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Wildlife Marking Techniques

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INTRODUCTION

All captive-animal and many field studies involving wildlife require individuals be marked for future identification. Marked individuals can provide detailed information on population dynamics, movement, behavior, and density estimates. We provide an overview of factors that should be considered before deciding to mark vertebrates (excluding fish), and address factors relevant to the selection of appropriate procedures. Others have addressed these issues previously. Stonehouse (1978) described general marking techniques for animals, and Murry and Fuller (2000) reviewed effects of marking on vertebrates. Marking methods for amphibians, reptiles, birds, and mammals were reviewed by Nietfeld et al. (1994). Methods for marking amphibians and reptiles have been reviewed by Woodbury (1956), Thomas (1977), and Swingland (1978) while Ferner (1979) and Donnelly et al. (1994) reviewed marking methods specifically for reptiles and amphibians, respectively. Spellerberg and Prestt (1978) and Fitch (1987) reviewed methods for marking snakes. Marion and Shamis (1977), the American Ornithologists' Union (1988), and Calvo and Furness (1992) reviewed marking methods for birds. The American Society of Mammalogists (1998) provided general guidelines for marking mammals. Barclay and Bell (1988) gave detailed information for marking bats. Although not covered in this chapter, overviews for marking fish were provided by Wydowsky and Emery (1983) and Parker et al. (1990). Hagler and Jackson (2001) provided an excellent overview of current techniques for marking insects.

Because of the wide diversity among vertebrate species, no single list of approved methods for marking is practical or desirable. The ultimate responsibility for the ethical and scientific validity of methods used rests with the investigator. In general, natural marks have the least adverse effect on individual animals and should be used whenever possible, whereas invasive techniques have the greatest potential for adverse effects. Moreover, many techniques require capture, recapture, and handling of animals that also might affect their behavior and survival. Separation of these effects from those caused directly by the marking method has yet to be evaluated in most cases.

CONSIDERATIONS PRIOR TO MARKING

Questions to Consider

Before attempting to mark free-ranging wildlife, the following checklist of species and situation-dependent questions should be considered.

1. Do the animals need to be marked or can natural markings be used instead?
2. Do the animals need to be marked as individuals or can they be marked as a group?
3. Do the animals need to be physically captured prior to marking or can they be marked without capture?
4. How visible do the marks need to be and do the animals need to be "recaptured" for the mark to be observed?
5. Will the marking method cause pain and/or decrease survival of the animal?
6. Will the proposed mark affect the animal's health, reproduction, movement patterns, and/or behavior?
7. How long will the mark be required to last to complete the study and how durable is the proposed marking method?
8. Will the proposed marking method interfere with other studies?
9. Will the marks promote public concern about the study and will the marks have to be removed after study completion?
10. Have the appropriate approvals (animal welfare and state and/or federal permits) to mark the animals been obtained?

Considerable thought should be given to these questions before the decision to mark wildlife is made. Techniques for marking wildlife fall into 3 main categories: natural, noninvasive, and invasive marks. If natural marks cannot be used, noninvasive marks are preferable over invasive marks. Although some marking techniques may be unique to a single species, most apply to a wide variety of species. Therefore, unlike previous chapters on this subject in The Wildlife Society's "Techniques Manual," we present marking information by methods. This has eliminated most repetition inherent in presenting this information by animal classes (i.e., amphibians, birds, mammals, and reptiles; Nietfeld et al. 1994). We consolidated general information on proper application of the technique, its retention time and visibility, and any adverse effects of the technique on marked animals (where this information is available). This allows the reader to more easily evaluate and compare individual methods. Additionally, we present these methods in sequence of what we consider most to least preferred. More detailed information, such as species or group, comments, and citations (in chronological order), is presented in tables. This allows readers to select an animal class, identify which methods have been used for the species or group of species of interest, and pursue the citations for more detailed information on the method's appropriateness for the specific application.

Marking Permits

Before an animal can be captured and marked, the appropriate local (e.g., animal welfare permits), federal, and/or state/provincial permits must be obtained. Wildlife species are regulated within state/provincial borders by the appropriate wildlife agency. The federal government regulates capture and marking of migratory birds and threatened and endangered species. Authorization to mark migratory birds and threatened and endangered species must be approved by the Bird Banding Laboratory, U.S. Geological Survey, Biological Resources Division, Laurel, Maryland 20708-9619, USA, or the Canadian Bird Banding Office, Canadian Wildlife Service, Ottawa, Ontario, Canada KIA OH3.

Natural Marks

The first questions to be considered when contemplating marking animals are: (1) is marking necessary, (2) can the study be conducted without recognition of individuals or a specific group of animals, and (3) if not, can animals be identified without use of applied marks? Perhaps the ideal method of recognizing individuals is to use their own "naturally" occurring unique traits, much as we identify other people by their physiognomic traits. Humans may be unable to differentiate individuals within some wildlife species, but there are others whose physical characteristics allow for individual identification using natural markings or distinct morphological characteristics. Many animals exhibit unique coat patterns (Table 1) or can be identified by unique color patterns (Fig. 1), scarring, fin or fluke notches, antler configuration, and/or other traits. Natural markings are most efficiently used on individuals with complex patterns, and analysis must be confined within a local population or region (Pennycuick 1978).

Natural markings have been used to identify individual mammals, reptiles, and amphibians more commonly than birds (Table 1). Unique plumage or bill patterns can be used as distinguishing features for birds, but such features are rare in avian populations and may change with molt and/or age. Thus, the potential for natural marking systems in birds is limited, but may have short-term application in conjunction with other markers for some species.

Marking as Individuals or Groups

If a study requires the use of applied marks, do the animals have to be marked as individuals or can they be marked as groups? Many herd/flock movement and dispersal studies only require that large numbers of individuals be marked in a given area and relocated later. For example, large numbers of white geese could be marked by placing dye in roost ponds and followed by searching for colored geese. Similarly, many mark-recapture or mark-resight studies conducted only to estimate population density do not require that marked individuals be differentiated from another.

Marking Without Capture

Capture may stress animals and marking without capture is preferred where practical. Remote marking of animals as individuals or groups has a long history (Table 2).

Fig. 1. Unique spots and stripes on 2 bobcats.

Table 1. Natural markings used to identify individual animals [a].

Group/Species	Method for identification	Citations
Amphibians & Reptiles		
Grass snakes	Ventral patterns	Carlstrom and Edelstam 1946
Viviparous lizard	Dorsal patterns	Carlstrom and Edelstam 1946
Slow-worm lizard	Throat patterns	Carlstrom and Edelstam 1946
Smooth newt	Belly patterns	Hagstrom 1973
Anoles	Distinctive patterns and tail regenerations	Stamps 1973
Warty newt	Belly patterns	Hagstrom 1973
Eastern newt	Dorsal spot pattern	Healy 1975
Dusky salamander	Dorsal color patterns	Forester 1977; Tilley 1977, 1980
Snakes	Distinctive characteristic on exuvia	Henley 1981
Snakes	Characteristic of subcaudal scales	Shine et al. 1988
Spotted salamander	Spot pattern	Loafman 1991
Patterned amphibians	Spot and stripe pattern	Doody 1995
Birds		
Bewick's swan	Bill patterns and body features	Scott 1978
Osprey	Using head marking patterns	Bretagnolle et al. 1994
Mammals		
Giraffe	Unique coat patterns	Foster 1966
Tiger	Unique coat patterns	Schaller 1967, Karanth 1995, Karanth and Nichols 1998
African lion	Identified by whisker patterns	Pennycuick and Rudnai 1970
Black rhinoceros	Unique ear markings, horn shape and wrinkle patterns	Mukinya 1976
Cetaceans/manatees	Unique color, scars, and fin or fluke notches	Würsig and Würsig 1977, Irvine et al. 1982, Irvine and Scott 1984
Urban dogs	Unique coat patterns	Heussner et al. 1978
African bushbuck	Unique coat patterns	Seydack 1984
Leopard	Pelt characteristics	Seydack 1984
Bobcat	Spot variation	Rolley 1987, Heilbrun et al. 2003
Cheetah	Pelt characteristics	Caro 1994, Kelly 2001
White-tailed deer	Antler, pelt, and body characteristics	Jacobson et al. 1997

[a] Scientific names are in the Appendix.

Table 2. Remote marking methods used to mark animals[a] as individuals and in groups.

Group/Species	Remote marking method	Citations
Birds		
Sage-grouse	Aniline dyes in tank buried on lek attached to spray head	Moffitt 1942
Ruffed grouse	Aluminum and bronze dust in nests found later on shed feathers	Bendell and Fowle 1950
Glaucous-winged gull	Thief detection powder on eggs and nests	Mossman 1960
Nesting terns	Blow dye from bottle using rubber tubing	Moseley and Mueller 1975
Nesting wood ducks	Rubber band with color marker in nest box hole	Heusmann et al. 1978
Cattle egret and gull eggs	Rhodamine B dye in oil-based silica gel placed on eggs; adults marked 2-6 months	Paton and Pank 1986, Cavanagh et al. 1992
Roosting blackbirds	Aerial application of liquid fluorescent pigmented material, visible under UV light in subsequent collections of marked birds	Otis et al. 1986
Wood stork	Pressurized canister with nozzle on pole with control lever	Rodgers 1986
Waterfowl	Fluorescent particles applied to lakes marked waterfowl for 8 weeks	Godfrey et al. 1993
Common tern	Device using refillable bottles filled with dye, remotely controlled	Wendelin et al. 1996
Mammals		
Deer	Treadle-type spray devices	Clover 1954
White-tailed deer	Self-affixing collar	Verme 1962, Siglin 1966, Taylor 1969
Mountain sheep	Manually-triggered dye-spraying device and modified Cap-Chur darts	Hansen 1964, Simmons and Phillips 1966
Moose	Manually-triggered dye spraying devices	Taber et al. 1956
Pronghorn	Collar-holder frame over water	Beale 1966
Hares and rabbits	Self-affixing collar	Keith et al. 1968
Dall's sheep	Spraying devices used from aircraft	Simmons 1971
Muskox	Paint-pellet pistols	Jonkel et al. 1975
Mountain sheep	Modified Cap-Chur darts	Turner 1982
Elk	Paint-ball guns	Herriges et al. 1989, Herriges et al. 1991
Red squirrel	Remotely applied collars	Mahan et al. 1994

[a] Scientific names are in the Appendix.

Mammals have been marked with paint-tipped arrows (N. J. Silvy, unpublished data) and paint balls (Table 2). Animals also have been marked using a manually triggered dye-spraying device, and dyes can be introduced into the animal's food to produce dyed fat, teeth, pelage, and droppings. Self-affixing collars have been developed for several species (Table 2). Dye-spraying devices affixed to aircraft have been used to mark large mammals and could be used for marking large numbers of white-colored birds (e.g., white geese, egrets). Dyes also can be placed on eggs and nests, marking the adults as they incubate their eggs (Table 2). Subsequent collection or observation of marked animals provides data on dispersal and population dynamics.

Marking After Capture

If animals must be captured, there are numerous marking techniques available. Although the most suitable marking techniques will depend on the needs of the investigator, Barclay and Bell (1988) suggested considering the following factors: duration of study, ability to relocate marked animals, number of animals to be individually identified, and the effect of the mark on the animal. According to Marion and Shamis (1977) and Ferner (1979), an ideal marking technique would: (1) involve minimal pain or stress, (2) produce no adverse effects on survival and behavior, (3) permanently mark individuals, (4) be easy to recognize at a distance, (5) be easy to apply, (6) be easy to obtain and/or assemble, and (7) be relatively inexpensive. Additionally, the selected marking technique should not conflict with other studies in the area and permission to use the techniques should be readily obtainable from the appropriate authorities. Most marking techniques do not satisfy all of these criteria and investigators must prioritize prior to mark selection.

Nietfeld et al. (1994) grouped markers into 3 categories relative to retention time: temporary, semi-permanent, and permanent. We prefer 2 groups: permanent and non-permanent. We define permanent marks as those lasting the life of the animal and non-permanent marks as all others. Permanent marks include branding, tattoos, ear notching, toe clipping, and other invasive techniques although scarring, tearing, and aging may reduce their effectiveness. Non-permanent marks generally are more visible and can be used with permanent marks to increase visibility of the animal, yet still have the animal marked for life. For example, a white-tailed deer (all scientific names are in the chapter Appendix) could be given a unique ear tattoo (permanent) as well as a numbered, brightly colored cattle-ear tag (visible). Animal size, however, limits the size of marks that can be applied, but color-coded marks still can enhance recognition. A point to remember when using

Table 3. Neck collars used on wildlife[a].

