Chapter 7

Supplemental Approaches to Studying Amphibian Biodiversity

Introduction

For the most part, the procedures described in Chapter 6 have been widely used and adequately tested, and we recommend them as standard techniques for field use. A number of other techniques appear promising, but they lack sufficient field testing, are more appropriate for research on single species than for studying general biodiversity, or provide data whose interpretation may be ambiguous. Nevertheless, workshop participants thought it important to bring these techniques to the attention of the potential user, and we describe them in this section. We encourage users to provide feedback about them to the editors for inclusion in future editions of this book.

Artificial habitats

Most of the traditional methods for surveying amphibians focus on concentrations of animals at their breeding sites. For many species, counts of adults, egg masses, or larvae provide reliable, quantitative estimates of population size. Although these techniques work well in many situations, they may be difficult to use in some bodies of water that are ephemeral, peculiar in form or topography, or support quantities of interfering vegetation.

A few herpetologists have experimented with artificial ponds, artificial cover, or other artificial "habitats" for increasing the efficiency and precision (i.e., repeatability) of surveys. Stewart and Pough (1983) and Townsend (1989) used "frog houses" made from sections of bamboo stalk to sample *Eleutherodactylus coqui* in Puerto Rico. These houses were designed to provide hiding and brooding sites. The bamboo sections were placed in arboreal situations, within easy reach of the researchers. This technique may be applicable to other anurans that use arboreal retreats. Fellers et al. (1988) described a more generic approach to providing artificial shelters, and Gascon (1992) described an artificial pond technique. Both of these approaches are recounted in detail here. The shelter technique has been used by J. W. Gibbons and B. W. Grant (pers. comm.).

The use of artificial cover and artificial ponds has been limited; hence we do not yet know the species and habitats for which these techniques may be useful. Likewise, interpreting the data collected may be difficult. The relationship of the sampled population to the overall population of the species in the area and the extent to which artificial habitats may lead to local population increases are not known. These techniques have potential advantages for sampling because they use standardized sampling units that can be replicated easily and applied consistently over time. Clearly, the techniques warrant further consideration and testing.

Sampling with Artificial Pools

CLAUDE GASCON

In this technique, artificial pools are randomly placed in the area to be sampled, during the breeding season. Pools are left in place for a period adequate to allow amphibians to locate them. The pools are checked frequently; all adults are counted visually, and larvae are sampled quantitatively.

Artificial pools can be used for two purposes. First, they can serve as "passive" devices to sample frog biodiversity. For example, artificial pools can be used to obtain data on presence-absence of certain species based on the presence of tadpoles or eggs; to survey adults of some species that call around the basins, especially those that use small isolated ponds for reproduction; and to compare relative abundances or species composition of amphibians in different areas or habitats. Because artificial pools do not sample all frog species in an area, they must be used in conjunction with other survey techniques to obtain complete species lists.

Second, artificial pools can be used for quantitative sampling of tadpole populations. Overall tadpole abundance can be estimated if one knows the abundance of tadpoles in the pools and the abundance and size of all tadpole habitats. Juvenile production also can be estimated if drift fences are used with the pools.

In both instances, the technique relies on the frogs to use the pools for reproduction. The presence of tadpoles and/or eggs in the pool indicates a reproductive population.

TARGET ORGANISMS AND HABITATS

Artificial pools have been used successfully in the Neotropics to monitor populations of tadpoles of species in the families Dendrobatidae, Hylidae, Leptodactylidae, and Microhylidae (Gascon 1992 and unpubl. data). In some cases, adult frogs are also encountered in or around the pools. For example, adult *Pipa arrabali* (an aquatic frog) used the pools in Amazonia, but in this case the adults remained in the pools, and no free-living tadpoles were found. Frogs of other families also were encountered around pools where they oviposited or deposited larvae that had hatched in terrestrial nests. Other species used them for cover to avoid predators.

Pools can be deployed in virtually any habitat in which amphibians that breed in pools or ponds are found. Pools are not very effective for monitoring frog species that occur in stream habitats and are obviously ineffective for species that have completely dissociated their reproductive cycle from bodies of water. The effectiveness of artificial pools depends on the number of pools deployed and the abundance of frogs in the area.

BACKGROUND AND RESEARCH DESIGN

For passive species inventory, the more pools that are set out, the better the chance of attracting adult frogs and later finding breeding individuals or tadpoles. Pools can be set out singly in different areas, or they can be grouped in threes or fours (grouped pools may be more attractive to frogs, but this assumption is untested). Pools are best placed in areas removed from existing water, but of similar general habitat, where they are likely to attract frogs.

When making comparisons across areas or habitats, more than one pool should be placed at each site, and equal numbers should be placed in each habitat area. This methodology will provide data appropriate for statistical analysis. It also may require some advance planning, if the total number of pools is limited or if many areas are sampled simultaneously.

For tadpoles, the sampling interval for the pools must be shorter than the developmental period of the tadpole of the most rapidly developing species. In other words, if a tadpole completes aquatic development in 3 weeks, then the basins should be visited and sampled at least every 2 weeks. Otherwise, entire cohorts may be missed.

Because the objective is to mimic natural habitats, the size of the pools is an important consideration. Pools can be smaller than natural sites but should be large enough to allow a "natural" type of assemblage to develop (i.e., accumulation of organic matter, presence of aquatic insects, and so forth).

FIELD METHODS

Pools should always be buried flush with the substrate. Although many species will use artificial basins that are above ground, other species (especially small ones) are less likely to deposit eggs or tadpoles in them. Leaf litter from the surrounding area should be placed in the pool. It is also important to place a stick or branch diagonally in the pool to provide an exit ramp for juveniles that cannot otherwise get out. The stick should be longer than the diameter of the pool, with one end resting on its upper lip.

For qualitative sampling, any type of dipnet can be used to catch the tadpoles. Repeated dipnetting will ensure that all species are caught. For quantitative monitoring of tadpole populations, the pools can be emptied completely, and all organisms identified and counted. This is best accomplished by emptying the contents into a bucket through a fine-mesh net. The contained organisms can be counted and returned to the pool. The bucket should have a volume larger than that of the pool so that no water is lost. This will ensure that the water level in the bucket is close to the top and that the contents of the net remain submerged at all times. As tadpoles are sorted they can be staged to provide additional information on the number of cohorts of each species.

Care always should be taken when checking pools. Tadpoles of some species are fragile and easily damaged by extensive manipulation. It is advisable to return some of the water to the pool and release the tadpoles there as they are counted. Other organisms, such as insect larvae, should be returned as well. These procedures should minimize tadpole mortality from handling, disruption of the associated nonamphibian assemblage, and the influence of these factors on population fluctuations of tadpoles.

Samples of all larval species should be collected and preserved as vouchers.

PERSONNEL AND MATERIALS

The most strenuous activity associated with this technique is digging the hole for each pool. This can be carried out by as many individuals as the investigator can recruit. Sampling for the presence of tadpoles and night surveys of the pools for associated adults can be done by a single person. In most cases, two persons will be needed to empty the pools (large pools will be heavy to lift) and to process the material for quantitative sampling of tadpole populations. In a study in the tropical forest near Manaus, Brazil, it took a technician and a researcher an average of 15 to 20 minutes to empty one artificial basin (53 liters of water) and identify and count all individuals present.

Any plastic washbasin approximating the size of a small naturally occurring pool will suffice for nonquantitative sampling. Pools that are to be emptied at each sampling period must be rigid enough to hold their shape when lifted, even if full of water and debris. Additional basic materials include shovel, notebook, pencils or permanent-ink pens, strainers or small dipnets, large buckets and fine-mesh netting for emptying basins, collecting bags, and vials of 10% buffered formalin.

DATA TREATMENT AND INTERPRETATION

All pools should be identified with a number or an alphanumeric code. Each time the pools are surveyed, the pool identifier, date, time, weather, pH, and oxygen tension should be noted. The pH and oxygen tension readings should be compared with readings from natural pools to make certain that both have the same characteristics. For passive sampling (yielding species richness data), the investigator needs to record the species present at each visit. Individuals of unidentified tadpoles can be collected and reared for future identification or compared with a reference collection. For quantitative sampling of tadpole populations, data should include the name and number of tadpoles at each developmental stage for each species. The investigator can also record the presence of predators (i.e., dragonfly naiads, aquatic insects) and their abundance. For easy field notation of developmental stages, a modified version of Gosner's (1960) staging system can be used (Gascon 1991).

Data collected in the field should be transferred to computer files constructed so that each record in the file represents the number of tadpoles of a given species in one pool on a particular date. Constructing data files in this way greatly facilitates indexing and retrieval of information. The essential fields are species, date, and pond identifier. For quantitative sampling, the number of tadpoles of each species present in the pond on each sampling date and their corresponding developmental stages should also be included.

Statistical treatment will vary with the objective of the study. If an investigator wishes to compare relative abundances between two or more areas or habitats, methods using either counts or proportions may be used (see Chapter 9). If data were collected over a sufficiently long period, then breeding phenology of species can also be determined. Histograms of the number of species present in the different areas or habitats as a function of time (per month or week) can be constructed easily. The investigator can also build a detailed phenological histogram consisting of the presence and absence of tadpoles of each species through time.

With more quantitative data, the investigator can construct time-series graphs to show variations in species abundances over time. For each species in each pool, the abundance of each developmental stage encountered can be represented on the same graph, using different symbols. It is also possible to count the total number of cohorts of each species present in each basin.

Sampling with Artificial Cover

GARY M. FELLERS AND CHARLES A. DROST

Amphibians frequently take cover beneath surface objects. Thus, artificial wooden cover objects can be added to the environment in standard arrays for sampling amphibians. The cover objects are checked, and data on amphibians present are recorded.

This technique allows for the development of a reliable index of population size for amphibians using a standardized set of artificial cover boards, and for evaluation of the condition of each species' population. The first objective can be met without addressing the second, but a monitoring program will be much more efficient in providing an "early warning system" for population declines if it addresses both objectives simultaneously.

TARGET ORGANISMS AND HABITATS

This technique is relatively new and has not been extensively tested. However, it worked well for salamanders on the Channel Islands in southern California, for a variety of salamanders in coastal Georgia (J. W. Gibbons and B. W. Grant, pers. comm.), and for forest amphibians in British Columbia (T. M. Davis, pers. comm). It has good potential for a wide variety of terrestrial amphibians that normally are found under surface cover.

In California, artificial cover was used most extensively in grassland habitats, but it was also tested on the ground among low-growing shrubs and over ice plant (*Mesembryanthemum* sp.). In Georgia it was used in bottomland hardwood forest, upland pine stands, and old-field habitat, and along the borders of wetlands.

BACKGROUND

Many species of amphibians can be found under surface objects during wetter periods of the year. By setting out a standardized set of cover objects, it is possible to determine the numbers of different amphibian species under a consistent, uniform amount of cover. Advantages of this technique, compared with other survey techniques, include (1) standard number of cover items of standard size; (2) little between-observer variability, especially when compared with techniques such as time-constrained or area-constrained searches; (3) limited disturbance to cover items (e.g., logs fall apart with repeated disturbance, natural cover decays and changes character with time); (4) modest investment of time and money to establish transects or plots; (5) limited training required; and (6) easy maintenance of cover items.

There are also several disadvantages: (1) the method provides only an index of population size; (2) use of artificial cover may vary among species, depending on their habits and on the availability of natural cover objects; (3) counts may vary with local weather conditions (e.g., recent rains or drought); (4) cover boards may be difficult to locate in habitats with fast-growing vegetation.

RESEARCH DESIGN

Cover boards of different materials and sizes can be used, and they can be arranged in different ways. When surveying for the salamander *Batrachoseps pacificus* on the Channel Islands of California, we used 30 × 30 × 5 cm (12″ × 12″ × 2″) pieces of untreated pine or fir, arranged in parallel lines or small grids. Larger boards may be more appropriate for other species. We tried plywood sheets as large as 122 × 122 × 1.25 cm (48″ × 48″ × 0.5″); cover boards that size generally attract a greater number of species and individuals. From a practical standpoint, however, their size may limit the number that can be deployed. The number of boards needed for adequate statistical analysis depends on the heterogeneity of the habitat, the site fidelity of the organisms, the size of the area to be sampled, and whether species presence or individual abundance data are needed.

We also have tested 0.5-cm-thick (¼″) plywood and 10-cm-thick (4″) thick boards, but have found them less suitable than boards 5 cm (2″) thick. Plywood works fairly well during the cooler times of the year, but 5-cm wood is much superior in its ability to retain moisture and provide a more stable thermal environment through-

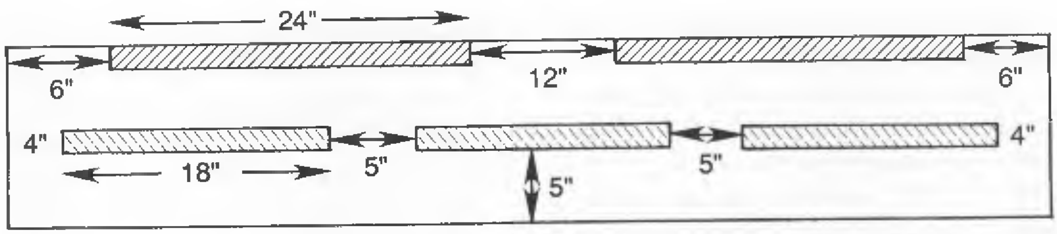


Figure 20. Diagram of the baseboard portion (viewed from above) of an artificial cover board designed to provide complex microhabitats for use in studying salamanders. Strips of cedar lathe (6 × 38 mm, or 0.25″ × 1.5″) in lengths of 46 cm (18″) or 61 cm (24″) are attached along the middle and edge of the baseboard (5 × 30.5 × 180 cm, or 2″ × 12″ × 72″), respectively. The strips along the edge are doubled, so that the lathe there rises above the baseboard about 12 mm (0.5″). The baseboard is placed on the ground with the lathe strips facing up. Two cover boards about 2.5 × 15 × 180 cm (1″ × 6″ × 72″) are placed on top the lathe strips, creating wedge-shaped spaces.

out the rest of the year. The 10-cm wood is also superior to plywood, but it is not appreciably better than 5-cm wood, so the extra expense and labor involved in deploying it does not seem warranted. Other types of cover material (e.g., corrugated metal) may work in some areas and habitats.

