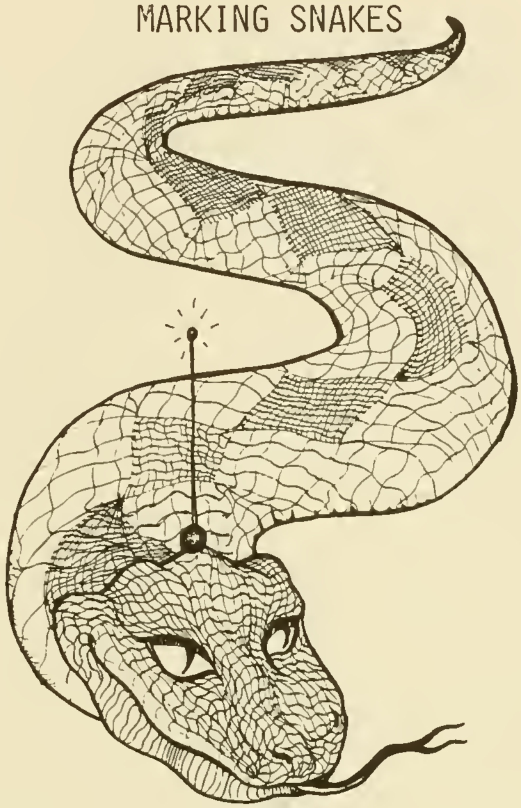
A REVIEW OF TECHNIQUES FOR MARKING SNAKES



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COVER ILLUSTRATION. Radiotrackers' ideal snake with a built-in antenna; drawn by Stephanie Ersek.

INTRODUCTION

Snakes present a serious difficulty to ecologists wishing to study them in the field. Due to their secretive behaviour and cryptic coloration, they are generally difficult to find, and because of their solitary lifestyle, they are usually only found as isolated individuals. Whereas turtles, lizards, and crocodilians lend themselves easily to marking methods, snakes are the most difficult reptiles to mark effectively for field identification. Nevertheless, researchers have ingenuously developed a variety of techniques for marking snakes. No less than twenty different methods have been used with more than fifty snake species (Appendix). These techniques fall into several categories: 1) scale-clipping; 2) tagging; 3) painting/coloring; 4) tattooing, 5) branding; 6) recording of integumentary and scale patterns; 7) incising; and radiotelemetry. These are summarized in a subsequent section.

An ideal marking method for snakes should satisfy most of the following criteria, as enumerated by Lewke and Stroud (1974) and Ricker (1956). It should: 1) be as free of stress and pain as possible; 2) not affect the mortality rate of the animals; 3) afford minimal opportunity for infection; 4) not affect behaviour; 5) not inhibit normal movement; 6) not inhibit the shedding process; 7) be permanent or at least long-lasting; 8) be easily read to identify accurately individuals; 9) be adaptable to all sizes of animals; 10) be easily employed in the field or laboratory situation; and 11) involve equipment and materials that are easily made or obtainable at a minimal cost.

Discussions of preferred methods of marking can be found in Brown and Parker (1976b), Clark (1971), Ferner (1979), Fitch (1949A; 1987), Kroll et al. (1973), Lewke and Stroud (1974), McGinnis (1967), Pendlebury (1972), Pough (1970), Reinert and Cundall (1982), Schmidt and Davies (1941), Spellerberg and Prestt (1978), Swingland (1978), Turner (1977), Weary (1969) and Woodbury (1948; 1956).

Considering the aforementioned references, enough information is available for ecologists to choose an effective tagging method for their investigations according to their budget and the hypotheses to be investigated. To permit ready access and evaluation of the different methodologies, I offer the following summaries of the various marking techniques along with the pertinent literature.

MARKING PROTOCOLS

Scale-Clipping

Subcaudal clipping (1).

