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Biological Diversity Handbook Series

Series Editor: Mercedes S. Foster

This series has been established by the National Biological Survey (U.S. Department of the Interior) and the National Museum of Natural History (Smithsonian Institution) for the publication of manuals detailing standard field methods for qualitative and quantitative sampling of biological diversity. Volumes will focus on different groups of organisms, both plants and animals. The goal of the series is to identify or, where necessary, develop these methods and promote their adoption worldwide, so that biodiversity information will be comparable across study sites, geographic areas, and organisms, and at the same site, through time.

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Measuring and Monitoring Biological Diversity

Standard Methods for Amphibians

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Myers 1990) and Ecuador (Duellman 1978) are clearly asymptotic (Fig. 8).

The number of reptile species cannot be separated from amphibians in some published graphs (i.e., Duellman 1978). Typically, a greater proportion of the species collected late in the sampling period has been fossorial reptiles and snakes, with a greater proportion of amphibians sampled earlier. In the only study to compare long-term species accumulation rates among taxa, 95% of the amphibian species but only 90% of the lizards and snakes had been taken after 20 years of collecting (Myers and Rand 1969).

If the time-constrained technique is used in similar habitats and with similar faunas, then resulting species accumulation rates from general, short-term collecting can be compared. If the areas are dissimilar, the SSS may be appropriate. An SSS produces lists of the species present in the first *x* number of specimens collected in each habitat. The number of species then can be compared directly.

For comparisons among sites with nearly complete species lists, real data can be compared with randomly generated lists to determine whether among-site differences are greater, smaller, or the same as randomly expected differences (Guyer 1990).

SPECIAL CONSIDERATIONS

General collecting is the most efficient way for experienced collectors to take the largest number of species in the least amount of time. No other collecting method is as productive in amassing species for a list and in obtaining series of specimens.

The precision of indices derived from SSS depends on the sampling efficiency in different habitats and the accuracy of the species identifications. Even seasoned herpetologists are less efficient when sampling unfamiliar habitats. For this reason, data collected over time by the same collectors are more comparable than data taken by many collectors.

The SSS is most comparable among sites when a variety of collecting techniques is used and search times are well distributed among habitats and times of day and night. For example, searches based primarily on collections of calling males cannot be compared meaningfully with searches made only in forests during the day. The SSS collections used for data analysis should be the result of individual collecting efforts, not of some passive technique such as pitfall arrays. Collectors using an SSS can reduce bias in collecting effort. Species caught with passive systems depend on trap location and individual species susceptibility, so many species are missed.

The species richness index derived from SSS needs to be tested to determine its generality and usefulness. First, tests of the variation due to collectors and time period can be determined by a two-way analysis of variance of the data from independent collections made by different collectors working in the same habitat at different times. Second, data derived from SSS can be compared among sites with well-known herpetofaunas to determine whether SSS produces concordant results.

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2. Visual Encounter Surveys

MARTHA L. CRUMP AND NORMAN J. SCOTT, JR.

A visual encounter survey (VES) is one in which field personnel walk through an area or habitat for a prescribed time period systematically searching for animals. Time is expressed as the number of person-hours of searching in each area to be compared. The VES is an appropriate technique for both inventory and monitoring studies.

The VES is used to determine the species richness of an area, to compile a species list

(species composition of an assemblage), and to estimate relative abundances of species within an assemblage. This technique by itself is not an appropriate method for determining densities (number of individuals per unit area) because not all individuals actually present in an area are likely to be visible during the survey. However, if repeated VESs are done in conjunction with a mark-recapture study, density can be estimated reasonably (Donnelly 1989).

Visual encounter surveys differ from transect sampling (technique 5). A VES can be done along a transect, in a plot, along a stream, around a pond, and so forth, and it samples all amphibians that are visible. Transect sampling uses lines of fixed length in fixed locations and focuses on surface-dwelling amphibians.

TARGET ORGANISMS AND HABITATS

The VES has been used most extensively for rapid evaluation of large forest areas, especially in uniform habitats where visibility is good. The VES works especially well for forest understory anurans that are active in the open (e.g., Toft et al. 1982) and for salamanders that live most or all of their lives in the forest litter but are on the surface after rains (e.g., Pough et al. 1987; Corn and Bury 1990).

