CHAPTER 2

Collecting and Marking

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The scarcity of extensive series of turtles in most herpetological collections is indicative of the difficulties involved in collecting these reptiles. Turtles are bulky animals. Not only do they take up large amounts of space in museums and live exhibits, but they also are difficult to process and transport in numbers in the field. Moreover, especially for aquatic turtles, the equipment involved in collecting them also is bulky and cumbersome. Despite these drawbacks, turtles are collected easily once they are located, and unlike most other reptiles, aquatic turtles are trapped easily. With the renewed interest in field studies of ecology and behavior, innovative and practical methods of collecting and marking turtles have been developed and refined.

More scientists are studying turtles now than ever before, and it must be remembered that some turtles, particularly the tortoises, suffer from the inroads of man. It is the duty of every investigator to practice conservation in every study. Immediate needs must be weighed continually against the irreversible course of extinction.

COLLECTION METHODS

Hand Collecting

Hand collecting takes about as many forms as there are collectors. One cruises an area and looks for turtles or turtle sign; when a turtle is found, it is collected by hand or with some appropriate device.

Generally, terrestrial turtles are simply picked up after being located visually. One's luck in locating them can be improved by first selecting suitable turtle habitat. Legler (1960a) reported that *Terrapene ornata* was found most often along fences, in ravines, and in and around piles of cattle dung, where it foraged for invertebrates that inhabit the droppings. He found that by riding a horse through his study area he more easily found turtles because his vision was less obstructed and he could cover the area more quickly.

Carr (1952) mentioned that hunters frequently find their dogs pointing box turtles (*Terrapene* spp.). Schwartz and Schwartz (1974) also noticed this phenomenon and made use of it in an ecological study. Their trained Laborador retrievers located and retrieved more than 90% of the total of 3832 box turtle captures. The dogs worked close to their masters, permitting the exact location of each capture to be plotted. The dogs commonly found turtles under debris, and in the fall they often dug turtles out from their hibernacula, 6 to 7 in. below the surface.

The giant Galapagos tortoises (*Geochelone elephantopus*) leave many characteristic signs (Pritchard, personal communication). In suitable habitat these turtles make permanent, well-defined trails. Slight excavations made where they sleep, droppings, and bent-over vegetation in new trails are other useful signs.

Individuals of *Gopherus polyphemus* can be dug out of their burrows, but it is more expedient to wait at the burrow and capture the tortoise as it enters or leaves. Woodbury and Hardy (1948) used a steel rod with a sharp hook to remove *G. agassizi* from their burrows, but this technique depends on the tortoise being within reach of the rod, a condition that is not always met.

During periods of hot, dry weather, many species of terrestrial turtles are attracted to water; thus a systematic search of pools, streams, and surrounding areas often yields specimens when searches of usual shelter and feeding sites do not.

Even aquatic turtles can sometimes be collected on land. Many freshwater species wander on land, especially during the spring and fall (Cagle, 1944b), and these can be collected easily by hand, often in great numbers. Sexton (1959) constructed "retaining fences" 10 in. high and 100 m long around a pond to detain temporarily turtles that were moving overland and to increase his chances of encountering the turtles.

Carpenter (1955) described "sounding" as a collecting technique: a metal rod with a blunt end is thrust into potential turtle-containing sites. By probing debris and masses of leaves, he found many turtles of five species and even located turtles hibernating 6 to 10 in. below the surface. The collector soon learns the sound of the rod hitting a turtle as opposed to a rock or log. Bishop and Schoonmacher (1921) located hibernating *Clemmys insculpta* by sounding into muskrat burrows and into mud of stream bottoms. Dobie (1971) used a sounding rod with a hook on one end to locate and remove *Macroclemys temmincki* from their underwater retreats. Smith (1947) collected *Trionyx spiniferus* by probing sand bars at the water's edge. The rate of capture by this technique may be enhanced greatly by first locating concentrations of soft-shells by cruising in a boat, then probing those areas of concentrations. Small isolated sandbars well separated from other burrowing substrate tend to have more burrowed turtles per unit than do large, extensive sandbars or mud flats.

The persistent burrowers (e.g., those belonging to the genera *Chelydra*, *Kinosternon*, and *Trionyx*) occasionally rest their heads on the substrate with the remainder of their bodies buried; such animals can be spotted visually in clear water. These turtles can also be located by walking in shallow water and looking for a small depression in the mud or sand; the depression results from the turtle retracting its head periodically after obtaining air. At times a swirl of mud is created by the withdrawal of the head.

In vegetation-choked areas of lakes and small streams a garden rake is useful. Walk slowly along the shore and look for heads or carapaces protruding above the surface, or for disturbances made by foraging or fleeing turtles; then quickly rake the vegetation-entrapped turtle onto shore. Goin (1942) described a specialized dredge for raking turtles out of water hyacinths.

"Noodling" or "muddling" involves feeling around with the hands or feet in the mud bottoms of shallow waters until a turtle is located. Cagle (1950) found this technique to be extremely productive in late summer and winter when turtles were locally concentrated in areas of receding water.

Gibbons (1968b) captured *Emydoidea blandingi* by first spotting the bright yellow chin as the head protruded from the water, then rowing toward it in a boat. The turtles seldom moved after they had ducked their heads under, and were easily collected. This is a productive technique with many turtles, whether capturing with the hands or with a dip net.

