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Measuring and Monitoring Biological Diversity

Standard Methods for Amphibians

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on environmental and microhabitat conditions in each patch can help to explain microhabitat sharing or avoidance patterns among species.

When patches are sampled across time or space, species or specimen data may be compared with inferential techniques in which the sampling unit is the individual specimen.

RECOMMENDATION

Randomized patch sampling is a particularly good approach for inventorying or monitoring species that are restricted to particular microhabitats.

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7. Straight-Line Drift Fences and Pitfall Traps

PAUL STEPHEN CORN

Straight-line drift fences typically are short barriers (5–15 m) that direct animals traveling on the substrate surface into traps placed at the ends of or beside the barriers. Traps (described below) can be pitfalls, funnel traps, or a combination of the two.

Drift fences with pitfall or funnel traps and pitfall traps without fences are used commonly to inventory and monitor populations of amphibians and reptiles. For example, 9 of 17 field studies reported for management of terrestrial vertebrates (Szaro et al. 1988) used these techniques to sample amphibians. Drift fences with pitfall traps can be used to determine species richness at a site and to detect the presence of rare species. They also can yield data on relative abundances and habitat use of selected species.

Pitfall traps arrayed in a grid without fences can also be used to study the population ecology and habitat use of selected species. Population density can be estimated with this latter technique if it used in conjunction with mark-recapture techniques (see Chapter 8). Drift fence arrays or pitfall grids can be left in place for long-term monitoring.

In this section, I discuss the use of this technique to obtain data on amphibians away from breeding ponds. Use of drift fences and traps to monitor amphibian activity at breeding ponds is discussed in the section "Drift Fences Encircling Breeding Sites," below (technique 9). Some materials and procedures are common to both techniques. Investigators contemplating the use of drift fences and traps in any context should read both accounts.

TARGET SPECIES AND HABITATS

Both arrays of drift fences and grids of individual pitfall traps have been used to sample amphibian assemblages in a variety of temperate habitats, including deciduous forests (Pais et al. 1988), coniferous forests (Jones 1988a), riparian woodlands (Friend 1984; Jones 1988b), wetlands (Beauregard and Leclair 1988), and sandhills (Campbell and Christman 1982a,b). Aquatic salamanders are difficult to trap with pitfalls, but drift fences with funnel traps at the ends have been used successfully to trap *Siren* and *Amphiuma* in seasonally flooded stream bottoms (D. E. Runde and K. M. Enge, unpubl. data).

Drift fences and pitfall traps capture some species more easily than others (Karns 1986; Corn and Bury 1990; Dodd 1991b). Anurans that are strong jumpers or climbers (e.g., *Acris, Gastrophryne,* most *Rana,* most *Hyla*) are more difficult to trap than terrestrial species (e.g., *Bufo, Scaphiopus*) that lack these abilities (Franz and Ashton 1989; Dodd 1991b). Accordingly, numbers of the former either should be omitted from an analysis or should be reported with caution. For example, several studies report the capture of large numbers of the eastern narrow-mouthed toad (*Gastrophryne carolinensis*) using drift fences (Campbell and Christman 1982a; Enge

and Marion 1986; Mengak and Guynn 1987). Because of the climbing ability of this toad, however, the numbers of individuals captured probably do not accurately reflect its relative abundance.

Drift fences and pitfall traps usually sample terrestrial salamanders very well but undersample species closely associated with specific microhabitats. For example, in forests of the Pacific Northwest, the primary habitats of the plethodontids *Aneides ferreus* and *Batrachoseps wrighti* are large pieces of fallen trees, whereas *Ensatina eschscholtzii* and *Plethodon vehiculum* commonly are abroad on the forest floor. *Aneides* and *Batrachoseps* are seldom caught in pitfall traps (with or without fences), but *E. eschscholtzii* and *P. vehiculum* are captured in large numbers (Bury and Corn 1987; Corn and Bury 1990).

Some groups—for example, caecilians or tropical arboreal salamanders—normally cannot be sampled with conventional drift fences. However, Vogt (1987) captured the arboreal salamander *Bolitoglossa platydactyla* with funnel traps suspended between branches of trees on a plastic walkway.

