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# A Comparison of Internal and External Radio Transmitters with Northern Leopard Frogs (*Rana pipiens*)

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Little information is available on post-breeding movements, habitat requirements, and mortality of northern leopard frogs (*Rana pipiens*) because they disperse into upland or other wetland habitats following reproduction and are difficult to detect (Waye 2001). Radio telemetry is used to examine these characteristics in other taxa, however, its usefulness for studying *R. pipiens* has not been established. An obstacle in deploying telemetry to study movement is finding a transmitter attachment method that does not adversely affect the animal's health and behavior and allows tracking over several months. The objective of our study was to evaluate existing external and internal radio transmitter attachment methods and adopt or develop a technique appropriate for *R. pipiens*.

Radio telemetry has been used to study movements of several ranid species, including *R. draytonii*, *R. luteiventris*, and *R. clamitans* (Bulger et al. 2003; Pilliod et al. 2002; Lamoureux et al. 2002). Researchers have used external belts or harnesses to attach transmitters to anurans (Bartelt and Peterson 2000; Bull 2000; Goldberg et al. 2002; Matthews and Pope 1999; Waye 2001; Hodgkison and Hero 2001; Watson et al. 2003; Muths 2003). A few studies successfully used surgical implantation as a method of radio tagging frogs (Goldberg et al. 2002; Lamoureux and Madison 1999; Werner 1991), as well as fish and salamanders (Beaumont et al. 2002; Colberg et al. 1997).

Surgical implantation has some advantages over harness attachment, including reducing skin lesions and rates of transmitter loss (Werner 1991). However, achieving the proper level of anesthetic without compromising survival is difficult (Goldberg et al. 2002; Green 2001). Prior to our study, surgical anesthesia had been tested in the laboratory (Goldberg et al. 2002; Lamoureux and Madison 1999), but it was unclear if it could be successfully performed in the field. In addition, the postsurgical fate and longevity of *R. pipiens* carrying implanted transmitters was unknown.

We evaluated four types of external attachments: nickel bead chains, aluminum bead chains, plastic cable ties, and sewing elastic in the field. When the belt attachments proved unsatisfactory for our purposes, we tested two types of internal attachment techniques on frogs in the laboratory: subcutaneous and peritoneal implantation. Following the laboratory studies, we tested the efficacy of peritoneal implants on *R. pipiens* in the field. We tracked these individuals for several months post-surgery to assess the usefulness of the transmitters for monitoring habitat use and movement over time.

We attached radio transmitter harnesses (model BD-2GHX, 1.85 g, 165 MHz band, 20-week life, whip antenna; Holohil Systems, Ltd., Carp, Ontario, Canada) to 26 wild *R. pipiens* adults from August to October 2000. Transmitters did not exceed 5–6% of the frog's total weight, below the 10% threshold recommended by Richards et al. (1994). We tested nickel (N = 15) and aluminum bead chain (N = 8) (Rathbun and Murphey 1996), plastic cable-ties (N = 8), and sewing elastic (N = 5) to find a harness material that allowed long-term radio tracking of individual frogs without restricting movements or causing injury to the frogs. Plastic cable-ties were plastic fasteners with a self-locking end, usually used in household or light mechanical applications. The sewing elastic was purchased at a fabric store; the cut ends were joined by thread stitches. Transmitters were attached to the harness by running the harness material through a rigid plastic tube affixed to the transmitter package by the manufacturer. The harness was attached around the waist of the frog so that the transmitter rested on the lower back of the frog just above the vent (Fig. 1). After shedding belts, several of the same frogs were refitted with a new harness; a total of 36 attachments were evaluated. Frequent escapes from the nickel bead chain belts within the first few weeks made it necessary to confine frogs in 1.8 m x 1.8 m enclosures placed along the edge of the wetland. Subsequent tests of aluminum bead chain, plastic cable ties, and sewing elastic harness materials and their effects on incidence of injury, transmitter loss, and behavioral changes were tested on frogs in the enclosures. On 12 October, the remaining 4 frogs in the enclosure were released and tracked with the telemetry equipment to their overwintering burrows. We estimated how far external radios could be detected with our receivers.

Subcutaneous and peritoneal surgical implantation techniques were developed and evaluated in the laboratory during winter 2001.

FIG. 1. Northern Leopard Frog (*Rana pipiens)* with external transmitter and whip antenna attached with elastic harness. (Photo courtesy of United States Geological Survey.)

