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"IN MY EXPERIENCE . . ."

IMPLANTABLE MICROCHIPS FOR INDIVIDUAL IDENTIFICATION IN WILD AND CAPTIVE POPULATIONS

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Maintaining individual identification is critical to studies of population estimation, dispersal, and behavior and to studies of demographic and genetic structuring of wild and captive populations (Otis et al. 1978, Pollock et al. 1990). The technique used to identify individuals should be humane, permanent, unambiguous, unobtrusive, yet detectable at a distance.

Several marking methods may be necessary to achieve desired results, one to provide a permanent mark and another for recognition at a distance (Rice and Kalk In Press). For example, metal numbered leg bands are used with color bands for birds, tattoos or freeze branding are used with ear tags for mammals, and web tags are used with shell notching for turtles. Behavior and morphology of the animal being studied dictates the type of marking method used. The implantable microchip, or passive-integrated transponder (PIT), satisfies most of the specifications outlined above.

Transponder systems have been described (Rao and Edmondson 1990, Zulich et al. 1992) and have been evaluated on bats (Barnard 1989), domestic and wild ferrets (*Mustela* spp.; Fagerstone and Johns 1987), house mice (*Mus musculus*; Rao and Edmondson 1990, Ball et al. 1991), sea otters (*Enhydra lutris*; Thomas et al. 1987), and a range of amphibians and reptiles (Camper and Dixon 1988; Table 1). These systems have many benefits. There are more than 34 billion possible unique alphanumeric sequences that are assigned during manufacture (Thomas et al. 1987). Application is quick, identification is exact and unambiguous, and a chip has the potential to last the lifetime of the animal. The main disadvantage of these small-sized chips is the limited detection range of 5.6 ± 0.6 cm (Int. Union for Conserv. of Nat. and Nat. Resour./Captive Breeding Specialist Group [IUCN/CBSG] Working Group on Permanent Animal Identification 1991). It is impossible to identify animals at a distance. Moreover, the reader has to be appropriately aligned to the PIT tag to activate it.

The objective of our review is to evaluate PIT tags for individual identification with a variety of vertebrates, in the wild and in captivity over extended periods, and to inform researchers about the state of the technology. Transponders are becoming a routine means of identification in zoos. With the recent endorsement by the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) of transponder technology for marking endangered species (CBSG News

Table 1. Summary of studies using passive intergrated transponder tags published from 1987–1993.

Author (year)	Species	Study duration (days)	No. tags examined	No. tags intact[a]	Implant site[b]
Fagerstone and Johns (1987)	domestic ferret (*Mustela putorius*)	225	23	18	sq on cranium medial to ear
	black-footed ferret (*Mustela nigripes*)	23	11	10	
	black-tailed prairie dog (*Cynomys ludovicianus*)	140	14	14	not reported
Thomas et al. (1987)	sea otter (*Enhydra lutris*)	27–48	6	6	sq base of neck
Camper and Dixon (1988)	frogs, toads	120	20	20	intra-coelomic
	alligator (*Alligator mississippiensis*)	120	1	1	subcaudal whorl
	snakes	120	20	19	sq in tail or intra-coelomic
	lizards	120	23	23	sq in neck or intra- or inter-abdominal
	turtles	120	31	31	drilled hole in marginal scute or as for lizards
Barnard (1989)	big brown bats (*Eptesicus fuscus*)	not reported	17	17	sq on dorsum
	house mice (*Mus musculus*)	30	4	4	sq on dorsum
Hamner (1989)	juvenile salmonids	401	not given	all read	intra-coelomic
Ball et al. (1991)	Norway rats (*Rattus norvegicus*)	365	10	10	sq mid-dorsum
Germano and Williams (1993)	blunt-nosed leopard lizard (*Gambilia silus*)	1,095	273	250	sq lateral fold or sq dorsum

[a] Number of tags that scanned successfully when implanted animals were scanned.
[b] sq = subcutaneous implantation.

1992), some managers may assume transponders provide an infallible means of permanent identification.

METHODS

The Transponder System

The system consists of a scanner, a reader, and a microchip that is implanted with a hypodermic needle. The rod-shaped microchip is sealed in biocompatible glass and is approximately 10 mm long. A copper coil inside the chip generates a unique, unalterable 10-digit alpha-numeric signal when activated by a low-frequency magnetic field from an external source. Several companies manufacture implantable PIT tags, and each company has different marketing agents distributing the chips (IUCN/CBSG Working Group on Permanent Animal Identification 1990, Rice and Kalk In Press). Although different systems all operate on the same principle, they are incompatible. There has been much discussion about manufacturing readers able to scan chips from different manufacturers (Blumer 1993), but there is no such scanner currently available commercially. We evaluated the Destron/IDI 400 kilohertz transponder system (Destron, Boulder, Colo.).