Drift fences and pitfall traps are also effective at capturing ground-dwelling organisms other than amphibians, including insects (Greenslade 1964; Luff 1975), reptiles (Jones 1981, 1986; Campbell and Christman 1982a; Vogt and Hine 1982), and small mammals (Spencer and Pettus 1966; Beacham and Krebs 1980; Williams and Braun 1983).

BACKGROUND

Drift fences intercept amphibians moving on the surface of the ground and redirect them into a pitfall or funnel trap. Pitfall traps without fences act in a similar manner, but individual traps intercept only a few centimeters of ground versus several meters for a fence. Therefore, large numbers of traps are needed if fences are omitted (Corn and Bury 1990).

If pitfall traps are used as live traps and population estimates are derived from mark-recapture data, biases from trap avoidance or trap attractiveness must be considered. Franz and Ashton (1989) observed only one recapture in drift fence arrays of *Gastrophryne carolinensis* tagged with radioactive (^{60}Co) wires. Conversely, Shields (1985) observed preferential use of pitfall traps by southern leopard frogs (*Rana sphenocephala*), possibly in response to warm or moist conditions inside the traps.

Pitfall trapping alone is insufficient if comparison of relative abundance among species within an assemblage is the objective. Drift fences with pitfall traps, however, effectively capture some individuals of most species, at least in temperate areas. Therefore, unequal capture rates are less of a problem for determining some indices of species richness. If one accepts the untested assumption that capture rates do not vary among habitats, trap data can be used to compare relative abundance of individual species among study areas.

If animals are released from traps, they must be marked to eliminate recaptures from calculations of relative abundance. If animals are not released, the researcher must consider the consequences for subsequent samples, especially if an area is to be sampled repeatedly. Drift fence arrays can decimate populations of small mammals (Bury and Corn 1987), but this effect has not been observed for amphibians. Corn and Bury (1991) operated the same grids of pitfall traps for 50 days in 1984 and 30 days in 1985 and removed all animals captured; captures of amphibians did not differ between the two years, except that one species was more abundant in the second year.

RESEARCH DESIGN

The objectives of a study determine the sampling design. Installation of arrays or grids of fences and traps is labor-intensive, and running the system can require significant funds and per-

sonnel time. Inventories of species present in different habitats may require less effort than comparisons of species' abundances and densities among habitat types. The objective of many inventories is to sample as many habitats as possible. Therefore, each habitat type may have only one array or grid. This methodology, however, reduces the probability of detecting rare species. Operating traps for a longer time may compensate for fewer arrays or grids.

Quantitative comparisons of species' abundances or densities among habitat types require replication—that is, multiple arrays or grids in each habitat type. This methodology makes detection of all species present in each habitat most likely.

Selection of the locations for arrays or grids should have a sound statistical basis. If a researcher is surveying different habitat types and more than one unit of each habitat type exists, habitats sampled must be selected at random from the larger pool, and arrays or grids must be placed randomly within them. To determine whether stratification is appropriate, a researcher must have fairly detailed knowledge of the habitat(s) in the study area. Decisions regarding stratification must be made before trap systems are installed.

The timing of trapping may also vary, depending on the study objectives. Vogt and Hine (1982) recommended operating arrays of drift fences opportunistically, after rainfall, to maximize captures. In other studies traps have been operated continuously for from 30 days (Corn and Bury 1991) to nearly two years (Campbell and Christman 1982a; Raphael 1988). Both sampling strategies have drawbacks. Opportunistic trapping may be logistically difficult, so that different sampling efforts are applied in different study areas, and short periods of trapping may not be adequate to verify presence of all species (Jones 1986; Bury and Corn 1987). Continuous trapping requires more personnel and may have a greater effect on resident animals, but continuous trapping can be scheduled to accommodate known seasonal variations in amphibian activity. Bury and Corn (1987) trapped in forests of the northwestern United States continuously for 180 days, beginning at the end of May, but captured few amphibians until the onset of rainy weather in October. Subsequent trapping was conducted for a shorter time (30 or 50 days) and was begun on 1 October (Corn and Bury 1991).