We set out cover boards in parallel lines, small grids, and "webs" consisting of several spokes radiating from a single central board. Our initial design consisted of two rows, 5 m apart of 30 boards each, spaced 5 m apart. This appears to be a reasonable density of cover material for small amphibians with relatively small home ranges. We marked the end board in each row with a metal tag showing the board number. Other boards were numbered with indelible ink.

A design to provide greater microhabitat complexity is currently being field-tested for amphibians in moist temperate forests of British Columbia, with promising early results (T. M. Davis, pers. comm.). The basic unit is a cover object consisting of three boards of untreated lumber. A recently cut (< 1-yr-old) 5 × 30.5 × 180 cm board is placed flat on the ground. Two other boards (2.5 × 15.3 cm) are placed on top of the base board but are separated from it with small strips of wood (Fig. 20). This design creates wedge-shaped spaces; water drips through the crack between the cover boards.

Grids potentially provide better information on movement and home range than do parallel transects. So far we have used only relatively small grids (9–25 boards, with spacings of 2–3 m). Larger grids (100 boards or more) will be necessary for reliable data on movements. For reasonably sedentary species, mark-recapture techniques may be used with such grids to estimate population size.

Cover boards arranged in the form of a web can be used to estimate density (Wilson and Anderson 1985), but a large array is required (e.g., a web with 12 rays of 12 boards each). Regardless of the arrangement used, it is important to place cover boards in areas that are representative of the habitat being sampled.

FIELD METHODS

Boards are checked by quickly lifting them and capturing all amphibians underneath. It is useful to have plastic bags or jars for temporarily holding specimens. Body length (SVL, or snout–vent length) can be measured either with a ruler fitted with a right-angle "stop" at one end or, in the case of salamanders, with a measuring tube (Fellers et al. 1988). Frogs and salamanders can be weighed in plastic bags of appropriate size. After being checked, the board is replaced directly on the ground; it should not be held up by vegetation or small rocks. Once the board is in place, the animals are released at the edge of the board. This is particularly important for species that must have both protection and the moisture available under the cover object.

A number of factors influence the number and diversity of amphibians found under artificial cover. These include time of day (or night), season or time of year, density of artificial or natural cover, and habitat type. Amphibians are encountered most frequently when the ground under the cover boards is moist. Data collected under poor conditions, or under different conditions from one year to the next, obviously are not suitable indicators of trends in amphibian population levels. For this reason, it is not possible to specify a sampling protocol that will work everywhere, because the schedule will need to reflect local weather patterns and the behavior of local amphibians. In California, sampling is most consistent if boards are checked just after a winter storm or two.

Cover boards should be checked several times, to accommodate seasonal differences in activity, both among species and for single species among years. Depending on the species or assemblages being sampled, it may be necessary to sample at weekly or monthly intervals throughout the peak season. The number of boards per transect, grid, or array should be evaluated after an initial sampling period. If a species of interest is rare or populations levels are highly variable, it may be necessary to increase the number of boards.

PERSONNEL AND MATERIALS

Transects can be checked by one person with experience in identifying local amphibians. Materials needed include cover boards (e.g., measuring 30 × 30 × 5 cm, 60 boards per transect); walking stick or pole used for locating boards in dense vegetation; spring scales and a ruler with an end stop, both of sizes appropriate for the anticipated species; plastic bag for weighing amphibians; plastic 1-gallon jar for shielding amphibians being weighed on windy days; water container and water for wetting amphibians that begin to dry; data forms; and waterproof pens.

DATA TREATMENT AND INTERPRETATION

The board number, species identification, body length, sex (if possible), weight, and any comments about the individual should be recorded for each animal located under a board on the transect. Use of a data form will ensure that all required information is recorded in a systematic manner.

If only a summary count is recorded for a transect, it will not be possible to determine within-sample variability. Data relating to microhabitat and successional changes along a transect will also be lost.

POPULATION INDEX. Data analysis will involve calculating a population index for each species along a transect. The procedure for doing this will depend on how the data are collected and the behavior of the amphibians sampled. For counts made primarily during periods of peak activity, it is appropriate to calculate the index by combining counts for a year and calculating the mean capture rate (animals per board) for each species. If transects are checked over a longer period, it is more appropriate to use either the peak count or the average of the three to four highest counts, because the pattern of use of cover boards may change with weather or behavior (e.g., migration, courtship). The best analytical procedure can be determined only after reviewing the patterns of abundance exhibited over several years. To help visualize changes in abundance, the data for each species should be graphed as capture rate (± standard error) by year.

Changes in population indices must be interpreted in light of recent weather patterns. As was noted earlier, data collected when conditions are not suitable for amphibians should not be used in analyses for trends in population size or composition.

Short-term changes in population indices can be examined by comparing indices between years using a chi-square or G test. Long-term trends can be examined using autoregressive time series analysis (Edwards and Coull 1987), which is appropriate for detecting trends in autocorrelated time series data.

Data should be examined for year-to-year fluctuations in numbers. Normal year-to-year changes may be relatively greater for some species than for others; it may be necessary to collect data for several years before the magnitude of these natural fluctuations can be determined. Until then, the observed changes will be difficult to evaluate. Data also may reveal local changes in distribution, particularly as habitats in the area change. Such changes would be expected when fires, hurricanes, or other disturbances initiate a successional process. Transect data will provide a baseline for documenting changes in both the abundance and microdistribution of amphibians.

WEIGHT–LENGTH REGRESSION. The relative mass of an animal can provide an indication of its health because healthier animals are likely to weigh more than less healthy individuals. Differences in relative mass between years may be evaluated by calculating a regression of weight on length for each year. Because weight has a curvilinear relationship with body length, it is appropriate to calculate the regressions as length versus cube root of weight; this approach provides a more linear relationship. Results for different years may then be compared to determine whether the regression lines or their slopes differ significantly (Zar 1974). If the weights of small individuals are reasonably constant, a shallower slope indicates that the animals are in poorer condition.

SPECIAL CONSIDERATIONS

In some habitats, vegetation can grow over boards and obscure them. It is useful to carry a walking stick or pole to tap the ground at stations where you cannot visually locate the boards. Tapping the ground is much more efficient than searching through the vegetation by hand. Also, boards occasionally crack and break apart with age. Such boards do not provide nearly as good shelter as intact boards, and data are not comparable to those obtained from entire boards. Extra replacement boards should be carried when checking transects. In some areas, the ground cracks and forms a depression under a board after a few years. When this happens, the board should be moved permanently to one side, and its distance from the other boards in the study noted.

CONTRIBUTOR: TED M. DAVIS

Acoustic monitoring at fixed sites

A. STANLEY RAND AND GEORGE E. DREWRY

Automatic acoustic monitoring of frog calls at fixed sites can provide continuous estimates of population size and breeding activity for target frog species. Fixed acoustic recording stations are placed where frogs of target species are known to call, and data on calling activity are recorded automatically through manipulation of the equipment. The technique can be used to quantify vocal activity of selected species using call rate (calls per unit time). It also can be used to average call intensity (sound energy) over time and record it automatically. The resultant data can be used to estimate number of calling males during the breeding season, to assess long-term changes in the number of calling males, and to compare populations of calling males at different sites.

The data also provide detailed records of daily and seasonal frog activity that reflect the influence of day-to-day climatic conditions. Although the equipment is expensive and installation requires substantial effort, once the system is operating, it collects data automatically with little additional investment of either time or money. The technique differs from the data logger-based technique earlier (see "Recording Frog Calls," under "Automated Data Acquisition," in Chapter 5) in being usable in more-complex sound environments and in providing preliminary analyses of the data automatically as they are gathered.

Target Organisms and Habitats

Acoustic monitoring is, as the title indicates, a technique for monitoring, not inventory. It does not generate species lists. Because only one or a very few recording stations are installed, relative abundances of calling males of at most a few species are obtained. Density data can be obtained for the area immediately surrounding the recording station if sampling methods that yield estimates of absolute numbers are used simultaneously. This technique is most valuable for comparing activity at single sites through time, rather than data from different sites.

This technique yields data on behavior and advertisement calls and estimates relative abundances of calling males. It can be used for any species with a locally unique call. Call rates can be counted for species with short calls given persistently, regularly, and antiphonally. Data can be interpreted for calls that overlap, if the calls overlap in a regular fashion. Target species must occur in densities sufficient to ensure that a number of calling males are audible from a particular recording site. The technique is more useful for species with prolonged calling seasons than for explosive breeders with short reproductive seasons. A system, particularly one in which a computer controls the data acquisition, can easily process data for several species at a time.

This technique is appropriate for almost any habitat, but the recording equipment must be safe from theft or vandalism and must be accessible for frequent inspection. The technique is probably best suited for permanent field stations where meteorological data also are being recorded. It is certainly appropriate for use in tropical forests (Drewry 1970).

Background

In many species of anurans, males call regularly and repetitively either from sites in their home ranges or from a restricted breeding area, so that a number of individuals are audible from any one spot. Calling males often space themselves relative to other calling males within the area. For these species the call rate and/or call intensity can be used to estimate numbers of calling males and their activity. Calling males are assumed to represent a fraction of the entire population, but that fraction likely changes over time.

The number and repeat rate of calls heard from a spot depends on call intensity, noise interference, number of males calling, and the level of calling activity. The maximum distance from which a male can be detected by a microphone of a given sensitivity is the radius of the area being sampled by that microphone. It should be kept in mind that the frequency spectrum and the intensity of calls reaching the microphone are influenced by differential transmission through the environment.

Although call intensity differs greatly among species, relatively little difference typically exists among males of the same species or among successive advertisement calls of individual males. Diel and seasonal patterns of calling generally are modulated by weather conditions. These influences must be considered when comparing years or sites. Although calls that overlap greatly in time cannot be counted easily, numbers of calling males can be estimated under certain conditions by analyzing several minutes of sound in the primary frequency band of the species under study and dividing intensity by the average intensity value characteristic of the male of that species. Corrections must be made for the effects of climatic variables (Drewry 1970).

Narins and Capranica (1977) described a technique for the automated analysis of animal vocalizations using a system that recognizes calls. Their technique was designed to make fine scale measurements of temporal features of calls, but it also could be used to count calls.

Research Design

Research design will depend on how calls are distributed in space and time and on whether the calls are being counted or their intensity is being measured. The placement of a microphone is critical to success of the technique. Local call rate variation throughout the habitat may be sampled by recording from several nearby but nonoverlapping areas. For averaging the sound energy over time in order to compare magnitude of calling effort, the location of the microphone relative to the calling animals should be adjusted to minimize the relative contribution of any single individual. Suspending the microphone well above the chorus is usually the easiest way to accomplish this.

Diel sampling should include at least all the activity maxima expected throughout the breeding season. The best time-sampling unit for counting calls is probably the call repetition interval (usually species-specific); use of this interval maximizes the likelihood that each call included is contributed by a different animal. For example, if a species characteristically calls every 3 seconds, a sampling unit of 3 seconds should indicate how many different individual males are calling. Data may be treated statistically and stored in a computer file. Data should be recorded, as well, for the following relevant physical variables: time of sunset, light intensity, rainfall, leaf wetness, relative humidity, and temperature.

Special Considerations

The only published study of frogs based on automatic call recording of which we are aware is that of Drewry (1970). The equipment now available is far superior to that which he used, but it has not yet been configured for this technique. Someone familiar with computer and recording equipment and computer programming would have to design a custom system in order to use the technique. One of the authors (A. S. Rand) is presently setting up a prototype system in Panama; operational details for the system may be available at a later time.

Tracking

A major difficulty in the study of amphibians is the relocation of known individuals. Relocation is a problem particularly away from breeding sites, where amphibians are less conspicuous (i.e., do not call) and more widely dispersed. The problem has restricted many investigations of amphibian ecology to breeding sites, although adults may spend only a fraction of their lives in such places. Most nonbreeding activities occur in other habitats. Any assessment of the status of amphibian populations or assemblages should identify which habitats are used and which are of greatest significance. This identification can be done with tracking, which involves the tagging and release of individuals and their subsequent relocation through the location of the tags that they carry.

Tracking of individuals is not essential to, nor sufficient by itself for inventory or monitoring studies. It can, however, provide information on habitat use and a means of testing assumptions implicit to the estimation of population size not available with other techniques. Tracking also can be used with other techniques to monitor populations (Chapter 8). Amphibians have been tracked successfully with thread bobbins, radio telemetry, and radioactive tags. These techniques have similar advantages, assumptions, and limitations.

The major assumption associated with all three techniques is that tracking devices do not alter the behavior of the individual in any significant way. Radio telemetry and radioactive tracking are advantageous in allowing individual amphibians in aquatic, terrestrial, or fossorial habitats to be relocated without handling. However, all three methods are intrusive and likely have some effect on behavior, at least immediately after installation of the device. Radio transmitters, radioactive tags, and receivers are expensive; tracking is time-consuming; and designing experiments to test the effects of the devices on individual behavior is nearly impossible. Therefore, the effects of these techniques on individuals are not yet well known. Nevertheless, because in certain situations tracking is the only method that can provide individual data on habitat use, these techniques are important tools for consideration.

Generally, only a few individuals can be monitored at a time using any of the tracking techniques. If different portions of the population exhibit different behaviors, it is unlikely that enough individuals can be tracked at one time to distinguish differential habitat use. Studies have shown that subadult frogs are more vagile than adults (e.g., Daugherty and Sheldon 1982; Breden 1987). Differences may exist within age classes (van Gelder and Rijsdijk 1987), and some frog species have three classes with different activity patterns: adult males, adult females, and subadults (Sinsch 1989a; M. P. Cohen and R. A. Alford, unpubl. data). Tracking studies should be planned with these differences in mind and ideally should include equal-sized samples from each class that behaves (or is expected to behave) differently. If equal sampling is not possible, studies should concentrate on classes that can be tracked, and data should be interpreted accordingly.