Visual surveys also can be used effectively for target species that inhabit easily identified habitats, such as logs or riparian zones, or habitats that are widely spaced, such as talus slopes. They are also appropriate for target species that are highly clumped, such as frogs at temporary ponds; in these cases, the surveys are done in the restricted areas of interest. For example, a VES can be carried out at an aquatic breeding site by setting up multiple transects from the edge of the water into the center of the site.

The VES can be used to inventory aquatic assemblages under certain conditions (e.g., relatively shallow, clear pools with minimal vegetation), but generally such surveys are better for monitoring only certain target species, because not all species in an aquatic assemblage can be observed equally. Frazer (1978) and Griffiths (1984) surveyed aquatic newts at night by VES using flashlights. The VES can also be used effectively to monitor larval amphibians in small, shallow pools where the water is clear and the vegetation is sparse.

A VES is often the best way to survey species that are rare or unlikely to be caught with traps. The technique is not appropriate for surveying canopy or fossorial species.

BACKGROUND

Because the VES is simple it has been used for a long time. The technique has been formalized as the time-constrained technique by Campbell and Christman (1982a) and as the time-constrained searches by Corn and Bury (1990). The results of a VES search are measured against the time spent in the search.

ASSUMPTIONS. The VES is based on the following assumptions:

1. Every individual of every species has the same chance of being observed during a survey (i.e., each individual is equally conspicuous to an observer; there are no differential effects of coloration, size, behavior, activity, or microhabitat preference on the likelihood of being encountered).
2. Each species is equally likely to be observed during each sampling session (i.e., there are no seasonal effects of activity, weather, predators, or competitors on a species' likelihood of being encountered).
3. An individual is recorded only once during a survey (i.e., the observer can keep track of all movement so as not to record multiple encounters for the same individual).
4. Results from two or more observers surveying the same area simultaneously are identical (i.e., there are no observer-related effects).

Although these assumptions have never been rigorously tested and the validity of the results of a VES is unknown, we know intuitively that the assumptions will not hold in most instances. Species do differ in their conspicuousness, and people do differ in their abilities to see amphibians. The resulting potential biases should be recognized and minimized to the extent possible. For example, comparable training and expertise of the individuals involved in a VES are crucial. Some people can develop an excellent search image for amphibians; others never do. Most people improve with practice. If more than one person is required to carry out a VES, individuals should conduct independent surveys in the same test area simultaneously, and their results should be compared. Biases between individual observers may reflect differences in the amount of time spent looking up versus looking down or differences in walking speed. With effort, such biases can be controlled.

LIMITATIONS Two obvious limitations are associated with a VES:

1. Not all strata or microhabitats within the habitat can be sampled with equal success.
2. Not all habitat types can be sampled with equal success. As a result, relative species abundances can be compared only among sites of the same habitat type.

Dissimilar habitats cannot be surveyed by VES with an equivalent degree of reliability because of differences in visibility; open habitats are surveyed more efficiently than are habitats with dense vegetation. Time of day can also affect a VES; most people find surveying the environment using natural light easier than surveying with a headlamp. Weather conditions can affect a VES; visibility generally decreases with rainy, misty, and cloudy conditions. Thus, surveys of areas to be compared directly should be done under comparable weather conditions, as much as possible, and at the same times of day or night.

RESEARCH DESIGN

The design for a VES will depend on the goals of the study (whether it is a one-time inventory or a long-term monitoring program and, if the latter, whether the intent is to determine phenology of species composition, phenology of species abundances, or both), the specific habitat and the size of the area to be surveyed, the desired periodicity of the sampling regime (diel and seasonal), and the species composition. For purposes of statistical analysis, censusing ten 100-m transects within a given habitat type is preferable to censusing one 1,000-m transect. Regardless of the experimental design, at some point early in the study the data and field methods should be evaluated and the methods modified as appropriate. Three basic sampling designs are used for the VES (Fig. 9): randomized walk, quadrat, and transect.

