ence 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-

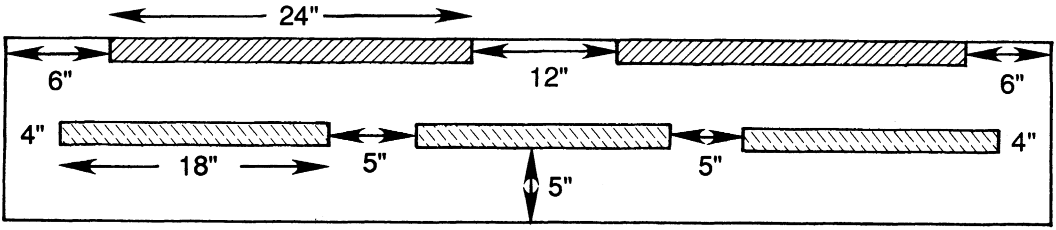

Figure 20. Diagram of the baseboard portion (viewed from above) of an artificial cover board designed to provide complex microhabitats for use in studying salamanders. Strips of cedar lathe (6 × 38 mm, or 0.25″ × 1.5″) in lengths of 46 cm (18″) or 61 cm (24″) are attached along the middle and edge of 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