Investigators have seldom used the same design for arrays of drift fences or grids of pitfall traps. Shields (1985) operated one hundred 3-liter pitfall traps spaced 10 m apart in a 10 × 10 grid; Raphael (1988) used ten 8-liter pitfall traps placed 20 m apart in a 2 × 5 grid; and Corn and Bury (1990, 1991) deployed thirty-six 8-liter pitfall traps 15 m apart in a 6 × 6 grid. D. B. Wake (pers. comm.), who uses 1-liter traps to live-trap *Ensatina eschscholtzii*, has 176 traps spaced 10 m apart in an 11 × 16 grid.

Several array designs for straight-line drift fences with pitfall and funnel traps are possible (see Vogt and Hine 1982). In most studies, three or four fences with pitfall and funnel traps are used (Fig. 11). An array is preferable to a single straight fence. Arrays intercept animals from any direction, whereas animals moving parallel to a single fence probably are not captured. Because arrays with three fences (Jones 1986; Bury and Corn 1987) use less material than those with four (Campbell and Christman 1982a), they are less expensive and less time-consuming to install. D. E. Runde and K. M. Enge (unpubl. data) found that arrays of different design, when tested side-by-side, yielded comparable results.

The length of the drift fence influences the number of animals captured, and the optimum length probably varies by habitat type. Vogt and Hine (1982) observed that single drift fences less than 15 m long captured fewer amphibians and reptiles than 15-m and 30-m fences, but the component fences of most arrays are either 5 or 7.6 m long (Fig. 11). Bury and Corn (1987) compared arrays of 2.5-m fences with those of 5-m

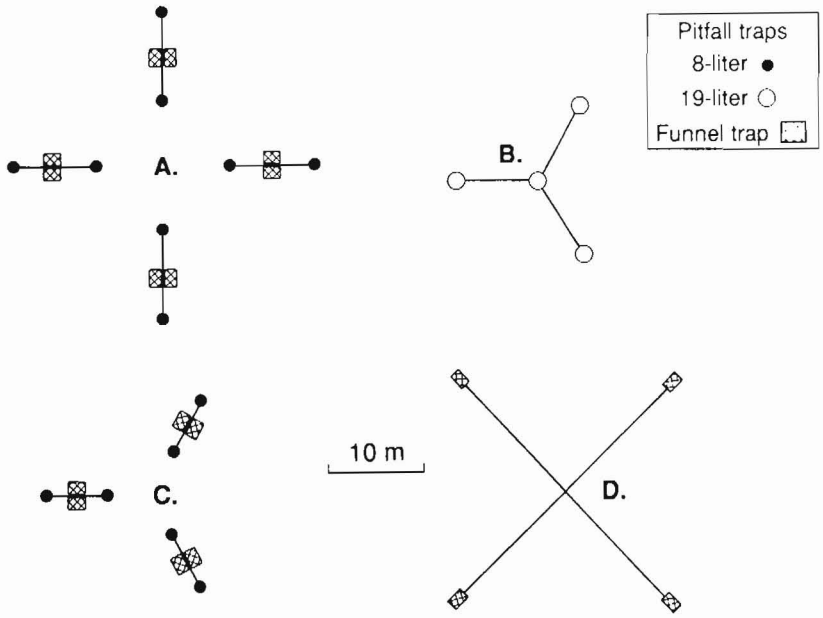

Figure 11. Designs for arrays of drift fences. A. Array used by Campbell and Christman (1982b). B. Array used by Jones (1981). C. Array used by Bury and Corn (1987). D. Array used by Dalrymple (1988). Fences and spacing are drawn to scale; trap sizes are not.

fences and found both adequate for sampling amphibians in coniferous forests in northwestern North America.

The pitfall traps that are used most often are 19-liter plastic buckets and 8-liter cans. Sometimes both are used in the same array. Funnel traps also may be effective for capturing amphibians (Campbell and Christman 1982a; Beauregard and Leclair 1988; D. E. Runde and K. M. Enge, unpubl. data), particularly in areas with saturated soils, where pitfall traps tend to fill with water. Some investigators have caught a variety of amphibians using a standard Campbell and Christman (1982a) four-fence array (Fig. 11A), in which the terminal pitfalls of each fence have been replaced with funnel traps (Vickers et al. 1985; Enge and Marion 1986). Indeed, K. M. Enge (pers. comm.) suggested that pitfall traps are not necessary if amphibians are the primary target animals.