The first method ever used to mark snakes for an ecological study was devised by Blanchard and Finster (1933). It consisted of completely removing three subcaudal scales with a pair of sharp scissors, using a code to designate those scales clipped. By counting caudad from the cloacal plate, and placing the left and right subcaudals on the respective sides of a dash, a typical code of "2,5-4" represents the second and fifth subcaudal on the left and the fourth subcaudal on the right as being marked.

This method or variations thereof have been used, at least until the recent advances in radiotelemetry, for the past fifty years by the overwhelming majority of ecologists. Published reports indicate that close to 50,000 snakes have been marked by subcaudal clippings. It has been employed in studies by Blaesing (1979), Blanchard et al. (1979), Carpenter (1952), Fitch (1949b, 1958), Fitch and Fleet (1970), Fitch and Glading (1947), Fukada (1959; 1960; 1978), Parker (1974), Reynolds and Scott (1982), Siebert (1950), Siebert and Hagen (1947), Test et al. (1966), and Tinkle (1957).

Although Blanchard and Finster (1933) warned that scales only partially removed would regenerate through time, subsequent studies demonstrated that certain species have the ability to completely regenerate even entirely removed subcaudals. Calström and Edelstam (1946) were the first to demonstrate this, and further noted how difficult and harmful subcaudal clipping was with juveniles. Conant (1948) described a zoo specimen of Elaphe obsoleta in which regeneration obliterated the original marks after five years. Regeneration was further verified by Fitch (1982), who studied twelve species of snakes over a 30 year period (22,000 individuals marked). He showed that regeneration of clipped scales was more rapid and complete in Elaphe obsoleta than in any other species that he studied. After a few years, many clipped scales were indistinguishable from natural injuries (Fitch, 1963a). Other species also possess good regeneration. For example, Diadophis punctatus are scared by bites from predators, and these scars are indistinguishable from those of clipping after two or three years (Fitch, 1975). Similarly, Fitch (1963b) observed regeneration in some Coluber constrictor after two or three years.

Ventral clipping (2).

Woodbury (1951) was the first to use ventral scales. He clipped a portion of the ventral scale on either side, designating the right side with a capital letter and the left side with a small letter. Scales were lettered craniad from the anal plate, and sex was indicated by M or F. Thus a code combination of "DaM" referred to a male snake with a clipped fourth ventral on the right and the first ventral on the left.

Brown and Parker (1976b) modified Woodbury's methodology to fulfill the eight criteria of Lewke and Stroud (1974) for a good marking method. The modified method is claimed to be satisfactory for at least four years and was used by Brown (1973), Brown and Parker (1974; 1982), Henderson et al. (1980), Jacob and Painter (1980) and Parker and Brown (1973; 1974a-b). The Brown and Parker protocol remove half of a ventral in combination of one to three clips with a total of 989 unique combinations. Ventrals are counted anteriorly from the anal plate on the left side in units from 1-9; on the right side they are counted in series of 10's (10-90), 100's (100-900), and 1000's (if necessary). A snake whose belly was clipped on the left side of ventral nine and the right side of ventral three and eleven would be number 239. Regeneration does not appear to occur as readily in the ventrals as in the subcaudals. No ill effects were noticed in markings of more than 1000 Coluber constrictor (Brown, 1973). This methodology appears superior for scale-clipping, although some ambiguity may occur such as misidentification of individual marks (Fitch, 1987).

Ventral and subcaudal clipping (3).

Fitch (1958, 1960) proposed a combination of subcaudals and ventral scale clippings. The first twenty subcaudals allow 362 unique combinations. A typical code of "U 5L 2R" represents markings on the fifth left and the second right subcaudals. Ventrals are used to indicate the next series of 362 marks. Counting craniad from the anal plate, "G 1L" designates the first ventral on the left or "G 1R" the first right ventral, etc. Fitch employed this technique in his later studies (1963a,b; 1965; 1975; 1982), and it was also used by Clark (1970) and Platt (1969).

