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The Condor 99:534–538

A NEW APPLICATION FOR TRANSPONDERS IN POPULATION ECOLOGY OF THE COMMON TERN[1]

PETER H. BECKER AND HELMUT WENDELN
Institut für Vogelforschung "Vogelwarte Helgoland," An der Vogelwarte 21, D-26386 Wilhelmshaven, Germany

Abstract. We injected transponders subcutaneously to mark single Common Tern (*Sterna hirundo*) adults and all chicks of a colony at Wilhelmshaven with the aim of establishing a completely marked colony. We present details on the equipment and methods and report preliminary results. Microtagged terns can be identified for life, not only at their nest when breeding, but also at resting places by fixed antennas at distances of < 11 cm. Thus, nonbreeders can be identified as well. We also weighed terns remotely to obtain information on their body condition. Body mass data as well as identification codes were electronically stored. Preliminary data indicated that adult survival was ≥ 87% and subadult survival until age two was ≥ 20%.

Key words: Common Tern, Sterna hirundo, *transponder, lifetime identification, marking technique, population biology, reproductive strategies.*

Long term studies of seabirds are costly and rare but essential to the understanding of their population ecology (Nisbet 1989). In small seabirds like terns, however, rates of survival, emigration, and immigration are not well known because of methodological problems. Individual color ringing has not proven successful. Rings are rarely visible at any distance and are not durable, and extensive trapping and retrapping of ringed adults can cause clutch desertion, trap-shyness, and unacceptable disturbance of the colonies (Nisbet 1978, Kania 1992). Furthermore, the removal of steel rings by African people on the terns' wintering grounds are a problem for population studies that use retrap or ring recovery analyses (Becker and Wendeln 1996). These obstacles also hinder the study of long-term aspects of population biology like lifetime reproductive success and fitness in relation to parental investment.

To investigate long-term aspects of Common Tern (*Sterna hirundo*) population ecology, we required a different method; marking birds with transponders

[1] Received 12 April 1996. Accepted 20 November 1996.

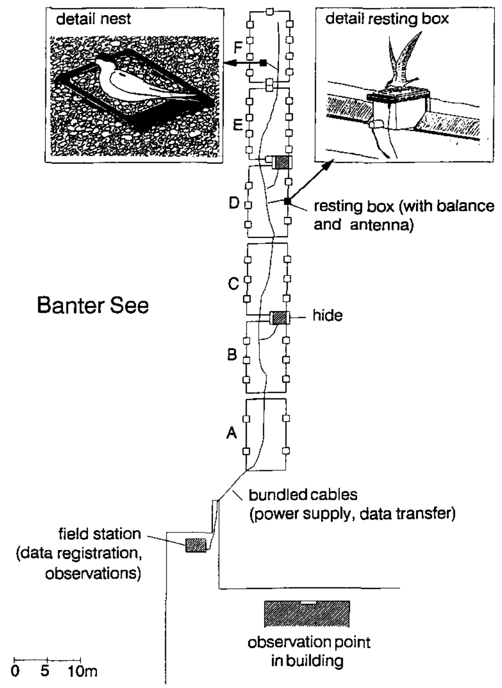

FIGURE 1. The Common Tern colony site Banter See in Wilhelmshaven (breeding islands A–F) and the electronic devices to identify the terns marked by transponders at the nest or at resting sites. These can be equipped with electronic balances to record the body mass of the terns. The detailed figures show a nest site (left) and a resting box (right) equipped with an antenna (black).

(Nogge and Behlert 1990, Wormuth 1991, Schooley et al. 1993) allowed us to meet the goals of our population study. In this paper, we describe the equipment and methods used as well as first results of our study. These techniques could open fascinating avenues of research into the biology of long-lived animals like seabirds on individual, population, and generation levels.

STUDY SITE, MATERIALS AND METHODS

THE COLONY

About 100 Common Tern pairs breed regularly at the colony site at Wilhelmshaven, Germany, southern North Sea coast, on six artificial islands of concrete in the Banter See (Fig. 1). The colony has been stable since at least 1980. Since 1994 the site has been protected against Brown rats *Rattus norvegicus*, an important predator during the breeding season (Becker 1991, 1996). The walls around the islands are equipped with 42 locations for terns to rest, and are designed for identification and recording body mass (4–10 resting boxes at each island, Fig. 1). The space between the boxes is blocked by wire so that the birds cannot rest there. The site is logistically favorable to investigate long-term aspects of population ecology of the Common Tern.