Too little experimentation on the efficacy of different array designs has been done, and too much variation exists among amphibian assemblages for me to recommend a single design for all situations. However, a three-fence array with funnel traps (e.g., Fig. 11C) is probably suitable for most studies. Individual fences should be at least 5 m long. This length is convenient because fences for one array can be cut from a single roll of aluminum (see below).

FIELD METHODS

CONSTRUCTION. Large pitfall traps are made from 19-liter plastic buckets. Smaller pitfall traps (8-liter) are constructed by removing both ends and one end, respectively, of two number-10 tin cans (i.e., 3-lb coffee cans) and fastening the open ends of the two cans together with duct tape (Fig. 12). Single number-10 cans or 4-liter plastic jars may be used if the ground is particularly difficult to dig and the target organisms are small. Traps are buried in the ground, with the opening flush with the surface. For 8-liter cans a plastic collar is constructed by cutting the bottom out of a 1-lb plastic margarine tub, which is then inserted at the top (Fig. 12). This collar

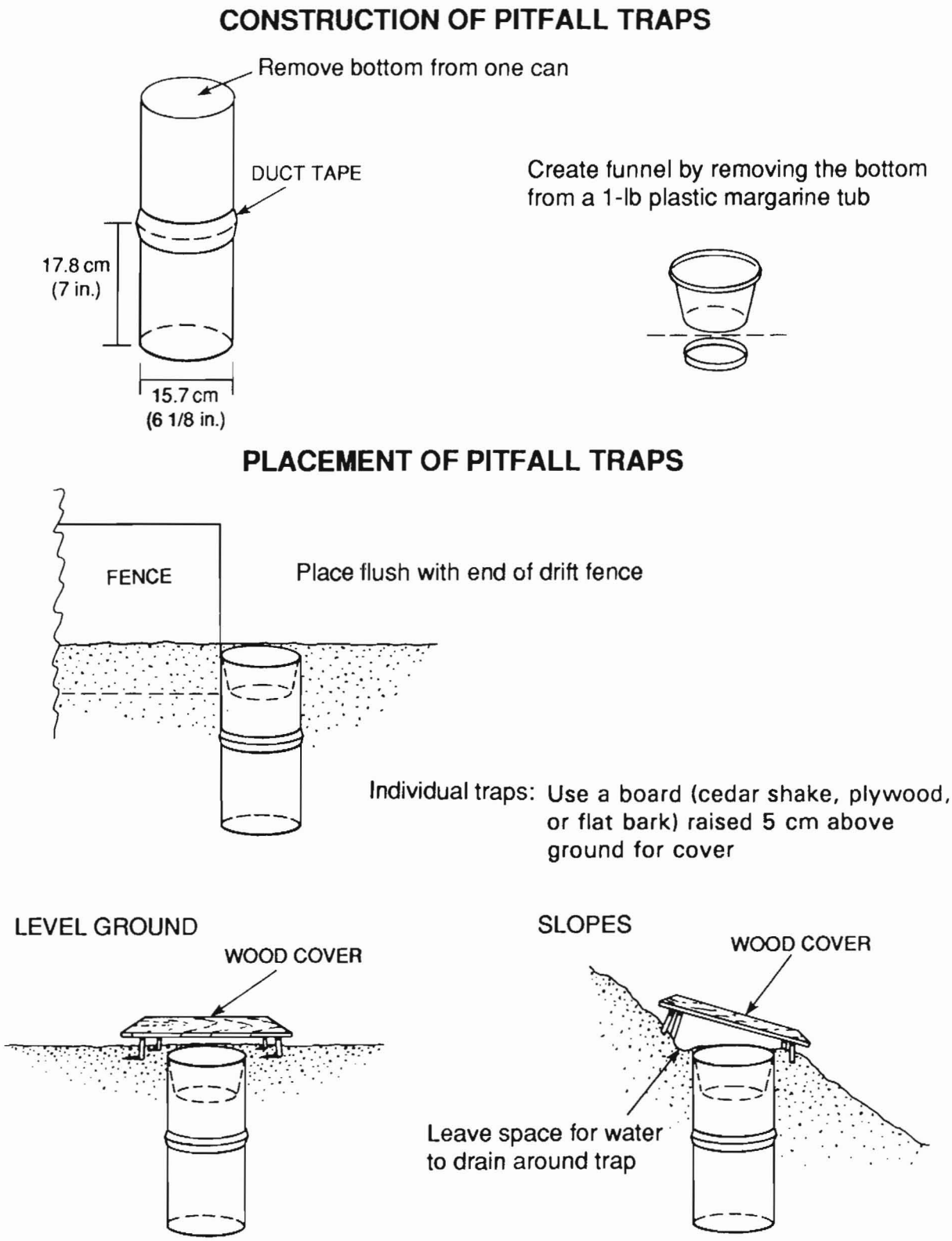

Figure 12. Construction of pitfall traps from two number-10 tin cans (reprinted with permission from Corn and Bury 1990).

keeps animals from crawling out of the trap (Vogt and Hine 1982). Pitfall traps should be closed when not in use. Plastic buckets come with lids, and although the shape of the buckets is often distorted after buckets are placed in the ground, lids will cover them effectively. The plastic lids from the margarine tubs can be used to cover 8-liter traps.

The hole for the trap is dug most easily with a posthole digger, which creates a hole with the correct diameter for 8-liter traps. A tile spade can also be used. Traps also may have a wood cover (Fig. 12). When the trap is open, the cover is raised above the opening. In hot, dry weather the cover protects trapped animals from desiccation and may inhibit predation by birds. The cover may also attract target animals.