Another variant of scale clipping was devised by Clark (1971). Only two marks are necessary with the designation of a basal starting point. For example, "BL-2L 3R" indicated a base mark on the left and the subsequent ventrals second left and third right are marked. To improve reliability, a scale is removed from the first dorsal scale row immediately adjacent to the basal marked ventral.

Henderson (1974), Lang (1969), and Saint-Girons (1964) used combined clipping methodologies, but did not provide full details on the numbering protocol.

The disadvantages of all clipping methods are the time required to mark each snake, the frequently drawing blood and possibility of infection, and the difficulty in marking small snakes (Weary, 1969).

Most recent researchers favor the combined ventral-subcaudal methodology of Prestt (1971) and Brown and Parker (1984). This method has been used successfully in studies on the population dynamics of colubrids and viperids (e.g. Brown and Parker, 1984; Feaver, 1977; Parker and Brown, 1974 a,b, 1980; Prestt, 1971; Spellerberg and Phelps, 1977).

Tags

Metal tags (4).

Hirth (1966) was the first to attach tags to snakes. He used uniquely numbered stainless steel tags clamped to the corner of the mouth. Fortunately, this location has not been used subsequently. Voris et al. (1983) attached numbered metal tags to the tail tips of sea snakes. He discontinued the tagging when it became apparent that the tags collected debris, wore holes in the tails, and were often lost.

Plastic plugs (5).

Pough (1970) described the use of colored plastic plugs or serially numbered metal tags attached to the tail via a buttoner device. The technique is presumably a quick and permanent method of marking snakes. The tags were partially inserted into the caudal musculature through the lateral subcaudal scales. Those inserted into ventral scales fell off. Plugs cannot be attached to snakes smaller than 250 mm SV. During Pough's studies there was no evidence of infection nor any indication that the plug interferes with shedding or locomotion.

Plastic disk (6).

Pendlebury (1972) initiated the attachment of colored disks to rattlesnake's rattles. A pair of disks are sewn on either side of the basal rattle segment. With the use of a pair of disks in ten color combinations 100 specimens can be uniquely marked. Two pairs of disks on each snake allows 10,000 unique combinations. This method, although limited to studies of rattlesnakes, has been used successfully by JACOB and Painter (1980), Reinert and Kodrich (1982), Stark (1984) and Brown et al. (1984).

Plastic tag/colored beads (7).

Thin, yellow plastic tags were successfully used by Voris et al. (1983) to mark sea snakes; these tags were embedded subcutaneously in front of the tail on the right side of the body. Similar red tags hooked through the tail were found to be less valuable. Hudnall (1982) suggested the use of colored beads to mark snakes.

Radioactive wire (8).

Barbour et al. (1969) first used a radioactive wire to mark snakes. A thin wire is inserted subcutaneously in the tail via a modified hypodermic syringe. The wires were radioactive Cobalt (Co^{60}) with a 50-80 microcurie dose. Hirth et al. (1969) and later Fitch (fide Ferner, 1979) used radioactive Tantalum (Ta^{182}) wire with 400 microcurie amounts. Snakes so marked can be located nine meters away when on the surface and three meters away when 30 cm below the surface. Tantalum and Cobalt have been the preferred source of radiation. Cobalt has a more powerful gamma radiation with a half-life of 5 years, whereas Tantalum has a half-life of only 6 months. The disadvantages of radioactive tags are that they may injure and eventually kill the snakes carrying them. Furthermore they are readily shed and then become hazardous to other animals or humans (Fitch, 1987). Radioactive tags are preferable to radiotransmitters in smaller snakes. The use of radioactive tags (and telemetry) are reviewed in Spellerberg and Prestt (1978), Swingland (1978) and Ferner (1979).

The major problem for the effective use of external tags is the choice of an adequate attachment site. The elongated, limbless body of snakes offers no satisfactory attachment sites. The possible sites are the free edges of the anterior ventrals, the cloacal plate, the lower jaw, or the base of the rattle in rattlesnakes. The tags must be attached in a manner to avoid interference with normal behavior and to reduce abrasion or loss of the tags.

