experimental birds.
[c] Exposure-days (Mayfield 1961) were counted from the day of radio application.

TABLE 3. Frequency of nest depredation and desertion among experimental and control groups of Least Terns and Snowy Plovers at Salt Plains NWR, 1983 and 1984.[a]

	Least Tern			Snowy Plover		
	Depredated or deserted	Hatched	% loss	Depredated or deserted	Hatched	% loss
Banded	0	10	0	3	63	4.5
Control	0	10	0	2	64	3.0
Radio-marked	1	14	6.7	0	15	0
Control	0	15	0	0	15	0

[a] Chi-square test for equal depredation and desertion frequencies between control and experimental groups (terns and plovers combined because of zeros in some cells): $\chi^2 = 0.17$, $n = 212$, df = 1, $P > 0.25$.

rather than assume that trapping caused desertion because it preceded desertion. Deserted nests belonged to banded plovers. We checked nests 1 d after trapping adults and found clutches depredated or surrounded by water. Hence, contrary sequences of events were possible: birds initially returned to nests but abandoned them when subsequently depredated or flooded, or birds initially abandoned nests which were subsequently depredated or flooded. Regardless of cause, we believe nest desertion less than 5% is tolerable, especially for a species that renests (Page et al. 1983).

Nest desertion and depredation among terns (6.7%) also was low in our study. Brubeck et al. (1981) had 7% nest desertion among 14 Least Terns captured with walk-in funnel traps and banded within 3 d of hatch. We trapped terns as early as 11 d prehatch (mean nest age, 6.1 ± 0.5 d prehatch, $n = 25$), equipped 62% of adults with radios, and still had low desertion.

Brubeck et al. (1981) also found that desertion rates among trapped terns varied among colony sites on the Texas coast. They suggested that Least Terns habituated to pedestrians and vehicles may be more tolerant of trapping disturbances than isolated birds. Birds on our study area may have habituated to 1–2 researchers during three consecutive field seasons; however, pedestrian and vehicle disturbance was minimal.

Our success possibly was related to reducing avian visual cues during handling and release. Welty and Baptista (1988:83) generalized that most birds gather more information about their environment from vision than from other senses. We did not, however, empirically determine effects of capturing and marking birds without masking them or without using boxes and trapper camouflage during bird release.

Despite the precautions we took, the possibility of avian injury existed. On two occasions, plovers were knocked flat by premature bail release of traps; birds revived within 20 s and later hatched their clutches. We minimized injury by not triggering the trap until a bird sat on or stood directly over its eggs.

In 3 of 84 captures, plovers kicked at least 1 egg 1–8 cm from the nest; none was damaged. Egg rolling was not observed with terns. Placement of the trap crossbar 10–12 cm from the nest center prevented egg damage when birds kicked eggs. Moreover, this distance prevented birds from being hit when bail rate (rate at which a tripped bail flopped over the nest) was less than 0.75 s.

Bail rates, critical to successful capture of birds, slowed as windblown salt and sand accumulated in spring coils. Bail rates more than 0.75 s enabled birds to escape capture. The problem was remedied by periodically cleaning springs and spraying them with rust solvent.

In addition to trapping precautions, radiotelemetry precautions were warranted. Shorebird radiotelemetry is in its infancy and most researchers (except Johnson 1987) have reported problems with radio attachment (Massey et al. 1988; J. G. Sidle, pers. comm.) and aberrant behavior of radio-equipped birds (Massey et al. 1988). Observation of radio-marked Least Terns and Snowy Plovers on our study area during a season of low nest predation (Hill 1985) indicated no obvious permanent or temporary behavioral changes sufficient to affect hatching success. During a season of consistently high predation, Massey et al. (1988) observed aberrant behavior in radio-marked California Least Terns (*S. a. browni*) and advised against the use of radios on Least Terns until smaller radios were available. Disturbance levels, handling and release procedures, and site of radio attachment were different in our study. We believe the most notable difference, however, was that Massey et al. (1988) placed radios above the center of gravity in the interscapulars, an area of skin that flexes in flight. The California terns pulled at their radios (B. W. Massey, pers. comm.). We placed radios low on the back to maintain the center of gravity and to avoid irritating skin between the wings.

In our study no birds pulled their radios off; however, some glues are brittle and may irritate skin. For nonchafing bonds lasting 3–4 months, some radio manufacturers advise against glues and recommend a latex-based, xylene solvent sold at pharmacies for bandage application (F. Anderka, pers. comm.).

Our results offer hope that fruitful radiotelemetry studies of shorebirds are possible. Marking Snowy Plovers with standard size leg bands or flags, however, may be inappropriate. Banded and flagged Snowy and Piping Plovers have a history of leg injuries under investigation by the U.S. Fish and Wildlife Service (A. Hecht and J. G. Sidle, pers. comm.). We advise researchers and managers to exercise best judgment and caution, especially when working with disturbed colonies on sensitive, threatened, or endangered species.

ACKNOWLEDGMENTS

This study was funded by Region 2 U.S. Fish and Wildlife Service (Contr. 93510-1240-750), Oklahoma Department of Wildlife Conservation (Nongame Res. Proj. As-85-R-121), Oklahoma Cooperative Fish and Wildlife Research Unit, and Oklahoma State University, Zoology Department. R. S. Sullivan graciously allowed us to camp on refuge lands. We thank V. A. Keener for field help, and O. E. Maughan, H. C. Miller, K. Cook. E. H. Burtt, Jr., and two anonymous reviewers for thoughtful comments on the manuscript.

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Received 17 May 1989; accepted 2 Jan. 1990.