Thread Bobbins

W. RONALD HEYER

In this technique, a bobbin loaded with thread is fastened to an amphibian; as the animal moves through the environment, thread is paid out. The researcher follows the thread to determine the movements of the individual. This technique is an inexpensive way to follow individual frogs for short distances (up to 50 m) during the observation period.

Because of the physical dimensions of the apparatus and its tether, this technique is probably limited to use with large (≥ 60 mm SVL) terrestrial frogs. Frogs with a trailing device often become entangled and drown when they enter water or die when they attempt to enter crevices (Dole 1965:241). The technique has been used successfully to track species of *Rana* and *Bufo* in the United States (Dole 1965, 1972; Tracy and Dole 1969).

It is assumed that the movements and pattern of activity of a frog fitted with the trailing device will be normal, and that the track of the thread actually reflects the path moved by the frog.

RESEARCH DESIGN AND FIELD METHODS

Trailing devices are made of sewing machine bobbins wound with white nylon sewing thread and mounted in a holder carried on the frog's back. The holder for the bobbin is made from a section of rigid plastic tubing with a flat plastic bottom glued on one end and mounted on an elastic band 6.3 mm wide (Fig. 21). A short wire, run through the holes in the top of the holder, keeps the bobbin in place. The elastic band is placed around the waist of a frog. The loose end of the thread is tied to a small stake placed at the site where the frog is released. As the frog moves, the thread unwinds through a wide slot cut in the back of the holder, and the frog leaves a trail of thread marking its route.

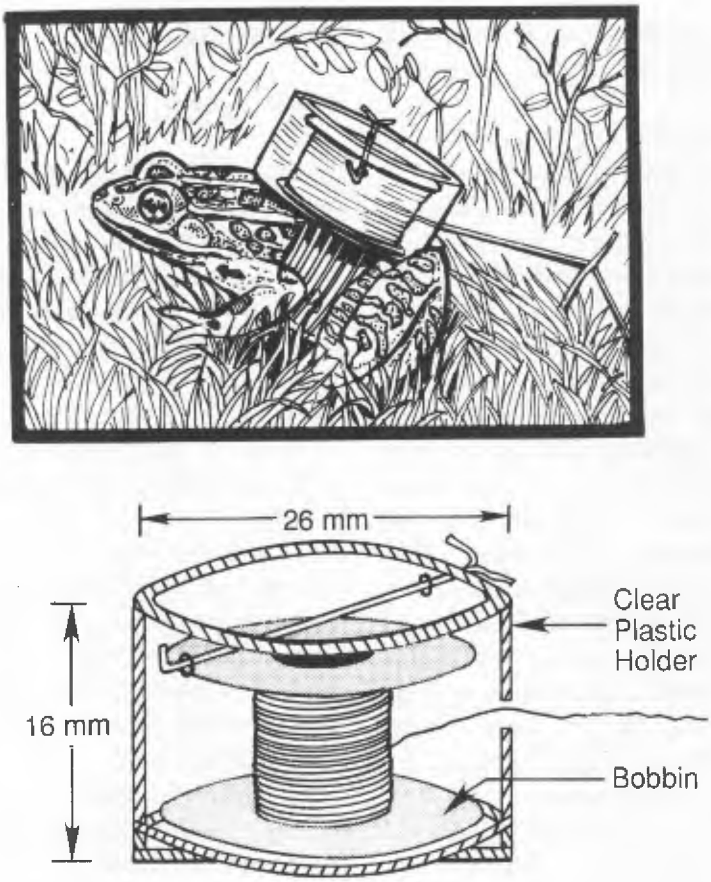


Figure 21. A trailing device, made from a thread bobbin, used for tracking amphibians. The devicc is attached to a frog with an elastic band, and the thread trails behind (above); details of the device are shown in the lower diagram. Redrawn with permission from Dole (1965).

When full, the bobbin device weighs about 8.5 g and holds about 50 m of thread, usually enough to trail moderately active frogs for 2 to 3 days. When frogs are very active, the thread lasts only 1 to 2 hours. The end of the thread is tied to the bobbin so that the frog cannot readily escape when the thread runs out. However, the frog can escape from the elastic band through vigorous movements and, thereby, avoid predators.

Frogs must be recaptured each time the thread is changed. If frogs are released slowly and gently, they usually will remain at the release point, so that no investigator-instigated movement results. The device apparently does not seriously hinder a large frog's ability to jump. However, it or the belt can irritate the skin on the hip and thighs. As soon as any irritation is noticed, the device should be removed. Frogs with trailing devices should be individually recognizable, either by dorsal patterns or by marking (Appendix 2).

PERSONNEL AND EQUIPMENT

Sewing bobbins and thread are available commercially, but the device must be assembled by the researcher. Materials are easily obtained. A single researcher can effectively use the technique.

DATA TREATMENT AND INTERPRETATION

The study site should be mapped before tracking is initiated. Travel routes are plotted in the field on graph paper, usually each morning and evening. After the trail has been mapped, the thread is removed from the field. Bobbins should be resupplied with thread as necessary.

Because activity varies with climate and among individuals, many frogs should be trailed for many days. Dole (1965), for example, followed 136 frogs for up to 35 days each. Maps derived from movement records of individuals can be compared and used to evaluate habitat use, to determine distances moved daily or weekly, and to estimate home range size. Because of the nature of the data, statistical analyses usually are inappropriate.

Radio Tracking

STEPHEN J. RICHARDS, ULRICH SINSCH, AND ROSS A. ALFORD

Devices that emit radio waves can be attached to individual amphibians for tracking movements. The radio waves are detected by a remote, transportable receiver. The closer the transmitter is to the receiver, the stronger is the signal that is received. The investigator follows the signal and locates the amphibian.

For studies of biological diversity, radio tracking can be used to investigate microhabitat use at a fine scale and to determine home range sizes, movement patterns, and daily and seasonal activities. These data may reveal habitats occupied away from breeding sites and may point to areas where conventional monitoring techniques can most profitably be used. Radio transmitters can also be used to monitor physiological parameters such as temperature, locomotory activity, and heart rate.

TARGET ORGANISMS AND HABITATS

This technique is restricted to medium and large amphibians (≥ 10 g), although some successful trials have been completed with smaller frogs (about 5 g; S. J. Richards, unpubl. data). The major constraint on radio tracking of amphibians is the size and mass of the transmitter-battery package. As a general rule, transmitter packages should not exceed 10% of body mass. As technology has improved, however, smaller transmitters have appeared on the market; transmitters with a total mass of less than 1 g are now available.

Animals can be tracked in both terrestrial and aquatic habitats. Successful projects have been carried out in the semiarid Chaco of South America (McClanahan and Shoemaker 1987), the Andes (Sinsch 1989b), the Rhineland of Germany (Sinsch 1988, 1989a), and tropical rain forest (S. J. Richards, unpubl. data). Implantable transmitters also work successfully for amphibians in aquatic environments such as streams (Stouffer et al. 1983) and are particularly useful for locating amphibians that burrow when they are away from breeding sites. Battery lives ranging from 5 to 95 days and detection distances from 10 to 100 m have been reported for 1.3-g to 11.6-g transmitters attached to free-ranging amphibians (van Nuland and Claus 1981; Stouffer et al. 1983; Bradford 1984; McClanahan and Shoemaker 1987; Fukuyama et al. 1988; Sinsch 1988, 1989b). Other investigators have used implanted transmitters to monitor amphibians in outdoor enclosures (Smits 1984; Smits and Crawford 1984; Shoemaker et al. 1987).

BACKGROUND

White and Garrott (1990) provided a detailed overview of radio tracking techniques, research design, and data analysis. Anyone contemplating radio tracking of amphibians should first read this book. Kenward (1987) also provided worthwhile information on designing a radio tracking study. We restrict our discussion to the particular problems and possibilities associated with radio tracking amphibians.

PROBLEMS AND PRACTICALITIES

One of the major assumptions of radio tracking is that the presence of a transmitter has little or no effect on an animal's normal behavior. However, given that the aim of the technique is to locate and observe animals in situations where they cannot normally be observed, it is difficult, if not impossible, to test whether the tracked animal's behavior is the same as that of an animal without a radio. A controlled study in which the behavior of marked and unmarked individuals can be compared (e.g., under seminatural conditions such as in an outdoor enclosure) may be necessary to determine whether transmitters affect behavior.

The use of radio tracking invariably involves compromises. Choosing the smallest possible transmitter clearly will reduce potential effects of the package on an animal's normal behavior. However, small packages have limited battery life, on the order of only a few days to several months. Battery life can be extended, however, by increasing pulse interval or reducing pulse length. Small transmitters also have limited transmission range, and implanted transmitters require the use of loop antennae, which further reduce transmission range.

Transmitter function can also be influenced by the habitat being investigated. Very high frequencies transmit over long distances in the open, whereas slightly lower frequencies travel shorter distances but have less attenuation and are more stable (van Nuland and Claus 1981). Thus, lower frequencies may be preferable when working in dense vegetation such as rain forest. Optimum frequency range needs to be determined for each project.

The most sensible approach is to develop a transmitter in collaboration with the manufacturer, rather than purchasing ready-made packages. That way, transmitter characteristics can be tailored to the needs of the project.

RESEARCH DESIGN

Transmitters can be attached to amphibians externally, or they can be implanted. Each method has advantages and disadvantages.

EXTERNAL ATTACHMENT. The moist nature of amphibian skin precludes direct attachment of transmitters with glue. Several investigators have used harnesses or waistbands to attach transmitters to frogs. Van Nuland and Claus (1981) developed a harness for larger amphibians, such as toads, that consists of a flexible latex cover with four holes cut to the diameter of a toad's legs. The legs pass through the holes, and the cover rides on the animal's back. The transmitter is glued to the dorsal surface of the harness. Some toads were able to remove the latex harness in brambles and in water (van Gelder et al. 1986).

Fukuyama et al. (1988) glued transmitters to a rubber waistband, which was slipped on to frogs as they arrived at a breeding stream in Japan. S. J. Richards (unpubl. data) did the same with *Litoria serrata* in Australian rain forest, using small elastic bands. Richards found that bands caused no apparent damage to skin, and no bands were removed by the frogs over a period of 4 days.

The major advantage of external attachment is that a surgical operation is not required. An external transmitter also can have a relatively long antenna, thereby increasing transmission range. However, carrying an external package may hinder the activity of frogs that shelter in confined spaces, may induce stress, and may increase the visibility of frogs to predators. External attachment probably should be used only for short-term studies of arboreal or terrestrial frogs. When attaching external transmitters to amphibians, care must be taken to ensure that the animals' normal movements are not hindered. Transmitters should not be brightly colored.

IMPLANTED TRANSMITTERS. For larger species or long-term studies, implantation is preferable to external attachment and has been used more commonly with amphibians. In this technique the body wall is opened and the transmitter package inserted into the peritoneal cavity. Implantation in the lymph space under the skin is also possible with very small transmitters. Stouffer et al. (1983) described the surgical technique used to implant transmitters in hellbenders (*Cryptobranchus alleganiensis*); this procedure has been used by most researchers.

The transmitter needs to be embedded in beeswax or a synthetic, nontoxic, waterproof substance such as heat-shrink plastic. The animals are anesthetized by immersion in an anesthetic solution (Appendix 1). The animal is ready when it is completely flaccid when handled. Animals should be continuously dampened with the anesthetic solution during the operation. The skin in the region of the incision is cleaned with antiseptic, and all instruments and gloves should be sterilized with ethanol. A single incision just large enough to insert the transmitter is made in the ventral surface, parallel or perpendicular to, and to the left of, the midline. The transmitter is inserted carefully into the peritoneal cavity to avoid disturbing the intestine and gonads. The wound is closed with an absorbable gut suture. Separate closure of the skin and the body wall with a few stitches each may be required. Animals revive after 15 to 30 minutes in fresh water and can be released after as little as 4 hours (Sinsch 1989b). Transmitters should be removed at the conclusion of the study, using the same procedure. Tracked amphibians should be identified with a unique mark so that individuals can be recognized and transmitters reclaimed if batteries fail.

In at least some species of toads (e.g., *Bufo spinulosus* and *B. calamita*), a sterile environment is not required for implantation operations. One of the authors (U. Sinsch, unpubl. data) did not use sterile techniques during several years of fieldwork on these species; mortality rate was less than 5%, and infection of the wound was never observed. Olders et al. (1985) reported similar results with *Bufo bufo*.

FIELD METHODS

Following the animal on foot with a portable receiver and hand-held antenna is probably the only way to track the signals of moving amphibians. Automatic tracking stations using triangulation systems (White and Garrott 1990) are of little use because of the limited range of the transmitters and because habitat features mask or reflect signals. A detailed map or grid system for the study area is essential. Locations of animals should be marked directly onto a map in the field or marked with flags and transferred to a map the next day.

Radio tracking is a time-consuming task. Depending on the type of habitat and the vagility of the species under investigation, it may take 1 to 2 hours after each interval between observations to locate each individual. If continuous tracking is done, the time between sightings should not exceed 1 hour. Given these constraints, we recommend a ratio of no more than 1:4 between investigators and animals with transmitters.

PERSONNEL AND EQUIPMENT

Radio tracking is extremely time-consuming and requires some expensive equipment. In addition to radio transmitters (discussed above), essential equipment includes a portable receiver, an antenna, and headphones to damp extraneous noise.

Technological advances in recent years have led to great improvements in transmitter performance and versatility. These improvements have particular advantages for amphibian studies, because miniature transmitters can now be fitted with a range of additional functions. Temperature-sensitive and movement-sensitive transmitters weighing only 2 g to 3 g are now available. Transmitters cost anywhere between U.S. $30 and $150, depending on size and functions.