In clear water, turtles may be captured by swimming after them. Bider and Hoek (1971) designed a floating blind to facilitate capture. "Water goggling" is a technique originally described by Marchand (1945b) for use in clear Florida streams. The collector wears a face mask and scans underwater while being towed by holding onto a handle on a boat. When he sights a turtle, he releases the handle and a short, rapid swim results in a capture. This method has the advantage of covering large areas quickly and is relatively efficient in capturing individuals of the genus *Graptemys*, which are extremely wary and difficult to capture by any other method. Chaney and Smith (1950) located basking aggregations of map turtles by day and collected them at night when the turtles were found resting on vegetation just below the surface.

Electric shockers have been used with some success (Dobie, 1971; Harris, 1965). Because most reptiles sink to the bottom after being shocked, Gunning and Lewis (1957) found that shockers are best used in shallow, clear water. In every instance in the laboratory they found that unretrieved individuals made a rapid recovery. Other methods utilized in fisheries research may also be applied to turtle collecting, for example, using seines and trammel nets. Carr (1952) found seining to be most effective in areas where large numbers of young are concentrated; mature turtles are more likely to elude the seines. Moll and Legler (1971) took more adult male *Pseudemys scripta* with trammel nets than with any of the six other methods they used. Several aberrant methods that yield specimens are not recommended because turtles and other organisms may be killled in the process: poisoning with rotenone may yield specimens of the genus *Trionyx*, which are more reliant on pharyngeal respiration than are other turtles. Even dynamiting may yield turtles (Webb, 1962). Shooting is unsatisfactory because most wounded turtles are not recovered.

The congregating habit of nesting females on beaches in some freshwater and marine species offers a unique opportunity for collecting. Roze (1964) and Carr (1967b) described techniques for *Podocnemis expansa* and *Chelonia mydas*, respectively.

Sea turtles are captured commercially with large mesh nets set across channels and sloughs in shallow grass flats (Carr, 1952). These nets, buoyed by floats, often are used in conjunction with wooden decoys that attract rutting males, therefore increasing efficiency of capture (Carr, 1952). During the breeding season, sea turtles are easy prey to various types of harpoons and spears as the animals drift preoccupied in copulation or asleep on the surface (Parsons, 1962). Carr (1952) described a more direct method of wrestling the turtle into boats or onto the beach by strong swimmers. Apparently, an important factor in maneuvering these large turtles is keeping the forward edge of the shell tilted upward to prevent the animal from diving.

One of the most unusual methods of capturing sea turtles involves the use of a remora (*Echeneis*). This fish is attached to a long line and allowed to swim among congregating turtles until it attaches itself to the carapace of a turtle, which is then pulled in. Parsons (1962) gave an excellent account of the historical development of this method.

Most freshwater turtles may be taken on baited hooks. Set lines, throw lines, float lines, trot lines, and hooks and lines of fishermen often catch turtles. Usually these methods are secondary to other methods of capture, but Dobie (1971) obtained 90% of his *Macroclemys temmincki* from trot lines of commercial fishermen. Strong recurved hooks set firmly on favorite basking sites may also snag turtles (Carr, 1952; Webb, 1962).

Trapping

Baited Traps. The basic tool of capture of most freshwater species is the baited funnel trap with its many variations (e.g., hoop nets). This device is simply a cylindrical or rectangular frame covered with cotton or nylon netting or wire mesh; an inverted funnel with a horizontally flattened opening projects into the body of the trap (Figure 1). The turtle enters the trap through the funnel and once in, cannot escape. Size, shape, number of funnels, and construction materials vary among collectors. Legler (1960b) described a basic, collapsible hoop net using four hoops of aluminum tubing with a cylinder of treated cotton netting. Other collectors have covered rectangular wooden frames with wire mesh. These traps are sturdy but are very bulky and are not collapsible. To capture *Trionyx muticus*, I use rectangular traps 8 × 20 × 24 in. with a single 8 in. throat, made entirely of 1 in. mesh chicken wire. Traps set in shallow water usually catch more turtles than those set in deep water. Not only is shallow water usually better turtle habitat, but a turtle captured in a trap in which he can readily obtain air is not so prone to activity; thus the animal is less likely to escape or to scare away other turtles (Lagler, 1943b). Inasmuch as water must be deep enough to cover