Holohil model BD-2GHX radio transmitters weighing 1.85 g with an internal loop antenna coated with epoxy resin were implanted using surgical procedures similar to those described by Goldberg et al. (2002). Other scientists with experience in anuran surgical implantation techniques were also consulted to refine the procedure (G. Birchfield, University of Missouri, Columbia, Missouri and S. Heppell, United States Environmental Protection Agency, Corvallis, Oregon, pers. comm.).

Nineteen *R. pipiens* adults weighing > 15 g, purchased from a biological supply company (Ward Biological Supply, Rochester, New York, USA), were held for several weeks prior to surgery to ensure that they were healthy and feeding. Frogs were fed live crickets daily. Immediately prior to surgery, frogs were anesthetized by placing them in a 1-gallon glass (3.79-liter) jar containing an aqueous solution of 0.02% tricaine methanesulfonate (MS-222, Finquel™, Argent Chemical Laboratories, Inc., Redmond, Washington, USA) buffered with sodium bicarbonate to pH 7 and kept at room temperature (22–23˚C). The MS-222 solution was deep enough that the frogs could just hold their heads above the surface of the solution with all four feet on the bottom of the jar. A frog was deemed appropriately anesthetized for surgery when it did not right itself when placed on its back and was generally unresponsive to touch (ca. 2–5 min.; smaller frogs were anesthetized faster). All surgical instruments and transmitters were sterilized with Benz-all™ (12.9% benzalkonium chloride solution, Xttrium Laboratories, Chicago, Illinois, USA); sterile gloves were used for each surgery. Anesthetized frogs were placed on a damp sterile sponge on their right side. An incision about 15 mm in length was made with surgical scissors through the skin and underlying muscle and peritoneum (peritoneal implant only) along the left side of the frog near the center axis (Fig. 2). A radio transmitter was inserted through the incision and under the skin (subcutaneous implant) or into the peritoneal cavity, avoiding excessive pressure on the internal organs. A Polysorb 6/0 suture package with a reverse cutting needle (United States Surgical Corporation, Norwalk, Connecticut, USA) was used to close the incision. The peritoneal incision was closed with a continuous suture technique with the single-instrument tie knot at the beginning and end of the incision (Summerfelt and Smith 1990). The skin incision was closed with 4–5 simple interrupted sutures with the single-instrument tie knot. After suturing, the skin incision was treated topically with Bactine™ antiseptic spray. Frogs were closely observed until they recovered from the anesthetic and were kept in the laboratory for up to 19 weeks post-surgery to assess transmitter loss, and health and behavioral effects. Frogs were weighed and snout–vent length measured at the time of the surgery and also weighed at the end of the study or at the time of death. At the end of the study, all live frogs were euthanized by emersion in MS-222 (Green 2001) and a necropsy was performed.

In spring and summer 2001 and 2002, 90 wild *R. pipiens* adults weighing approximately 30 g or more were captured adjacent to their breeding site (i.e., pond or wetland) and received peritoneal implants of radio transmitters (Holohil BD-2GHX, 1.85 g, loop antenna). Three study sites were used in 2001 and two in 2002. The study area was located in Houston and Winona counties in Minnesota, part of the Driftless Area Ecoregion of North America. Rolling hills with steep riverine drainages and erosive soils support a less intensive agriculture than in many parts of the Mid-

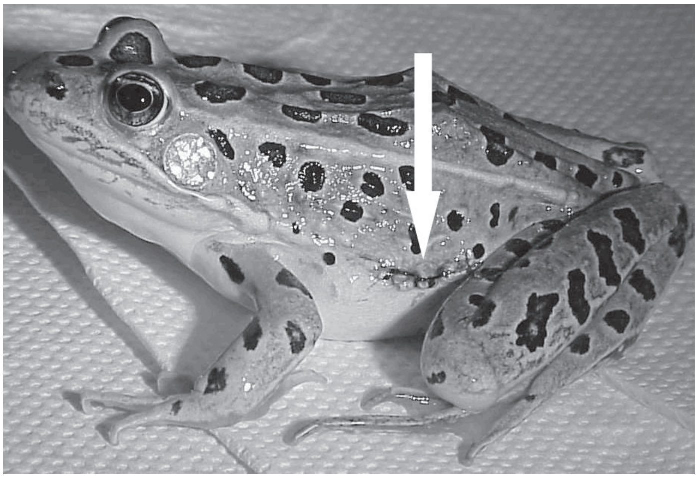

FIG. 2. Northern Leopard Frog (*Rana pipiens)* with transmitter surgically implanted showing incision location (arrow). (Photo courtesy of United States Geological Survey.)

west, with agriculture occupying 30–40% of the landscape, along with woodlands and some grasslands (McNab and Avers 1994).