Receivers must cover the frequency band of the transmitters and be capable of monitoring as many frequencies as are likely to be in use at one time (i.e., the maximum number of amphibians to be tracked simultaneously). For work with nocturnal amphibians an illuminated dial is a great advantage; durability also is important. Most receivers available today are of good quality, and price may be the major consideration when making a selection. Receivers cost between U.S. $600 and $1,000.

A frequently used antenna is the 3-element yagi, which is both highly directional and excellent at distinguishing between reverse and true bearings (Kenward 1987). However, this antenna is cumbersome in dense vegetation such as rain forest, and one of the many types of smaller antennae now available may be more suitable in such environments. A loop antenna can be useful for final location of concealed animals. Suitable antennae now cost between U.S. $75 and $300.

Radio tracking equipment is manufactured by dozens of specialist companies in Europe, North America, Australia, and New Zealand (see Appendix 6 for vendors). These companies usually employ biologists experienced in wildlife radio tracking, who normally are pleased to help design transmitters and to provide advice on the equipment most appropriate for a given project.

DATA TREATMENT AND INTERPRETATION

The type of data recorded and the analysis required will depend on the objectives of the study. Pertinent data for each sighting usually will include date, time, position, habitat, microhabitat, activity, and temperature (if temperature data are being transmitted). Environmental parameters should be recorded and include, where relevant: rainfall (past and current), air and water temperatures, wet bulb temperature, soil temperature, humidity, cloud cover, and moon phase. The establishment of a long-term weather station to record environmental variables, including maximum and minimum temperatures and rainfall, on a continuing basis would be advantageous (see Chapter 5).

If statistical procedures are to be used, they must be planned prior to the study to determine the amount and the type of data to be collected. A major problem with radio tracking is the low number of individuals that can be tracked at a given time. Statistical comparisons among individuals are difficult, and most studies to date have been descriptive, reporting patterns of movement and habitat use. White and Garrott (1990) provided a summary of statistical design and examples of statistical analyses suitable for radio tracking data that included tests for habitat preference and techniques to estimate survivorship and population size.

Tracking with Radioactive Tags

RAY E. ASHTON, Jr.

The use of a radioactive tag on an amphibian allows a high level of dependability in the relocation of study animals even if the animal is underground or underwater. Small amounts of radioactive material emitting alpha and gamma radiation can be inserted into the amphibian and detected by a portable scintillation counter. The closer the counter is to the emitting material, the greater the number of rays intercepted and read by the scintillation counter. An investigator can track and locate the emitting source by always maximizing the reading on the counter.

TARGET ORGANISMS AND HABITATS

This technique seemingly has wide applicability to most amphibians in a wide variety of habitats. At present, it is the only tracking technique that can be used with small individuals. A summary of the detectability of cobalt-60 tags is presented in Table 6. The technique has been used successfully on frogs and salamanders that inhabit burrows or use rocky retreats. Animals have been

Table 6. Maximum Detection of Cobalt-60 Tags through Natural Barriers[a]

Barrier type	$\bar{x}$ thickness (m)
Air (specimen on surface of soil)	5.00
Water	0.70
Sand	0.80
Soil	0.50
Limestone	0.40
Granite	0.35
Wood (pine)	1.00

[a]Figures are for detection of cobalt-60 tags (30–45 microcuries) using a Thyac III survey meter, a Thyac model 491 scintillation probe, and earphones for audible detection. Data taken from Karlstrom 1957, Harvey 1965, and Ashton 1975.

tracked from 1 to 69 weeks, moving distances of up to 1,822 m in a day (Barbour et al. 1969; Ashton 1975; R. E. Ashton, Jr., unpubl. data).

BACKGROUND, PROBLEMS, AND RESEARCH DESIGN

The technique is rooted in the physics of radioactive decay, which will not be described here. Drawbacks associated with the technique include bureaucratic problems involved in obtaining permits to use radioactive materials and procedures for handling the tagging material safely. Initial costs are high, and research areas where the tagged animals will not come into contact with people not involved in the study may not be available. The loss of animals and tags is low, apparently no greater than with radio transmitters. The method has not been used much by researchers probably because of concerns stemming from an ignorance of radioactive materials and inexperience with their use. The concerns are misplaced. As long as approved safety procedures are followed, no known deleterious effects to either the researchers or the tagged animals will result.

Regulations governing radioactive material are rather stringent in most countries, and permission to use these materials may not be given if radiation sources are lost because tagged animals disappear after release. Therefore, it is advisable to evaluate the suitability of radioactive tagging for a particular species carefully before selecting it as a technique for the study. Tree dwellers or species that burrow deep in the ground, beyond detection range of the equipment, are not good candidates. They are simply too difficult to find often enough to obtain information on movement and microhabitat use. Amphibians that move 15 m or more several times during a week also are extremely difficult to follow on a regular basis.

Amphibians caught at breeding sites can move long distances, and relocating tagged individuals may be difficult and time-consuming. The best results are obtained when an amphibian is located and tagged within its home range. Finally, at least 50% to 75% of the attempts made to locate each tagged animal should be successful if the study is to succeed.

A major problem in determining suitability of radioactive tagging for a particular species is the lack of adequate information on movements and microhabitat use of most species. Therefore, a pilot project is often required to address the issue. Two individuals of the same species are tagged and followed at 24-hour intervals for 3 to 4 weeks. If the animals disappear or other problems are encountered, then the project should be stopped and another species or technique selected.

Selecting a study site is almost as important as selecting a species. Generally, home ranges of suitable species are less than 100 m^2. However, animals often are first captured outside their core activity areas. Because a researcher will traverse a study site for weeks or months under all conditions, the site should be rather easy to work without causing considerable alteration. Another concern is security. For safety reasons, the research area should be secure from use by humans, or the tagged animals should not be so mobile that they will move into areas used by people.

To some degree, the size of the study area can be determined during the pilot project. Each tagged animal must occupy an area free of other tagged animals; otherwise individual identification will be impossible unless the animal is recaptured. To ensure that crossover (movement of one tagged animal into the area occupied by another tagged animal) does not occur, the area around the tagged animal should be at least twice the diameter of the expected home range or twice the longest distance traveled by tagged animals during the preliminary study. It usually is not necessary to have tagged animals separated by such great distances that they use different breeding areas. Animals are often conspicuous during the reproductive period and usually do not require recapture for identification. However, handling animals at the breeding site appears to be less disruptive than handling them at other times.

Time and money available for these personnel-intensive studies will determine the length of time an animal can be studied. The longer an animal can be studied, the more valuable are the data collected. The duration of the study influences the selection of type of isotope used to make the radioactive tags. The longer the half-life, the longer the tag can be detected. Tantalum has been used successfully for studies lasting less than 100 days. Cobalt-60 is the usual tag of choice because it has a half-life of 5.2 years, making a 40- to 50-microcurie tag effective for at least 3 years.

Cobalt-60 is relatively easy to obtain; however, it (as well as other isotopes) must be modified for use as a subcutaneous or in-muscle tag. It is important to put the cobalt-60 into an aluminum alloy wire or otherwise suspend it in another solid metal. The wire should be sealed in a gold or platinum tube, or it should be plated. Plating is cheaper and just as effective. The outer metal layer prevents rejection of the tag by the animal's tissues. It is important that the ends of the tube or plated wire be melted to a smooth rounded surface to reduce tissue damage during insertion. Isotope for tags usually can be obtained from the radiation control or nuclear physics departments within universities or research centers.

Radioactive tags are expensive and cost about U.S. $100 each.

FIELD METHODS

Field behavioral studies are extremely labor intensive. For the first 7 days, animals are tracked at frequent intervals throughout the day. After the first week, the tagged animal are followed an average of 2 hours per day and thereafter are monitored at intervals of 24 to 48 hours. If animals are monitored at longer intervals, then the time required to relocate each one increases greatly. Actual time spent depends on a number of factors, including changes in distances moved and microhabitats used.

I highly recommended that the number of tagged animals in the field at any one time be low. The maximum number that I was able to track at one time was 15, under ideal habitat conditions and with animals that were easy to follow. Loss of tagged animals to predation, injury, or other causes will occur. Replacements of lost animals can be made during a long-term study.

During the breeding season, animals usually move more frequently, and during peak breeding periods, they should be monitored closely. Close monitoring provides interesting data and helps to prevent animal loss. Animals should be monitored at different times during the day and night to provide a better picture of behavior and microhabitat use. Once located, a tagged animal should not be disturbed. Animals observed without harassment yield valuable behavioral data. At night, red filters should be placed over lights.

Walking over the same piece of study area every other day for long periods can cause considerable habitat change. Such changes can alter the behavior of the tagged animals, because microhabitats, food availability, and other factors may be affected. Once movement patterns of animals become obvious, the investigator should modify his/her approach to the home range to reduce impact on the area.

Many researchers have a desire to see the tagged animal, especially if it has not been seen after weeks of detecting radiation and hearing the roar over the earphones. As long as the animal has been moving, however, it should not be disturbed. Moving even a few leaves can affect relative humidity enough to cause an animal to abandon its burrow and never return. There is no way to determine if the researcher's interference caused this change.

If an animal has not moved after 10 weeks, then the researcher should attempt to find it, being careful to cause as little disturbance as possible. With experience, the researcher will learn to interpret behavior and how to respond to it. If a "reliable" animal suddenly disappears from its home range, it is likely to have been eaten. A wide area should be surveyed immediately; the missing tag may be recovered if the predator or the uneaten portion of the animal that contained the tag is located.

PERSONNEL AND MATERIALS

MONITORING EQUIPMENT. Monitoring equipment should be as sensitive as possible and should include earphones. Normally, such equipment is designed for light field use, not the grueling day-after-day field monitoring required in this type of study. A few simple modifications will help ensure equipment serviceability. Connections where probe wires enter the aluminum housing and the connection to the survey meter are prone to loosening; these should be strengthened. Rubber sleeves help to stiffen the wires, keeping them from bending and pulling at these sites. Also, a 3-m wire provides some flexibility in using the probe.

The most delicate part of the equipment is the scintillation probe. It should be encased in water-resistant rubber or foam. Factory repairs of a probe can cost U.S. $500 or more. Many universities have electronics shops that can handle simple repairs more cheaply. Encasing the probe in a plastic or aluminum pipe 1 to 2 m long can increase efficiency by extending the search radius and allowing the probe to be held closer to the ground or extended into trees. A counterweight at the opposite end of the probe increases maneuverability and ease of handling.

ADDITIONAL EQUIPMENT. Additional equipment needed will depend on the data required for the project. Data on temperature, moisture, and incident light taken wherever a tagged animal is found can be extremely valuable in developing a picture of microhabitat use. If a species is fossorial, probes will be required for monitoring. Specialized equipment for measuring oxygen levels, water quality and chemistry, and stream flow will be required when working with aquatic species. Automated weather stations near the study area can provide useful data (see "Automated Data Acquisition," Chapter 5).

Standard safety equipment is required and includes a lead storage bottle and a secure facility in which to store radioactive tags. Radiation monitoring badges for individuals may be required by permit regulations.

DATA TREATMENT AND INTERPRETATION

One of the greatest frustrations in doing field behavioral studies on animals that are secretive and only infrequently seen is the long period of time required to collect a small amount of data that gives only a glimpse of a species' behavior. Because major shifts in behavior take place seasonally in most temperate species, animals should be observed throughout a year if possible.

Data collected in such a study should include the following:

1. Date and time of sampling, including hours since last check and sighting.
2. Distance moved from previous site, and compass heading.
3. Weather conditions, including precipitation since last check, maximum and minimum temperatures, range of barometric pressure since last check, and phase of the moon.
4. Microhabitat data, including temperature, relative humidity, and moisture on the surface and at the site of the animal; percentage of sun or shade and percentage of vegetative cover over the site; depth below the surface and type of cover (e.g., rock, leaves, soil, log); presence in and description of retreats (e.g., burrows, cracks, hollows under logs); and pH of soil.
5. Activity at time of observation (active or not; if active, whether moving on the surface, moving underground, feeding, breeding, and so on).
6. For aquatic sites, water level fluctuations between checks; levels of dissolved oxygen, carbon dioxide, and nitrogen (various forms); pH of the water; and turbidity.

Because of the type of data collected and the relative paucity of those data, even over a long period, it is important to determine—before the study begins—how data will be collected and managed. Results of tracking studies usually are descriptive and are not treated statistically. Frequently, microhabitat data have to be grouped to provide adequate sample sizes with which to work.

SPECIAL CONSIDERATIONS

PERMITS. Use of radioactive materials often is controlled by governmental agencies, and regulations are not uniform from country to country. The requirements for use of radioactive materials in the United States are given here as an example.

All states in the United States require that individuals have permits for the use of radioactive materials. Generally, states issue permits to universities, allowing those institutions to authorize the use of radioactive materials by individuals. Typically, a professional radiation safety officer and a radiation safety committee oversee the use of radioactive materials on campus. Before applicants can be issued permits, they must do the following:

1. Complete a radiation safety course (usually provided at the university).
2. Receive some training or be experienced in the proposed technique.
3. Provide a plan for safe handling and storage of radioactive materials before, during, and after the study. (Most committees also require routine dosage monitoring on the researcher.)
4. Be authorized to use radioactive materials in the research area and show that the area is secure.
5. Agree to submit routine reports for review.

Authorization from an animal care committee may also be required by some institutions. The requirements that such a committee may impose on the researcher are difficult to determine. However, it can be shown that this method is as humane as any other similar technique and is often the only method available for tracking small amphibians. The effects of radiation on tagged animals are discussed in Griffin (1952).

TAGGING. Experience has shown that the greater the stress on the study animal from capture and handling, the greater the deviation in its behavior. Erratic movements, usually longer and more frequent than normal, are observed immediately after the initial release or after the animal has been recaptured. In fact, most animal losses occur within 72 hours after tagging and release; most animal deaths occur within the first 7 days. Animals held in captivity for 24 hours or longer are less likely to survive once released. For these reasons, it is important to handle study animals with great care and to capture, tag, and release them as quickly as possible. The entire operation should take less than 5 minutes.