Reproductive success averaged 1.23 fledged chicks per pair per year (1981–1995; Becker 1996). Since 1980, all chicks have been banded. The terns use marine and freshwater areas for foraging (Wendeln et al. 1994, Wendeln and Becker 1996).

THE PRINCIPLE OF THE PASSIVE TRANSPONDER SYSTEM

The transponder system provides an electronic means of animal identification without disturbance by repeated trapping and handling. The transponder (or microchip) is implanted subcutaneously and it provides an individual code of 10 alphanumeric places. The transponder does not require a battery (i.e., passive transponder with unlimited lifespan), but is activated and read by hand-held or stationary readers at a distance of ≤ 11 cm, regardless of the angle of scan, light or environmental conditions.

THE HARDWARE OF THE ID-2001 SYSTEM

ID-100 implantable passive transponders (Trovan/-AEG; size 2.2 × 12.0 mm, weight 0.1 g, cost $5), are glass-encapsulated and packed individually in sterilized stainless steel needles ready for injection by a special injector. The ID-2001 system antenna supplies energy to the passive transponder without contacting it (average maximum reading distance 11 cm, IUCN/CBSG Working Group 1991; cost about $550), and receives the unique ID-code which is transmitted by a cable (3–5 m) to the ID-2001 system board, where it is decoded (cost about $670 per board). One board is linked to one antenna. We used aluminum boxes to house the system boards and sheltered these with plastic roofs to protect them against moisture and feces. The code was transmitted by a network (protection is important to avoid cable damage) via serial ports (RS 485) to a computer that collected the data; the computer was located in a field station on the coastline (Fig. 1). A hand held reader was used to check the transponder code before and after implantation or in trapped birds. The electronic balances for weighing birds were connected to the processor via serial ports (RS 232) (see Wendeln and Becker 1996 for details).

THE REGISTRATION SYSTEM USED AT THE COLONY SITE

The 22 system boards and antennas used on the islands interacted on-line with the host processor while performing real time data collection. The data from both the transponder system boards and the eight disposable electronic balances were registered by a looped program (cycle variable in time, most 10 sec). The last four records of the transponder and body mass data always were shown at the monitor and stored after a set number of readings.

To record the microtagged terns of the colony, we distributed the system antennas among the nests or resting boxes (Fig. 1); eight resting boxes additionally were equipped with electronic balances to weigh birds remotely. The probability of obtaining a reading from a microtagged tern varied with the transponder's position within the bird and with the position of the bird relative to the antenna. The antennae were checked

TABLE 1. Numbers of Common Terns of the Banter See colony marked with transponders from 1992–1995.

	Adults				
Year	Breeders tagged[a]	Breeders returned	Native prospectors 2–3 yr old (2 yr)	Total	Fledged young tagged[a]
1992	33	—	—	33	116
1993	34	20[b]	—	54	102
1994	22	43[c]	17 (17)	82	190
1995	12	58[d]	34 (16)	104	176

[a] Newly marked birds.
[b–d] Including birds with transponders replaced (b: 4; c: 3; d: 4).

manually by putting a transponder in the antenna and replaced when a low reading distance (< 3 cm) was recorded. We are developing an automatic check of the antennae. With the use of this equipment we could (1) identify the nest sites and mates of all tagged breeders (we installed the antenna at each nest after 10 days of incubation, recording microtagged terns for one to three days), (2) identify the tagged breeders and nonbreeders present at the colony site from start to finish of the breeding season using antennas distributed alternately among the resting boxes, and (3) record automatically the body mass of selected microtagged adults throughout the breeding season when they rested on the electronic balances (islands A–D, Fig. 1; see Wendeln and Becker 1996). During each season we collected data on reproductive biology of many breeding pairs (Becker 1991, 1996).

One year was needed before a satisfactory software configuration was achieved to process and store the transponder and body mass data and to find a way of data reduction. The development of methods to reduce the data for analysis is crucial (Wendeln and Becker 1996).

IMPLANTATION OF THE TRANSPONDER

The needle with the pre-positioned transponder is attached to a special injector. We injected the transponders subcutaneously into the bird's back (1992, 1993) or breast (along the carina sterni, since 1994). Since 1993, the injection opening was closed with surgical glue (Histoacryl-blau, Braun, Melsungen, Germany). We tagged the chicks at about 14–18 days of age (mean fledging age is 25 days), when they had a mean (± SD) mass of 120 ± 9 g (n = 190, 1994). We used nest traps to catch adults during incubation, when their average mass was about 132 g (details in Wendeln and Becker 1996).