A *randomized-walk design* is appropriate when a large area is to be sampled. Prior to going into the field, the observer chooses at random a sequential series of compass directions (preferably at least 50); he or she also selects at random a number of meters (up to 50 m) to be walked in each selected direction. The start point can be determined by breaking the area into blocks, randomly selecting one, and starting from the middle of it. All amphibians observed within 1 m on either side of the path are recorded. This design (Fig. 9A) satisfies the assumption of randomized sampling, which allows statistical comparisons among replicated walks in different areas or habitats. Because the VES is a time-constrained field technique, the time spent per unit area must be specified for each investigator and for each area to be compared.

A *quadrat design* is appropriate for sampling a specific area thoroughly. A quadrat of given dimensions is established (we recommend 10 × 10 m or 25 × 25 m, depending on amphibian densities). The quadrat is then systematically sampled by walking parallel paths across the plot (Fig. 9B) or by walking a zigzag pattern between numbered stakes (Fig. 9C) (Hairston 1980a,b; Aichinger 1987; Donnelly 1989; Nishikawa 1990). If area grids have been established, the exact location of each individual encountered can be noted relative to the distance markers (this information could be used to examine spatial distribution patterns within the habitats). Multiple (at least 10) randomly placed plots can be used to test for changes in species richness or

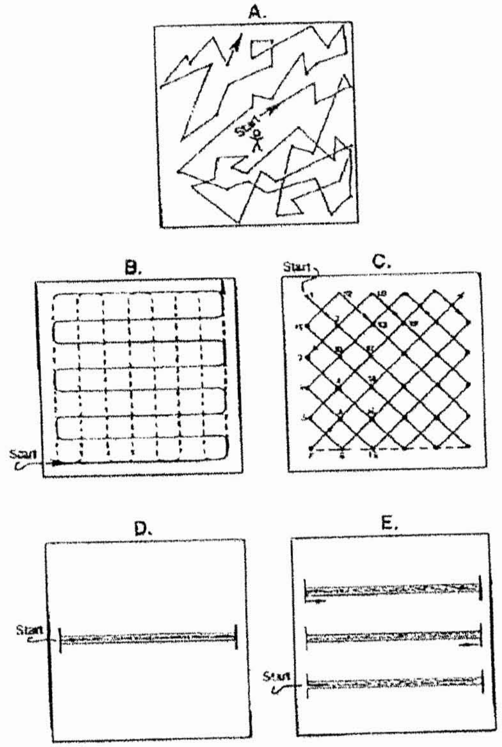

Figure 9. Experimental designs for visual encounter surveys. A. Randomized walk design. The observer chooses a series of compass directions at random and walks each in sequence for a given number of meters, also determined at random. B–C. Quadrat design. An area of given dimensions is systematically sampled either (B) by walking two sets, at right angles, of parallel adjacent paths across the plot or (C) by walking a zigzag pattern between numbered stakes (i.e., in this example, 1 to 13 in numerical order, then 10–14–8–15–6–16–4–17–2–18–19 and so forth). D–E. Transect design. A single transect (D) or multiple parallel transects (E) are set up, and areas on either side of the path are systematically sampled.

relative abundances over time or to determine differences in species richness or relative abundances among sites at one time. Breeding ponds can be surveyed using this design by constructing a checkerboard of boardwalks or paths at the site (Fig. 9B). Again, time spent per unit area must be standardized among fieldworkers and among sites to be compared.

A *transect design* is appropriate for sampling across microhabitats known to be different or potentially so. In the simplest case, a single transect of prestablished length (Fig. 9D) is laid out and walked (Jaeger 1978; Pough et al. 1987; Crump and Pounds 1989); all animals observed within 1 m of the transect path are recorded. If desired, the exact location of each individual can be noted according to its position relative to previously established distance markers. For large areas, 10 or more transects 100 m long and spaced 20 m apart in the area of interest are appropriate (Fig. 9E). As with the other designs, time spent per unit area must be standardized among workers and areas.

If only one inventory is to be done, it must be scheduled for the time of year, time of day, and weather conditions in which the maximum number of species are expected to be active. Because at any one time of year some species will be inactive, a one-time inventory should be interpreted as a minimal estimate of species richness for the area.

For long-term monitoring programs, sampling periodicity is crucial. One must sample often enough to ensure that within-year variation does not obscure year-to-year differences. Because activity patterns of amphibians are greatly influenced by weather, VESs should be done during each season of the year. Time of day likewise greatly affects behavior patterns, and time of the survey can bias both species composition and abundance data if not taken into consideration.