We conducted our surgeries in the field near the capture site to reduce transport stress and avoid accidental transfer of diseases from the laboratory to native populations. In 2001, surgeries were conducted outside under a canvas tent and in 2002 surgeries were conducted in a vehicle. Frogs were observed closely for up to 4 h after surgery to monitor recovery from the anesthetic. Frogs were released and tracked from the ground with a hand-held Yagi antenna and receiver system (Advanced Telemetry Systems, Inc, Isanti, Minnesota, USA). Individuals were located 4–5 days per week during 2001 and daily in 2002; frogs were tracked from the time of implant until October, or until frogs died, radio contact was lost, or transmitters failed. To assess health status, some frogs with transmitters were weighed every 30 days following release during 2001. To minimize disturbance, frogs were not weighed after release in 2002. We estimated how far implanted radios could be detected with our receivers.

Of the 15 frogs fitted with nickel bead chain belts and released, 10 shed their belts within two weeks and the remaining frogs developed skin lesions and the belts were removed (Table 1). Of the frogs fitted with aluminum bead chain, sewing elastic, or plastic cable-tie belts and confined in enclosures, 18 of 21 harness attachments applied to these frogs failed within 1 to 3 weeks (transmitter was shed, Table 1). Eight of 11 frogs developed skin lesions within two weeks and 7 were released. Among the four frogs released with transmitters from the enclosure in October, one frog shed its transmitter within five days and the remaining three frogs were tracked for 14 days, when tracking ended.

Overall, external belts were tested on 26 frogs; the belts caused skin lesions in 14 frogs and transmitters were retained a median of 10 days after attachment (Table 1). Thirty transmitters were shed out of 36 attachments. None of the harness materials we evaluated performed satisfactorily. When we tightened the belts, the frogs developed skin lesions; when we loosened the belts, they shed them. We were able to detect external transmitters with whip antennas at distances ranging from 100 to 200 m in the field.

The time required to achieve a surgical level of anesthesia during our laboratory trials was short and variable (range = 1.5–3 min) despite constant environmental conditions. Most frogs began feeding within four days post-surgery and their incisions healed within two weeks of surgery.

During the first laboratory trial (surgery on 15 February 2001), three frogs received subcutaneous implants and four frogs received peritoneal implants (Table 2). During the subsequent trial (surgery on 2 March 2001), all 12 frogs received peritoneal implants. One of three frogs receiving subcutaneous implants in the first trial failed to recover from anesthesia and one frog experienced suture rupture after 19 days. The third frog retained its transmitter until the trial ended. We discontinued subcutaneous implants after the first trial because they created a lump on the frog's ventral surface that threatened to rupture the sutures. All four frogs receiving peritoneal implants in the first trial survived the surgery, 3 frogs lived from 6 to 49 days post-surgery, and the remaining frog lived to the end of the observation period (116 days, Table 2).

In the second trial with peritoneal implants, all 12 frogs survived the surgery, three frogs died within 10 days of surgery, one escaped from its cage after 95 days, and the rest survived to the end of the observation period (Table 2). After initial healing of the suture site, 8 of 12 frogs developed small skin lesions near the

TABLE 1. Fate of frogs (*Rana pipiens*) fitted with radio transmitters attached with four types of harness materials, 1 August to 26 October 2000. Includes frogs observed in the field and in enclosures adjacent to the breeding pond.

| Harness type | Frogs (N) | Attachments (N) | Transmitter shed (N) | Min-max days until transmitter shed[c] (median) | Frogs with skin lesion (N) | Min-max days until skin lesion (median) | Min-max days transmitter retained[d] (median) |
|---|---|---|---|---|---|---|---|
| Nickel bead chain | 15 | 15 | 10 | 2–10 (2.0) | 5 | 3–19 (6.0) | 2–23 (3.0) |
| Aluminum bead chain[a] | 3[b] | 8[a] | 6 | 2–31 (7.5) | 2 | 9–13 (11.0) | 2–31 (13.0) |
| Sewing elastic[a] | 4[b] | 5[a] | 5 | 2–41 (20.0) | 2 | 8–9 (8.5) | 2–41 (21.5) |
| Plastic cable-ties[a] | 5 | 8[a] | 7 | 2–37 (10.0) | 4 | 7–20 (16.5) | 2–42 (11.5) |
| Total | 26[b] | 36 | 30 | 2–41 (4.0) | 14 | 3–35 (10.0) | 2–42 (9.5) |