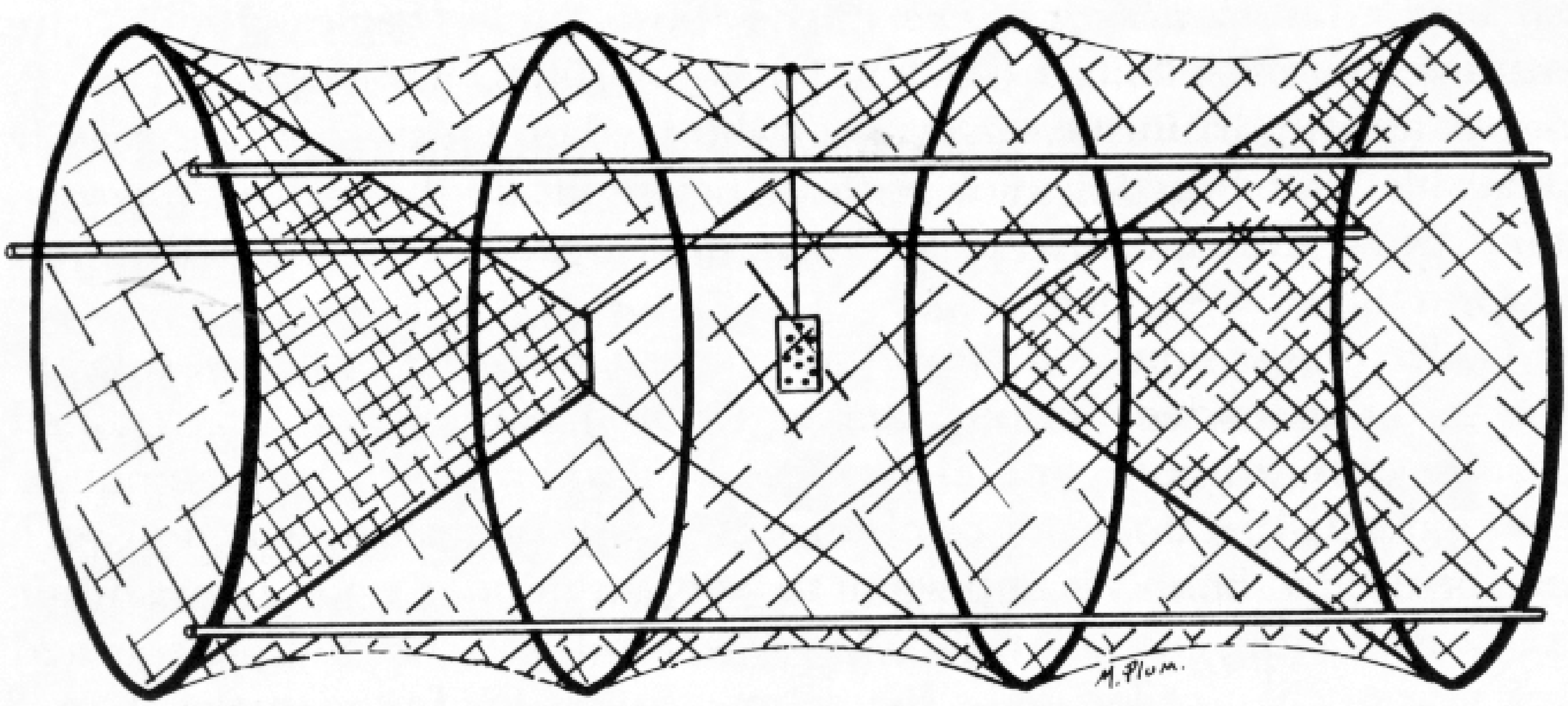

Figure 1 A baited hoop net.

the throat of the trap, rectangular traps have the advantage of lying flush with the substrate; thus they can be set in shallower water than the conventional hoop nets. The size of the vertical opening of the throat apparently is not critical. Turtles do not seem to be hindered by having to push through the low opening (Legler, 1960b). A low vertical opening is preferable because it decreases the chances of escape. Individuals of *Chelydra serpentina*, with body thicknesses exceeding 4 in. frequently push through a 1 × 20 in. throat opening designed for softshells. In running water, traps should be set with the funnel side facing downstream so turtles may follow the bait scent into the trap. Traps always should rest on the bottom in shallow water and should be firmly anchored with a line. Generally, efforts to trap turtles in deep water with floating funnel traps have been unsuccessful.

Fyke nets have also been borrowed from fisheries. These are large hoop nets with two drift fences that extend diagonally outward from the single throat opening. These traps probably do not increase capture rate over that of conventional hoop nets (Lagler, 1943b), and they are much more bulky and difficult to set.

A complete list of the baits that have been used to attract turtles would be quite extensive. Some of the more popular and productive baits include chopped fresh or canned fish, chicken entrails, and other fresh meat.

The type of bait to be used should be chosen in consideration of the type of turtle to be trapped, the relative ease of acquiring and storing bait, and the particular trapping situation at hand. An omnivorous species such as *Chelydra serpentina* would be much more apt to be attracted by bananas than would the purely carnivorous *Trionyx muticus*. Attracting large herbivorous turtles is a perennial problem, yet to be solved. Fortunately, however, some of the purely herbivorous types, such as adult *Pseudemys scripta* in the Rio Grande (Legler, 1960b), are attracted by meat baits. Clark and Gibbons (1969) characterized adult *P. scripta* as "opportunistic carnivores" who feed on meat when it is readily available. Some turtles, such as those belonging to the genus *Graptemys*, tend to be unresponsive to any bait, although they occasionally enter traps.

Collecting in remote areas often necessitates carrying bait and keeping it for extended periods. Legler (1960b) pointed out that canned sardines are a good general purpose bait where fresh bait cannot be maintained. If it does not catch turtles, it will catch fish, which in turn can be used as bait. It is important to be open-minded and opportunistic in any collecting endeavor. A collector who refuses to change established baits even when collecting is sparse may collect far fewer turtles than if he had experimented with several different kinds of bait on each population in order to determine the most attractive. Lagler (1943b) noted that *Trionyx spiniferus* often are attracted by such atypical bait as unspoiled watermelon rind.