Group/Species	Materials and comments	Citations
Amphibians & Reptiles		
American alligator	Vinyl-plastic tape	Chabreck 1965
Birds		
Geese, brant, swans, ducks, and cranes	Plastic collars of flexible vinylite, flexible plastic, rigid acrylic resin, and aluminum with or without letters and numbers with retention up to 11 years on adult geese, but should not be used on goslings because few are retained; icing not a problem with aluminum neckbands, but collared birds may move from breeding areas	Aldrich and Steenis 1955, Helm 1955, Craighead and Stockstad 1956, Idstrom and Lindmeier 1956, Ballou and Martin 1964, Huey 1965, Sherwood 1966, Lensink 1968, MacInnes et al. 1969, Fjetland 1973, Greenwood and Bair 1974, Koerner et al. 1974, Ankney 1975, Chabreck and Schroer 1975, Raveling 1976, Maltby 1977, Craven 1979, Abraham et al. 1983, Zicus et al. 1983, Pirkola and Kalinainen 1984, Hawkins and Simpson 1985, Zicus and Pace 1986, MacInnes and Dunn 1988, Ely 1990, Samuel et al. 1990, Campbell and Becker 1991, Johnson et al. 1995, Castelli and Trost 1996, Menu et al. 2000, Schmutz and Morse 2000
Game birds	Colored plastic neckbands	Taber and Cowan 1963, Marestrom et al. 1989
Mammals		
Foxes	Metal collar slit for expansion	Sheldon 1949
Ungulates	Plastic, aluminum, nylon fabrics, polyethylene rope with flags, rubberized machine belting, and self-adjusting plastic collars for young	Ealey and Dunnet 1956, Progulske 1957, Fashingbauer 1962, Lightfoot and Maw 1963, Harper and Lightfoot 1966, Knight 1966, Hawkins et al. 1967, Craighead et al. 1969, Hanks 1969, Phillips and Nicholls 1970, Beale and Smith 1973, Brooks 1981, Keister et al. 1988, Hölzenbein 1992
Hares	Leather collar	Hewson 1961
Polar bear	Nylon webbing	Lentfer 1968
African elephant	Rubberized machine belting	Hanks 1969
Feral goats	Galvanized steel chain	Rudge and Joblin 1976
Cetaceans and manatees	Rubberized belts	White et al. 1981
Bats	Spiral bird rings and keychain collars	Moran 1985, Wilkinson 1985
Coyote	Vinyl plastic collars	Gionfriddo and Stoddart 1988

[a] Scientific names are in the Appendix.

color-coded marks is that many people are red/green color-blind. Therefore, selection of contrasting colors that can be recognized at a distance by all individuals involved with the project is important.

The use of marks can influence behavior, particularly color marks used on birds, and can increase predation (Kessler 1964, Burley et al. 1982). The combination of stress and mortality associated with capture and the affect of the mark itself could decrease survival more than either capture or marking alone. Thus, it is important to examine whether necessary data can be obtained without use of marks. If not, researchers must ascertain whether marking animals is likely to result in reliable knowledge that can be used to better manage the population. Further, they should realistically weigh the benefits of this knowledge against the discomfort or harm done to the individual animals. There is no simple checklist that will delineate the most appropriate marking technique(s) for all potential research projects.

NONINVASIVE MARKING TECHNIQUES

Neck Collars

Many different neck collars have been designed for field identification of free-ranging animals (Table 3). Properly fitted collars (Fig. 2) should not restrict feeding, circulation or breathing, or cause entanglement. Collars may be fixed in size or expandable to allow for growth. Many neck collars are placed too loosely on animals (Fig. 2). A loose collar (especially if the collar has the added weight of a radio transmitter) will slip up and down an animal's neck when it lowers and raises its head. This can cause abrasions and possible open sores that can lead to infection and possibly death. If a collar is extremely loose, the animal may get a foot caught in the collar as it extends its front feet to stand from a bedding position. If a collar is placed too tightly around an animal's neck, the collar may cut off blood circulation that can lead to tissue sloughing, infection, and death. During the rut, necks of many

Fig. 2. Oversized neck collar (right) that could allow animal to place leg through collar. Collar should fit snug around neck just below head (left).

male ungulates swell and collars must expand to allow for this swelling. Collars made with nylon elastic will allow expansion of the collar. Collars for fawns may be made entirely of folded nylon elastic with folds stitched together with thread that breaks with pressure of neck growth and allows the collar to expand with the growing animal (Fig 3).

Silvy (1975) developed Boltaron (thermal plastic) expandable collars (Fig. 4) for male white-tailed deer that were 7.4 cm wide and made to fit the neck contours of deer of each gender in each age class. The open ends of the "U"-shaped collars for female deer were riveted (brass split rivets) and no elastic straps were used (Fig. 5). Collars for male deer had elastic straps on the inside that were attached by rivets at the bottom of the "U". Straps passed through brass welding rod guides embedded in the open ends of the plastic collar permitted expansion and contraction. Because the weight of a radio package was on the elastic straps in the "U"-shaped collars, the rubber in the elastic straps degraded over time and the collars sagged. This problem was solved by design of a "C"-shaped collar with ends overlapping at the side of the neck with elastic bands to resist expansion that completely opened the "C". This allowed the weight of the collar and radio to be supported by the Boltaron and not by the elastic. Once a male's neck returned to normal size after the rut, the Boltaron collar returned to its normal shape and reduced tension on the elastic straps. Collars were of 2 thicknesses (0.2 or 0.3 cm Boltaron) and of 2 colors (black or white). Various colors of scotch-lite reflective tape in the form of numbers, letters, or other symbols were attached to collars for ready identification of deer during both day and night. Radios were mounted (using dental acrylic) on, and antennas were either stainless-steel whips or copper wire embedded in the Boltaron collar. Stainless-steel whips tended to break due to salt-water etching; this was not a problem with embedded copper wire antennas.

Typically, collars are highly visible, but their longevity depends on the material used, climate, and behavior and gender of the animal involved. Most studies report either no or insignificant adverse effects of neck collars on breeding-related activities, social behavior, and physical damage beyond minor hair or feather wear and irritation. Neck collars on birds (Fig. 6), however, have been observed to disrupt pair bonds, lower success in agonistic encounters, contribute to starvation, and increase mortality through severe icing. Icing is not a problem with aluminum neck-collars, probably due to their conductive properties.

Fig. 3. Elastic (expandable) radio collar on white-tailed deer fawn.

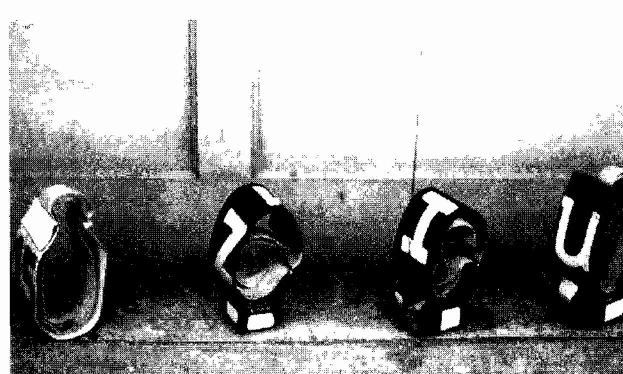

Fig. 4. Expandable neck collars for male ungulates.

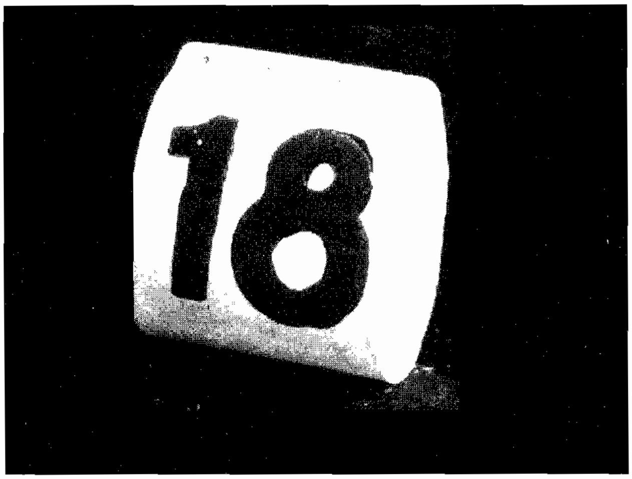

Fig. 5. Non-expandable female ungulate neck collar with holes for brass-split rivets.

Bands

Metal bands (Fig. 7) bearing an identification number and return address are the oldest and most common method of marking wild birds (Table 4). Although states and provinces are required to use their own bands for resident game birds, the U.S. Fish and Wildlife Service and the Canadian Wildlife Service issue bands for migratory birds. Aluminum bands are sufficient for marking many species, but are easily damaged by abrasion and corrosion. As a result, monel, incoloy, stainless steel, and titanium bands sometimes are used for long-lived and marine birds.

Colored bands made from plastic or other materials have been used alone or in conjunction with metal bands (Fig. 8) to mark individuals of a variety of species (Table 4). Colored bands are primarily intended to permit rapid identification of individuals without requiring recapture. Color bands deteriorate relatively quickly and are best for short-term studies. Soft plastic, wrap-around bands have the lowest durability and color retention (Anderson 1981), which is somewhat greater in laminated wrap-around bands (Lumsden et al. 1977, Anderson 1981). Retention is higher in wide versus narrow plastic bands. Painted bands are of limited use because abrasion or paint removal by birds results in rapid marker loss (Childs 1952).

Fig. 6. Plastic neck collar on tundra swan.

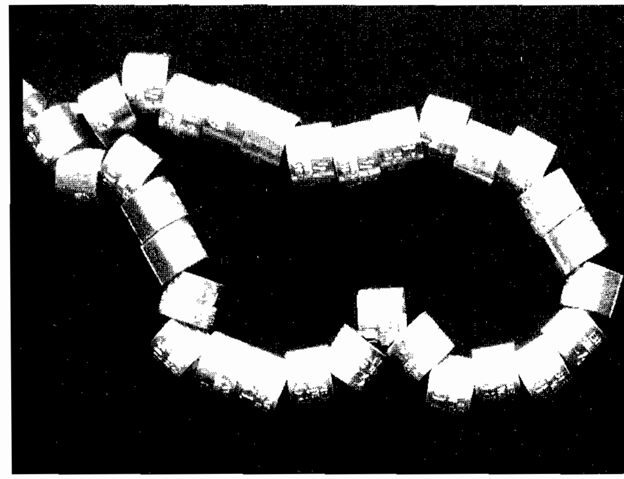

Fig. 7. Standard butt-end bands used on the legs of birds.

Arm and Wing Bands

The attachment of bands to the forearms has been the most widely used technique for marking bats and penguins (Table 4). Flipper bands, made initially of aluminum and more recently from monel metal and stainless steel, have been used on penguins. Several markers are available for bats, including serially-numbered metal bands, color-anodized aluminum bands, numbered and unnumbered colored plastic bands, and celluloid rings. In bats, injuries caused by bands often result due to motion of the forearms during flight. Celluloid rings produce fewer injuries. Bands attached to the bat's back legs are not effective markers due to band loss.

Leg Bands

The butt-end or split ring metal band is widely used for most avian species (Table 4). Lock-on bands are used on raptors and other birds capable of removing butt-end bands. Rivet bands are used for eagles, which are capable of removing both butt-end and lock-on bands. Close-ring bands often are used to mark birds raised in captivity.

Bands should fit properly, allowing movement, and young birds may be ringed with the aid of wax or other materials that yield with growth. Morrow et al. (1987) developed equipment to return nestlings to their tree nest following flushing and banding. Birds can mutilate and

Fig. 8. Butt-end aluminum band (right leg) and colored plastic band (left leg) placed on greater prairie-chicken.

Table 4. Bands used on arms, wings, tails, and legs to mark wildlife[a].