To facilitate successful use of the technique, and investigator should do the following:

1. Flag the exact capture locality so that the animal can be returned to it after tagging.
2. Practice the tagging technique on a preserved specimen before working on living individuals.
3. Have everything ready for tagging before an animal is captured. Tags usually are 2.0 × 0.3 mm and fit easily into the barrel of an 18-gauge hypodermic needle. The needle should already be loaded with the radioactive tag and plunger (a thin stiff wire that will easily slide through the needle barrel).
4. Sterilize the hypodermic needle, plunger, and tag with an agent such as ethyl alcohol.
5. Make sure that the hypodermic needle is sharp. Even new needles may require sharpening.
6. Wear surgical gloves for safety of the animal and the researcher. Salts and oils from the researcher's fingers add to the stress of the animal being handled.
7. Place the animal in a wet zip-lock plastic bag and tag it directly through the plastic. Salamanders or frogs can be restrained in the proper position at the corners or bottom of the bag so the needle can be inserted rather easily. In salamanders, the tag should be injected into the musculature of the tail, dorsally and near the base. In frogs, the tag should be inserted between the musculature and skin at the juncture of the body and legs.
8. Weigh and measure animals while they are in the plastic bag (also see Appendix 1).
9. Mark the animal, preferably with a "finger printing" method (Appendix 2).

Night driving

H. BRADLEY SHAFFER AND J. ERIC JUTERBOCK

Night driving is a kind of line transect in which the transect is a road. The investigator drives back and forth over a certain section of the road and counts the amphibians (and other organisms) that cross it per unit time.

The technique was first used by Klauber (1939) who noted its effectiveness in sampling nocturnally active desert snakes (see also Dodd et al. 1989). For amphibians, it is one of a cluster of techniques that provide estimates of species richness and relative abundance for actively moving individuals. Depending on the proximity of the road to breeding, overwintering, or other habitat, the technique can also provide information on movements and habitat use for many species.

We recommend using night driving in conjunction with other techniques to provide species richness data for inventories and to monitor particular species that must cross a road to reach a breeding pond. Night driving by itself cannot provide reliable quantitative estimates of absolute abundance for most species.

Target Organisms and Habitats

Night driving is most effective for surveying highly mobile amphibians as they cross a road. In general, these are animals migrating to and from a breeding site or animals that are mobile when foraging. This technique is not particularly effective for animals with small home ranges (e.g., some plethodontid salamanders—Jaeger et al. 1982), especially if the road is heavily traveled. Individuals whose home ranges include the road are killed by vehicles fairly quickly, so that sedentary species soon disappear from night driving samples. Mobile species continue to cross the road and continue to be killed by vehicles.

Night driving requires a road and a car. Thus, in general, habitats in primary forest, in wilderness areas, or between roads cannot be surveyed with this technique. The best roads for night driving are those recently put through a previously undisturbed habitat and those with relatively low vehicle use (especially after dark) that are located near a breeding site. Warm, rainy nights provide optimal conditions for night driving.

Background

Because the road is a relatively neutral part of an amphibian's habitat, night driving provides a reasonable estimate of the general composition of assemblages of actively foraging species or those migrating to breeding sites. (This is not true for desert snakes for which the road is a heated corridor of habitat that attracts individuals.) J. E. Juterbock (unpubl. data) encountered all but one species of anuran (*Pseudacris ocularis*) known to occur in the Everglades National Park in his night driving survey of the main park road. If a road is situated near a breeding site, it can provide a reasonable estimate of the number of animals moving to the site. Relative abundances of visible, mobile species can be estimated even when a road is far removed from a breeding site.

The effects of road traffic on amphibian populations are virtually unknown. A road may be a barren corridor, with all but the commonest, most mobile species eliminated by vehicles, or it may constitute a perfectly reasonable transect through a habitat. To determine the magnitude of the effect requires comparison of independent estimates of population size based on night driving and on transects away from a road, and this has not been attempted. Campbell and Christman (1982a) provided comparative data on species richness in Florida using night driving, quadrat sampling, time-constrained general collecting, and trapping; their results indicated that night driving was by far the most productive technique. Campbell and Christman (1982a) did miss several small species (*Acris gryllus, Hyla femoralis*, and *Limnaoedus* [= *Pseudacris*] *ocularis*) and one large ranid (*Rana grylio*), although all other native anurans were recorded. Night driving provides quantitative data that can be compared with data from other night driving surveys or from surveys of the same section of road over time. This technique is of equivocal value in providing comparative density estimates among different species with different movement patterns.

An investigator using night driving for amphibian sampling makes the following implicit assumptions:

1. Species do not treat a road as a barrier to dispersal.
2. Individuals do not learn to avoid roads, or are not attracted to them.
3. Features associated with the road itself (e.g., runoff, burrow pits and ditches) do not affect species richness or abundance in the immediate vicinity of the road.
4. Individuals are sampled only once during an evening (important for relative density estimates).

The following limitations apply to night driving:

1. Sedentary species with restricted home ranges may not be sampled in their usual proportions in the assemblage, because they are quickly eliminated from roads.
2. Small immobile species are harder to see from a moving vehicle than are large active species.
3. Habitat specialists, especially arboreal species, may be missed.

Research Design

For night driving, the experimental unit is the stretch of road to be surveyed. Thus, the research design consists of choosing a section of road to survey and determining the number of times to drive it. To maximize the number and types of species recorded, it is useful to plan a route passing near a series of breeding sites. Because most amphibians are active during rains, night driving on rainy nights is often much more productive than driving on dry nights. For many species, especially in the western United States, species move to their breeding ponds during the first rains of the season (Stebbins 1962), and those nights provide the best time for estimating relative abundance of migrating individuals. In contrast, some species have special migrations that can be sampled only during specific periods (e.g., the autumn premigration of *Ambystoma* in the midwestern United States—Johnson 1977).

Because individuals being sampled with night driving almost always are moving, the most informative data are obtained by sampling one stretch of road several times in an evening. Cruising speeds of 20 to 35 kph permit most investigators to see all individuals, yet allow for a reasonably long transect to be covered. We often wait at the end of the road for about 15 minutes between passes. In this way, 30 km of road can be surveyed twice in less than 3 hours, and two to three round-trips are feasible on a given evening.

One of the most important potential uses of night driving is repeated monitoring of set routes during a season and over many years for quantification of changes in species richness and relative abundance. For data to be maximally informative, sampling procedures must be consistent from year to year and from survey to survey. Thus, the same section of road should be surveyed at the same speed at the same hour after sunset. Although some researchers believe that surveying on the same date each year is the best strategy for consistent, interpretable results, we think that comparable weather conditions are more important. Thus, night driving on the night of the first heavy rain of the year or on the first night on which a critical temperature is reached provides more appropriate comparative data than do surveys based on the same date. Of course, if activities of many groups of night drivers are being coordinated on a regional basis (see "Group Activities and Field Trips," below), the only feasible strategy may be to use a common date, given that weather patterns vary across large areas.

Field Methods

Field methods for night driving are simple: one picks a stretch of road and drives along it slowly, stopping briefly, as necessary, to note all amphibians seen. A strong flashlight is essential for locating and identifying each animal after it is spotted in the vehicle headlights. We have found that a detailed map of the area through which the road passes can greatly enhance the interpretation of night driving results. All ecologically relevant features of the area, including breeding ponds and streams, habitat transitions, changes in elevational or exposure, and proximity to human activity, are noted on the map, along with distances from each end of the survey section. As animals are discovered, the exact distance along the section can be noted.

It is assumed that individuals are seen only once during a night and that they are accurately identified. To confirm this assumption, each animal can be given a date-specific mark (e.g., one toe clipped for each evening). An animal should be released off the road in the direction it was moving, after time, mileage, species, sex, approximate age (adult, subadult, newly metamorphosed), direction of movement, and weather conditions are recorded. Obviously, it is crucial to record the mileage at the end of each section of the route so that position of each capture on the road can be plotted later.

Personnel and Materials

A single person can conduct a night driving survey, although teams of two persons are optimal (one person to drive and one to capture the animal, record data, and process road kills). Besides a car, an investigator needs a flashlight, note pad, ice chest, dry ice (if tissue samples are collected), plastic bags, and a marking pen.

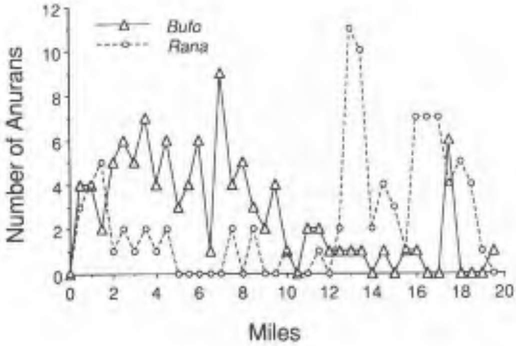


Figure 22. Distribution of *Rana sphenocephala* and *Bufo terrestris* along a road transect through the Everglades National Park. The total numbers of each species observed along each 0.5-mile segment of road between October 1988 and April 1989 are plotted. Differences in abundances of the two species in different parts of the transect correspond to different habitat types along the road.

Data Treatment and Interpretation

There are so many problems in determining the effects of the road on the animals that it is pointless to use the road as a sampling transect for estimating total population sizes. However, by simply counting the number of individuals encountered per drive through or per night, it is possible to develop a reliable estimate of the number of animals crossing that particular stretch of road. These data apparently provide good estimates of species richness at a site (Campbell and Christman 1982a; J. E. Juterbock, unpubl. data). Assuming that migration patterns remain constant, these numbers can be compared over time to follow trends in abundance and habitat use by each species. For example, a 7-month survey of *Bufo terrestris* and *Rana sphenocephala* based on extensive night driving revealed differential use of habitats along the road (Fig. 22).

Special Considerations

One unique aspect of night driving is that recently killed animals are routinely encountered on the road. These animals, even if badly mutilated, can (and should) be collected as voucher specimens to document the species that were present on each survey. Each specimen should be assigned a number, placed in a separate plastic bag, and stored on ice until it can be preserved (Appendix 4). Tissue samples for molecular genetics research almost always can be taken from these specimens (see Appendix 5), which should be numbered, placed in a zip-lock bag, and immediately placed in a separate container with dry ice to prevent tissue degradation. Later, tissue samples can be removed and transferred to an ultracold freezer or to liquid nitrogen for long-term storage.

Stopping for amphibians at night on a road can be dangerous. Drivers should use common sense and follow accepted safety practices.

Geographic information systems

GIS and Remote Sensing Techniques

LEE-ANN C. HAYEK AND ROY W. McDIARMID

INTRODUCTION

A geographic information system (GIS) is a computerized tool that integrates geographic or spatial information with data on the physical or biological attributes of the space. The technology combines cartography with relational databases and analytical tools. Spatial data recorded on commercially available or manually produced maps are digitized and linked to multiple databases from other sources through identifiable attributes (e.g., latitude and longitude, boundary values). These databases can include positional and geographic material at a wide range of scales (e.g., soil and contour maps, satellite images), site-specific information (e.g., water temperature of ponds, drainage patterns, kinds of biological associates, soil topography), or data from a particular study (e.g., abundance of calling males, dates of site use for frog reproduction).

In a computer-based GIS application, large volumes of data can be maintained and manipulated efficiently and integrated with other measurement tools. Spatial data and records of associated amphibian biodiversity can be treated separately or overlaid and integrated with, for example, global positioning systems (Slonecker and Carter 1990), satellite image processing (Roughgarden et al. 1991), or remote sensing procedures (Ehlers et al. 1991). The quality of visual and automated analyses of relationships among many kinds of geographic features and types of data is unequaled by the quality of analyses carried out with manual methods. The capability of the GIS to process spatial data distinguishes it from related computer graphics systems. Not only can data from multiple sources be combined in a GIS but also, as data such as, for example, changes in water level or reductions in habitat area are entered, the accuracy of the changes can be checked and the relevant maps and associated amphibian microhabitat or diversity data updated in the GIS. These spatial capabilities enable geo-referenced information to be created and used in a context completely different from that in which it was collected. Complex evaluations can be done rapidly, and spatial as well as some temporal changes in habitat features can be detected and analyzed. Because each computer analysis can be carried out quickly and at relatively low cost, successive analyses are now practical and can enhance planning and decision making.

A computer-based GIS provides a useful method for integrating quantitative data obtained from amphibian inventory or monitoring projects (Chapter 6) with ancillary data associated with their microhabitats (Chapter 5). However, to our knowledge no one has used computerized GIS technology to analyze amphibian populations or habitats. Several investigators have used a GIS in wildlife habitat studies of mammals and birds (e.g., Davis and DeLain 1986; Lancia et al. 1986; Ormsby and Lunetta 1987; Johnston and Naiman 1990; Pereira and Itami 1991). Hodgson et al. (1988) evaluated the seasonal availability of wetland foraging habitat for the wood stork (*Mycteria americana*) using GIS, and Palmeirim (1988) used remote sensing data to map habitats of bird species. These authors used land cover types and spatial habitat characteristics (such as minimum patch size and distance to quadrat edge) together with bird counts to estimate population sizes. Generally, the results obtained have been more informative and reliable for species that are relatively abundant and restricted to specific habitats than for species that are rare, wide-ranging, or generalists with regard to habitat use.

APPLICATION

A researcher interested in learning how species use certain habitats or in managing geographically defined sites and their contained biota could use GIS profitably. The GIS provides computer methods for delineation and management of specific habitats of different sizes and distributions (bogs, wet meadows, patches of emergent vegetation along lake shoreline) or of areas associated with certain map features (ponds, talus slopes, caves). This technique also can provide for random selection of study sites within well-defined areas (i.e., strata), so that many of the more consequential threats to internal and external validity of the study are minimized or avoided. Decisions about the use of space in managing for biodiversity can be facilitated. For example, the locations of a series of breeding sites within a protected area or the locations of optimal sites for detailed study and possible animal reintroductions can be determined.