Snakes in the Wild

We implanted PIT tags in pine snakes (*Pituophis melanoleucus*) living in Atlantic, Ocean, and Burlington counties in the New Jersey Pine Barrens. Most snakes were implanted either when we examined them in their hibernaculum in March or during the late June nesting period (Table 2). Because pine snakes excavate hibernacula with their head and necks (Burger et al. 1988, Burger and Zappalorti 1991), we implanted PIT tags 10–15 cm anterior to the cloaca in the coelomic cavity. PIT tags were scanned before and after implantation to make sure that the tags were functioning. Although the scanner had the capability to store as well as read numbers, we manually recorded PIT-tag numbers as we implanted them. Implantation was done under guidelines of the Rutgers State University Animal Care Review committee (87-017).

Captive Animals

At the Wildlife Conservation Park (formerly Bronx Zoo), Bronx, New York we implanted PIT tags in ≥500 individuals representing approximately 70 species of mammals, birds, and reptiles from 1990–1992. Implant site varied by species (Elbin 1991). Birds and mammals reported herein were implanted subcutaneously on the breast or between the shoulder blades, respectively. Typically we had opportunistic access to animals with PIT tags, scanning them while they were being moved or receiving veterinary treatment. At the time of the study, 26% of 513 implanted zoo animals were available for tag evaluation.

In all species, basic implantation was the same. We prepared the site by disinfecting the surface with alcohol. Shaving or feather plucking was not necessary, although care was taken to avoid subcutaneous feather shafts and inverting hair follicles into the implantation hole. We used commercial tissue adhesive (cyanoacrylate) to seal the hole made by the implantation needle. When possible, either through recapture of an animal in the field or repeated handling of a zoo animal, PIT tags were read within the first year after implantation.

OUR OBSERVATIONS

We implanted 513 PIT tags in 68 captive species and 163 PIT tags in 1 wild species from 1990–1992. None of these animals experienced adverse effects (infection, migration, rejection) related to implantation of the PIT tags. Marking success, measured by reading PIT tags (i.e., number of intact PIT tags) at various times after implantation generally exceeded 90% among species (Table 2). Captive species listed in Table 2 are those in which we were able to scan more than one individual or those that had been implanted for >12 months.

Snakes in the Wild

We recaptured 100 snakes in late June or early July when they were nesting and 63 snakes in March the following year while they were hibernating. Thirty-six snakes were recaptured 2 years after implantation, 29 snakes were captured 3 years after implantation. All snakes retained the tags and all tags were readable. Twenty snakes were examined 4 months after implantation, 51 were examined after 12 months, 6 were examined after 16 months, 36 after 24 months, and 29 after 36 months (Table 2).

Captive Animals

Some problems occurred reading PIT tags in waldrapp (ibis) and silvery marmoset. The failed chip in the waldrapp may have fallen out of the bird. The needle hit the root of a

Table 2. Success of reading transponders implanted in 10 animal species at The Wildlife Conservation Park, Bronx, New York, from 1990–1992 and in pine snakes at the Pine Barrens, New Jersey, from 1990–1993.

Species[a]	No. implanted	Recapture interval (months)	No. reexamined	No. intact tags[b]
Pine snake (*Pituophis melanoleucus*)	163	4	20	20
		12	51	51
		16	6	6
		24	36	36
		36	29	29
Waldrapp (*Geronticus eremita*)	29	8	5	5
		41	19	15
Bali myna (*Leucopsar rothschildi*)	5	15	1	1
Pen-tailed bettong (*Bettongia pencillata*)	28	18	21	20
Silvery marmoset (*Callithrix argentata*)	4	8	4	1
White-handed gibbon (*Hylobates lar*)	2	10	2	2
Patagonian hare (*Dolichotis patagonum*)	8	24	6	6
Naked mole rat (*Heterocephalus glaber*)	2	8	2	2
Rock hyrax (*Procavia capensis*)	16	1	3	3
		11	1	1
		13	1	1
Himalayan tahr (*Hemitragus jemlahicus*)	9	10	9	9
		12	3	3
		23	1	1

[a] Pine snake was the only species examined in the wild.
[b] Number of tags that scanned successfully when implanted animals were scanned.

feather shaft when we implanted the tag, causing an enlarged hole. The chip probably fell out after implantation. The marmosets also may have lost their PIT tags. A lump was palpated at the implant site in the marmoset whose PIT tag did read. The other 3 marmosets may have lost them.

Our implantation protocol now requires scanning the animal for its PIT tag immediately after implantation. This extra step ensures that the chip is still working and is in the animal. We carry a demonstration chip with the scanner to ensure that the machine and cable connections are functioning. We are currently using intramuscular implantation on birds to decrease the chances that the PIT tag will fall out.

DISCUSSION

Most published studies on PIT tags have been done with mammals. Fagerstone and Johns (1987) tested transponder implants in domestic ferrets before using them in wild black-footed ferrets. These early PIT tags did not migrate or cause inflammation, but the encasement material (polypropylene) developed leaks, allowing body fluids to seep in and damage the electronics of the PIT tag. Thomas et al. (1987) experienced no reading failures of transponders used to identify individual sea otters.