Group/Species	Materials and comments	Citations
Amphibians & Reptiles		
Frogs	Butt-end bird bands on toes	Kaplan 1958
Bullfrog	Plastic waist bands	Emlen 1968
Lizards	Colored metal rings around thigh	Subba Rao and Rajabai 1972
Racerunners	Colored plastic bands glued to tails	Paulissen 1986
Anurans	Waist bands	Rice and Taylor 1993
Birds		
Passerines, terns, doves, pheasants, grouse, vultures, parakeets, geese, parrots, and swallows	Butt-end metal bands	Young 1941; Wandell 1943, 1945; Elmes 1955; Dunbar 1959; MacDonald 1961; Kaczynski and Kiel 1963; Hamerstrom and Mattson 1964; Henckel 1976; Burtt and Tuttle 1983; Hatch and Nisbet 1983*a*, *b*; Nisbet and Hatch 1983, 1985; Bailey et al. 1987; Marestrom et al. 1989; Meyers 1994; Powell et al. 2000; Menu et al. 2001
Penguins	Flipper bands of aluminum, Teflon, monel metal, and stainless steel	Sladen 1952, Penny and Sladen 1966, Cooper and Morant 1981, Sallaberry and Valencia 1985
Waterfowl	Plexiglass, butt-end leg bands	Balham and Elder 1953
Doves and waterfowl	Reward bands give higher reporting rates	Bellrose 1955, Tomlinson 1968, Henny and Burnham 1976, Nichols et al. 1991, Reinecke et al. 1992
Raptors	Butt-end and lock-on (can only be removed by eagles) leg bands	Berger and Mueller 1960, Environment Canada 1984, Robson 1986, Young and Kochert 1987
House sparrows	Colored tape around metal leg bands	Gullion 1965*a*
Finches and grouse	Colored anodized and aluminum butt-end leg bands	Gullion 1965*b*, Cohen 1969, Godfrey 1975, Stedman 1990
Small birds	Nylon wing tag fastened with a strap around the humerus	Hewitt and Austin-Smith 1966
Captive birds	Close-ring leg bands put on nestlings	Cohen 1969, Godfrey 1975
Finches, geese, oyster-catchers, loons, cranes, woodpeckers, juncos, owls, blackbirds, magpies, & goldfinches	Colored leg bands can affect mate selection, sex ratio of surviving offspring, and longevity	Marin 1963; Ogilvie 1972; Wheeler and Lewis 1972; Reese 1980; Burley 1982; Burley et al. 1982; Goss-Custard et al. 1982; Forsman 1983; Seguin and Cooke 1983; Burley 1985; Hoffman 1985; Burley 1986*a*, *b*; Ratcliffe and Boag 1987; Strong et al. 1987; Burley 1988; Hagan and Reed 1988; Cristol et al. 1992; Metz and Weatherhead 1993; Forsman et al. 1996; Watt 2001
Gulls	Butt-end, color leg bands, and rings	Mills 1972, Kadlec 1975, Spear 1980, Ottaway et al. 1984, Shedden et al. 1985
Raptors, ravens, and woodcock	Color fabric wrapped around wing	Kochert 1973, Morgenweck and Marshall 1977, Kochert et al. 1983
Ducklings	Florist's wax or plasticine filled leg bands	Spencer 1978; Blums et al. 1994, 1999
Seabirds and sandpipers	Butt-end and color leg bands; banding tibia rather than tarsus increases longevity and legibility	Anderson 1980, Perdeck and Wassenaar 1981, Zmud 1985, Colclough and Ross 1987, Reed and Oring 1993, Bart et al. 2001
Mammals		
Bats	Bands cause injuries and neonates need room to grow; best attached to forearm as bands are ineffective if attached to hind leg or pollex; do not band during hibernation as populations decline	Davis 1963*b*, Perry and Beckett 1966, Cockrum 1969, Bonaccorso and Smythe 1972, Bateman and Vaughan 1974, Bonaccorso et al. 1976, Bradbury 1977, LaVal et al. 1977, Morrison 1978, Stebbings 1978, Keen and Hitchcock 1980, Hooper 1983, Moran 1985, Phillips 1985, Racey and Swift 1985, Bell et al. 1986, Barclay and Bell 1988
Small rodents	Leg rings	Fullagar and Jewell 1965
Elephants	Plastic tail collar	Viljoen 1986

[a] Scientific names are in the Appendix.

remove bands, and loss of bands has occurred from nestlings. The main causes of loss of leg bands, however, are abrasion and corrosion from saltwater and feces. Vultures, which excrete down their legs, should not be leg banded as excrement loading of the band can lead to loss of the leg or foot. Ice build-up on banded passerines in

Box 1. Shrinkage of spiral plastic leg bands result in leg damage to mourning doves.

Recaptures of mourning doves banded with spiral plastic leg bands revealed these bands were constricting and resulting in loss or severe damage to the legs (Atherton et al. 1982). Band color and temperature affected band shrinkage. Dark colored bands experienced greater shrinkage than light colored bands. Higher temperatures caused bands to shrink more than bands kept at low temperatures. Acetone-treated bands fused coils of the band together to help prevent shrinkage. Birds with "fleshy" legs such as doves and pigeons should have spiral plastic leg bands treated with acetone prior to the birds being released.

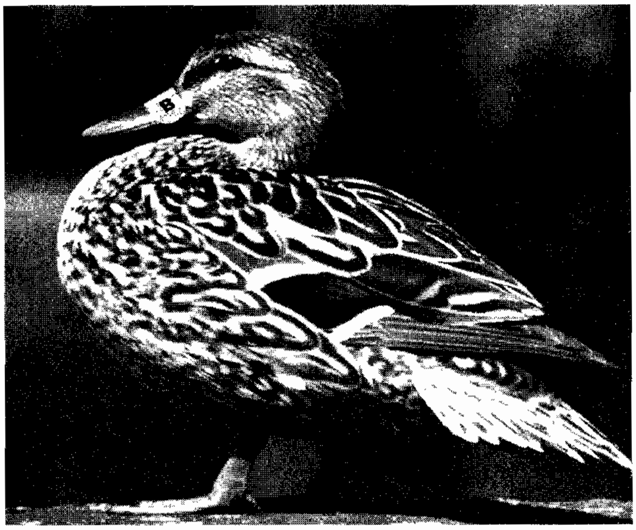

Fig. 9. Nasal saddle on the bill of a female mallard.

cold climates also may cause impairment of leg movement or leg loss. Colored plastic bands have caused severe leg abrasions (Reed 1953), band constriction has amputated legs (Atherton et al. 1982) (Box 1), and band displacement can cause crippling in web-footed species. Leg-band loss can lead to inflated mortality estimates and errors in estimations of population size, especially for long-lived species (Nelson et al. 1980).

Nasal Discs and Saddles

Nasal discs and saddles (Fig. 9) have been used extensively to mark waterfowl (Table 5). Nasal tags are generally made from rigid or flexible plastic or nylon, marked with patterns or numbers, and attached by a short nylon or stainless steel pin through the nares. Discs may snag on vegetation and tangle in nets during trapping and probably increase mortality of diving ducks (Table 5). Nasal saddles that properly fit the size and shape of the bill of particular waterfowl species reduce such hazards. Entanglement in fences and traps has resulted in tag loss and icing on nasal saddles may increase mortality.

Backpacks, Harnesses, and Ponchos

Markers designed to lie on the back have been used frequently to mark upland game birds, waterfowl, and other birds (Table 6). Backpacks (Fig. 10) generally are made from flexible plastics or plastic-coated nylon fabric and are attached by a leather or nylon cord harness that passes around each wing base. Nylon straps last longer than those of leather. Backpack markers also have been modified into ponchos. Back tagging typically is considered too cumbersome for small birds, but a backpack marker that protruded from the bird's back, making it more visible, has been used to mark starling-sized birds. Numbered plastic circles glued to the back of birds as small as hummingbirds have been used, but are lost during molt. Rope harnesses have been used to individually mark large mammals (Table 6).

Trailing Devices

Trailing devices have been used to study movements of amphibians and reptiles with limited movement (Table 7). These devices usually consist of a freewheeling bobbin or spool holding thread or light string attached to an animal's body. In some aquatic situations, lines with floats are attached directly to the animal. Bobbins have been glued to an elastic band secured around the animal, or in the case of turtles, attached to the carapace with waterproof tape. To study movements, one end of the line is secured to a stake at the point of capture and, as the animal moves, the trailing thread is released along the route of movement. Usefulness of the device depends on the amount of thread the bobbin or spool can hold and the speed and distance moved by the animal. The bulkiness of these devices can interfere with normal movement patterns and the waistband attachment can cause skin irritation. These devices have been used to study movement patterns both in terrestrial and aquatic systems, and to locate belowground depth of animals at night.

Table 5. Nasal discs and saddles used to mark waterfowl.

Tag type/Group	Comments	Citations
Nasal discs		
Waterfowl	Snagged on vegetation and tangled in nets used to trap ducks; tag loss high on geese	Bartonek and Dane 1964, Sherwood 1966
Nasal saddles		
Waterfowl	Less tangling than nasal discs, but icing may increase mortality; fewer lost when saddles are sized to shape of bill; problems with small ducks due to large size of saddles and shape of duck bill and nares	Sugden and Poston 1968, Doty and Greenwood 1974, Greenwood and Bair 1974, Joyner 1975, Greenwood 1977, Koob 1981, Davey and Fullagar 1985, Lokemoen and Sharp 1985, Evrard 1986, Byers 1987

Table 6. Backpacks, harnesses, and ponchos used to mark birds and mammals[a].

Group/Mark type/Species	Comments	Citations
Birds		
Backpacks with straps		
Gray partridge, grouse, and pheasant	Leather retained up to 1 year	Blank and Ash 1956, Gullion et al. 1962, Labisky and Mann 1962, Boag et al. 1973
American coot	Leather retained 1 year	Anderson 1963
Small birds	Cumbersome for small birds	Hester 1963, Furrer 1979
Bald eagles, falcons	Could be seen from long distance	Southern 1964, Kenward et al. 2001
Backpacks glued on back		
Gull chicks	Circular numbered tag to synsacrum	Cuthbert and Southern 1975
Hummingbirds	Glued back tags	Baltosser 1978
Ponchos		
Grouse, partridges, and pheasant	Back tag modified into ponchos	Pyrah 1970, Marestrom et al. 1989
Mammals		
Harnesses		
Peccaries and deer	Braided rope harness	Bigler 1966

[a] Scientific names are in the Appendix.

Nocturnal Tracking Lights

Light sources attached to animals allow them to be visually tracked at night, providing information on movements and foraging behavior. Chemical and radioactive lights can be used alone or in conjunction with radio telemetry (Table 8). Evidence suggests that use of optical light sources does not increase predation of marked individuals or adversely affect their behavior, although this potential exists. Conversely, marked predators might have less success capturing prey and a constant light source may cause undue stress in bats.

Cyalume, a chemical light source, has been used to monitor the activity of wildlife (Table 8). The light was obtained by mixing dibutyl phthalate and dimethyl phthalate liquids and sealing the mixture in small, clear spheres that were glued to animals. Varying the proportions of this mixture controls the brightness and duration of light emission. Battery-operated "pin lights" and neon lights have been used for nocturnal observations of mammals (Table 8). Light intensity or blinking sequence can be varied on neon lights for individual-animal identification.

Fig. 10. Northern goshawk with backpack tag.

A light-emitting diode (LED) and flasher have been used to track wildlife at night (Table 8). The device produced consistently timed flashes that could be used for individual identification. A similar system with individually programmable flashes, a light-sensitive flasher, and optional attachment of a radio transmitter to the same circuit was later developed. Battery size and light source intensity influenced the lifespan and visibility of the marker. Use of binoculars or night vision scopes greatly increased the distance at which these markers could be seen.

Betalights are a radioactive light source consisting of phosphor excited by tritium gas in glass capsules. The capsules can be produced in any shape and size with different colors. The useful range varies from about 50 m to 1 km depending on shape, size, and viewing method. The lifespan of Betalights is about 15–20 years. Acceptable radiation levels should be considered when these light sources are used. Colors at different intensities can be used to increase the number of individuals identifiable. Betalights have been used on crabs (Wolcott 1977), birds, and mammals (Table 8). For birds, the most effective location for the Betalight was on a radio antenna away from the bird's body. Betalights did not increase mortality of radio-marked boreal owls, although hunting success could be affected.

Tapes, Streamers, and Bells

Tapes, streamers, and bells have been applied to animals to make them more readily detectable within the natural environment. Fluorescent tapes and bells also allow the animal to be detected and located more easily at night. The effect of these methods on animal survival requires further study.

Table 7. Trailing devices applied to amphibians and reptiles[a] to follow movements.