In addition, the GIS provides a unique approach to integrating quantitative data from an amphibian inventory or monitoring project with geographic and climatic data from the study site, including data obtained through remote sensing (e.g., Rango 1989). A GIS also may be useful for discovering changes in the distribution of habitats important to amphibians, for identifying patterns and trends in the climatic or hydrologic data that may be related to demographic changes in amphibian populations through time, and for modeling the consequences of such changes.

BACKGROUND

Terms and applications used in other spatial information technologies are sometimes confused with those used in a GIS. To avoid confusion, we place any integrated information system that has a geographic component in the GIS category. For biodiversity purposes we view *spatial data* simply as data that represent real objects of any scale on earth; these objects can be converted conveniently to (x,y) coordinates, such as latitude and longitude or locations on a sampling plot or transect. The element that distinguishes the GIS from other information technologies (database management systems or spreadsheets) and graphics systems is the processing of this spatial data. Links between spatial data sets allow for analyses of factors important in the spatial variability of habitats and can be used to develop predictive models of habitat suitability.

Spatial data occur in three basic forms within the context of most GIS applications: *points, lines,* and *polygons* (or *areas*). These three are sufficient to describe all relevant features on a two-dimensional landscape. For example, a forest or breeding pond would appear as a polygon or area; a stream, cliff face, or road would be a line; and a log, cave mouth, or spring would appear as a point. Spatial data are structured topologically and rely on mathematical relationships between contiguous data elements (lines, points, and polygons). Topological relationships are built from simple to complex: points are the simplest elements, lines are sets of connected points, and areas or polygons are sets of connected lines.

Raster and *vector* are two major types of GIS and are distinguished by how the computer handles data. A raster GIS uses points in a network of *grid cells* and is efficient for handling complex mathematical manipulations and modeling. A vector GIS is used when accurate calculations of distance and area are needed. The same general operating principles apply to both approaches, and many software packages now incorporate both capabilities.

Computerization of data allows for the association of three kinds of information with each item of spatial data: the coordinate location of the feature (where it is); the name and associated attributes of the feature (what it is); and the relationship of the selected feature to other nearby components of the environment (map topology). The use of map topology is an essential element and distinguishes a GIS from other types of computer graphics systems. The expression of map topology allows for complex *spatial analyses* (the quantitative study of the patterns of points, lines, and polygons defined by coordinates in two-dimensional or three-dimensional space) within a GIS, including site suitability studies and delineation of buffer zones (e.g., individuals' ranges) and patterns of habitat use. It also provides for information retrieval based on specific map locations (e.g., breeding ponds).

The quantitative results of any monitoring or inventory effort may be analyzed with a GIS, provided that supplementary locality or geographical data are available. Spatial data usually are recorded on maps and then digitized for computer entry. Digital maps are produced with digitizers (manual), interactive computer data terminals, or scanners. These processes are expensive. Spatial data available from other sources (e.g., satellite images, remote sensing, aerial photographs) must be entered into databases (e.g., Ehlers et al. 1991) and linked with the amphibian database.

Database management systems currently available have capabilities for data storage, retrieval, updating, and logical query. A GIS is able to perform these functions graphically, using the locations of geographic features and the information obtained from an inventory or monitoring project. Maps and information are stored in a hierarchical and spatial format to allow for complex queries not available with other systems.

A key aspect of GIS output is the derivation of new data. By generating solutions to complex, spatially oriented research questions, a GIS introduces unique combinations or views of the data that were not in the original database. For example, the boundaries of a species' distribution across habitats may be generated from a logical overlay of specific values for rainfall, vegetation, elevation, slope, aspect, and other factors relevant to an amphibian's existence.

DATA ANALYSIS AND INTERPRETATION

GIS are predicated on the idea that visual presentations of geographical data usually are more effective than tabular ones. The ability to detect patterns in the data is enhanced by visual inspection of the output, the nature of which will vary with the intended audience and the questions asked. Printed thematic maps are common products.

The mathematical theory and statistical methods underlying geographical science applications have been adapted for use with GIS and are appropriate for assessing sites and for monitoring change with data collected from a network of sampling locales (e.g., Lyon et al. 1987). These analytical methods would be especially suitable for producing contour maps of amphibian abundances within microhabitats or between habitats that could be characterized by available satellite imagery (e.g., Palmeirim 1988). Geographical-statistical methodology has been used most frequently in GIS applications involving meteorological, hydrological, and soil data (Cliff and Ord 1981). These methods also have been applied to analyses of wildlife habitats to select sampling sites for vegetation (Davis and DeLain 1986; Pereira 1989) and to monitor foraging habitat of the wood stork (Hodgson et al. 1988).

Surprisingly, usually only simple univariate measures (e.g., range, mean, variance) can be calculated within GIS. However, spatial data layers can be exported from a GIS for more-complex statistical treatment with a computerized statistical package (e.g., SYSTAT, SAS, SPSS, BMDP). These analyses then can be included with the visual presentations in the GIS. Linear models can be used to identify habitat suitability based upon topography, vegetation, and hydrology. For example, densities of beaver colonies in boreal landscapes were predicted using multiple regression techniques that modeled vegetation and hydrologic patches on a landscape (Broschart et al. 1989). Likewise, critical habitat features for endangered red squirrels were identified using logistic regression to rank active and inactive sites with respect to elevation, slope, aspect, distance to open area, estimates of canopy closure, and other habitat descriptors (Pereira and Itami 1991). Bayesian methodology also has been suggested for statistical analysis of data in a GIS framework (Strahler et al. 1978; Strahler 1980). However, a Bayesian statistical approach requires a priori knowledge of species distributions or geographic patterns, and such knowledge usually is unavailable in spatial work.

Frequently, the quality of data used in GIS applications is poor; data often come from several sources and contain errors of unknown magnitude and direction. Working with such problems is not equivalent to working with sampling errors; there may be no way of estimating the size or direction of these errors and no way of correcting the problem.

An important statistical consideration in GIS applications is that spatial data are characterized by nonindependence of neighboring observations. In a geographical sense, *nearness* implies similarity and *distance* denotes dissimilarity in both two-dimensional and three-dimensional plots. Most computerized packages are not designed to deal with this type of data, and variance probably will be underestimated. It is possible to overcome such problems, but only with difficulty. For example, most GIS programs do not allow for export of data about common or overlapping boundaries; such capability could be used to adjust for these spatial effects. We believe that in most cases emphasis should be on exploratory rather than confirmatory statistical analyses, and we warn investigators to seek expert advice from mathematical statisticians before attempting such analyses.

SPECIAL CONSIDERATIONS

Three points need to be considered before attempting to use a GIS application with amphibian data. First, the volume of data to be incorporated into a GIS application often determines the kind of computer hardware needed. Small to moderate volumes of information from associated databases can be handled on a personal computer with MS-DOS or Macintosh OS, although a UNIX system may be required for some applications. Hundreds of gigabytes of data require a mainframe. The availability of hardware, in turn, often limits the choice of operating system and the range of GIS products that can be created.

The second consideration is that no proven criteria for selecting an appropriate GIS system exist. Many articles have been written on the "best" approach to selecting a specific GIS (e.g., Braden and Webster 1989). Frequently, they suggest that a potential user compare a list of features across different GIS products. The major drawback to this method is that technical terms (e.g., overlay, transfer properties) have not been standardized across products and companies, possibly because of rapid development within the field. A second approach is for the potential user to identify systems used for applications similar to his or her own. For amphibian work this could prove difficult, if not impossible, because the GIS has been so little used with amphibians. Although an amphibian expert would know his or her particular needs, this knowledge would not be of use in choosing between general-purpose or specifically designed GIS applications, because the user would not know if the properties of the system were relevant for the amphibian study questions. A third possibility is to base the choice on the system architecture (the set of rules used to design the system). The key to the system architecture is the *data model*, or the set of rules used by the system to represent geographic information in discrete, digital form in the database. Braden and Webster (1989) argued that this is the only objective and reliable basis upon which to classify GIS software, because it allows the user to choose a system based on specific research needs. GIS data modeling is one of the most active research and development fields at present. Users are being provided with increasing numbers of choices for customizing their systems with fewer restrictions to analyses.

The third major consideration regarding use of a GIS involves computer graphic systems. Although these systems are related to the GIS, they cannot be used in place of it for complex data sets, because they are more severely affected than GIS by small errors in the data. A cursory review of this field will show the interested user that the simple act of creating a map for interpretive purposes may be risky. A slight change in class interval, scale, or other variable, or a subtle change of color shading in a small area can lead to significant errors and, often, to incorrect interpretations. If the data themselves are incorrect, mapping will invariably amplify, not diminish, the error. For example, the most extreme effect in percentage can occur in the area with the smallest population. Data must be examined from several perspectives, and an overemphasis on either the visual (easily done with computer graphics) or the inferential can lead the user to incorrect decisions. Openshaw (1990) discussed some methods for exploratory visual analysis of spatial data (e.g., fuzzy pattern analysis, visualization enhancers, automatic spatial response modelers) that are less likely than simple graphic presentations to mislead the user.

REMOTE SENSING AND MANUAL OVERLAY

One can use a GIS to identify and quantify change. Change is detected by comparing remotely sensed imagery (data obtained from aircraft or satellites) with mapped data or by comparing previously obtained images with recent images. In either case, highly accurate images are required. Remote sensing systems often provide immense amounts of data that can overwhelm computer processing and storage capabilities. Regardless, such data, once collected, can be interpreted by either manual or computer-assisted image analysis procedures. Image processing and interpretation of remotely sensed data usually require that ancillary data and information verified by on the ground investigation (ground-truthed) be integrated with aerial photographs or satellite images. The GIS permits this integration. Manual overlay systems (manual GIS), albeit limited in scope, have been part of remote sensing methodology for many years. The overlaying of contour, elevation, area, and volume measures (photogrammetry) and environmental variables or ground cover information (photo interpretation) has served as an excellent manual GIS tool. Several examples of the use of manual GIS for studies of amphibians with specific habitat requirements are described in the next section. We know of no specific examples of the use of a computer-based GIS combination with inventories of amphibian populations or habitats or with data from programs for monitoring species or sites to ascertain changes in biodiversity. We think that such applications will be forthcoming. The GIS is particularly appropriate for such work.

CONTRIBUTOR: DANIEL G. COLE

Manual GIS Application for Habitat Specialists

J. ERIC JUTERBOCK, SAMUEL S. SWEET, AND ROY W. McDIARMID

A number of amphibian species, because of the uncommon and often spatially isolated habitats they occupy, are difficult to inventory and monitor with standard inventory techniques. Many of these species are restricted to specific habitats that can be located on maps or detected with some form of remote sensing. Therefore, such species are amenable to study with a GIS. Although a computer-based GIS would be most efficient (see the previous section) and especially useful for long-term study of certain species or entire amphibian faunas on dedicated research sites, considerable information on ecological and geographic distributions of populations of amphibians can be obtained with a manual GIS application.

The approach we describe in this section is used to determine the distribution and status of populations of selected species by locating their habitats by remote sensing. Whether relative abundance, density, or population size is estimated depends primarily upon characteristics of the population and the effort expended. In situations in which the assumptions of mark-recapture estimation techniques (Chapter 8) are not obviously violated, absolute population estimates are possible and often preferable (see "Special Considerations," below).

TARGET ORGANISMS AND HABITATS

Any species of amphibian may be studied with remote sensing techniques, but for some species the method is much better than the available alternatives. The manual overlay approach may be the only efficient method for locating and studying amphibians restricted to uncommon and often spatially isolated habitats. Examples of salamanders in this category include *Aneides aeneus*, which is restricted to rock outcrops with abundant crevices in the Appalachian Mountains of eastern North America; *Typhlotriton spelaeus*, *Eurycea lucifuga*, and other *Eurycea* and *Typhlomolge* species, which are confined to caves or limestone ravines with permanent water in the Ozark and in the Appalachian mountains, and on the Edwards Plateau, respectively; and *Plethodon shenandoah*, which is found on north-facing talus slopes in Shenandoah National Park, Virginia.

Frogs in this category include habitat specialists with moderate to limited distributions, such as *Bufo microscaphus californicus*, which is restricted to the subset of stream terraces adjacent to suitable breeding pools in southern California and adjacent Mexico, and *Ascaphus truei*, which is found only along clear, cold, rocky streams in humid forests in the northwestern United States and adjacent Canada.

Frequently, species within restricted habitats have irregular patterns of activity, so that individuals are unevenly accessible to investigators and therefore are difficult to sample by most standard procedures. Their patchy distribution, irregular activity, and certain other ecological and behavioral characteristics also preclude accurate estimation of population size by standard techniques. Ohio populations of *Aneides aeneus* illustrate the point well. Individuals, already restricted to crevices in sandstone or dolomite outcrops, are territorial (Cupp 1980), and females are observed at the surface of the outcrops only irregularly when they are brooding eggs (Juterbock 1989).

Troglodytic salamanders pose other problems. Observed population densities of such species often vary, despite the seeming constancy of their environment. In repeated visits to a site, individuals may not be seen at all or may vary in number by an order of magnitude.

Salamanders, especially those in marginal (e.g., seasonally dry) environments, may be highly responsive to rather subtle environmental cues, such that the animals only rarely are in sites that can be sampled by standard techniques. Some species of *Batrachoseps* are notorious in this respect, as are *Plethodon* species in the Allegheny Mountains and the Cumberland Plateau, much of the Ozarks, central Texas, and northern New Mexico. Some benefits accrue from persistent sampling efforts if environmental variables are monitored regularly on-site, because the responses of the animals can then be used to refine otherwise crude interpretations of limiting conditions.

Many other species of amphibians fall into one of the above categories and may be good prospects for study with an analysis of remote sensing data and manual overlay techniques (e.g., *Plethodon larselli*, *P. petraeus*, and *P. punctatus*—Buhlmann et al. 1988; several species of *Batrachoseps* and *Eurycea tynerensis*—Tumlison et al. 1990; species of frogs with highly restricted distributions, such as *Hyla andersoni*, *Rana okaloosae*, and *Eleutherodactylus cooki*, as well as *Rheobatrachus silus*, which is now possibly extinct—Tyler 1989).