The aforementioned tags can be stitched to the skin with heavy thread, thin wire or nylon. Utmost care must be exercised when attaching tags to avoid injury. For example, pinched skin undergoes necrosis thereby modifying the snake's normal behavior and increasing the likelihood of tag loss (Fitch, 1987).

Painting/coloring

Brush paint (9).

Fitch (1960) painted red, yellow, orange, and blue enamel marks on snakes to check on their shedding cycle. Pough (1966) used quick drying waterproof paint to number the basal rattle segment of rattlesnakes. This method has been further altered for rattlesnakes by Brown et al. (1984). The head and neck of snakes were painted by Parker (1976) for field identification.

Spray painting (10).

Henderson et al. (1981) used rapid-drying fluorescent spray paint (non-toxic) to mark arboreal snakes. Three quarters of the animals spray-painted were later observed. Plummer (1985) also used spray paint to mark *Opheodrys*.

Water color pencil (11).

Stebbins (1966) suggested the use of Mongol water color pencils to temporarily mark specimens for field observations.

The preceding three methods produce temporary marking, nonetheless they facilitate the recognition of individuals without recapture in a variety of field situations. The marks are lost with the shed exuvia or through wear. As Fitch (1987) points out, these methods have additional useful applications, such as for group markings of snakes to obtain capture-recapture ratios that can serve for a Petersen index census. In population studies based on permanent marking systems, these temporary marks provide the best method for investigating ecdysis cycles.

Most species of snakes however are too secretive for regular or long-term observations, so the short duration of paint marking is of little use. Another major disadvantage is that the colored marks render marked individuals more conspicuous to visually oriented predators, hereby distorting the capture-recapture ratio (Fitch, 1987).

Tattooing

Battery powered tattooing (12).

Imler (1945) was the first researcher to tattoo snakes with a battery-operated unit. He tattooed the venter of bullsnakes with a special code number. This method was subsequently redescribed by Woodbury (1948, 1951) for marking rattlesnakes at a den. Using a portable tattooing outfit and India ink, he tattooed large numbers of snakes on their throats, subcaudals and/or ventrals, and areas lacking pigments. Disadvantages include the tendencies of the tattoos to fade and the necessity of tattooing unpigmented or lightly pigmented areas.

Electric powered tattooing (13).

Weary (1969) improved the tattooing method by employing an inexpensive pyrographic needle (50 W unit operated from a 110 volt source) or a soldering pencil (powered by a 12 volt battery) to burn/scar scales without drawing blood.

Tattooing is more labor-intensive than scale clipping and usually involves the transport of bulky equipment. Also a major drawback is that during marking, there is a high risk of injury and even death if the needle penetrates too deeply and pierces the body cavity. Fitch (1987) points out two additional problems limitimg the widespread use of these techniques. First, in darkly pigmented individuals and species of snakes, the numbers are difficult to read accurately and second, especially in snakes marked as juveniles the ink spreads and sometimes blurs the numbers.

Branding

Hot (flame) branding (14).

Clark (1971) described the use of a heat source, a Bunsen burner in the laboratory or a small propane torch in the field, to brand numbers on snakes by heating a branding wire of 20% chromium/80% nickel (Chromel A) and applying it to the scales.

Cold (freeze) branding (15).

Lewke and Stroud (1974) employed a superchilled branding instrument of copper wire to mark snakes. The technique was devised by Farrel (1966) for use with livestock. Of the three coolants tested (dry ice and 95% ethyl alcohol, Freon 12, and Freon 22), dry ice and alcohol was the most successful. Chromatophores are destroyed by quick-freezing the skin surface. The brand appears as a white area (Fitch, 1987).