Group/Species	Materials	Comments	Citations
Box turtle	Wooden spool and thread with housing	Attached to carapace with waterproof adhesive tape	Stickel 1950
Northern leopard frogs >60 mm	Glued bobbin to elastic band around waist with stake to mark point of capture with sewing thread tied to it	50 m of thread lasted from 1 hr to 7 days; weighed 8.5 g; shortened jumping ability and had difficulty swimming and entering crevices, waistband caused skin irritation	Dole 1965, Grubb 1970
Tiger salamander	Sutured numbered plastic float through tail with monofilament line	Line sufficiently long to allow individual to move through the deepest part of lake	Whitford and Massey 1970
Box turtle	Thread trailer and radio transmitter	Attached to carapace	Lemkau 1970
Box turtle	35-mm film canisters to hold wooden spool and thread	Attached to caudal end of carapace, avoided interference with mating	Reagan 1974
Green sea turtles	Fiberglass-coated floats attached to 24-m lines; 3-v flashlight bulb powered by batteries attached to float; fiberglass mast topped by orange pennant	No adverse effects reported	Carr et al. 1974
Lizards	Small piece of foil attached to 30-cm light string around lower abdomen	Allowed measurements of subterranean depth of lizards at night, located buried lizards for body temperature readings	Deavers 1972, Judd 1975
Turtles	Low-friction thread-release mechanism	Similar to spincast fishing reels	Scott and Dobie 1980

[a] Scientific names are in the Appendix.

Tapes

Colored tapes have been used to improve band retention and field recognition of birds (Table 9). Colored fabric, rip-stop nylon, and reflective tape with or without coded numbers have been used to mark other animals. Highly reflective plastic tape strips and plastic-covered tape with coded numbers were glued to the head of bats as temporary individual markers. Colored plastic adhesive tape was used as a durable visual marker on the horns of mountain sheep and as a short-term marker on the quills of porcupines. Labels on colored plastic tape have been used to mark individual eggs in bird nests. The tape label was firmly applied to the egg near the apex, and a different color or color combination was used for each egg laid within a clutch. These markers were not lost prior to hatching.

Streamers

Many types of streamers (Fig. 11) and flags made from materials such as fluorescent plastic, polypropylene, polyurethane, hypalon, orthoplast, nylon-coated vinyl, and vinyl tubing have been used to visibly mark wild animals (Table 9). Nylon-coated fabric streamers were retained for several months to years. Different lengths and color codes provided a means of individual identification at a distance. Streamers often are attached to plastic or metal tags or collars to increase animal visibility.

Table 8. Nocturnal light sources for tracking wildlife[a].

Group/Species	Light source	Comments	Citations
Birds			
Black skimmer	Cyalume or light-emitting diodes	Sealed plastic bulb on back	Clayton et al. 1978
Long-eared owl	Light-emitting diodes	Studied nest behavior	DeLong 1982
Boreal owl	Betalights	On radio antennas	Hayward 1987
Mammals			
Bats	Pin light with battery	Glued to fur	Barbour and Davis 1969
Bats	Cyalume	Glass spheres glued to fur	Buchler 1976, LaVal et al. 1977
Mule deer	Neon light with battery	Neck collars	Carpenter et al. 1977
E. Badger	Betalights	On radio transmitters	Kruuk 1978
Am. Beaver	Light-emitting diodes	Neck collars	Brooks and Dodge 1978
Rabbits	Betalights	Attached to ear tags	Davey et al. 1980
Wallabies	Light-emitting diodes	Neck collars	Batchelor and McMillan 1980
Rodents	Betalights	Glued on head	Thompson 1982
Bats	Cyalume in gelatin capsule tag and lightsticks tag	Miniature lightsticks provided equal or superior results	Hovorka et al. 1996

[a] Scientific names are in the Appendix.

Bells

Bells have been used in conjunction with other individual marking methods (e.g., color-coded ear tags and collars) to facilitate locating and monitoring movements of deer, collared peccaries (Fig. 12), and green iguanas (Table 9). Periods of auditory observation of peccaries provided movement data comparable to those gained from telemetry and allowed activity patterns and habitat use of the animal to be identified. Bells, however, could attract predators.

External Color Marks

Dyes, fluorescent pigments, bleaching, inks, and paints have been used as short-term external markers to identify wildlife at a distance (Table 10). No adverse physiological effects have been reported for these markers when properly applied on mammals. For birds, no obvious behavioral changes were noted other than temporarily increased preening. Certain markings could disrupt pair bonding, however, and altered intraspecific recognition mechanisms in birds may severely alter social interactions (Rohwer 1977).

Dyes

Waterproof dyes should yield an easily recognizable

Table 9. Tapes, streamers, and bells applied to wildlife[a] for individual or group identification.

Group/Species	Materials	Comments	Citations
Amphibians & Reptiles			
Am. alligator	Flexible chain or plastic strip attached to anchor tag	Beneath skin on side of tail, slow healing	Chabreck 1965
Bullfrog	Nylon waistbands painted with black numerals	Recognizable up to 8-12 months with binoculars	Emlen 1968
Iguanas/lizards	Colored Mystik cloth tape	Around neck	Minnich and Shoemaker 1970
Green iguana	Bells on fishing line	Around neck	Henderson 1974
Spotted turtle	Adhesive with numbers	On carapace	Ward et al. 1976
Amphibians & lizards	Colored beads	Around neck	Nace and Manders 1982, Fisher and Muth 1989
Skink	Pressure sensitive tape	Around neck	Zwickel and Allison 1983
Bullfrog	Reflective tape	Cemented to head	Robertson 1984
Birds			
Pheasants	Plastic streamers, tags	Attached to tail feathers, neck	Trippensee 1941, Taber 1949
Stilt, grackle, gull, and heron nestlings	Plasticized PVC tape	Attached to leg	Downing and Marshall 1959, Carrick and Murray 1970, Willsteed and Fetterolf 1986
Wild turkey, blackbirds, gulls, waterfowl, and raptors	Leg streamers	Attached on leg through slits in the marker or to bands	Campbell 1960, Fankhauser 1964, Thomas and Marburger 1964, Guarino 1968, Arnold and Coon 1971, Royall et al. 1974, Frentress 1976, Platt 1980, Cline and Clark 1981
Gull eggs	Colored plastic tape	Attached to apex of egg	Hayward 1982
Mammals			
Deer and collared peccary	Bells	Used to observe behavior	Jordan 1958, Gruell and Papez 1963, Ellisor and Harwell 1969, Schneegas and Franklin 1972
Gray squirrel	Plasticized PVC tape	Attached around neck with slot and notch system	Downing and Marshall 1959
Ungulates	Colored streamers of plastic, nylon, and nylon-coated fabrics (Herculite, Saflag, or Annortite), and plastic ear pennants	Attached to ears, horns, Achilles tendons, or to other marking devices; some reluctance of does to accept tagged fawns, but survival similar to nontagged fawns	Knowlton et al. 1964, Harper and Lightfoot 1966, Miller and Robertson 1967, Queal and Hlavachick 1968, Downing and McGinnes 1969, Jonkel et al. 1975, Ozoga and Clute 1988, Panagis and Stander 1989
Bats	Reflective plastic tape strips with numbers	Glued to head fur, temporary markers	Williams et al. 1966, Daan 1969
Polar bear	Colored flagging tape	Ear marker	Lentfer 1968
Cetaceans	Streamers and flags	Secured with steel barbs, nylon darts, umbrella anchors, and anchor rivets	Evans et al. 1972, Mitchell and Kozicki 1975, White et al. 1981
Mountain sheep	Colored adhesive tape	On horns	Day 1973
Porcupine	Colored tape or flags	On the quills or radios	Pigozzi 1988, Griesemer et al. 1999

[a] Scientific names are in the Appendix.

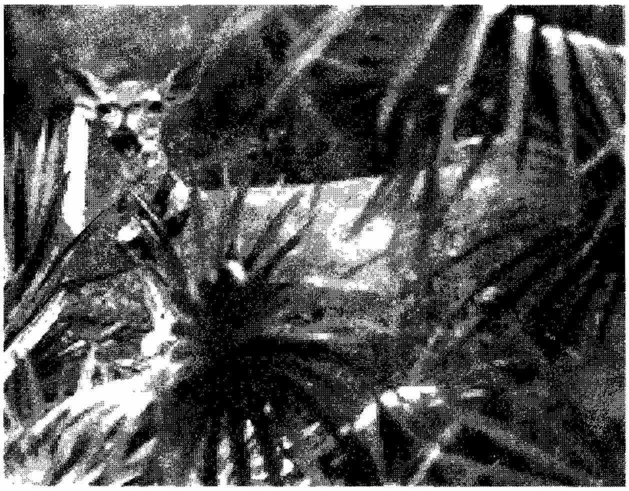

Fig. 11. Neck collar and ear streamer on white-tailed deer.

Fig. 13. Colored dye being applied with brush to the white portion of a white-winged dove wing.

color, resist fading, and be nontoxic, harmless to plumage, capable of use with a wetting agent or solvent to ensure quick penetration and coverage, and fast acting in a cool solution (Patterson 1978). Picric acid, Rhodamine B Extra, and Malachite Green yield strong color and exhibit good penetration and retention (Handel and Gill 1983). Avian species with light plumage are most effectively marked with dyes. Dipping, brushing (Fig. 13), and spraying have been used to apply dyes. To avoid hypothermia in cool weather, dye-marked birds should be thoroughly dried before release.

Bleaching

Bird feathers and mammal furs have been bleached and colored using human hair dyes or lighteners mixed with hydrogen peroxide (Table 10). Skin and feather damage can occur if tissues are bleached at too high a temperature or for too long a period. Animals also may be susceptible to hypo- and hyperthermia during the bleaching process.

Fluorescent Pigments

Trapped animals have been dusted with fluorescent pigments so that a fluorescent trail can be traced using ultraviolet (UV) lamps the following night (Table 10). The amount of vegetation cover, precipitation, and ambient light influenced trail detection. This technique enables collection of detailed information on home range, movement patterns, and habitat within a few days. To increase the duration of this marker beyond the second night, capsules containing pigments can be attached. A promising marker for aquatic mammals is a paste made from fluorescent pigments, vehicle binder, and solvent. It has visibly marked aquatic mammals for up to 2 years with no adverse behavioral effects or tissue abnormalities. Codit white reflective liquid also has been used to mark fresh-water animals.

Fig. 12. Bell attached to collared peccary that allows investigators to follow herd movements.

Inks

Ink has been used to mark salamanders, terrapins, turtle eggs, iguanas, lizards, bird eggs, and deer (R. R. Lopez, unpublished data; Table 10). On deer, ink proved superior to paint for duration and visibility. Marking pens have been used to number eggs within clutches. No harmful effects were observed, but marking pens should be used with discretion until possible embryo toxic effects are evaluated.

Paints

Liquid and spray paints usually are applied to the skin, pelage, horns, or feathers (Table 10) and persist for a few weeks to several months. Individuals must be repainted, as paint is lost due to shedding, molting, and grooming. How these marks influence the behavior of species for which colors have seasonal social significance is unknown. Paints should be dry before animals are released.

INVASIVE MARKING TECHNIQUES

Internal Markers

Chemical, particle, and radioactive markers have been injected or fed animals to either physical mark individual animals or groups of animals (some chemical markers) or to detect byproducts from marked individuals (fecal markers). These methods require animals to be captured prior to marking.

Table 10. Dyes, paints, stains, pigments, ink, and bleaches used to externally mark wildlife [a].