Although it is widely held that putrid baits are best for attracting turtles, data reveal that fresh bait is by far the most productive (Lagler, 1943b; Breckenridge, 1955; Tinkle, 1958a; Legler, 1960b; Webb, 1962; Ernst, 1965). Lagler (1943b), in a summary of collecting methods, stated that the freshness of any bait seems to be an important factor in determining its value as an attractant. Legler (1960b) found that putrid or partly decayed bait was much less effective than was fresh bait. Ernst (1965) compared six different baits in attracting three species. Only with *Chelydra serpentina* was putrid bait more likely to be attractive. Only an hour after replacing day-old fish in an empty trap with fresh fish, I found that the trap contained 14 *Trionyx muticus*.

The last example illustrates another important point. Baits seem to be the most effective in the first few hours of immersion in water. Although Lagler (1943b) felt that checking intervals of less than 12 hr would disturb turtles and lower the yield, Legler (1960b) found that traps that were checked and rebaited at 1 or 2 hr intervals had a higher capture rate than did traps left for much longer periods. If bait cannot be changed, it will continue to attract turtles for several days, especially if the water is not too warm, although efficiency decreases. Bait should be enclosed in a container to prevent the first turtle that enters from eating it all. Quarter-inch hardware cloth folded into small boxes or 35 mm film canisters with holes punched in them make satisfactory containers.

Nonbaited Traps. Various types of nonbaited traps have been used. These traps have the advantage of not requiring the constant attention of the collector in renewing the bait, yet always remaining operative. Generally, these traps take advantage of the turtles' natural behaviors, which lead them into the trap. Sexton (1959) placed large funnel traps made of chicken wire at the mouths of the inlet and outlet streams of his study pond. A drift fence channeled any turtle attempting to leave the pond via the streams into the traps. He found that *Chrysemys picta* tended to migrate out of the pond in the spring in large numbers, and these traps were efficient in their capture. Gibbons (1970d) utilized a series of pitfall traps in conjunction with drift fences placed around a pond to collect aquatic turtles that wandered on land. Of 199 adult and juvenile turtles seen on land near the pond, only 13 were not caught in these traps. Gibbons (1968c) constructed cylinders of wire mesh, 3 ft in diameter, and 5 ft high, and stood them on end near shore. A 1 ft square door was cut near the bottom with the free edges of the mesh extending inward. Each trap was accompanied by a drift fence. Any turtle moving along the shoreline was channeled into the trap. The tall cylinder left room for fluctuations in water level to prevent drowning the captured turtles. Other investigators have used unbaited funnel traps set in areas of turtle concentrations for random swim-in capture.

Legler (1960a) set unbaited small-mammal live traps along ravines and rock fences ("natural drift fences") and collected a few *Terrapene ornata* in them. Auffenberg (personal communication) uses two methods for trapping gopher tortoises. One involves placing a one-way hinged door of clear Plexiglas over the mouth of the burrow. This allows the turtle to leave but not reenter, and increases the chances of finding it near the burrow opening. Alternatively, Auffenberg sinks a small wooden box or large can immediately in front of the burrow mouth with the edge of the container flush with the surface of the ground. Ideally, upon leaving the burrow, the turtle falls into the pit and remains there until collected.

The various attempts to trap terrestrial tortoises have generally been unsuccessful in terms of time and energy spent by the collector. For most species in most situations, collecting by hand remains the most effective method, after maximizing one's chances of encountering tortoises. Often a collector can have his needs most quickly filled by soliciting specimens from local residents.

The basking habit characteristic of many aquatic turtles can be used to the advantage of the collector. Basking traps in all forms of sophistication have been used extensively. One of the simplest involves attaching a wire mesh basket to the side of a sunning station with the top of the basket flush with the surface of the water. Upon leaving the basking site, the turtles plunge into the water and into the wire basket. Since the top is flush with the surface, the turtles may leave at will and natural movements are not greatly disturbed. This may be a desirable feature in some population studies. Capture rate may be greatly enhanced if the collector makes a sudden appearance from the side opposite the basket. Carr (1952) related that 20 to 30 *Pseudemys floridana suwanniensis* may be taken at one time. Turtles that bask on land may be captured as they rush from their basking sites to the water by suddenly erecting a previously placed collapsed net with a pull cord that extends to a blind (Robinson and Murphy, 1975). Breckenridge (1944) suggests sinking a barrel into water until the rim is near the surface. A cover slightly smaller than the opening is suspended by two nails fixed on opposite sides of the lid. This pivotal lid dumps any turtle climbing onto the barrel. This trap may also have bait placed near the center of the lid. A major disadvantage is that