Funnel traps consist of rounded tubes (or rectangles) with an inwardly directed funnel-shaped opening at one or (usually) both ends. They are constructed from window screen (Karns 1986) or rigid hardware cloth (Vogt and Hine 1982). Window screen can be purchased in rolls 76 cm wide. The body of the trap is constructed from a piece 90 cm long, and the cut ends are stapled together along the length of the tube. If the cut edges are folded before stapling, the tube is about 25 cm in diameter by 76 cm long. The funnel part of a trap is made from a square piece of screen rolled into a cone and stapled. The diameter of the large opening of a funnel matches that of the tube. A funnel is placed in one end of the tube, and the distal margins of both are attached to each other with staples. If only a single funnel is used, a piece of screen is stapled to the other end of the tube to close the trap. If two funnels are used, the funnel at the other end is attached to the tube with paper clips, so that it and animals can be removed easily from the trap. Funnel traps are placed parallel to the drift fence, midway along each side. Traps should be shaded with loose bark, palm fronds, litter, or plywood.

Drift fences can be constructed from a variety of materials, including hardware cloth, tar paper, window screen, or plastic. The preferred material is 50-cm-wide aluminum valley flashing (weatherproofing material), which comes in 15.2-m rolls. Desired lengths can be cut with tin snips. A mattock or hoe is used to dig a trench 20 cm deep for the length of the fence; the fence is placed in the trench, which is backfilled with soil. Occasionally an ax is needed to cut large roots. Loose dirt is tamped down and smoothed alongside the fence to create a runway, and small obstacles (twigs, rocks) are removed. In forests, aluminum fences 5 to 7 m long usually are self-supporting for a few months. Fences in open areas, fences left in place for several years, longer fences, or fences made from other materials need supporting stakes. Pitfall traps are placed at the ends of the fence so that no gaps occur between the fence and the rim of the trap. If desired, the edge of the trap can be slit and the fence run a short distance into its mouth (Jones 1986). An individual number is affixed to each trap for data recording purposes. Trap numbers can be written on the drift fence with a permanent marker.

For safety, fieldworkers should always wear gloves when handling the aluminum, because of sharp edges. In wet weather, tools quickly become coated with slick mud, so fieldworkers should exercise extreme caution when handling a mattock or an ax.