Group/Species	Materials	Comments	Citations
Amphibians & Reptiles			
Tortoises, turtles, and snakes	Colored paints	On carapace of tortoises and on rattles or head of snakes	Woodbury and Hardy 1948, Pough 1966, Bennett et al. 1970, Bayless 1975, Medica et al. 1975, Bennion and Parker 1976, Parker 1976, Brown et al. 1984
Terrapins	Ink	Injected into skin	Burger and Montevecchi 1975, Burger 1976
Frogs and tadpoles	Neutral red, whole-body dye	Some immediate deaths and affected growth	Herreid and Kinney 1966, Guttman and Creasey 1973, Travis 1981
Lizards	Paints/indelible pencil/felt-tipped pen	Lost with shedding; survival same as toe clipping	Tinkle 1967, Jenssen 1970, Stebbins and Cohen 1973, Tinkle 1973, Henderson 1974, Vinegar 1975, Fox 1978, Jones and Ferguson 1980, Simon and Bissinger 1983
Salamanders	Fluorescent pigments	Good for short-term studies	Taylor and Deegan 1982, Nishikawa and Service 1988, Ireland 1991
Frogs and toads	Panjet dye	Lasted up to 2 years	Brown 1997
Juvenile frogs	Tetracycline bath	Failed as marker	Hatfield et al. 2001
Birds			
Small birds, ducks, gulls, pheasants, eagles, swifts, terns, geese, swans, and blackbirds	Dyes	Visibility up to 2 km	Butts 1930, Price 1931, Wadkins 1948, Jones 1950, Winston 1955, Kozlik et al. 1959, Ellis and Ellis 1975, White et al. 1980, Malacarne and Griffa 1987, Underhill and Hofmeyer 1987, Paullin and Kridler 1988, Belant and Seamans 1993
Ruffed grouse, cattle egrets, and bird eggs	Printer's ink	Lasted up to 12 months for cattle egrets with no harmful effects to eggs	Bendell and Fowle 1950, Boss 1963, Siegfried 1971, Olsen et al. 1982
Mourning dove and northern cardinals	Model airplane paint and spray paints	Preening resulted in feather loss; pair-bond disturbance	Swank 1952, Frankel and Baskett 1963, Goforth and Baskett 1965, Dickson et al. 1982
Mammals			
Squirrels, deer, terrestrial mammals, and pinnipeds	Dyes (Gentian violet, Biebrich scarlet, picric acid, Nyanzol A, Rhodamine B, Woollite, clothing and aniline, and human hair dyes with peroxide or hair bleach)	Ear tags and toe clipping best for long-term marking	Baumgartner 1940, Fitzwater 1943, Webb 1943, Hansen 1964, Simmons 1971, Day 1973, Brady and Pelton 1976, Bradbury 1977, Gentry 1979, Pitcher 1979, Johnson et al. 1981, Gentry and Holt 1982, Henderson and Johanos 1988, Hurst 1988
African elephant, bovids, bats, antelopes, and aquatic mammals	Paints, paint-sticks, and spray paints	Applied to hide, horns, or pelage; must remain dry for 15-30 minutes	Pienaar et al. 1966, Hanks 1969, Watkins and Schevill 1976, Gentry and Holt 1982, Clausen et al. 1984, Irvine and Scott 1984, McCracken 1984
Seals and small mammals	Fluorescent pigments	Adequate for <2 years for seals and small mammals dusted after trapping; trail followed with UV lamps	Griben et al. 1984, Lemen and Freeman 1985, Boonstra and Craine 1986, Dickman 1988, Mullican 1988, Mikesic and Drickhamer 1992, Stapp et al. 1994
Woodrat, rats, and pangolin	Capsule containing fluorescent dust	Long-term tracking and trail deposition	Goodyear 1989

[a] Scientific names are in the Appendix.

Chemical Markers

Organic stains placed in the tail-fin cavity or caudal region with a hypodermic needle have been developed as a reasonably permanent marker for amphibians (Table 11). During metamorphosis, the mark was reabsorbed with the tail with no ill effects.

Table 11. Internal particle and chemical markers used to study wildlife [a].

Group/Species	Materials	Comments	Citations
Amphibians & Reptiles			
Salamanders	2:1 Liquitex acrylic polymer to distilled water	Injected into the lateral, proximal, caudal region	Woolley 1973
Salamander larvae	Fine grained fluorescent pigments mixed as paste	Administered with heated probe; short-term tag	Ireland 1973
Frog and salamander larvae	21:20 ratio of mineral oil to petroleum jelly and stains (Oil Red A and Oil Blue M)	Tail fin cavity with a 22-gauge hypodermic needle, no effect on animals	Seale and Boraas 1974
Birds			
Duck and passerine eggs	Food dyes	Injected into egg; hatched young marked for few days	Evans 1951, Rotterman and Monnett 1984
Bait-consuming birds, raptors	Microtaggants (small, color-coded plastic particles)	Fed in baits	Johns and Thompson 1979, Nietfeld et al. 1994
Bait-consumers	Iophenoxic acid and Mirex	Iophenoxic acid ineffective	Larson et al. 1981
Waterfowl	Tetracycline	Injected; detected in eggs; egg-laying rate decreased	Haramis et al. 1983, Eadie et al. 1987
Mammals			
Small mammals	Dyes in food	To mark fat, teeth, pelage, and feces Observed in urine on snow	New 1958, 1959; Kindel 1960; Nass and Hood 1969
Cottontail rabbits	Dye pellets placed under skin	Fed in baits; more intense in mandible and teeth and in young animals	Brown 1961
Coyote, rodents, skunks, raccoon, seals, dolphins, whales, bears, and white-tailed deer	Tetracycline group	Force-fed beads	Owen 1961, Yagi et al. 1963, Linhart and Kennelly 1967, Crier 1970, Nelson and Linder 1972, Best 1976, Geraci et al. 1986, Garshelis and Visser 1997, Taylor and Lee 1994, Van Brackle et al. 1994
Collared peccary	Glass beads	Accuracy with field ID	Sowls and Minnamon 1963
Ground squirrels	Nyanzol A and D fur dyes	Picric acid worked best	Melchior and Iwen 1965
Snowshoe hares	Picric acid and Rhodamine B	Fecal tracer; for <30 days	Keith et al. 1968
Nutria	Codit white reflective liquid	Fecal tracer	Evans et al. 1971
Nutria	Powered aluminum pigment	Stained fat deposits	Evans et al. 1971
Rats and rabbits	Sudan black, orally	Fecal tracer	Taylor and Quy 1973, Cowan et al. 1984
Rabbits and Virginia opossum	Rhodamine B	Fed in baits	Evans and Griffith 1973; Morgan 1981; Cowan et al. 1984, 1987
Bait consuming mammals	Fluorescent acetate floss fibers	Systemic marker, produces fluorescent banding of claws and hair	Randolph 1973, Johns and Thompson 1979, Cowan et al. 1984
Coyote, gophers, and mountain beaver	Rhodamine B	Fluorescent in blood	Ellenton and Johnston 1975, Johns and Pan 1981, Lindsey 1983
Rats	Quinacrine dehydrochloride	Fed in baits	Johns and Pan 1981
Bait-consumers	Microtaggants	Fed with bait	Johns and Thompson 1979
Dogs and foxes	Iophenoxic acid	Fed with bait	Baer et al. 1985, Follmann et al. 1987
Coyote	Chlorinated benzenes		Johnson et al. 1998

[a] Scientific names are in the Appendix.

Rhodamine B taken orally acts as an internal marker, coloring the gall bladder, gut, feces, urine, and oral and urogenital openings producing fluorescent banding of feathers in birds (Table 11). These bands were most evident in primary and secondary feathers. Rhodamine B may become visible within 24 hours of dosing and persist for several weeks. Scanning for fluorescence using portable UV lamps allows trapped animals to be examined and released immediately, thus, reducing stress. Use of Rhodamine B as a systemic marker may be limited to certain periods of the year in birds, because banding probably occurs only in actively growing tissue. Rhodamine B has been used to detect bait consumption, density estimation, and examination of movements. Fisher (1999) summarized the literature on Rhodamine B and concluded the long-term effects of a single dose and the short succession of low dose on live animals should be investigated. She recommended Rhodamine WT as an alternative systemic bait marker.

Certain members of the tetracycline family of antibiotics, given orally or intravenously, combine with calcium in bones and teeth of mammals and eggshells of birds to produce a characteristic yellow fluorescence under UV light (Table 11). Tetracyclines are persistent, quantitative markers that can cross the placental barrier. They have been used to obtain mark-recapture population estimates and to identify the percentage of predators that consumed baits.

Quinacrine dehydrochloride, a fluorescent chemical marker, can be detected in blood with fluorometric and chromatographic analytical techniques (Table 11). Iophenoxic acid, an iodine-containing compound, and mirex, an organochlorine pesticide, have been used as blood and tissue markers for bait-consuming birds and mammals. Codit white-reflective liquid and Sudan black also are satisfactory fecal tracers for most mammals.

Particle Markers

Microtaggants, small plastic particles that are coded by colored layers, do not cause bait aversion, remain intact and, due to their fluorescent and magnetic properties, can be readily recovered from gut or fecal samples (Table 11). Fibers of fluorescent acetate floss also have been tested for measuring bait consumption by birds and mammals and individual movements in small mammals. As with microtaggants, floss fibers are quantitative, nonpersistent markers. Floss fibers do not affect bait palatability and are more economic than microtaggants. Powdered aluminum placed in baits also has been used as a fecal tracer.

Radioactive Markers

Radioactive tracers have been used to identify and acquire information on behavior of amphibians, reptiles, and mammals but have received little attention for birds. The 3 primary methods of marking animals with radioisotopes are inert implants, external attachments, and metabolizable radio nucleotides (Table 12). Inert implants are suitable for monitoring specific movements, such as nest visits by birds and small mammals, using a manual or automated detector (Griffin 1952, Bailey et al. 1973, Linn 1978). Radioactive wires, pins, and capsules containing isotopes have been inserted subcutaneously in small rodents and bats as inert implants. Radioactive material can be attached to external leg bands and forearm tags, or the bands/tags can be made radioactive. Radioactive material also can be fed, injected, or implanted into the animal in a metabolizable form. These materials may be incorporated into the tissues of the animal, passed on to offspring, or voided in feces and urine; thus, they can be used for many purposes besides tracking (Linn 1978). This approach has been used to estimate population abundance of a number of species.

Table 12. Radioisotopes used for marking wildlife [a].

Group/Species	Radioactive materials	Comments	Citations
Amphibians & Reptiles			
Toads, salamanders, and snakes	Cobalt	Injected	Karlstrom 1957; Breckenridge and Tester 1961; Barbour et al. 1969*a*, *b*; Ashton 1975
Northern fence lizard	Gold	In tubing around waist	O'Brien et al. 1965
Salamanders, turtles, skinks, lizards, and snakes	Tantalum	Injected, local ulceration in salamanders	Bennett et al. 1970, Madison and Shoop 1970, Ward et al. 1976, Ferner 1979
Salamander larvae	Sodium	Injected	Shoop 1971
Birds			
Semipalmated plover	Tantalum	Radioactive-leg bands	Griffin 1952
Ring-necked pheasant	Calcium	ID chicks from fed hens	McCabe and LePage 1958
Mammals			
Voles	Phosphorus	Injected	Miller 1957
Bats & small mammals	Iodine	Injected, capsules on rings, implanted, or fed	Gifford and Griffin 1960, Johanningsmeier and Goodnight 1962
Harvest mice	Gold	Implanted	Kaye 1960
Small mammals	Cobalt	Implanted or in capsule on rings	Linn and Shillito 1960, Barbour 1963, Schnell 1968
Small mammals	Tantalum	Implanted	Graham and Ambrose 1967, Schnell 1968
Small mammals, opossum, rabbits, foxes, E. badger, bobcat, black bear	Zinc	Injected, fed	Nellis et al. 1967, Schnell 1968, Gentry et al. 1971, Pelton and Marcum 1975, Kruuk et al. 1980, Conner 1982
Black bear	Magnesium	Injected	Pelton and Marcum 1975
Small mammals	Sulphur	Passed through mother's milk	Dickman et al. 1983
Rodents	Radionuclides	Mother-offspring relatedness and male reproductive success	Tamarin et al. 1983, Scott and Tan 1985
Raccoon	Cadmium	Injected	Conner and Labisky 1985
Coyotes	Several tested	Implanted	Crabtree et al. 1989

[a] Scientific names are in the Appendix.

Table 13. Passive integrated transponders (PIT) used to mark wildlife [a].

Group/Species	Comments	Citations
Amphibians & Reptiles		
Frogs, toads, alligators, snakes, lizards, turtles, sea turtles	Only 1of 118 PIT tags failed, lasted up to 2 years	Camper and Dixon 1988, Brown 1997
Blunt-nosed leopard lizard	250 of 273 scanned successfully	Germano and Williams 1993
Pine snake	92% retained PIT tags	Elbin and Burger 1994
Neonatal snakes	No effect on growth and movement	Keck 1994
Rattlesnakes	No effect on growth and movement	Jemison et al. 1995
Desert tortoises	Detected as they entered culverts	Boarman et al.1998
Great-crested newt larval stage	Up to 2 years	Cummins and Swan 2000
Birds		
Captive birds	Success varied with species and year	Elbin and Burger 1994
Northern bobwhite chicks	5% lost PIT tags	Carver et al. 1999
Mammals		
Black-footed ferret	6 of 48 failed	Fagerstone and Johns 1987
Sea otter	6 of 6 successfully scanned	Thomas et al. 1987
Big brown bat	17 of 17 successfully scanned	Barnard 1989
Mice	4 of 4 successfully scanned	Rao and Edmondson 1990
Norway rat	10 of 10 successfully scanned	Ball et al. 1991
Ground squirrels	No effect on squirrels	Schooley et al. 1993
Captive mammals	Success varied with species and year	Elbin and Burger 1994
Voles	Used to monitor runways	Harper and Batzili 1996
Naked mole rat	Survival not different from toe-clipped	Braude and Ciszek 1998

[a] Scientific names are in the Appendix.