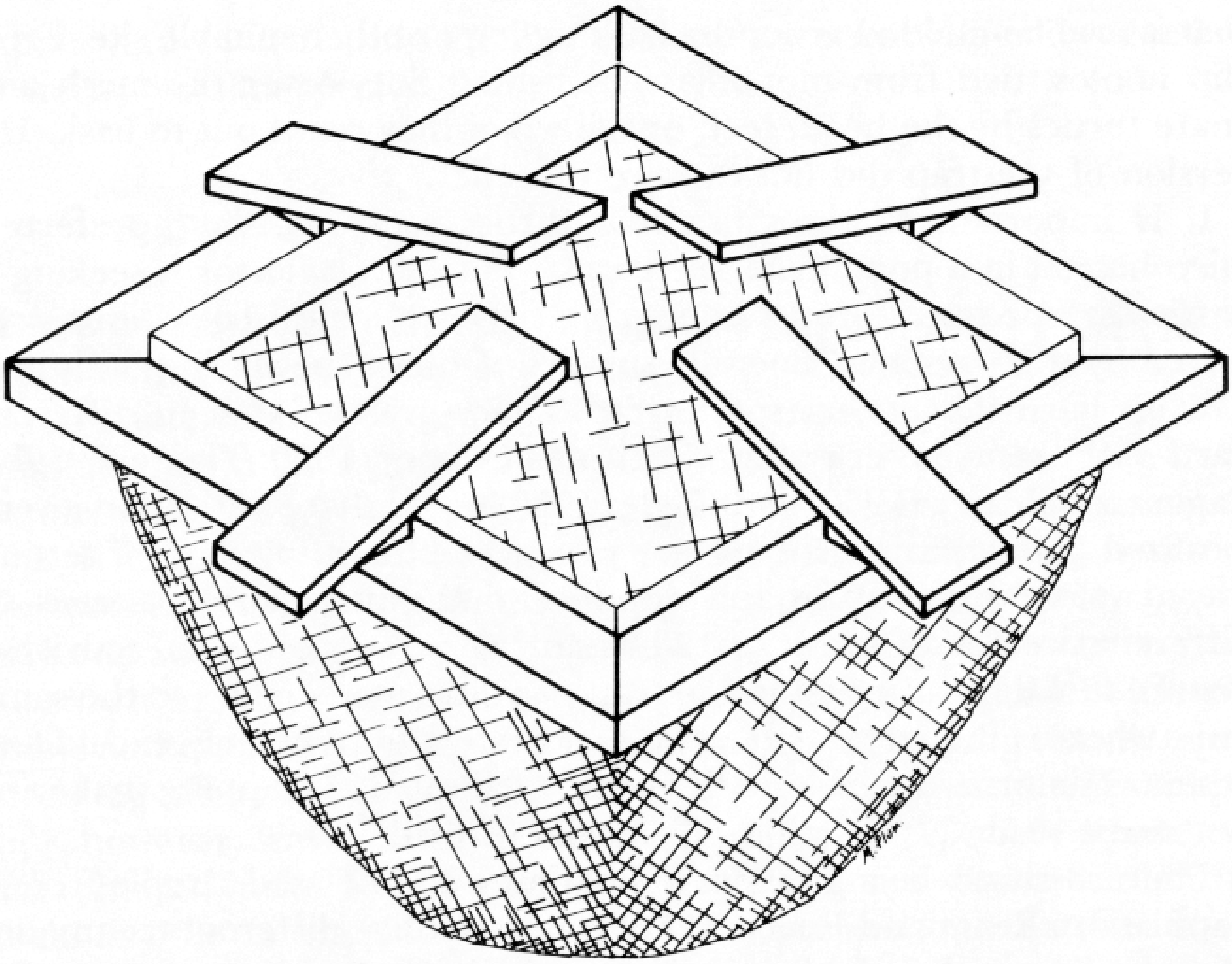

Figure 2 Basic design of a floating basking trap. Turtles basking on the inclined boards plunge into the bag upon leaving their basking station.

this trap does not compensate for changes in water level, which characterize most bodies of water.

Floating basking traps are not only easier to set up but are also immediately responsive to water level fluctuations. Cagle (1950) described a basic floating basking trap that is commonly used along the Mississippi River by commercial collectors. It consists of a square wood frame from which a net or wire bag is suspended in the middle. Boards angled up from the outer edge toward the center of the trap permit turtles to crawl out to bask but not to crawl out once they have plunged into the bag (Figure 2). Some modifications of this basic basking trap include using other types of material for the inclined board (e.g., wire mesh, closely spaced nails driven into the frame at an angle) and replacing the inclined board with single or multiple movable treadles (see Lagler, 1943; Breckenridge, 1955; Ream and Ream, 1966).

Braid (1974) described an innovative basking trap modified from similar traps designed to snare birds of prey. Called the "bal-chatri" trap, the device consists of a wire mesh base cut to a desired size and shape so that it may be molded around a basking log or other suitable site. Erect slip nooses, tied from monofilament fishing line, cover the mesh and snare turtles by the head, feet, or tail when they crawl out to bask. His version of the trap did not capture juveniles.

It is important to recognize that turtles seek out their preferred microhabitat in a pond, lake, or stream. Thus if a collector is seeking a particular species, he must know about the ecological conditions preferred by that species. Generally surveys of turtle species in ponds and streams have shown that species ratios vary greatly between different parts of the same water system (Cagle and Chaney, 1950; Tinkle, 1959b). Cagle and Chaney (1950) and Cagle (1950) noted that even within a very localized habitat, catches may vary with type of bait, method of setting traps, water temperature and depth, and the behavioral patterns of different size classes and sexes. Thus during periods of sexual activity, a mature female that is first in the trap may lure many males to the same trap, whereas if a large aggressive male enters first, he may exclude all others. The many variables influencing total catch in trapping make any systematic study of trapping efficiencies difficult.