[a] Observed in enclosures. Some frogs were re-fitted with another attachment after shedding the first one.
[b] One frog was switched from aluminum bead chain to sewing elastic after 13 days.
[c] Includes only frogs that ultimately shed their transmitter harness.
[d] Includes all frogs, including those that had the harness removed due to lesions and those that retained the harness until the end of the study period.

TABLE 2. Fate of frogs (*Rana pipiens*) undergoing laboratory surgeries, 2001. Fate codes: NRA) Non-recovery from anesthesia; PSC) Death due to postsurgical complications; ESC) Escaped; SES) Survived to end of study; and OTH) Other.

| Trial number | Frog ID | Implant location | Surgical weight (g) | Final weight (g)[a] | Days survived post-surgery | Days until skin lesions | Days until lesions healed | Fate | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Sub-Q | 20.8 | 20.8 | <1 | - | - | NRA | |
| 1 | 2 | Peritoneal | 15.1 | - | 6 | 4 | Did not heal | PSC | Transmitter broke through sutures day 4 |
| 1 | 3 | Sub-Q | 23.3 | 35.2 | 74 | 19 | Not recorded | OTH | Transmitter broke through sutures day 19; euthanized day 74, necropsy unremarkable |
| 1 | 4 | Sub-Q | 19.9 | 39.1 | 116 | - | - | SES | Necropsy unremarkable |
| 1 | 5 | Peritoneal | 29.3 | 45.8 | 116 | - | - | SES | Transmitter encased in tissue adjacent to gastrointestinal system |
| 1 | 6 | Peritoneal | 23.6 | - | 14 | - | - | PSC | Cause of death unknown |
| 1 | 7 | Peritoneal | 24.7 | 30.2 | 49 | - | - | PSC | Infection not associated with sutures |
| Summary | Trial 1 | | 22.4 (4.2)[b] | 34.2 (9.4)[b] | 49[c] | - | - | | |
| 2 | 1 | Peritoneal | 24.5 | 10.0 | 6 | - | - | PSC | Suture failed |
| 2 | 2 | Peritoneal | 23.9 | 17.5 | 9 | - | - | PSC | Emaciated, hole in incision, bleeding |
| 2 | 3 | Peritoneal | 25.0 | 42.5 | 134 | 39 | Did not heal | SES | Transmitter encased in connective tissue |
| 2 | 4 | Peritoneal | 25.7 | - | 3 | - | - | PSC | Emaciated, sutures healed |
| 2 | 5 | Peritoneal | 25.6 | 40.6 | 134 | - | - | SES | Transmitter encased in connective tissue |
| 2 | 6 | Peritoneal | 28.1 | 43.5 | 134 | 68 | Did not heal | SES | Transmitter encased in tissue adjacent to gastrointestinal system |
| 2 | 7 | Peritoneal | 27.9 | 47.5 | 134 | 46 | 18 | SES | Transmitter encased in tissue adjacent to gastrointestinal system |
| 2 | 8 | Peritoneal | 25.6 | 51.6 | 134 | 33 | 39 | SES | Transmitter expelled day 98 |
| 2 | 9 | Peritoneal | 28.9 | 47.9 | 134 | 36 | Did not heal | SES | Transmitter encased in tissue, 'captured' by gastrointestinal system |
| 2 | 10 | Peritoneal | 42.9 | 46.1 | 134 | 42 | 17 | SES | Transmitter encased in connective tissue, high internal parasite load |
| 2 | 11 | Peritoneal | 47.5 | 65.1 | 95 | 31 | Did not heal | ESC | Transmitter expelled day 34, escaped from cage day 96 |
| 2 | 12 | Peritoneal | 31.3 | 53.2 | 103 | 51 | 22 | SES | Transmitter expelled day 89, necropsy unremarkable |
| Summary | Trial 2 | | 29.7 (7.6)[b] | 42.3 (15.7)[b] | 134[c] | 40.5[c] | 20[c] | | |