To evaluate transponder implantation and durability, we ringed the adults with the steel ring of the ringing center, Helgoland, and with an individual color ring combination. We marked the young of each year with the steel ring and added a colored ring indicating year class. We measured body mass, wing length, length of the ninth primary of the marked birds and also bill length in adults.

TABLE 2. Return rate, minimum number emigrated and minimum % survival of adult Common Terns of the Banter See colony marked the year before by transponders and/or color rings.

	No. of adults			
Year	Marked	Returned	Emigrated	Survival
1993	33	27 (82%)	2	88%
1994	61	52 (85%)	?	85%
1995	72	63 (88%)	?	88%

DEFINITIONS

Adults: birds ≥ 2 years old (third calendar year); subadults: birds < 2 years old; adult survival: annual survival rate of birds ≥ 4 years of age (fifth calendar year); adult mortality: annual mortality rate of adults ≥ 4 years of age; subadult survival: survival until age 2 (third calendar year) of young hatched at the colony site; native prospectors: young hatched at the colony site that are visiting the colony in later years; native recruits: native prospectors that breed at the colony; breeder: adult breeding bird; foreign adults: unidentified birds that immigrated from other colonies.

RESULTS

By 1995, 101 Common Tern breeders and 584 fledglings were fitted with transponders (Table 1). In each year since 1993, less than 2% of the chicks lost their transponder during the time between marking and fledging. We were able to replace the lost transponders in such cases. We know of only two chicks which fledged without transponders during the four years of this study (2 of 586, 0.3%). In 1992 and 1993, the loss of transponders in adults was a major problem. When transponders were implanted on the back (1992), 11 of 27 (41%) adults returning in 1993 had lost them. With implantation on the back and the injection opening closed with glue (1993), 6 of 35 (17%) adults returning in 1994 had lost their tags. When we implanted transponders along the carina at the breast and glued the injection opening (1994, 1995), only 1 of 36 (4%) terns lost its transponder (4%). The loss of transponders mostly occurred soon after release of the bird. None of the adult terns which returned with a transponder one year after tagging lost the transponder subsequently. The number of microtagged adults increased with time (Table 1). By 1995 about 30% of the breeders had already been tagged with transponders.

Site fidelity in adults was high; 82–88% of adults returned between years (Table 2). In 1993, two adults emigrated to another small harbor colony 2 km away, where they continued to breed in subsequent years. Assuming that the terns which did not return were dead, the minimum annual adult survival of Common Terns of the Banter See colony was between 85 and 88% and averaged 87% (Table 2). These data include some birds which had lost the transponders (see above) but were still identifiable by color rings.

In 1994 and 1995, the first transponder-tagged young from 1992 and 1993 returned to the colony as two-year old native prospectors (Table 1). In 1994, 17 of the 116 chicks from 1992 were identified (15%). In 1995, 16 of the 102 (16%) chicks marked in 1993 returned. Two of the 2-year-old prospectors bred in 1994 (native recruits), and 5 of the 18 (28%) 3-year-olds bred in 1995, when no 2-year-olds nested. The prospectors arrived at the colony site very late in the season, mostly during July and August, whereas the breeders had arrived during late April or early May.

We observed some fluctuation in the return behavior of 2- and 3-year-old prospectors from the year class of 1992. Only 12 of these birds were present at the colony site in both 1994 and 1995. Five prospectors at the colony site in 1994 were not recorded again in 1995, when six individuals that were not recorded prospecting in 1994 arrived. Thus subadult survival until age two was at least 20%.

In 1995, the median age of breeders was 8 years (n = 47). Five birds were 3-years old (see above, native recruits), and three had the highest detectable age of 15 years (we began ringing chicks in 1980). From 1990 to 1995, the average reproductive success of the colony was 1.4 chicks fledged per pair (range 0.23–2.41, n = 38–62 pairs each year).

DISCUSSION

Marking animals by electronic chips is now used widely and recommended for animals in zoos, agricultural stock, horse racing, domestic breeding, laboratory animals, and in the international trade with endangered species (CBSG 1992). This marking method also has proved valuable for wild birds (Elbin and Burger 1994), including penguins (Gendner et al. 1992, Fraser and Trievelpiece 1994) and White Storks (Michard et al. 1994). The applicability of this method in field and laboratory studies is immense and might open new avenues of research into various aspects of bird biology.

With transponders it is now possible to identify wild birds and to record their occurrence, body mass or other parameters automatically and without handling them. This has special advantages for long-lived smaller species, like the terns in our study, for which ringing has not proved successful for investigating populations. The small reading distance of the antennas, however, limits their applicability to sites that are regularly used by individuals, such as resting or nesting sites and nesting holes. Sites also must allow for the operation of electronic equipment in the field. For multiannual data collection, species characterized by high site-fidelity meet these requirements. The transponder is relatively cheap, but the antenna system to identify the individual codes of the birds is expensive (see above); this limits the applicability to special projects.