A major disadvantage of using radioactive markers is the restrictions imposed by state or federal regulations. These tags also can cause illness or death of marked animals, be lost, and constitute a hazard to other animals including humans. When selecting a radioactive marker, one should consider availability, type of radiation, energy levels emitted, physical and biological half-life, toxicity, and metabolic characteristics (Pendleton 1956).

Transponders

Passive integrated transponder (PIT) tags have been developed as permanent markers and tested on amphibians, reptiles, birds, and mammals (Table 13). The tags consist of an electromagnetic coil and a custom-designed transponder chip that emits a uniquely programmed alphanumeric analog signal when excited by a scanning wand that discharges electromagnetic energy. The PIT-tag reader displays the code and can store this information for later retrieval. PIT tags are implanted subcutaneously (Fig. 14) with a special syringe and canula (needle).

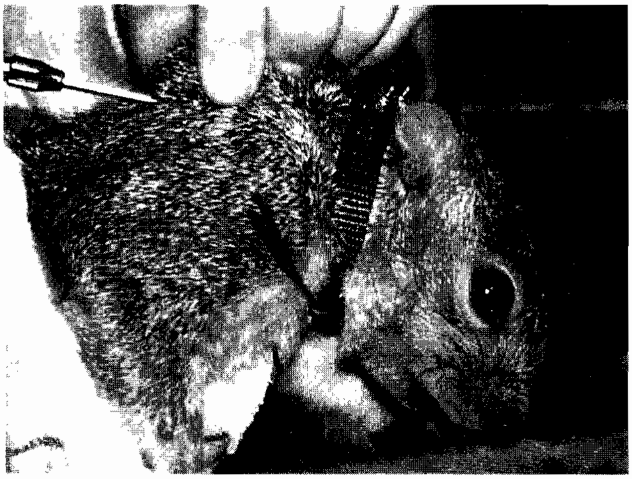

Fig. 14. Implanting a PIT tag into a radio-marked fox squirrel.

No adverse effects of transponders have been observed in animals, but PIT tags are not as permanent as first thought; they can fail and be lost (Box 2). The major dis-

Box 2. Passive integrated transponders (PIT) should not be used as sole device to mark wildlife.

Recent research using PIT tags to mark fox squirrels provided a 17% unsuccessful scan rate after a 3-month period since implantation. Recaptured squirrels also were marked with radio collars. In a separate study on pocket gophers where PIT tags were the only mark used, only 1 of the original 13 pocket gophers marked was ever recaptured in 1 year of trapping. Loss of tags, tag breakage, or trap avoidance by previously trapped gophers were possible explanations for the low recapture rate. However, because both the fox squirrels and pocket gophers were tagged in the nape of the neck and both species used areas (holes is trees or burrows in the ground) that rubbed the nape of the neck, this may have caused PIT tags to be lost or crushed. We recommend that PIT tags not be the sole marking device used to mark wildlife.

Table 14. Wildlife[a] marked using tattoo techniques.

Group/Species	Tattoo location	Comments	Citations
Amphibians & Reptiles			
Snakes	Skin	Method was permanent	Woodbury 1956
Frogs	Skin of the venter	Etched grooves with ink	Kaplan 1958
American alligator	Light skin under tail	Legible for several months	Chabreck 1965
Salamander	Subcutaneous	Fluorescent-elastomer	Davis and Ovaska 2001
Birds			
Nestling starlings	Abdomen	India ink dots using syringe	Ricklefs 1973
Birds of prey	Underside of wing	Captive birds, long lasting	Havelka 1983
Mammals			
Bats	Wing membranes	Slow process	Griffin 1934
Hares and rabbits	Ear	Used Franklin Rotary Tattoo	Thompson and Armour 1954, Keith et al. 1968
Bears	Upper lip, axilla, or groin	Permanent mark	Lentfer 1968, Johnson and Pelton 1980
Deer fawns	Ear	Permanent mark	Downing and McGinnes 1969
Cottontail rabbit	Ear	Permanent mark	Brady and Pelton 1976
Dolphinids	Fin	Proposed only	White et al. 1981
European Badger	Inguinal area	Electrically-powered pen	Cheeseman and Harris 1982
Pere David's deer	Ear	Permanent mark	Carnio and Killmar 1983
Beluga whale	Skin	Unsatisfactory	Geraci et al. 1986
Rats and mice	Ear	Permanent mark	Honma et al. 1986
Marsupial young	Pinnae	Fluorescent pigments	Soderquist and Dickman 1988
Porcupines	Ear	Not necessary with collars	Griesemer et al. 1999
Rodents	Subcutaneous	Chinese ink	Leclercq and Rozenfeld 2001

[a] Scientific names are in the Appendix.

advantage of this system, however, is the reader must be close (few cm) to the animal to record the code, which may necessitate recapturing the animal. Remote readings can be made (Table 13); a reader tube can be inserted into burrows or nesting cavities, or along travel routes, reading the transponder number each time the marked animal passes.

Tattoos

Tattoos provide an efficient means of permanently marking a wide range of species (Table 14). Best results are achieved by tattooing lightly pigmented areas free of hair (inside of ear [Fig. 15], inside legs or arms, lips) or feathers (under wings). Standard or rotary pliers, electric tattooing pencils, and syringes filled with ink have been used to inject contrasting dye (e.g., green or black) (Table 14). Small quantities of fluorescent pigments also have been used to make tattoos that are visible only under UV light. Although tattoos generally cause fewer problems (no added weight, inconspicuous to predators) than other marking techniques, they have the disadvantage of requiring animal recapture for identification. Tattoos often are used with more visible, but less permanent marking methods.

Fig. 15. Numeric characters tattooed on the inside of an ear of a white-tailed deer.

Tags

Tags, as used here, differ from bands in they penetrate some part of the animal's body and generally inflect pain, at least during insertion. With amphibians and reptiles, tags are usually placed through the shell, scutes, fore flipper, scales, tail fin, rattles, or tail (Table 15). In birds, tags generally are placed within the patagium of the wing or the webbing of the foot. Tags typically are placed within the ear, webbing of foot, flipper, or dorsal fin of mammals. Tag loss increases with time since tagging and may result from infection, wear, grooming, or fighting. Bilateral placement of tags and using them in conjunction with more permanent markers (e.g., tattoos) minimizes the chance of losing the identity of an animal over a long period. Study duration and required tag visibility are factors that influence tag choice. Many types of tags require recapturing the animal for identification.

Ear

Tags, manufactured from metals and plastics (Fig. 16) in a variety of shapes, sizes, and colors with identifying numbers stamped into the surface, are commonly used for marking mammals (Table 15). Tag-closing mechanisms can be interlocking, self-locking, or a rivet design that can-

Table 15. Tags used to mark wildlife [a].

Group/Species	Tag type	Citations
Amphibians & Reptiles		
Frogs, toads and snakes	Metal jaw tags	Raney 1940, Stille 1950, Hirth 1966
Frogs and turtles	Bands, rings, and plates fastened through holes in shell	Kaplan 1958, Lonke and Obbard 1977, Graham 1986, Layfield et al. 1988
Am. Alligators	Monel tag to dorsal tail scute	Chabreck 1965
Snakes and turtles	Buttons to caudal musculature	Pough 1970, Froese and Burghardt 1975
Sea turtles	Monel metal and plastic tags in fore flipper	LeBuff and Beatty 1971, Bacon 1973, Pritchard 1976, Bjorndal 1980, Pritchard 1980, Frazer 1983, Balazs 1985, Eckert and Eckert 1989
Rattlesnakes	Colored discs through rattle	Pendlebury 1972, Stark 1984
Turtles	Titanium disks held by adhesive	Gaymer 1973
Hellbender	Floy T-tags	Nickerson and Mays 1973
Turtles	Wooden dowel in scute	Davis and Sartor 1975
Snakes	Colored beads on line	Hudnall 1982
Birds		
Waterfowl	Streamers pinned to head	Gullion 1951
Penguins	Flipper bands made of aluminum, Teflon, monel metal, and stainless steel	Sladen 1952, Penny and Sladen 1966, Cooper and Morant 1981, Sallaberry and Valencia 1985
Am. Woodcock	Plastic neck tag attached with surgical clip	Westfall and Weeden 1956
Waterfowl, turkey, gulls, cranes, coot, willet, vultures, blackbirds, large passerines, woodpeckers, and pigeons	Patagial tag using various materials to attach tag through patagium	Anderson 1963; Knowlton et al. 1964; Mudge and Ferns 1978; Tacha 1979; Bartelt and Rusch 1980; Howe 1980; Wallace et al. 1980; Jackson 1982; Seel et al. 1982; Baker 1983; Curtis et al. 1983; Southern and Southern 1983, 1985; Sweeney et al.1985; Szymczak and Ringelman 1986; Cummings 1987; Hart and Hart 1987
Wood ducks, gull chicks, geese, and ducklings in eggs	Fingerling fish tags attached to foot web through hole in egg	Grice and Rogers 1965; Alliston 1975; Haramis and Nice 1980; Ryder and Ryder 1981; Seguin and Cooke 1985; Blums et al. 1994, 1999
Mammals		
Bats	Fingerling ear tags	Mohr 1934, Stebbings 1978
Rabbits, squirrels, sea lions, deer, caribou, fox, goats, seals, bears, mice, coyote, beaver, elk, porcupine, and moose calves	Plastic or metal ear tag with and without streamers	Trippensee 1941, Scheffer 1950, Tyndale-Briscoe 1953, Labisky and Lord 1959, Craighead and Stockstad 1960, Knowlton et al. 1964, Miller 1964, Harper and Lightfoot 1966, Miller and Robertson 1967, Downing and McGinnes 1969, Larsen 1971, Day 1973, Hubert et al. 1976, Rudge and Joblin 1976, Hobbs and Russell 1979, Stirling 1979, Warneke 1979, Johnson and Pelton 1980, Beasom and Burd 1983, Alt et al. 1985, LeBoulenge-Nguyen and LeBoulenge 1986, Gionfriddo and Stoddart 1988, Ostfeld et al. 1993, Griesemer et al. 1999, Swenson et al. 1999
Fox squirrel	Fingerling toe tags, bands on toes	Linduska 1942, Cooley 1948
Big game	Plastic streamer through slit in ear	Craighead and Stockstad 1960
Hares, nutria, sea otter, and seal pups	Tags placed on hind-foot web or rear flipper	Keith et al. 1968, Evans et al. 1971, Johnson 1979, Miller 1979, Ames et al. 1983, Henderson and Johanos 1988
Cetaceans	Plastic and bolt tags to dorsal fin	Norris and Pryor 1970, Irvine et al. 1982,Tomilin et al. 1983
Whales	Discovery marks and spaghetti tags (stainless steel projectiles) shot from shotgun	Clarke 1971, Evans et al. 1972, Mitchell and Kozicki 1975, Leatherwood et al. 1976, Brown 1978, Irvine and Scott 1984, De La Mare 1985, Miyashita and Rowlett 1985, Kasamatsu et al. 1986

[a] Scientific names are in the Appendix.

Fig. 16. Plastic numeric numbered tags attached to both ears of a collared peccary.

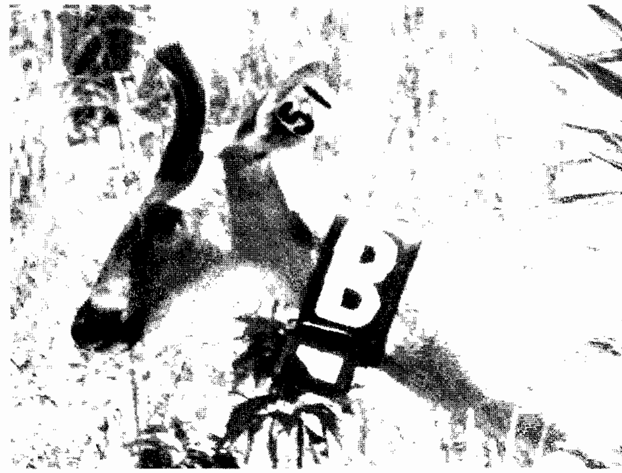

Fig. 17. Plastic domestic livestock ear tag used on white-tailed deer.

not be easily pried apart once the rivet is flattened. Tags may be self-piercing (Box 3) or inserted through a hole pierced with a knife or punch provided with the tagging kit. Ear tags usually are placed on the lower, inner region of the ear characterized by heavier cartilage and where the tag is best protected from being torn out. Tags should be loose enough to not interfere with blood circulation; puncture marks should be treated appropriately to prevent infection and ensure healing.