There also may be a problem of obtaining an unbiased sample from a population. Ream and Ream (1966) compared five different techniques of capturing turtles and found that no single method was adequate for obtaining an unbiased sample. Each method seemed to capture large numbers of a particular size or sex and lesser numbers of the other classes. This phenomenon is common in population studies, and it undoubtedly has contributed to the unbalanced sex ratios often reported, thus influencing population composition data. To solve this problem, some investigators have stressed the use of diversity in collecting techniques (Mossimann and Bider, 1960; Ream and Ream, 1966). Others have attempted to develop unbiased sampling techniques (Bider and Hoek, 1971).

Collecting methods have been and will continue to be studied with regard to improving their efficiency and practicality. The methods described and reviewed above have proved themselves over time and should serve as a springboard toward innovative ideas.

One point is crucial. Check local wildlife and fisheries laws before collecting. Some states require a scientific collecting permit and/or a fishing license to take turtles. Hoop nets and similar traps are often illegal for catching fish and must be clearly marked as turtle traps. Czajka and Nickerson (1974) provide regulations governing collecting of reptiles in all states. However the provisional collector should consult the appropriate state wildlife agency before collecting, because laws change rapidly and an increasing number of states are passing laws designed to protect nongame species.

MARKING

Field studies often require the recognition of groups or individuals in order to trace their movements, ontogenetic development, roles in behavioral interactions, and so on. The various methods of marking have been devised in an attempt to fulfill these needs. There are three basic requirements of a good mark. First, it should be relatively permanent. This is especially important in such a long-lived animal as a turtle. However in many species there are large size differences between hatchlings and adults, and it is difficult to develop a mark that will not become outgrown or otherwise obliterated. Second, a mark should be clearly visible and capable of being accurately read by the investigator. A numbered tag offers little chance of misreading. A system of notches or toe clips, however, leaves more chance for misreading, especially when several hundred individuals are involved. Last, the mark should hinder the turtle as little as possible. Gibbons (1968c) pointed out that one basic assumption that is essential in population studies is that marking has no influence on an individual's chance of remaining in the population. Any marking system should be analyzed to determine the extent to which it might hinder the animal in its locomotor or other physical movements, in its susceptibility to predation, or in its sexual or social interactions.

Shell Mutilation

The shell has been the target for most turtle marking systems. Woodbury (1956), in a symposium on marking animals in ecological studies, provided a good review of the methods used up until that time. Some investigators carve numbers into the carapace. Nichols (quoted by Cagle, 1939) carved numbers in the carapace of *Terrapene carolina* and found that the numbers remained distinct for 10 to 15 years. However this method is time-consuming and laborious, and cannot be used for species that molt their outer plates. Many workers have experimented with notching the edge of the marginal laminae of the carapace. Cagle (1939) developed a system that could be used to identify up to 2516 individual turtles by notching the laminae using four separate marks. By marking a plastral scute or clipping a toe, the series could be used over again and theoretically, an almost infinite number of possible combinations could