An important decision to be made during the design of the fieldwork is whether to capture each amphibian encountered to obtain additional information. If individuals are captured, measured, and weighed, less time will be available for additional survey work. If animals are captured, investigators must also decide whether to mark each one individually. Mark-recapture studies yield valuable information on population dynamics, but, again, less area can be surveyed. Marked animals are likely to be recaptured frequently in studies that involve area searches, so marking may be worth the effort. In contrast, the chance of recapturing individuals along a transect is fairly slim and, thus, probably does not warrant the additional time.

FIELD METHODS

Procedures for a VES are straightforward. Habitats are searched, either along a transect or in a plot, and the number of animals encountered per unit of time is recorded. The length of time and intensity of the search, the boundaries of the area to be searched, and the search pattern should be specified in advance. For example, instructions for a survey of salamanders should specify the type(s) of substrate to be examined (e.g., every possible cover item or just logs), whether or not the cover items will be turned over or torn apart, and the maximum amount of time to be spent tearing apart substrates (e.g., a single log). Search methods must be standardized among fieldworkers to reduce bias in the results.

For a complete inventory, all possible microhabitats are searched: ground, water, tree trunks, stems, and upper and lower surfaces of leaves as high as the observer can see accurately enough to identify the animals. Time spent per unit area is standardized as much as possible within a given habitat type, but habitats with differing heterogeneities will require different survey times. When animals are encountered, they are identified and, if need be, captured and measured or collected as vouchers. The VES can be performed at several levels of intensity, as follows.

Among the least intensive surveys are counts of animals active on the surface (e.g., Hairston 1980b; Pough et al. 1987; Nishikawa 1990) or of animal-associated items (e.g., burrows of salamanders—Dodd 1990, 1991a). This type of VES is particularly useful for species that are active on the surface of leaf litter or that climb plants on rainy or foggy nights. Under such wet conditions, a large proportion of the population may leave underground retreats and move to the surface. This method is especially suited for inventory of habitats containing endangered species where habitat disturbance must be avoided.

The intermediate-intensity search is one in which the field crew, in addition to counting already exposed animals, turns over surface objects such as rocks and logs and counts the animals uncovered. The cover objects must be returned to their original positions to minimize habitat disturbance. This type of search generally yields higher return per unit time than a low-intensity search because many amphibians hide under cover objects when conditions are not suitable for surface activity.

At the most intense level of VES, surface objects are turned, decayed logs and bromeliads are torn apart, and litter is raked. These activities obviously change the habitat; long-term effects of this type of search have not been measured for any habitat or target species. Habitat disturbance increases with increasing search intensity, but more animals are encountered. Intense surveys are probably the most reliable in terms of sampling the most species, especially rare ones.

For some studies, it is useful to set up a transect or grid system with permanent distance markers before the survey begins, so that the exact location of every animal can be recorded at the time of encounter. This allows the investigator to calculate interindividual distances, record detailed microhabitat data for specific sites where amphibians have been found repeatedly, evaluate the homogeneity of the area searched, and if a mark-recapture study is done, obtain valuable information on individual animal movements through time.

Depending on the goals of the study, the animals encountered can be observed only (assuming that positive identification can be made without holding the animal), or they can be captured temporarily for positive identification and measurement (see Appendix 1) and then released at the site of capture. Voucher specimens should be preserved and deposited in an established research museum collection (see Chapter 5). Many groups of amphibians are undergoing significant taxonomic revision, and sibling species are often difficult to distinguish in the field. Museum collections provide a basis for verifying field identifications, which greatly enhances the reliability and usefulness of surveys.

PERSONNEL AND MATERIALS

The number of persons needed to execute a VES depends on habitat complexity, size of the area to be sampled, and level of survey intensity. If reasonably short forest transects are to be surveyed, only one person may be needed; surveying a large breeding pond may require several persons, each doing a transect from the shore into the center of the pond. All persons involved must be well trained in the same search techniques, and interobserver differences must be considered. If animals are common and data are taken for each individual, designating a person as data recorder can speed the operation and keep the pace of the survey more uniform.