The implantation of the tag takes little time, and we found no influence of tagging on the terns' behavior (see also Nogge and Behlert 1990, Ball et al. 1991, Wormuth 1991, Elbin and Burger 1994). The problems of transponder losses during the pilot years of our study were serious but were solved by changing and glueing the injection site. We estimate that less than 5% of the breeders were not registered (individuals which had lost their clutch before being recorded by the nest antenna and which had not produced a second clutch). The percentage of nonbreeders not recovered by our system is difficult to estimate, but we assume it is less than 5%.

The results from our population study are preliminary, because the first cohorts of native prospectors have not yet completely bred. However, the population parameters found during the first years of study—$<$ 13% adult mortality and at least 20% subadult survival—correspond to data of Common Tern populations in North America (Nisbet 1978, DiCostanzo 1980). Adult mortality and survival from fledging to age three (subadult survival $\times$ adult survival = 17%) approximately balance the reproductive output of 1.4 chicks per pair per year. The fluctuation of occurrence of prospectors observed at the colony site is of special interest. If survival from age two to three is equivalent to adult survival, we would expect 15 of the 17 terns at the colony site in 1994 to have returned in 1995, rather than the 12 we observed. We eventually hope to determine whether this difference is an indicator of emigration, which remains difficult to assess either by our techniques or by banding. However, we will be able to distinguish immigrants as untagged birds, when the majority of colony members is marked by transponders.

We plan to continue to microtag all chicks which fledge. This will provide an extensive transponder-tagged colony to perform integrated population monitoring. We also wish to follow the fate, reproductive strategies and lifetime reproductive success of many individuals for years, and examine the effects of such factors as age, experience, mate change, previous breeding success, body condition, foraging strategy, and environmental conditions. Our data on individual terns from four breeding seasons show the potential of our study design (see Wendeln and Becker 1996). We hope to obtain insight into the population ecology of the Common Tern on the individual, generation and population level.

For assistance in the field, we thank T. Becker, A. Behnke, B. Felgner, J. Grafe, G. Hayungs, A. Hube, U. Kikker, S. Mickstein, J. Mürdel, J. Scharlemann, U. Siebolts, S. Thyen, M. Wagener, S. Wais, M. Weitere, and M. Wilkens. M. Wagener also helped with data storing and evaluation. We thank S. Bauer and K.-D. Kronas (Kronas Lehrsysteme, Meldorf), J. Dasmann (D. A. Elektronik, Tecklenburg), C. Schildmann (Anitech, Oldenburg), G. Frerichs, R. Nagel, R. Neuking, and T. Ritter for ideas and advice in creation of hardware and software facilities for the special demands of the recording systems. Braun, Melsungen, made available surgical glue. The Standortverwaltung of the Bundesmarine, Wilhelmshaven, supported the study by giving access to rooms in their building. The study was performed under license of the Bezirksregierung Oldenburg and the Niedersächsisches Landesamt für Ökologie. We thank the Deutsche Forschungsgemeinschaft for financial support (Be 916/3), and M. Gochfeld and two anonymous reviewers for their comments which helped improve the paper.

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The Condor 99:538–543

FAT LOADS AND FLIGHTLESSNESS IN WILSON'S PHALAROPES[1]

JOSEPH R. JEHL, JR.
Hubbs-SeaWorld Research Institute, 2595 Ingraham St., San Diego, CA 92109, e-mail: jjehl@hubbs.sdsu.edu

Abstract. Fat loads of about 45% of total body mass are maximal for most shorebird migrants. In preparing to fly nonstop from staging areas in North America to South America, some late-staging adult Wilson's Phalaropes (*Phalaropus tricolor*) amass greater loads (to 54%) and for a brief period become too heavy to fly. This condition is associated with rapid mass gain, but may involve other factors. Despite ostensibly ideal conditions at staging areas, the phalaropes' greatest rate of fat deposition (3.4–3.6% lean body mass·day^{-1}) is only 60–70% of the theoretical maximum.

Key words: Wilson's Phalarope, Phalaropus tricolor, *migration, energetics, fat, flightlessness.*

Except for periods associated with the loss of remiges, as in the molt migration of waterfowl or other birds (Salomonsen 1950, Jehl 1990), the loss of flying ability is very rare among volant birds. The most extreme

[1] Received 1 August 1996. Accepted 8 December 1996.