[a] Final weight does not include transmitter.
[b] Mean (SD)
[c] Median

suture site 31–68 days post-surgery; in four frogs these healed spontaneously. Nine of the 12 frogs continued to feed, behave normally, and gain weight (Table 2). Three frogs expelled their transmitters at 34, 89, and 98 days post-surgery, probably via the gastrointestinal system; we found no exit wounds elsewhere. The nine frogs that survived more than 10 days all gained weight (mean = 16.0 g ± 6.2 SD) by the end of the observation period. Overall, three transmitters broke through the skin shortly after surgery, three frogs expelled the transmitter, and necropsies revealed that four frogs had encased the transmitter in connective tissue adjacent to or inside the gastrointestinal tract (Table 2).

Among the 90 wild frogs surgically implanted with radio trans-

TABLE 3. Fate of frogs (*Rana pipiens*) undergoing field surgical implantation of radio transmitters, April–July, 2001–2002. Fate is the number of frogs experiencing that outcome: A) Failure to recover from anesthesia; PM) Killed by predator or mower; U) Frog found dead–unknown causes; T) Transmitter failure; M) Missing; R) Recovered transmitter without frog; and S) Survived to end of study.

| Year | Site | Frogs (N) | Min-max weight (g) (mean, SD) | Min-max locations (N) (median) | Min-max days tracked (N) (median) | Fate | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A | PM | U | T | M | R | S |
| 2001 | StN | 20 | 35.9–69.2 (46.1, 10.2) | 4–67 (36) | 6–119 (48) | 3 | 5 | 1 | 1 | 5 | | 5 |
| | ShA | 7 | 41.5–78.7 (56.1, 12.9) | 21–71 (44) | 28–102 (58) | | 1 | | 1 | 3 | | 2 |
| | Urb | 17 | 35.1–58.2 (43.9, 6.7) | 6–66 (14) | 7–108 (20) | 7 | 2 | | 1 | 7 | | |
| 2002 | StN | 20 | 30.0–71.8 (42.9, 11.1) | 5–76 (25) | 4–114 (31) | 1 | 3 | 1 | 1 | 9 | 2 | 3 |
| | HoA | 26 | 27.6–61.1 (36.5, 3.5) | 2–84 (12) | 1–124 (25) | 6 | 5 | 9 | 3 | 3 | | |
| Total | 4 | 90 | 27.6–78.7 (43.0, 10.0) | 2–84 (23.5) | 1–124 (38.5) | 17 | 16 | 11 | 7 | 27 | 2 | 10 |

mitters, 17 did not recover from the anesthesia. Eleven of the 17 mortalities were associated with elevated anesthesia solution temperatures (> 25°C). In the initial field surgeries, anesthesia solution temperatures were allowed to equilibrate with ambient (air) temperatures because this strategy had been successful in the laboratory. Two episodes of poor surgical survival associated with surgeries conducted on warm days led us to conclude that anesthetic solution temperatures might be the problem. We began to control the solution temperature to < 25°C, regardless of air temperatures, and subsequently 30 of 31 frogs survived the surgery.

Of 77 frogs that survived the surgery and were released, 27 frogs died (predators, N = 8; alfalfa mowers, N = 8; unknown causes, N = 11), 7 were recaptured live with transmitter failures, 27 were lost (fate unknown), 2 transmitters were recovered without the frog (fate of frog unknown), and 10 frogs survived long enough to enter hibernation (Table 3). Of the 11 frogs found dead due to unknown causes, 9 frogs died within 10 days and 2 frogs died within 60 days post-surgery. Eight of the deaths occurring within 10 days post-surgery occurred following a rapid decrease (from 25 to 0°C) in air temperatures. Sores near the incision, similar to those observed in the laboratory, were noted in three frogs. Frogs were tracked for up to 124 days post-surgery (median = 38.5 days). Three failed transmitters were sent back to the manufacturer for diagnosis; battery failure and component malfunction were identified as the causes.

In 2001, most frogs monitored (15 of 19) gained weight (mean = 12.8 g ± 14.7 SD). Most frogs were detected hiding in grass or near hedgerows of crop fields. We were able to detect transmitters with internal loop antennas at distances ranging from 50 to 75 m in the field and the longest single-day movement we observed for an individual frog was 313 m.