Although this method is a good field-marking technique, a disadvantage is that the mark is not evident until after ecdysis and there is a minimal size limit of the branding iron used. Branding shares the same problems and disadvantages with tattooing. It is labor-intensive, sometimes causes injuries and may be difficult to read with heavily pigmented snakes.

Recording integumentary and scale patterns

Natural marks (16).

Calström and Edelstam (1946) employed the innovation of recording a snake's color pattern because each has a unique pattern. They photographed or sketched the fourth through eighth ventrals (from anterior end) of _Natrix natrix_. These patterns were sufficient, in conjunction with other scuttelation data to reidentify individuals. Snakes with distinctive skin patterns like _Coronella_ and _Vipera_ were treated in the same manner by recording their dorsal patterns. The use of this technique was considered feasible for _Pelamis_ by Kropach (1973). Fitch (1987) suggests a methodology for recognition of individual _Agkistrodon contortrix_ based on the arrangement of complete and incomplete "hourglass" marks on the body.

Scale formulae (17).

Blanchard and Finster (1933) mentioned an unsuccessfull attempt to recognize individuals with scuttelation data. However, Fukada (1978) described recording the arrangement of temporal scales in _Elaphe climacophora_ as an adjunct to scale-clipping.

Both of these pattern-recognition techniques are labor intensive in recording and recognizing specific patterns and furthermore prone to reading errors. As Fitch (1987) suggests, natural marks should be noted and used to confirm the identification of individuals based on other marks or tags.

Incisions

Tail-notching (18).

In Kropach's unpublished dissertation (1973), he described a tail notching protocol for seasnakes. He (Kropach, 1975) later elaborated on this technique.

Radiotelemetry

Fitch (1987) recommends two fundamental criteria that should be met for the use of radiotransmitters. The transmitters should be small enough not to burden the snake during its normal activities such as feeding and locomotion, yet large enough to have a sufficient transmission range for easy localization.

Oral insertion (force fed) (19).

McGinnis and Moore (1969) pioneered the use of radiotelemetry in snake studies, adapting the technique used for lizards by McGinnis (1967). They force-fed a _Boa constrictor_ with a miniature temperature sensitive transmitter with a range of 100 meters. Various types of radio transmitters, antennae and battery sources have been used subsequently in snake studies. Transmitters are coated with paraffin/beeswax mixture or silicone, and are either palpated into the animal's stomach or sewn into a food item and then force-fed. Battery life ranges from a few days to several months. Orally inserted radiotransmitters have been used by Brown and Parker (1976a), Brown et al. (1982), Fitch and Shirer (1971), Galligan and Dunson (1979), Hammerson (1979), Henderson et al. (1976), Jacob and McDonald (1975), Jacob and Painter (1980), Johnson (1972), Landreth (1973), Montgomery and Rand (1978), Moore (1978), Nickerson et al. (1978), Osgood (1970), Parker and Brown (1972), Reinert (1981) and Reinert and Kodrich (1982).

Some disadvantages of this method are that the effective range of the transmitter is small, the transmitter may be regurgitated, and the transmitter in the stomach may cause behavioral changes in the snake. Fitch and Shirer (1971) tied a string around the body and sewed it to a ventral scale to prevent their snakes from losing the transmitters. Early studies demonstrated that the beeswax covering are digested by the snake, causing the transmitter to malfunction.

Surgical insertion (20). In order to alleviate the above mentioned problems, Fitch and Shirer (1971) surgically implanted transmitters into the abdomens of snakes. Brown and Parker (1976a) encapsuled their transmitters in polyethylene and inserted them abdominally with minimal bleeding. The sutures healed completely within two weeks. Other workers using this method include Brown and Parker (1982), Henderson et al. (1980), Jacob and Painter (1980). Reinert and Cundall (1982) improved the transmission of radiotelemeter by the implantation of both the transmitter and the antenna, the latter subcutaneously. Their transmitters had a maximum range of 1.5 km, a vast improvement over previous techniques. Further examples of studies using this technique are those by Reinert et al. (1984) and Madsen (1984).