Although implantation is quick and virtually painless, an animal must be restrained to be processed. Large and dangerous animals may need to be anesthetized to be implanted and read. Even smaller animals must be restrained during scanning because of the short detection distance. We had no difficulty with the PIT tag implant procedure. Barnard (1989) experienced difficulties in implanting PIT tags into small-bodied mammals (captive big brown bats). Two PIT tags were deposited through the skin and outside the bats' bodies.

Implanted PIT tags did not seem to affect animals physiologically or behaviorally. In laboratory rats (*Rattus* spp.), subacute inflammation occurred in cells surrounding the implant ≤ 2 weeks after implantation, subsiding within 12 weeks. After 1 year, fibrous connective tissue surrounds the implant (Ball et al.

1991). Camper and Dixon (1988) implanted 95 amphibians and reptiles with no ill effect attributed to implantation. Dixon has implanted >7,000 snakes with no failures (J. R. Dixon, Texas A&M Univ., College Station, pers. commun., 1993). Hamner (1989) showed that there were neither behavioral responses nor mortality associated with implantation of tags into fish. PIT tags in fish decreased by 90% the need to handle animals to verify identification.

Site location can play a major role in the success of the implantation process. Agreement on implantation site is most critical at zoos since animals are moved between zoos. General scanning of animals to locate PIT tags is time consuming and increases handling and stress to the animals. Elbin (1991) recommended implantation sites based on suggestions from zoo professionals and experience with handling protocols and captive behavior of different species. Alternate implantation sites should be used if the behavior or handling procedures for that study species makes the recommended site difficult to read. Implant site must be recorded and any deviation from the standard must be noted.

Snakes present problems for implantation of PIT tags in that their entire body is often in contact with a substrate and their method of prey capture and swallowing often requires agility of their mouth, neck and body. Pine snakes provide particular problems because of their nesting and hibernation behavior. Unlike most snakes, pine snakes excavate nests in the sand; their hibernacula may be ≤2.5 m below the ground and involve tunnels >45 m long.

We based the implant site for pine snakes on their locomotive and digging behavior, rather than the general snake guidelines used in zoos. There are a number of marking techniques for snakes in the wild, including scale clipping, branding (Clark 1971), and implanting with radios (Reinert and Cundall 1982). All these methods have difficulties: scale clipping can disappear with shedding or cause injury, branding can cause injury or fade, and both methods can be difficult to read and labor intensive. Implanting radios also is time consuming and expensive. PIT tags thus provide an accurate, permanent, and relatively inexpensive method of identifying snakes.

Thomas et al. (1987) selected an implantation site (base of the neck, dorsal side) in otters that would enable them to scan the animals unrestrained. Germano and Williams (1993) had low PIT-tag success in blunt-nosed lizards until they realized that tags were breaking through regions of tight skin or were being cracked during aggressive encounters. They decreased tag failure by using intra-abdominal implantation.

Fagerstone and Johns (1987) found malfunctioning PIT tags in 1 of 11 wild black-footed ferrets and 18 of 23 captive domestic ferrets. The single failure in the wild animals occurred in an animal with head and neck wounds. Scanning failure may have been due to scar tissue or PIT-tag failure.

Transponder technology is good, but it is not yet perfect. In our view, the benefits of using PIT tags for animal identification far outweigh proximity constraints, occasional chip failures, and initial cost. Identification of recaptured PIT-tagged Pine Barren pine snakes was quick and efficient. In zoo collections we suggest that all individuals within the collection have unique and unambiguous identifiers, and we have already found that the benefits of PIT tags justify their use. Transponder implantation has been incorporated into routine husbandry practices. Although the initial cost is relatively high, ranging from $850–1,000 (1992 dollars) for a scanner-reader unit and $4.20 (unsterile bulk shipment of chips) to $10.00/chip (pre-loaded 12-gauge syringes), the benefits of fast, efficient, and accurate individual identification are even higher.

We recommend using PIT tags for individual animal identification in the field or captive situations. However, until the effective life span of implanted PIT tags has been documented, we cannot assume that PIT tags will last the lifetime of the animal. They cannot yet be used in place of other permanent animal identification methods such as numbered metal bands, tattoos, freeze branding, or ear notching. Researchers and managers should either use 2 PIT tags or a PIT tag and another more traditional back-up method.

SUMMARY

We describe and review the use of implantable microchips (PIT tags) as a reliable means of individual identification that has many advantages over traditional methods. Transponders are implanted and do not alter the appearance of the marked animal. They produce a unique code that is deciphered electronically when the implanted chip is scanned. We tested the permanence by repeatedly scanning several species of vertebrates implanted with PIT tags over varying times. All 163 wild snakes and most (92%) of 103 captive animals that were implanted and examined retained their PIT tags in a readable condition. Difficulties with the initial implantation were encountered. Limitations to the use of PIT tags include the initial cost of the system and the short distance required to activate the chip.

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