Aluminum, monel metal, and plastic tags available for domestic livestock (Fig. 17) work well on ungulates. Fingerling fish tags have been used in the ears of bats since the 1930s. These tags may not be suitable for large-eared bats or species that exhibit rapid ear movement synchronized with their echolocation emissions, or for medium- to large-sized bats due to poor retention. Delrin button tags are satisfactory for marking several species.

Wing

Wing tags commonly are used on birds (Table 15). They generally are made from flexible plastic-coated nylon fabric (Fig. 18), and rigid or upholstery plastic and attached through the patagium using a stainless steel or nylon pin, pop-rivet, or the marker itself. Durability and colorfastness are functions of material composition and manufacturing (Nesbitt 1979, Young and Kochert 1987) with some materials lasting ≤ 10 years. Tag loss generally is low the first year (Patterson 1978, Stiehl 1983), but gradually increases in subsequent years (Patterson 1978). Double pinning tags reduced marker loss. Streamers often are used with wing tags to make them visible at a distance. If used, they should be sufficiently large for observational purposes, yet not so large as to hinder flight.

Wing markers often have no consistent effect on birds, although the initial adjustment period ranges from a few days to 2 weeks. Light feather wear and patagium callusing commonly have been noted. Severe abrasion has been observed occasionally with some species, and consistently with falcons. Abnormal replacement of feathers may occur and flight can be affected. Double pinning greatly reduces feather abrasion and callusing. Reported effects of wing markers on reproductive and social behavior also are variable. For many species, no significant influence on fledging success was found when ≥1 adult was marked (Young and Kochert 1987). However, reduced brood size, lengthened mean renesting interval, decreased social status, interference with migration, altered habitat selection, increased mortality, and effects on parental behavior (Brubeck et al. 1981) have been documented. Saunders

Box 3. Placement of self-piercing metal ear tags is important to retaining tags.

It has been our experience when using self-piercing metal ear tags on white-tailed deer, that placement is important for retention of tags. Tags should be placed near the base of the ear and the metal tag should be flush with the edge of the ear. If space is left between the tag and the edge of the ear, there is greater probability that brush or other foreign objects will become entangled in the tag and rip it from the ear. The tag should not be so tight as to roll the edge of the ear, but should be flush with the edge of the ear. Care also should be taken not to puncture any veins in the ear when applying the tag.

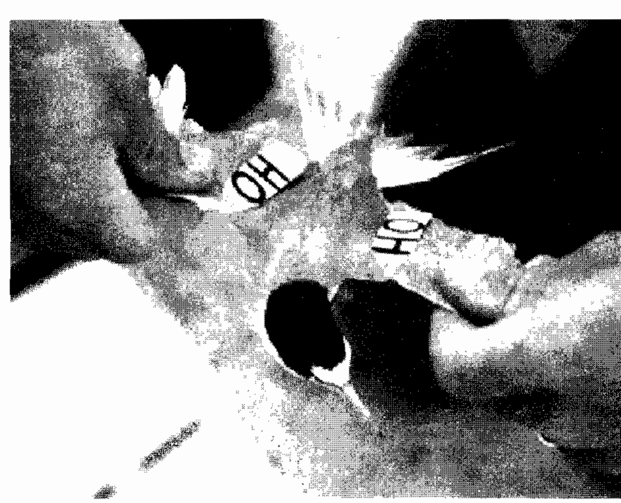

Fig. 18. Patagial-wing markers on a least tern.

Table 16. Wildlife[a] marked using hot-iron, freeze, chemical, and laser branding techniques.

Group/Species	Brand type	Comments	Citations
Amphibians & Reptiles			
Tortoises, snakes, toads, frogs, turtles, anoles, lizards, and hellbender	Hot iron	Tortoises and turtles branded on carapace	Woodbury and Hardy 1948, Weary 1969, Clark 1971, Taber et al. 1975
Snakes, sea turtles, frogs, iguanas, and salamanders	Freeze	Tailed frogs branded on ventral surface	Lewke and Stroud 1974, Daugherty 1976, Ferner 1979, Bull et al. 1983
Anurans	Chemical	Silver nitrate	Thomas 1975
Turtles and snakes	Laser	Ruby laser	Ferner 1979
American alligator	Freeze	Tail and rear foot pad	Jennings et al. 1991
Birds			
Mallard duckling	Freeze	Branded feather tracts and premaxillae	Greenwood 1975
Mammals			
Mountain sheep, African ungulates, seals, and bovids	Hot iron	Branded horns and/or body	Aldous and Craighead 1958, Hanks 1969, Ashton 1978, Summers and Witthames 1978
Livestock, lab animals, pets, white-tailed deer, rodents, squirrels, mongoose, seals, dolphins, beaver, bats	Freeze	Branded body	Newsom and Sullivan 1968, Farrell et al. 1969, Hadow 1972, Farrell and Johnston 1973, Lazarus and Rowe 1975, Hobbs and Russell 1979, Rood and Nellis 1980, Russell 1981, Irvine et al. 1982, Miller et al. 1983, Pfeifer et al. 1984, Sherwin et al. 2002
Seals	Explosive hot-iron device	Branded body	Homestead et al. 1972
Dolphins	Pressure stencil on dorsal fin	Lasted for at least 2 years	Tomilin et al. 1983

[a] Scientific names are in the Appendix.

(1988) contended that patagial tags should not be used on rare, vulnerable, or endangered species unless no other marking technique would work.

Other Appendages

Tags designed for marking ears also have been used to mark foot webs (birds, mammals), interdigital webbing of the hind foot (aquatic mammals, birds), flippers (sea turtles, aquatic mammals, sea birds), wings (birds, bats), and dorsal fins (cetaceans) (Table 15). Migration of the tags, injury to the dorsal fin, and covering of the tag with algae were problems associated with dorsal fin tags. For marking fore flippers, monel metal tags are more durable than plastic tags, although they may be less visible on marked animals and exhibit significant rates of loss. Aluminum tags, which wear and corrode easily, are regarded as inferior to stainless steel or monel metal tags for species inhabiting saltwater.

Self-piercing fingerling fish tags, monel metal tags, plastic and metal ear tags, and Delrin button tags also have been used to mark the hind foot webs of mammals and birds with good retention. Web tagging has been used to mark ducklings in pipped eggs—part of the shell and membrane of an egg were removed, a foot extracted, tagged, and replaced, and the hole covered with masking tape. Web tagging did not affect hatching success or survival after nest departure.

Body

Metal and plastic tags have been used to tag the shells of turtles, rattles of snakes, scutes of turtles and alligators, tails of amphibians, and snakes (Table 15). With the exception of turtles, other marking methods typically are recommended over body tags.

Jaw

Jaw tags have been used for amphibians and reptiles, but often were lost and caused irritation (Table 15). Numbered monel metal tags had to be clamped into the corner of the mouth, a technique that has not been widely used and is not recommended.

Branding

Branding provides an inexpensive, permanent, and visible means of marking animals. Hot iron, freeze, chemical, and laser branding all have been used to mark wildlife (Table 16). In addition, brand-like marks have been produced using a special clamp to hold a stencil on either side of the dorsal fin of cetaceans, causing the epithelium under the pressurized area to be exfoliated and replaced by demelanized skin that remained distinct for at least 2 years. This procedure, however, required 4 days for the depigmented tissue to be produced limiting its value as a field marker.

Fig. 19. Freeze branding mark on hip of Thomson's gazelle.

Fig. 20. During the imping process, a feather of a captured bird (left) is clipped and a feather of contrasting color (right) is attached to it by means of a double-pointed needle.

Hot-iron Branding

Historically, hot-iron branding was used to permanently mark domestic livestock. Hot branding has almost no role in modern wildlife management and is not recommended because it causes extreme pain and can produce open wounds that become infected. Currently, the only commonly used application of this technique in wildlife involves marking the horns of bovids.

Freeze Branding

Freeze branding, a technique originally developed for livestock, is a more humane marking method. Highly conductive branding irons are super cooled, most commonly in a mixture of dry ice and methanol or liquid nitrogen, and placed on a shaved and washed area of the skin. The epidermis is temporarily frozen, destroying the pigment-producing melanocytes in the hair follicles and causing regrowth of white (Fig. 19) as opposed to pigmented hair. Freeze branding has been used successfully to mark a variety of wildlife (Table 16). Freeze branding, if properly applied, rarely results in infection. However, freezing the skin for too long can cause scab formation or tissue necrosis, resulting in formation of new cells with intact melanocytes, which creates an indistinct mark. On lightly pigmented animals, however, these can produce a dark mark that can be read at a distance. A disadvantage of freeze branding is that the brand cannot be read until after the animal molts its pelage.

Chemical Branding

Anurans have been branded using silver nitrate or a silver nitrate- potassium nitrate mixture. The silver nitrate caused a brown mark to form immediately with the dark mark fading into a light mark within about 2 weeks. The method was recommended for dark-colored amphibians.

Laser Marking

Ruby lasers have been used to mark snakes, but were unsuccessful in marking a turtle (Table 16).

Tissue Removal

The effect of most tissue-removal marking methods on survival and fitness is not adequately known and is a topic that should be rigorously investigated (Society for the Study of Amphibians and Reptiles 1987). Alternative marking techniques should be used if excessive pain, behavioral changes, or decreased survival is expected.

Feather Imping

Imping (insertion of a colored feather into the clipped shaft of a bird's rectrices or remiges) (Fig. 20) using a double-ended needle, cement or "super glue," and a toothpick has been used to mark birds until molting (Table 17). Rectrices typically are used, although remiges are suitable if the replacement feather closely matches the one cut off. Imping is probably less effective than painting feathers.

Feather Clipping

Portions of vanes are clipped in different sizes and shapes from the shaft of several adjacent feathers, creating unique holes in the wings or tail that are used to identify birds (Table 17). Clipping should be performed to not impair flight. This technique is most suitable for gliding species and is of limited value for sedentary species because the marks cannot be observed on perching birds. Moreover, the number of combinations producing effective marks is limited. Dyed feathers or colored tape attached to natural feathers, attached with wire to the rachis of natural feathers whose vanes have been clipped off, or glued to plumage in unnatural, conspicuous patterns also have been used on birds. All of these marks are lost during molt.

Fur Removal

The removal of fur in a unique pattern is a non-permanent, humane means of marking mammals (Table 17). The marked animal generally is identifiable until the next molt. Hair may be removed with mechanical clippers, chemicals, or heat, allowing recognition of individuals at a distance. Depilatory pastes have been used to mark numbers on mammals, but can be extremely irritating to the skin of seals. Hair burning ("hair branding") produces a sharp, highly visible mark on fur seals and does not damage the skin; however, a fire source and a series of irons are required

Shell Notching

The most commonly used marking technique for turtles is notching the shell (Table 17). Marks on turtles may not be permanent. To avoid weakening the shell, marginals at the bridge or junction of the plastron and carapace should not be notched.

Scale Clipping

Scale clipping with scissors or clippers is the most com-

Table 17. Tissue removal methods used to mark wildlife[a].