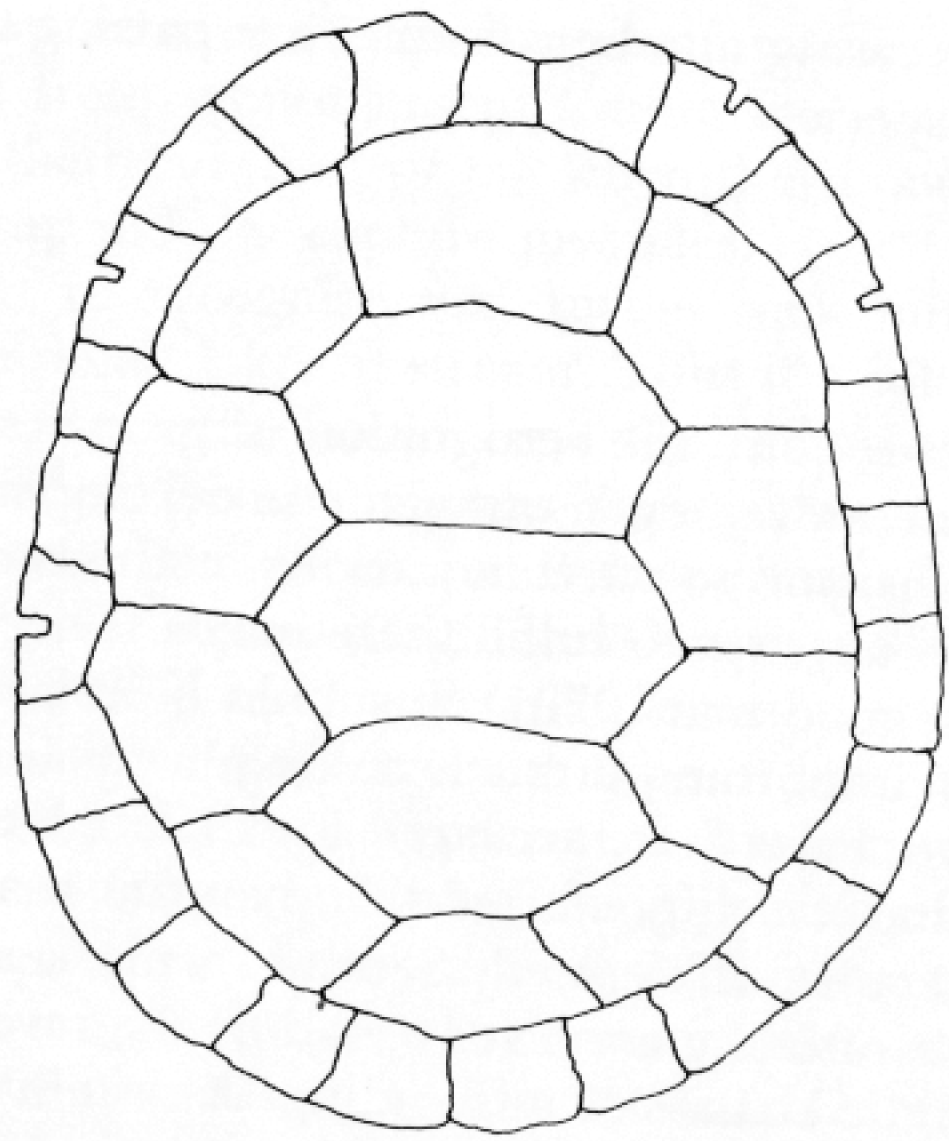

Figure 3 Carapace of an emydine turtle (*Deirochelys reticularia*, KU 3400, Juv). Marginal notches have been added to illustrate an individual marked 4,7–2,4.

be attained. The notching is done by a small file or hacksaw, or with a penknife or scissors on young turtles whose shells have not completely ossified. For speed and for application of a clean-cut mark, Cagle (1944b) substituted a small electric grinder to apply the marks. The marginals are numbered from anterior to posterior on each side and the identifying number of a turtle is the series of numbers representing the specific marginals notched. Thus 4,7-2,4 would be an individual whose fourth and seventh left marginals and second and fourth right marginals are notched (Figure 3). Cagle's system or modification of it is widely accepted and is used by many modern workers. Modifications include utilization of more or less than four notches, drilling holes in the marginals instead of notching, and using different ways of numbering the marginal laminae. Although adult turtles will usually retain the marks for years, it is often necessary to remark young turtles when they are recaptured, since the comparatively rapid growth of the shell may have occluded the marks. Certain techniques may be better suited to particular situations. For this reason the notching system may never be standardized, nor need it be.

The Trionychidae may be marked similarly in spite of their lack of laminae. By viewing the carapace dorsally and imagining the face of a clock superimposed on it, one can cut notches on the edge of the carapace at desired locations to represent numbers corresponding to hours of the clock. Breckenridge (1955) used a leather punch to mark *Trionyx ferox* and found that although the holes in the vascular carapace healed quickly, they were still discernible at 3 to 5 years as shallow sinuses. While working with a population of *T. muticus*, I have recognized individuals marked 3 years previously by Henry S. Fitch, an earlier worker with the same population. The marks were originally cut as notches with a penknife. Although the notches eventually heal and fill out to the margin of the carapace, a V-shaped piece of scar tissue remains. This scar tissue is most easily seen when viewed on the whitish ventral surface.

Problems may arise in differentiating between intentionally applied marks and wounds acquired by an animal in the field. Generally, wounds are irregular in shape in contrast to the smooth outline of marks. This is also a reason for marking more than one scute. Rarely will an accidentally "marked" turtle fit a combination of special marks or be the size of the turtle indicated in the worker's records.

Woodbury (1948) described the manufacture and use of an electric tattooing device that could be used on the clear plain ventral surface of members of the Trionychidae. Breckenridge (1955) used a tattooing device to inject ink into the plastron of *T. ferox*. Conceivably this method could be affected by growth if hatchlings were tattooed. The pigment granules might be dispersed to such an extent that it would be impossible to interpret the numbers.

Woodbury and Hardy (1948) used branding to mark *Gopherus agassizi*. They discovered that if the burn was too deep and affected the underlying dermal tissue, a slow regeneration process was initiated that completely obliterated the brand within a few years. This regeneration could be avoided by using a white-hot wire and burning the shell very quickly. By branding various combinations of plates, a large number of individuals could be marked uniquely. Weary (1969) described the use of an electric branding outfit that can be used in the laboratory. Clark (1971) described a technique in which numbers are formed by bending Hoskins Chromel "A" resistance wire (Malin and Co., Cleveland, Ohio). By heating the bent wire with a small propane torch, numbered brands can be conveniently applied in the field. Clark found that the brand was clearly legible 36 days after marking. No infection or alteration by growth and healing processes marred the brand during this short time. Clark stated that the wire must be left in contact long enough to produce a lasting and legible mark, but not long enough to penetrate the dermal layer and initiate regenerative processes.

Tag Marking

The application of various types of numbered tags has also been popular in turtle studies. Unfortunately, this method is particularly subject to the drawbacks of growth in large species. Carr (1967b) pointed out that it is difficult to devise a single tag that will identify both a 3 oz hatchling and the 300 lb adult turtle. For this reason, tags may be used with the most confidence on small species or on adults of large species. There have been some recent efforts to tag hatchling sea turtles by injecting certain materials into the body and later analyzing tissue samples. For example, Forbes (1972) injected europium chloride in a citrate complex. Turtles that had been marked were identifiable by subjecting tissue samples to neutron activation analysis. Such a sophisticated procedure may be necessary to provide lifelong marks in large species; however it does not solve the problem of providing unique marks to individual turtles.