A VES requires minimal equipment: data paper, pencils or pens with permanent ink, and a millimeter ruler and spring balance if body length and weight are to be taken. Plastic bags and a marking pen are needed if amphibians are to be collected. Potato rakes are useful for searching in leaf litter. If microhabitat measurements are to be taken, appropriate instruments are needed (see Chapter 5). If the transect is to be marked at regular intervals, numbered flagging tape or permanent stakes should be set in place prior to the survey. For nighttime surveys, headlamps are required.

DATA TREATMENT AND INTERPRETATION

The kinds of data to be collected depend on the goals of the study and the time and personnel available. Minimum data to be collected during an inventory of an area that does not contain grids with distance markers include (1) the number of individuals of each species encountered, (2) the total time searched, and (3) the size of the area searched. For inventories and monitoring surveys in areas with distance markers, location within the transect or grid system should be recorded in addition to microhabitat data and the minimum elements previously listed (Chapter 5) for each amphibian encountered. If desired, wet mass and reproductive condition can be recorded. If animals are taken temporarily to a laboratory facility, much of this information can be recorded after the survey is completed to avoid taking up valuable field time. Another option is for a second person to follow the primary VES searcher and record additional data while the first person continues the survey.

Well-organized data sheets that incorporate the minimum data elements (see Chapter 5) and include extra space for notes that do not fit preestablished categories are recommended for use in the field. Data sheets can be simple or complex, depending on the goals of the study (Fig. 10).

A main application of VES generally is determination of the composition of an amphibian assemblage. The list of species compiled for the area surveyed can be compared with species lists from other areas. Mean numbers of individuals can be compared statistically, and coefficients of association calculated (see Chapter 9). Before any data are interpreted or compared, however, effects of the biases noted previously must be estimated (see "Assumptions" and "Limitations," under "Background," above).

As discussed previously, if relative abundances are to be compared among sites, then habitat structure, weather, and search techniques must be similar for all samples. For example, if the project is designed to determine the effects of disturbance (e.g., logging) on amphibians, then separate VESs would be conducted in logged and unlogged parts of a forest. If, however, the researcher wishes to compare two forests, then all VES transects must be located in forest habitats; it would be inappropriate for some transects to include forest edge ecotones while others did not. Until VESs have been validated and we have some idea of their variability and their relationships to actual population levels, data gathered during VESs should not be used to report individual species densities. Dodd (1990) used a Fourier series to estimate salamander burrow densities along transects; this technique may have limited usefulness in the analysis of other transect data.

If long-term monitoring is done, phenology of presence and activity of various species can be presented graphically with histograms or frequency curves. If activity patterns are to be interpreted in light of climatic factors, then correlations, multiple regressions, and analyses of variance may be appropriate types of analysis. Tests of differences in species' activity levels under different weather conditions or among seasonal components of the year are also possible.

SPECIAL CONSIDERATIONS

Campbell and Christman (1982a) surveyed amphibian assemblages in four habitat types in Florida and compared results from intensive VESs with those from road cruising, litter removal–quadrat sampling, and drift fence–pitfall arrays. Fifteen of the 22 species known to be present were recorded with road cruising, and 12 were recorded with VESs. Quadrats and drift fence–pitfall arrays yielded 6 and 7 species, respectively. Bury and Raphael (1983) compared techniques and recommended that VESs be combined with a drift fence–pitfall array to sample the herpetofauna more effectively. The VES can be validated by repeated sampling of the same areas or by comparison of results of VESs with those from surveys done in the same areas using different methods that estimate true population sizes. The need for validation is urgent. The VES done in conjunction with mark-recapture techniques is useful for studying population trends through repeated sampling of the same areas.

Visual Encounter Survey

Date ______ Name of observer(s) ______

Place ______ Area searched ______

Weather conditions ______ Air temperature ______

Time begin survey ______ Time end survey ______

Habitat description ______

No.	Species	Sex	SVL	Substrate	Location	Activity	Time
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							

Figure 10. Sample data sheet for a visual encounter survey in which specific data are recorded for each individual encountered. If the survey requires only abundance data, the lower part of the data sheet can be redesigned so that individuals of each species seen on the survey can be recorded with tick marks; marks for each species are totaled later.