Group/Species	Type	Comments	Citations
Amphibians & Reptiles			
Snakes	Subcaudal scale clipping	Permanent mark (regeneration 4-5 years) scars; marks not lost by tail breakage and marks persisted 4 years; 92% of the time shed skin from clipped racers could be precisely identified.	Blanchard and Finster 1933, Carlstrom and Edelstam 1946, Conant 1948, Woodbury 1956, Weary 1969, Pough 1970, Brown and Parker 1976, Ferner 1979
Turtles	Toe clipping and shell notching	Notches on young turtles may not be permanent	Cagle 1939, Ernst 1971
Frogs, toads, newts, iguanas, hellbenders, and other lizards	Toe clipping	Depending on species, some toe regeneration; should avoid clipping thumbs of toads due to use in amplexus	Martof 1953, Jameson 1957, Efford and Mathias 1969, Briggs and Storm 1970, Brown and Alcala 1970, Minnich and Shoemaker 1970, Hillis and Bellis 1971, Clarke 1972, Dole and Durant 1974, Richards et al. 1975, Daugherty 1976, Jones and Ferguson 1980, Hero 1989, Huey et al. 1990, Dodd 1993, Golay and Durrer 1994
Salamanders	Toe clipping	Only successful marking method	Hendrickson 1954, Woodbury 1956, Heatwole 1961,Twitty 1966, Hall and Stafford 1972, Wells and Wells 1976, Davis and Ovaska 2001
Amphibian tadpoles and salamanders	Tail-fin notching	Tadpoles had higher mortality than staining, salamanders regenerated tail in 1 month	Turner 1960, Orser and Shure 1972, Guttman and Creasey 1973, Ferner 1979
American alligators	Toe clip, tail-scute notch, and web punch	Permanent marks	Chabreck 1965, Jennings et al. 1991
Eastern newt	Amputating 1 limb	Not recommended	Healy 1974
Alpine newt	Skin transplantation	95% retention rate after 3 years	Rafinski 1977
Birds			
Large to medium size	Dyed and painted feathers or colored tape attached to cut feathers	These marking techniques are temporary	Edminster 1938,Kozicky and Weston 1952, Neal 1964, Dickson et al. 1982, Ritchison 1984
Medium and large	Imping	Used double-ended needle or cement	Wright 1939, Hamerstrom 1942, Sowls 1950
Penguins and zoo birds	Web punching	More practical than using leg bands, fighting destroyed marks	Richdale 1951, Reuther 1968
Pheasants, raptors, and frigate birds	Feather vane clipping leaving holes in wings or tail	Most suitable for gliding species; reduced breeding success of pheasants	Geis and Elbert 1956, Enderson 1964, Snelling 1970, Gargett 1973, Garnett 1987
Nestling gulls	Grafting the pollex to the skin of the head	Resulted in alula feathers growing from the head region	Coppinger and Wentworth 1966
Mallard	Alula clipping	Did not affect growth rate, behavior, or flight capability	Burger et al. 1970
Nestlings	Toenail and toe clipping	Toenail clipping remained for at least 18 days	Murphy 1981, St. Louis et al. 1989
Mammals			
Bats, beaver, nutria, and seals	Web punching or slits	Distinct after 2 years in fur seals	Aldous 1940, Scheffer 1950, Davis 1963*a*
Small mammals, hares, coyotes, and seal pups	Toe clipping	Best to take only 1 toe per foot	Baumgartner 1940, Dell 1957, Sanderson 1961, Melchior and Iwen 1965, Ambrose 1972, Andelt and Gipson 1980, Riley and William 1981, Fairley 1982, Gentry and Holt 1982, Pavone and Boonstra 1985, Korn 1987, Wood and Slade 1990
Small mammals	Ear punching or clipping	Some effect on movement and behavior	Blair 1941, Honma et al. 1986, Wood and Slade 1990

(*Continued*)

[a] Scientific names are in the Appendix.

Table 17 (*continued*). Tissue removal methods used to mark wildlife[a].

Group/Species	Type	Comments	Citations
Mammals (*continued*)			
Rats and seals	Depilatory paste	Caused extreme skin irritation in seals	Chitty and Shorten 1946, Gentry 1979
Bats	Wing hole punching	White scar lasted 1-5 months	Bonaccorso and Smythe 1972, Bonaccoorso et al. 1976, Stebbings 1978
Juvenile bats	Claw clipping	Lasted only a few weeks	Stebbings 1978
Seals	Hair burning	Does not burn skin	Gentry 1979
Seals, European badger, and mice	Fur removal	Lasted until next molt	Gentry 1979, Stewart and MacDonald 1997, Johnson 2001

[a] Scientific names are in the Appendix.

monly used method of marking snakes (Table 17). Pieces should be cut from the subcaudals, which leaves "permanent" scars. Subcaudal cuts can be numbered on each side beginning at the proximal end of the tail. No adverse effects have been reported for snakes, but regeneration could be a problem and clipping is difficult on small or young snakes. Ventral scales are larger and are easier to clip than subcaudal scales, and scars in this area cannot be lost by tail breakage.

Toenail Clipping

Clipping the toenail rather than toes (Fig. 21) is preferable for short-term studies of small mammals and nestling birds (Table 17). Clipped toenails remained sufficiently blunt at the tip to be distinguished throughout the nestling period when birds are too young to be banded, although the nails eventually grow back. This method also has been used in bat nursery roosts, but the marks lasted only a few weeks.

Toe Clipping

Toe clipping is widely used to individually mark anurans, small mammals, small turtles, and lizards (Table 17). The nail and first joint of the toe are removed with sterile dissecting scissors. The technique is inexpensive, rapid, and permanent but, at times, clipped toes cannot be distinguished from other causes of toe loss. Kumar (1979) developed a toe-clipping code for identification of up to 9,999 animals using no more than 2 digits clipped per foot. No direct adverse effects of toe clipping were reported for small mammals, and none of the extensive studies documented harmful effects caused by clipping toes of lizards. Toe clipping, however, caused a temporary reduction in capture rates. Toe clipping is not advised for bats because the toes are essential for roosting and grooming. This technique also has been used for identifying tracks of marked individuals. Suitable conditions (e.g., snow) are required for track identification. Ecologists generally avoid toe clipping tree frogs and salamanders for long-term studies because of their regenerative capabilities. Although toe-clipping amphibians and reptiles has disadvantages, it is still the most common marking technique used for anurans.

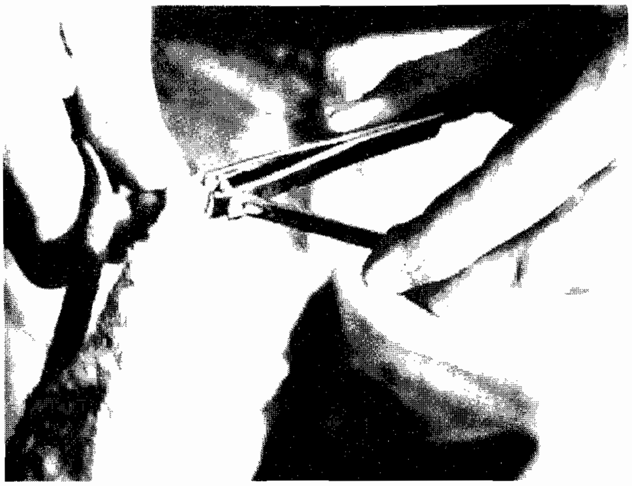

Fig. 21. Clipping the toenail rather than the toe is preferred for short-term marking studies of small mammals.

Ear Punching and Notching

The ears of many small mammals can be marked by punching or clipping them in a variety of coded systems (Table 17). Large-eared ungulates, carnivores, and primates have been marked by cutting 1 or 2 notches at preselected coded sites on the margin of the ear allowing for a number of combinations. Ear notching or punching (using a leather punch) for large mammal species permits identification of marked animals at a distance. Notches usually last longer than tags, although they can be distorted by infection, growth, or injury (Ashton 1978). Ear notching is not advisable for mammals that use their ears for orientation and prey location or have valve-like ears that function during deep-sea dives. The ethical implications of these techniques should be considered.

Web Punching

Slits or holes punched into foot webs, flippers, or wing membranes have been used to mark many birds and mammals (Table 17). The marks are permanent, but unclean cutting may produce a small scar rather than a hole. Leather punches usually produce clean holes. Although some marks on web-footed birds are altered by injury or healing, most marks are identifiable. Some authors reported this method was more practical than leg bands. The major disadvantage of web punching is that birds must be recaptured for the web holes to be read. There are some questions of the ethics of this technique.

Tail Clipping

Notches clipped from a tail fin is a traditional method for marking amphibian tadpoles and some salamanders (Table 17). Fin clipping, however, produced higher mortality than did staining techniques. Scutes clipped on the tails of crocodilians have proved useful in long-term studies.

Skin Transplantation

This method involves removal of skin from one part of the body and transplanting it to another. Although this method has been successful in amphibians and some birds (Table 17), we do not recommend it.

Amputation

Healy (1974) marked post-larval metamorphs of the eastern newt by amputating one limb at the middle of the zeugopodium, but few individuals were recaptured (Table 17). Newts regenerated the limb, usually within a month. Amputation is not recommended.

SUMMARY

If there is a need to recognize individual animals, use of natural markings is the preferred alternative. If this is not feasible, marking animals without capture is the next best option. These methods eliminate stress associated with capture. For animals that must be captured prior to marking, noninvasive techniques are preferred, but are not without problems. They can interfere with reproductive behavior (color marks), increase predation risks (color marks), and cause injury or increased mortality (band constriction, icing, entanglement of marks). Noninvasive methods generally are preferred because application of many invasive marks causes pain. The advantage of some invasive techniques is that many are "permanent." For example, tattoos probably are the most permanent marking method available for many species, but have the disadvantage of requiring the animal to be in hand (recaptured, found dead) to be identified. Use of PIT tags also offers a relatively permanent marking method (some are lost or become inoperable), but have the same primary disadvantage as tattoos—animals usually must be recaptured for identification. If animals only need to be marked for a limited time, then permanency of the mark is not a factor. There are both noninvasive (e.g., dyes) and invasive (e.g., toe-nail clipping) marking methods that can be used for sort-term studies yet have little affect on the animal. The ultimate responsibility regarding which method should be used to mark wildlife for a particular study depends on the ethical and scientific validity of method, and rests with the investigator.

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LITERATURE CITED

ABRAHAM, K. F., C. D. ANKNEY, AND H. BOYD. 1983. Assortative mating by brant. Auk 100:201–203.

ALDOUS, M. C., AND F. C. CRAIGHEAD, JR. 1958. A marking technique for bighorn sheep. Journal of Wildlife Management 22:445–446.

ALDOUS, S. E. 1940. A method of marking beavers. Journal of Wildlife Management 4:145–148.

ALDRICH, J. W., AND J. H. STEENIS. 1955. Neck-banding and other color marking of waterfowl: its merits and shortcomings. Journal of Wildlife Management 19:317–318.

ALLISTON, W. G. 1975. Web-tagging ducklings in pipped eggs. Journal of Wildlife Management 39:625–628.

ALT, G. L., C. R. MCLAUGHLIN, AND K. H. POLLOCK. 1985. Ear tag loss by black bears in Pennsylvania. Journal of Wildlife Management 49:316–320.

AMBROSE, III, H. W. 1972. Effect of habitat familiarity and toe clipping on rate of owl predation in *Microtus pennsylvanicus*. Journal of Mammalogy 53:909–912.

AMERICAN ORNITHOLOGISTS' UNION. 1988. Report of committee on use of wild birds in research. Auk 105 (Supplement): 1A-41A.

AMERICAN SOCIETY OF MAMMALOGISTS. 1998. Guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists. Journal of Mammalogy 79:1416–1431.

AMES, J. A., R. A. HARDY, AND F. E. WENDELL. 1983. Tagging materials and methods for sea otters, *Enhydra lutris*. California Fish and Game 69:243–252.

ANDELT, W. F., AND P. S. GIPSON. 1980. Toe-clipping coyotes for individual identification. Journal of Wildlife Management 44:293–294.

ANDERSON, A. 1963. Patagial tags for waterfowl. Journal of Wildlife Management 27:284–288.

———. 1980. The effects of age and wear on color bands. Journal of Field Ornithology 51:213–219.

———. 1981. Making polyvinyl chloride (PVC) colored legbands. Journal of Wildlife Management 45:1067–1068.

ANKNEY, C. D. 1975. Neckbands contribute to starvation in female lesser snow geese. Journal of Wildlife Management 39:825–826.

ARNOLD, K. A., AND D. W. COON. 1971. A technique modification for color-marking birds. Bird-Banding 42:49–50.

ASHTON, D. G. 1978. Marking zoo animals for identification. Pages 24–34 *in* B. Stonehouse, editor. Animal marking: recognition marking of animals in research. University Park Press, Baltimore, Maryland, USA.

ASHTON, JR., R. E. 1975. A study of movement, home range, and winter behavior of *Desmognathus fuscus* (Rafinesque). Journal of Herpetology 9:85–91.

ATHERTON, N. W., M. E. MORROW, A. E. BIVINGS, IV, AND N. J. SILVY. 1982. Shrinkage of spiral plastic leg bands with resulting leg damage to mourning doves. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 36:666–670.

BACON, P. R. 1973. The orientation circle in the beach ascent crawl of the leatherback turtle, *Dermochelys coriacea*, in Trinidad. Herpetologica 29:343–348.

BAER, G. M., J. H. SHADDOCK, D. J. HAYES, AND P. SAVARIE. 1985. Iophenoxic acid as a serum marker in carnivores. Journal of Wildlife Management 49:49–51.

BAILEY, E. E., G. E. WOOLFENDEN, AND W. B. ROBERTSON, JR. 1987. Abrasion and loss of bands from Dry Tortugas sooty terns. Journal of Field Ornithology 58:413–424.

BAILEY, G. N. A., I. J. LINN, AND P. J. WALKER. 1973. Radioactive marking of small mammals. Mammal Review 3:11–23.