All external attachment techniques we tested proved inadequate for tracking *R. pipiens* over long time periods because frogs shed their belts quickly or developed lesions that required release. In comparison, *R. pipiens* with peritoneal implants were tracked for up to 4 months during our field study. Tracking durations reported from other studies deploying belts on anurans also have been relatively short, for example, 1–20 days for *R. pipiens* (N = 24, Waye 2001), 11–126 days for *R. luteiventris* (N = 71, Bull 2000), up to 30 days (mean = 16–21 days) for *R. sylvatica* (N = 11, Muths 2003), 5–12 days for *Eleutherodactylus augusti* (N = 5, Goldberg et al. 2002), 9–13 days for *Littoria nannotis* (N = 19, Hodgkison and Hero 2001). Twelve of 38 *Bufo boreas* shed their belts within two weeks (Bartelt and Peterson 2000). Further, nearly all studies reported skin lesions associated with the belts, although recent work by Muths (2003) using craft elastic strung with glass beads shows promise of belt retention without injury.

We found that nonrecovery from anesthesia was a major mortality factor for *R. pipiens* receiving surgical implants. Most surgical failures appeared to be associated with elevated MS-222 solution temperatures (> 25°C). Ambient temperature fluctuates more in the field than in the laboratory, so this problem did not arise during our laboratory trials. We ultimately achieved success in surgical implantation and recovery of the frogs using a mobile laboratory suitable for both the surgery and postsurgical observation of the frogs. After our surgical experiences, we found recommendations for limiting the temperature of MS-222 to ≤ 25°C when used as an anesthetic for amphibians (Green 2001).

Goldberg et al. (2002) also reported that achieving the appropriate level of anesthesia was the most difficult part of surgery, although temperature of the anesthetic solution was not mentioned. Werner (1991) implanted radio transmitters into six *Bufo americanus,* with no reported mortality using a 0.01% solution of MS-222 for 15–20 min. Lamoureux and Madison (1999) performed 23 surgeries on *Rana clamitans* with no reported mortality; they used a 0.5% solution of MS-222 to anesthetize the frogs, but did not report exposure times. Lamoureux et al. (2002) performed 27 surgeries on *R. clamitans* with one surgical death.

Laboratory testing of terrestrial salamanders has demonstrated that responses to MS-222 anesthesia vary among species and depend upon both pH and concentration (Lowe 2004). Lowe also suggests using aqueous pH buffers to prepare the MS-222 rather than neutralizing the solution with sodium bicarbonate. It is likely that anurans also have species-specific responses to MS-222 (Green 2001). We conclude that reliable, safe application of MS-222 as a surgical anesthetic for amphibians is possible under controlled conditions (solution concentration, pH, temperature, and exposure time) and with some initial exploratory laboratory testing of the target species.

Presumably, the mortality of frogs that recovered from anesthesia but died from unknown causes within 10 days was related to the surgery. The majority of these deaths (8 of 10 frogs) coincided with a rapid decrease in ambient temperature within days of surgery. An early April period of warm temperatures in 2002 (highs >25˚C) induced breeding behavior in adult *R. pipiens* and was followed by a temperature drop to near 0˚C. Mortality may have resulted from the combined stress of recent emergence from hibernation, breeding activity, an extreme fluctuation in ambient temperature, and surgery. Avoiding this type of mortality will be difficult because of the need to implant transmitters while *R. pipiens* are concentrated at breeding ponds for brief periods in spring, a time of unpredictable weather conditions in the upper Midwest. Rudolph et al. (1998) also found that snakes implanted with radio transmitters had higher mortality when implants occurred late in the season when temperatures were colder. Frogs are at high risk of predation in the immediate post-surgical period because individuals vary in the time it takes to fully recover from anesthesia. Protecting frogs from predation during the surgical recovery period may improve immediate post-surgical survival. Field enclosures provide predator protection and concealment, but not climate-controlled conditions.

Although the surgical implants resulted in health effects, primarily mortality within 10 days of surgery, *R. pipiens* that survived past 10 days behaved normally and gained weight, both in the laboratory and in the field. Our laboratory trials indicated that frogs experienced low mortality from 10 to 134 days post-surgery, although some small skin lesions developed. In the field, frog mortality occurring after 10 days post-surgery was apparently unrelated to the surgery, as evidenced by good health (e.g., weight gain and apparently normal behavior). We observed that predation and hay mower strikes were the primary non-surgical mortality factors for *R. pipiens*. Ours may be the first direct evidence of mortality due to hay mower strikes reported from a telemetry study. This has obvious conservation implications for amphibian populations. For example, frequently-mowed hay fields located adjacent to amphibian breeding sites may reduce post-breeding survival.