Surgical implantation method involves anesthetizing the snake and inserting a foreign object into the body cavity. Although the healing process and fibrotic encapsulation may be rapid, behavioral alterations may occur (Fitch, 1987).

During the past two decades, the quality, longevity and distance of the emitted signals have been ameliorated. In conjunction with better radiotelemetry units, more efficient computerized radio-telemetric systems are now available to monitor free-ranging snakes (Stanmer, 1988). Furthermore, the implantation techniques are more refined (Weatherhead et al., 1984).

Fitch (1987) suggests that radiotelemetry may be the choice technique for most ecological research involving the marking of snakes. It allows for quick and effective monitoring of individuals in open terrain. In closed biotopes such as swamps, subterranean habitats or rainforests, the situation is less favorable.

SUMMARY

Ecologists have a variety of different techniques at their disposal for the marking of snakes for field studies. With the sophistication now present in radiotelemetry, snakes can be tracked over long distances and recordings can be made for lengthy periods of time, such as overwintering in hibernacula.

The following appendix and bibliography identify the various published marking techniques and the primary literature sources.

The most widely used method for marking snakes may remain the ventral and subcaudal scale clipping. It is permanent, cost-efficient, and it allows the unique marking of each individual in a population. This method also has no permanent ill effect on the marked animals.

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Appendix - This list is a partial overview at best of the species of snakes that have been tagged for field studies. Many more species have been marked in Masters theses and Doctoral dissertations as well as other publications that are not listed in the zoological records. See numbers in text for the identification of methods.

TAXON	METHODS USED
FAMILY BOIIDAE	
Boa constrictor	19
Morelia spilotes	19
FAMILY COLUBRIDAE	
Carphophis amoenus	8
Carphophis vermis	1,3
Coluber constrictor	1,2,3,4,8,12,19,20
Coronella sp.	16
Coronella austriaca	3
Diadophis punctatus	1,2,3,8,17
Elaphe climacophora	1
Elaphe obsoleta	1,3,19
Elaphe quadrivirgata	1
Elaphe subocularis	1
Helicops angulatus	19
Heterodon nasicus	3
Heterodon platyrhinos	3
Lampropeltis calligaster	1,3,19
Lampropeltis triangulum	1,2,20
Leptophis depressirostris	19
Liophis reginae	1
Masticophis lateralis	19
Masticophis taeniatus	2,3,4,8,9,12,19
Natrix natrix	16,17,20
Nerodia fasciata	19
Nerodia sipedon	1,3,19
Nerodia taxispilota	19
Opheodrys aestivus	10
Opheodrys vernalis	1
Oxybelis aeneus	3
Pituophis melanoleucus	1,2,3,12,19
Rhabdophis tigrinus	1
Spilotes pullatus	19
Storeria dekayi	1,3,8

Storeria occipitomaculata	1
Thamnophis butleri	1
Thamnophis elegans	1
Thamnophis ordinoides	1
Thamnophis radix	1
Thamnophis sirtalis	1,3,5,19
Uromacer catesbyi	10
Uromacer oxyrhynchus	10
FAMILY HYDROPHIIDAE	
Enhydrina schistosa	4,7
Laticauda colubrina	3
Pelamis platurus	18
FAMILY VIPERIDAE	
Agkistrodon contortrix	1, 3, 9, 16,19
Bothrops atrox	19
Crotalus atrox	1, 9, 19
Crotalus cerastes	19
Crotalus horridus	1, 2, 3, 19, 20
Crotalus mitchelli	19
Crotalus molossus	1, 9
Crotalus scutulatus	1, 9
Crotalus viridis	1, 2, 6, 8, 12, 19, 20
Sistrurus catenatus	6, 19
Trimeresurus flavoviridis	19,20
Vipera sp.	16
Vipera berus	20

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