Carr (1967b) experimented with oval monel metal plates wired to the posterior edge of the carapace of female sea turtles. He was frustrated by the quick loss (often less than 2 weeks) of the tag caused by the vigorous courtship and mating activities of rutting males. Carr has had the most success with the application of metal tags of the type used in animal husbandry for attachment to the ears of livestock. The ear tags are attached to the posterior edge of the front flipper and meet all the basic requirements discussed above. Tagging remains a current topic in the *Marine Turtle Newsletter* (N. Mrosovsky, Ed., University of Toronto). Metal tags attached to the carapace have also been used on freshwater and terrestrial species with some success (Wickham, 1922; Pearse, 1923a; Bogert, 1937; Miller, 1955).

Gaymer (1973) marked giant Aldabran tortoises (*Geoghelone gigantea*) by placing numbered, ¾ in. titanium disks into shallow depressions cut in the carapace. The disks were fixed in place by a metal-resin adhesive. Fifty-nine of 150 marked tortoises were relocated after one year; only 2 disks had been lost.

The various brands of "pop rivet" tools available in most hardware stores offer some promise in tag marking. Small aluminum rivets with back-up plates may be applied to the shell through a small hole drilled in the carapace. The back-up plate provides a convenient place to stamp an identifying number. Breckenridge (1955) marked 39 *Trionyx ferox* using brass rivets but never recaptured a single turtle with a rivet in place, although some were recaptured showing rivet holes. I have experienced a 50% loss rate of rivets in as little as 2 months in *T. muticus*. The tissue surrounding the rivet apparently becomes necrotic, and the rivet falls out. However the use of pop rivets in hard-shelled species could be rewarding because the rivets are quickly applied, provide a visual identification number, and protrude very little from either side of the shell. Pough (1970) provides a similar marking method with a device designed to attach buttons by the use of small plastic bulbs. The bulbs are attached through holes drilled in the marginal scutes. Although Pough gave no data pertaining to the retainment of bulbs, he suggested that such plastic bulbs applied to a hatchling would be clamped in place as the shell grew and retained throughout life, particularly if applied to individuals of small species.

Other Marking Techniques

Application of paint to the shell has been used in some short-term studies. Woodbury and Hardy (1948) painted different combinations of scutes in various colors to mark individuals of *Gopherus agassizi*. They found that the paint wore thin after a year or two, although one red-marked tortoise was positively identified 8 years later. Miller (1955) wrote numbers in India ink on the shell of *G. agassizi* and covered them with clear lacquer. He later improved his method by carving numbers into the shell, filling them with pigment, and then covering them with lacquer. Painting has also been used on aquatic species (Tinkle, 1958a; Moll and Legler, 1971). Moll and Legler found that the numbers on hatchling *Pseudemys scripta* remained legible for 1 to 2 months or until the scutes were shed. Since many factors tend to obliterate paint marks this method is, at best, useful only under specific conditions (e.g., short-term behavioral studies) and should be used in conjunction with other more stable methods.

In order to study movements, Carr (1967b) marked *Chelonia mydas* by attaching brightly colored Styrofoam floats to a line that was tied to the carapace of the turtle. He felt that this did not appreciably affect turtle activity. Because of the curvature of the earth's surface, these floats were not visible for more than 1 mile. Therefore Carr attached a helium-filled balloon to the float by a 20 ft line; this increased visibility to about 8 miles. A sausage-shaped balloon offers less resistance to air than does a spherical balloon, thus is less likely to be blown down by winds (Carr, 1967b).

In studying short-term movements of *Trionyx muticus*, I have used as floats small (ca. ½ × 6 in.) sausage-shaped balloons, inflated with 1 atm of pressure. By using different colored balloons, each marked with specific numbers of rings (using a permanent felt-tipped pen), numerous individuals may be identified at a distance through binoculars. The balloon is attached to the posterior edge of the carapace by a fine, stiff wire. Stiff wire has less chance of becoming fouled on obstructions and, if it does become fouled, readily pulls out of the carapace because of the pressure exerted by the turtle.

Davis and Sartor (1975) used a similar method, attaching a wooden dowel in a hole drilled in the nuchal scute and color coding the end of the dowel with paint or plastic tape. Obviously, these two methods are practical only in comparatively obstruction-free waters.

"Turtle trailing," originally used by Breder (1927), is a technique in which a spool of thread is attached to a terrestrial turtle, the free end anchored at some specific spot, and the path of the turtle determined by following the unwinding thread. The original construction of the device was literally a trailer that the turtle pulled. Stickel (1950) improved the technique by mounting the entire device on the carapace, and Emlen (1969) further modified and improved the device in his work on terrestrial homing in *Chrysemys picta*. Both Breder and Stickel used the method in studying home range and movement in *Terrapene carolina*, and the method has become almost standard practice in field work with turtles of this genus (e.g., Legler, 1960a; Dolbeer, 1969; Metcalf and Metcalf, 1970; Reagan, 1974; Schwartz and Schwartz, 1974).

Bennett, Gibbons, and Franson (1970) tagged three species of aquatic turtles with radioactive tantalum-182 in order to study distance from and depth of burrowing from temporarily dried-up ponds. The apparent relative insensitivity of some turtles to gamma radiation (Atland, Highman, and Wood, 1951; Cosgrove and Davis, 1965) and the ease with which small radioactive tags may be inserted into holes drilled in the carapace make this type of "remote sensing" an ideal method for locating turtles when short distances are involved. For longer distances the various types of biotelemetry (see Chapter 3) may be extremely productive.

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