BACKGROUND

The manual GIS has not been used often with amphibians, and the theoretical foundation is undeveloped. The technique is useful for habitat specialists and for restricted populations for which standard sampling techniques are not suitable. Dodd (1990, 1991a) employed a manual

GIS application in conjunction with a standard technique for which theory is well established to study the fossorial salamander *Phaeognathus hubrichti*. He used geological maps to locate a formation to which the species was restricted and then overlaid contour maps on the formation map to identify sites with steep slopes where the salamanders burrow. He then surveyed several sites, estimated burrow density with line transect techniques, and argued that burrows provide an index of density for this species. Presumably, other species that use specific microhabitats (e.g., burrows, crevices in rock ledges, holes in bamboo stems, bromeliads of certain shapes and sizes) within habitats that are easily detectable with remote sensing could be inventoried effectively with a similar approach. Sweet (1982) used geologic and topographic criteria to determine the location and temporal reliability of springs on the Edwards Plateau, Texas, and demonstrated that the distribution of the salamander *Eurycea neotenes* could be delimited using these characters. Having established limiting values, he then estimated the total distribution of the species and the number of extant populations, using manual GIS techniques.

Any overlay application, whether manual or computer aided, requires good maps or aerial photographs, and their availability should be established before attempting a study. Actual on-site verification (i.e., ground-truthing) of identified habitat also is essential and should be incorporated into any study using remote sensing for amphibian studies. Finally, to make effective use of the technique, investigators must be aware of seasonal variation in activity and other peculiarities of the life history of the target species.

RESEARCH DESIGN

Habitat-restricted species that can be studied effectively with some form of remote-sensing manual GIS fall into two categories: species that are inaccessible much of the year but periodically occupy a site or behave in a way (e.g., spring migration to a specific breeding site) that allows them to be sampled by standard inventory techniques, and species that are continuously inaccessible and not easily sampled.

Many amphibians in the former group select highly specific habitats for breeding and do so under relatively specific weather conditions. If these habitats or breeding sites can be detected with remote sensing, and if the periodicity of utilization of the habitat or site can be determined, then the species usually can be inventoried or monitored readily during the breeding season (see "Surveys at Breeding Sites," Chapter 6). Using the same information, larval and metamorphosing individuals may be more easily located and sampled than juveniles or adults (see "Quantitative Sampling of Amphibian Larvae," Chapter 6). Sampling design generally would follow that outlined for the standard technique.

Some form of manual GIS also may be useful for identifying the presence of specific habitats that contain continuously inaccessible species. However, detecting abundances or determining densities within these habitats may be very difficult. Considerable effort with repeated samples, especially if variance is high, has to be put into one or two sites before data obtained from those sites can be extrapolated to others. Even then, projecting estimates of population size and density obtained at one site to similar sites identified with remote sensing is fraught with problems. Variations in species densities between sites are common, and we do not advise projecting densities without some ground sampling. Amphibian activity often is closely tied to local weather conditions. When weather varies between sites, ground-truthing may give very different results, even when actual densities are nearly the same. Workers should make such projections with extreme caution.

METHODOLOGY

Conceptually, the approach is relatively simple. To utilize remote-sensing data for amphibian studies, the investigator (1) establishes the general distribution, habitat requirements, and life history parameters of the target species; (2) estimates the amount (ha) of suitable habitat available; (3) determines the population densities and proportion of the habitat(s) occupied at one site; and (4) multiplies the density by the area of occupied habitat and extrapolates for all areas, if an estimate of minimum population size for the total area is desired.

Obtaining data on distribution and habitat requirements may be a simple matter for well-known species such as *Aneides aeneus* (Juterbock 1989) or *Eurycea lucifuga* (Guttman 1989), or it may require detailed habitat analyses, as for *E. tynerensis* (Tumlison et al. 1990) and *E. neotenes* (Sweet 1982). Ways of estimating habitat availability include consulting geologic, topographic, and soil maps, aerial photographs, and previous surveys; driving roads to look for appropriate habitat; and using other forms of remote sensing. Ideally, the ecobehavioral characteristics of the target species will allow estimation of relative abundance or density with one of the recommended standard techniques. Unfortunately, there often is no efficient substitute for iterative sampling in arriving at a realistic picture of a species' true ecological or distributional range, by a process of successive approximation. We cannot emphasize too strongly that accurate and realistic assessments of occurrence or abundance are labor-intensive and require continuing efforts to "think like the target species." In practice, an index such as minimum population size may be the best available estimate. Once data for a few sites are obtained and predictions of density estimates for other sites seem reliable, projections for all available habitat units are possible. It is always necessary to ground-truth a significant sample of the habitat units to get some idea of the accuracy of the density estimates within the total habitat. If habitat units are sufficiently large, it may be useful to apply the same principles within a unit and to index population size only for a portion of any single unit.

PERSONNEL AND EQUIPMENT

There are no fixed personnel requirements. Good maps, aerial photographs, or other kinds of geographical information are needed. Specific field expenses and personnel needs will vary with the project, be defined by the selected techniques, and especially depend on the project length. If mark-recapture techniques are used, other field equipment may be required. Typically, we have worked alone, often over several field seasons, using a flashlight, a camera, some anesthetic, and scissors for marking.

DATA TREATMENT AND INTERPRETATION

The data to be recorded will vary with the species and the goal of the project. If it is necessary to identify habitat characteristics first, a wide variety of physical and, perhaps, biotic factors must be evaluated (Tumlison et al. 1990), with the provision that much useless effort can be avoided by thinking through the candidate factors and eliminating those that are not likely to make a significant contribution. The tendency is often to adopt habitat parameters and measures from a standard menu developed for bird or mammal studies, the great majority of which are simply irrelevant to amphibians. Once the specific type of habitat is known, its extent must be determined (e.g., number of ponds, linear meters of rock outcrop or spring flow). To index or estimate population size, the techniques discussed earlier in this chapter should be applied.

Analysis and interpretation of relative abundance and density data are described with the standard sampling technique selected.

SPECIAL CONSIDERATIONS

Assumptions critical to population estimates, especially assumptions relating to equal likelihood of capture for all members of the population, often are violated when sampling species with restricted habitat requirements or behavioral peculiarities. In such cases only relative abundance estimates are possible. In populations in which individuals of a certain age, size, or sex are more likely to be caught than others, as with brooding females of plethodontid salamanders or calling or territorial males of many anurans, marking new individuals over an extended period may allow an estimation of minimum population size. Any standard estimator that allows for mark-recapture data that are biased by unequal catchability can be used.

As with any indirect estimator, caution must be used in interpreting projections derived from this approach. To provide for acceptable extrapolations, the original data delineating the habitat and determining the degree of habitat use must be extensive, and the abundance and density estimates accurate. Sites for intensive investigation should be representative of those available and should include both prime and marginal areas. If the variance of the population estimators obtained from the intensive surveys is great, it may be preferable to rank habitats (e.g., marginal, good, excellent) and to project estimates accordingly, rather than to assign an average number of individuals to all habitats in the range of the target species.

Group activities and field trips

ROY W. McDIARMID AND MAUREEN A. DONNELLY

Organized field trips and similar group activities can be valuable components of survey and monitoring programs when projects are labor-intensive and require considerable field effort. Volunteers, students, and nonspecialists can monitor populations at specific sites or survey species and habitats simultaneously across broad geographic areas (e.g., states, provinces, or regions). These activities can provide worthwhile data and a positive educational experience for the participants if the specific goals of the project are clearly specified before the fieldwork begins, and the field trip leader is knowledgeable of the biology of target species and the habitats to be surveyed. We support such programs, provided that they use the techniques recommended in this book or follow some other rigorously defined set of standards (see "Regional Surveys" under "Examples of Group Activities," below). In that way, data obtained will be comparable with data from other projects.

Target Organisms and Habitats

Organized group activities can focus on a variety of species and habitats. Wetland sites with small permanent or temporary ponds in which amphibians breed are particularly suitable. Because participants in group activities often are nonspecialists, such programs work only where the amphibian fauna is well known and identification guides are readily available. Even so, eggs and larvae, which indicate reproductive activity at a site and should be noted, are difficult to identify. Volunteers probably should not attempt identifications unless these can be confirmed with voucher specimens.

Background

Organized group trips can be an integral part of a college or high school course curriculum, an annual meeting sponsored by a regional herpetological society, an educational program sponsored by a wildlife or conservation group, or a regional monitoring effort (e.g., state and province monitoring and survey projects). If the trips are conducted on a regular basis (e.g., first week-end of April, day after first summer rains, week after spring thaw) and if quantitative sampling methods are used, data gathered can provide valuable information on amphibian species richness, relative abundance, and density.

Data taken on field trips must be collected in a standardized way if they are to provide reliable information. Quantitative data are more informative than qualitative data, and preferable, especially if comparisons among samples or sites are a goal of the project. Nevertheless, the use of standardized field techniques and data collection methods can be tedious, and the field trip sponsors should consider the enjoyment factor in the project design. For example, members of a regional herpetological society may be more interested in capturing all amphibians observed in 3 hours at a given site than in searching carefully along a transect line or in plots of known size. The results from such a time-constrained search can be used to generate a species list for the site (= species richness). In contrast, however, careful searching along a transect or in a plot can generate data on density and relative abundance, as well as a species list. If an organized group visits the same site year after year and uses the same sampling methods, changes in the local fauna over time can be assessed (= monitoring). Likewise, observations that changes in amphibian density or species composition at a site are correlated with successional changes in aquatic habitats may be useful in making decisions regarding management of wetlands for select amphibian species.

Research Design

Sampling methods must be standardized among sites or within sites between sampling periods. Breeding activity of many species is associated with warming temperatures or the first heavy rains after a dry period. Specific dates of these phenomena vary from year to year at a site, but with some flexibility, groups can schedule their activities to coincide with such events. The lack of experience of the participants may require that sampling procedures be simplified, but the project goals and data quality must not be compromised. The research design discussed for each field survey technique used should be reviewed (see Chapter 6).

Personnel and Materials

Personnel and materials are those outlined for the specific techniques used. A data coordinator or center is recommended, and probably required, for larger projects.

Data Treatment and Interpretation

Data sheets designed to facilitate recording pertinent information and to minimize decision making are essential to the success of group activities, especially if different groups are sampling species or sites at the same time in different geographic areas. Standardized data sheets also are essential for monitoring the same site through time. Scoring by choosing from specific alternatives often is easier for the volunteer than filling in blanks and makes data handling easier. Several practice trips may be required to perfect the procedures and develop useful data sheets. Data sheets should be field-tested as part of the development process.

Data gathered during group activities should be analyzed according to the recommendations given in Chapter 9 and those made for each technique in Chapter 6.

Special Considerations

Organizers of group activities must provide participants with training, pertinent background information, sampling protocols, and data sheets. They should follow techniques outlined in this book to maximize the information obtained during organized events. Because these projects often are staffed by volunteers, sponsors should appoint a data coordinator (or establish a data center) to receive completed data sheets from participants. An efficient and effective means for disseminating project results and their interpretation to the participants (e.g., a newsletter) is also essential to a successful ongoing project.

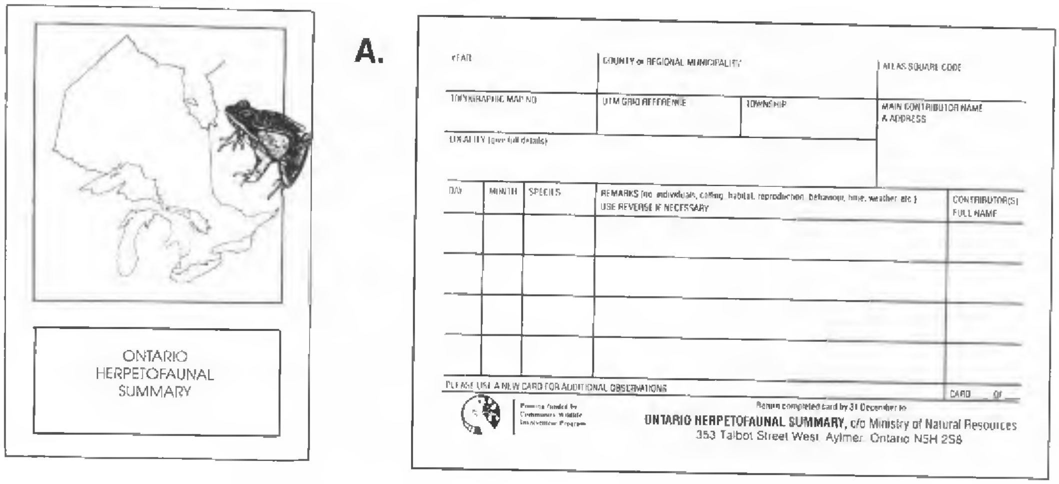
Examples of Group Activities

STATE AND PROVINCE SURVEYS

We briefly describe three successful ongoing programs that effectively use interested volunteers to inventory or monitor amphibians over large geographic areas. Two programs were designed to monitor frogs in Wisconsin or in Illinois; the third was designed to inventory amphibians and reptiles throughout the province of Ontario. Additional information on these programs is available from the Wisconsin Bureau of Endangered Resources (P.O. Box 7921, Madison, WI 53707, USA), the Illinois Department of Conservation (Carl N. Becker, Chief, Division of Natural Heritage, 600 North Grand Ave. W., Springfield, IL 62706, USA), and the Ontario Herpetofaunal Summary (Ontario Field Herpetologists, RR #22, Cambridge, Ontario N3C 2V4, Canada). For a brief description of the Wisconsin program, see also "Field Methods" under "Surveys at Breeding Sites," Chapter 6.