Even surgical implantation does not ensure that frogs will retain the transmitters for the duration of studies. With subcutaneous implants, transmitters can break through the sutures and be lost within days of surgery. Conversely with peritoneal implants, some frogs retained transmitters a month or more before expelling them, presumably via the gastrointestinal tract. Shedding transmitters via the gastrointestinal tract also has been observed in fish (Marty and Summerfelt 1986), but to our knowledge, has not been previously described in frogs.

Another challenge to the use of internal implants with a highly mobile species like *R. pipiens* is the limited detection range that we observed for transmitters with internal loop antennas (50–75 m). Undoubtedly, this was a factor in the high rate of missing frogs (35%) we experienced. Likewise, Goldberg et al. (2002), using somewhat smaller transmitters, detected external transmitters at distances > 200 m, whereas detection was limited to 6–40 m with implanted transmitters. Although external implants have longer detection ranges, they may be of limited value in some studies because of their short retention times. If tracking frogs over several months is needed to meet study objectives, frogs may need to be tracked more frequently to reduce loss rates due to long distance movements between tracking events. In the case of *R. pipiens*, tracking events may need to occur at intervals shorter than 24 h. In summary, we believe surgical implantation holds the most future promise for tracking *R. pipiens* over relatively long periods with minimal health effects.

Our data indicate that both external belts and surgical implantations of radio transmitters can have significant health risks for frogs. For those studying movements of rare species, this presents a dilemma because high morbidity and mortality are unacceptable in small populations. We make several suggestions for limiting morbidity and mortality. First, we found that all attachment methods required significant skill and experience to be successful, a non-trivial problem for beginning researchers. We suggest that novices spend time practicing attachment techniques with someone skilled in the desired method. If possible, practice the technique on a common frog species similar in size to the target species, perhaps a species available from biological supply companies. Belt retention and skin lesion development may be species- and perhaps habitat-specific, therefore, we suggest testing the best available external belts on the target species in field enclosures. If external belts are retained long enough to achieve the research purposes without causing skin lesions, belts are the best solution. If not, proceed to surgical implantation.

Likewise, we recommend practicing the initial surgeries in the laboratory on a similar non-target species under the supervision of someone skilled in the technique. Because anesthetics and dosages are species-specific (Green 2001), anesthesia concentration, pH, exposure time, and temperature should be tested on the target species in the laboratory. Surgeries should be conducted under controlled conditions. If a vehicle is available that provides protection from adverse weather and temperature extremes, field surgeries can be done; otherwise, conduct surgeries in the laboratory. This decision will also depend upon the distance from the field site to the nearest laboratory. We recommend that frogs be protected from predation for at least 24 h post-surgery in the laboratory or in a field enclosure. Frogs should display feeding and/or escape behaviors before release. Track frogs at least daily and more frequently during wet weather to minimize loss of study subjects.

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# A Successful Trap Design for Capturing Large Terrestrial Snakes

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Large scale trapping protocols for snakes can be expensive and require large investments of personnel and time. Typical methods, such as pitfall and small funnel traps, are not useful or suitable for capturing large snakes. A method was needed to survey multiple blocks of habitat for the Louisiana Pine Snake (*Pituophis ruthveni*), throughout its historic range in Louisiana and Texas, to obtain presence-absence data and to obtain specimens for radio-telemetry studies (Himes et al. 2002; Rudolph and Burgdorf 1997; Rudolph et al. 2002).

We required a method that was feasible with respect to cost of materials, time necessary to service traps, ease of installation, and efficiency in capturing snakes. The trapping method needed to capture large, mobile species, but not small, litter-dwelling species. We ultimately designed a large four-entrance funnel trap, with extensive drift fence arms to guide snakes toward the trap opening. These traps have been in use since 1993 to survey large snakes in Arkansas, Louisiana, and Texas. This trap design also was used to examine the impact of roads and vehicle-related mortality on large snakes (Rudolph et al. 1999).

Traps consisted of 121.9 x 121.9 cm (48 x 48 in.) tops and bot-