The Wisconsin Bureau of Endangered Resources (WBER) and the Illinois Department of Conservation (IDC) initiated their monitoring programs in 1984. Prospective volunteers contact the agency (WBER or IDC) and receive a packet consisting of an introduction to the project, a detailed set of instructions, route assignments, species accounts, and data sheets (Fig. 14). The accounts include a brief description of each species of frog, to aid in identification; information on its breeding biology, habitat use, and other aspects of its natural history traits; and a tape recording of its call. Volunteers are required to learn the calls and to record data three or four times a year. They drive a predetermined route on one or more prescribed dates and estimate the number of calling frogs of each species that they hear along the route, either by listening at preselected sites on the route or by listening for calling frogs at predetermined intervals along the route. An index of calling activity is generated for each species at all sampled sites. These efforts provide the agencies with information on state species richness, statewide distribution patterns, calling phenology, relative abundance of calling males, and habitat use. Agency personnel analyze the data.

The Ontario Herpetofaunal Summary was started in 1984 to compile information on distributions and life histories of species of amphibians and reptiles in Ontario, Canada. The project is staffed entirely by volunteers and coordinated by individuals in the Ontario Field Herpetologists club. Sources of data include records from an ongoing field observation program begun in 1984, pre-1984 field notes and files of local naturalists, literature reports, and museum and university collections. Observations are submitted annually on preprinted data cards (Fig. 23A) to compilers who verify the information and enter it into a computer that plots records on a map of Ontario marked with a 10×10-km grid. In the first 7 years of its operation, the field observation program involved an extensive network of nearly 2,500 volunteers who contributed more than 50,000 observational records to the project (Fig. 23B). Data are stored in a dBASE file and used to produce annual species accounts that include maps; information on habits, habitats, breeding biology, and behavior; and other relevant aspects of the distributions and life histories of Ontario amphibians and reptiles (summary data for the western chorus frog, *Pseudacris triseriata*, are presented in Fig. 24). A newsletter and these annual summaries provide background data and baseline information for future research, contribute to a global examination of issues related to declining amphibians, aid na-



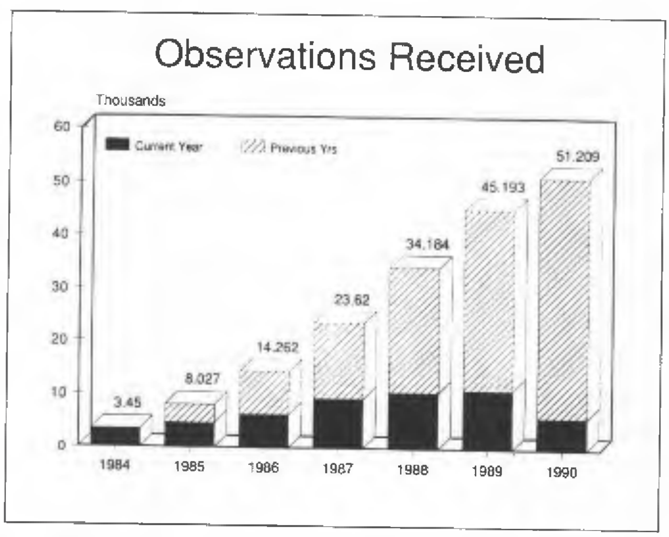
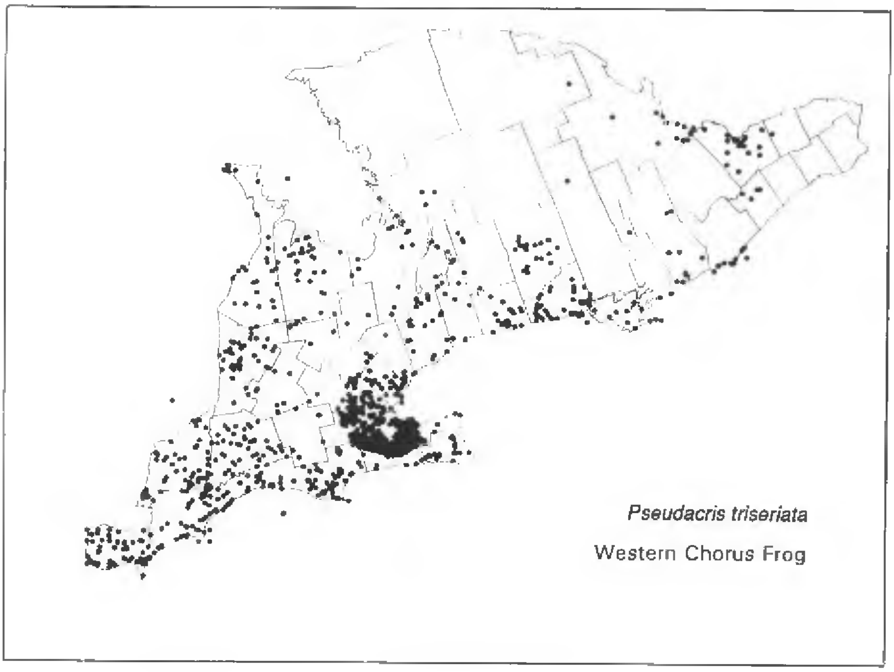


Figure 23. Ontario Herpetofaunal Summary. A. Observation data card. B. Cumulative summary of all observations received from 1984 through 1990.

tional and local agencies in making appropriate decisions on management and land use practices that may affect amphibian populations, supply data to organizations charged with the conservation of amphibian species, and generally contribute to an increasing public awareness about the importance of amphibians in a healthy environment. This impressive effort should serve as a model for other groups interested in similar issues.

HERPETOLOGICAL SOCIETY FIELD TRIPS

Members of regional herpetological societies are enthusiastic and generally knowledgeable about local species of amphibians and reptiles, and enjoy the interaction of organized events. Annual field trips often are popular aspects of regional society programs and can provide useful quantitative data on amphibian populations if the goal of the excursion is clearly identified, A.



B.

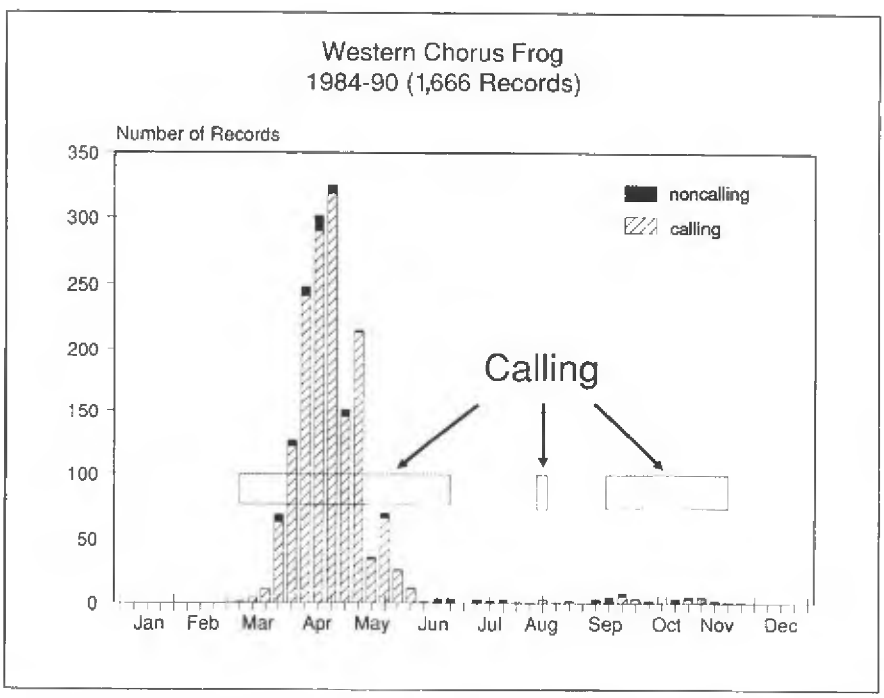


Figure 24. Distributional and phenological data for the western chorus frog (*Pseudacris triseriata*). A. Distribution in southern Ontario. B. Monthly plot of activity. Data are from the Ontario Herpetofaunal Summary.

Amphibian Population Survey

Country ____________________
State ____________________
County ____________________
Site name ____________________

Date ____________________
Surveyor name ______________
Society name ______________
Time (24 hr system) ______________

Site latitude/longitude
Site elevation ______________

Weather, previous 48 hr:

temperature	moisture
___ unseasonably warm	___ unseasonably warm
___ unseasonably cold	___ unseasonably cold
___ normal	___ normal

Species

Codes
A = adult
J = juvenile
L = larvae
E = eggs

	Ambystoma tigrinum	*Ambystoma texanum*	*Eurycea longicauda*	*Necturus maculosus*	*Typhlotriton spelaeus*	*Acris crepitans*	*Bufo americanus*	*Bufo cognatus*	*Bufo debilis*	*Gastrophryne olivacea*	*Hyla chrysoscelis*	*Pseudacris crucifer*
Total number seen (add letter E if # is estimate)												
Calling?												
Amplexing or copulating pairs present?												
HABITAT DATA												
Aquatic												
stream												
permanent												
intermittent												
river												
natural lake												
reservoir												
pond												
floodplain												
upland												
marsh												
floodplain												
upland												
bog												
ditch												
seasonally flooded												
spring or rock seep												
Terrestrial												
upland												
mountaintop												
slope												
lowland												
floodplain												
streamside												

Air temp. ___ (°F or °C) **Water temp.** ___ (°F or °C) **pH** ___ **water** ___ **soil**

Nearby land characteristics

___ crops ___ active livestock pasture ___ unused pasture ___ prairie ___ woodland
___ town ___ industrial ___ other (what is it?)

Figure 25. Sample population survey sheet modified from one used in the survey of Kansas amphibians.

AMPHIBIAN SURVEY DATA SHEET – US FISH & WILDLIFE SERVICE, 4512 McMURRY AVE, FT. COLLINS, CO 80525-3400

(circle choice for shaded variables; supply value for others) (ver. 2/7/92)

DATE	BEGIN TIME	END TIME	OBSERVERS

LOCALITY

STATE	COUNTY	MAP NAME	OWNER	ELEVATION (circle scale) M FT

T	R	S	SECTION DESCRIPTION	UTM ZONE	NORTHING (or LAT)	EASTING (or LON)

AMPHIBIAN AND/OR GARTER SNAKE SPECIES PRESENT (INDICATE NUMBERS IN CATEGORIES IF POSSIBLE) — CIRCLE METHOD AND INDICATE IF VOUCHER SPECIMEN WAS COLLECTED

SPECIES	ADULTS/JUVENILES	CALLING?	TADPOLES/LARVAE	EGG MASSES	METHOD:
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO

FISH PRESENT? YES ??? NO	FISH SPECIES		
ENTIRE SITE SEARCHED? YES NO	IF NO, INDICATE AREA	METERS OF SHORELINE M² OF HABITAT	

PHYSICAL AND CHEMICAL ENVIRONMENT (CHEMISTRY VARIABLES OPTIONAL - USE EXTRA SPACES FOR ADDITIONAL MEASUREMENTS)

WEATHER: CLEAR OVERCAST RAIN SNOW	WIND: CALM LIGHT STRONG		
AIR TEMP (circle scale) °C °F	WATER TEMP (circle scale) °C °F	COLOR: CLEAR STAINED	TURBIDITY: CLEAR CLOUDY
pH	ANC		

SITE DESCRIPTIONS - (SKETCH SITE AND PUT ADDITIONAL COMMENTS ON BACK OF SHEET)
OMIT THIS SECTION IF DATA HAVE BEEN COLLECTED ON A PREVIOUS VISIT

ORIGIN:	NATURAL	MAN-MADE	DRAINAGE:	PERMANENT	OCCASIONAL	NONE	
DESCRIPTION:	PERMANENT LAKE/POND	TEMPORARY LAKE/POND	MARSH/BOG	STREAM	SPRING/SEEP	ACTIVE BEAVER POND	INACTIVE BEAVER POND
SITE LENGTH (M)	SITE WIDTH (M)	MAXIMUM DEPTH:	< 1 M	1 – 2 M	> 2 M		
STREAM ORDER	1	2	3	4	5 +		
PRIMARY SUBSTRATE:	SILT/MUD	SAND/GRAVEL	COBBLE	BOULDER/BEDROCK	OTHER		
% OF POND LAKE MARGIN WITH EMERGENT VEGETATION:	0	1 – 25	25 – 50	> 50			
EMERGENT VEGETATION SPECIES (LIST IN ORDER OF ABUNDANCE)							
NORTH SHORELINE CHARACTERS:	SHALLOWS PRESENT	SHALLOWS ABSENT	EMERGENT VEG PRESENT	EMERGENT VEG ABSENT			
DISTANCE (M) TO FOREST EDGE	FOREST TREE SPECIES:						

Figure 26. Sample amphibian survey data sheet developed by the U.S. Fish and Wildlife Service and recommended by the Declining Amphibian Populations (DAP) program. The back of the sheet is marked with a grid to facilitate mapping of the survey site. Some data categories are also explained on the back of the survey sheet.

data collection is carefully organized, and field methods are standardized. We include two sample data sheets developed for different amphibian survey programs (Figs. 25 and 26). Either could be customized easily for other areas or needs. Regional societies may wish to use one form for the group leader and another for the other field volunteers. The group leader would be responsible for providing information on the locality, elevation, vegetation, habitats, date, weather conditions, number of volunteers, and so forth. The volunteers would record only time and species-associated data such as microhabitat, number of individuals, size, life history stage, and so on. Well-organized field trips can enhance camaraderie among society members and involve the group in an effort of potential importance to the conservation of local amphibian species and habitats. Officers of regional societies should consult a local herpetologist (if knowledgeable persons are not members) or state or federal agency personnel when selecting areas or habitats to be sampled and species to be studied.

Regional societies have contributed successfully to a survey of *Hyla andersoni* populations and habitats in North Carolina (R. E. Ashton, Jr., pers. comm.), efforts to monitor amphibians and reptiles in Ontario, Canada, and annual HERPCOUNTs in Kansas (a program for monitoring amphibians and reptiles that is sponsored by the Kansas Herpetological Society—E. Rundquist, pers. comm.). Additional information about field trip organization, methods, and data handling is available from G. R. Pisani.

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