OPERATION. Ideally, traps should be checked daily, before noon, but with a large number of study areas, this schedule may not be possible. Traps should always be checked at least every three days. If the number of study sites is such that all traps cannot be opened on the same day, traps must be closed in the same order in which they were opened. This procedure ensures the same trapping effort for each area. Because traps can contain dangerous snakes and invertebrates, either long forceps or a small, stout aquarium net should always be used to check them.

If captured animals are to be released, they must be marked. Stockwell and Hunter (1989) released all animals but apparently did not mark them. They then reported total captures for each species. Because numbers of recaptures were unknown, their numbers of captures are difficult to interpret. Animals should be marked and processed in the field. If that is not possible, marking and processing can be done in the laboratory. Dead mammals, live amphibians, and dead amphibians should be placed in separate small plastic bags; all specimens from a single array or grid should be placed together in a larger bag. A cooler with reusable ice containers is best for transporting specimens from the field. Each day's catch should be processed on returning to the lab to reduce the likelihood of specimen and information loss. Processing of individuals to be marked and returned to the site should begin immediately. Live amphibians can be kept for a day or two in a cool place or refrigerator if processing must be delayed, but they must be checked frequently. Dead amphibians should not be frozen (Scott and Aquino-Shuster 1989; Appendix 4). Specimens should be processed by the person(s) who checked the traps, to minimize the introduction of inaccuracies into the data. See Appendices 1 and 4 for information on handling and preserving amphibians.

PERSONNEL AND MATERIALS

Installation of drift fences and pitfall traps is simple but labor-intensive. A large crew (4–6 people) can install three to six arrays or two grids per day. Fewer people are needed to check the traps once they are open. One person can check an array or a grid of 36 traps in an hour or less, depending on the number of animals captured. Several sites can be checked in one day, depending on the travel time between study areas.

Construction materials are expensive. Required items include posthole diggers, 15-m tape or measured nylon rope, plastic flagging (1–2 rolls), waterproof ink markers, aluminum flashing (in rolls 15 m long × 50 cm high, 1 roll per array) or suitable alternative for the fence, 19-liter plastic buckets, number-10 tin cans, 1-lb margarine tubs, and wood covers. Most items can be obtained from building supply stores.

Materials required for operation include a waterproof notebook and paper, large and small plastic bags, large forceps, a plastic cup or long-handled spoon, a small dipnet, and a small cooler with reusable refrigerant.

DATA TREATMENT AND INTERPRETATION

The species and the array and trap numbers of all individuals caught are recorded in the field. This record is important for quality control and should become a permanent part of the data set. It provides critical information during the initial processing of specimens and is a valuable reference for the questions that inevitably arise even after the data have been processed. The study area, date, and array and trap numbers are written in pencil on a small piece of waterproof paper and placed in each bag of specimens.

If animals are released, information must be recorded on formal data sheets at the time the animals are handled. If animals are retained, formal data sheets are completed when the animals are processed. Formal data sheets can be drawn by hand as needed, but preprinted forms are more convenient (Fig. 13). Several software packages can be used to design forms, and many word processing programs have table generation capabilities.

Proper identification of animals is essential, especially if animals are released. Identifications of preserved animals can be verified later. Discarding badly decomposed specimens from traps after field identification is risky. For example, a field crew in southern Washington captured more specimens than it was prepared to handle (Corn et al. 1988). Many small mammals were discarded in the field; the rest were preserved as skulls and deposited in the U.S. National Museum of Natural History. When the skulls were

Locality:	Oregon, Lane County, H.J. Andrews Experimental Forest

Technique	Province	Stand Number	Habitat	Day	Month	Year	Trap Night	Collector's Name
PIT	COAST RANGE	737	OLD GROWTH DOUGLAS FIR	22	10	85	22	P.S. CORN

Catalog Number	Species	Trap Column	Trap Row	Snout-Vent Length (mm)	Total Length (mm)	Mass (g)*	Sex	Age
15524 4	PLVE	A	1	80	38		M	S
15524 5	PLVE	A	1	68	35			S
15524 6	PLVE	F	2	95	48	19	F	A
15524 7	PLVE	B	1	94	47	16	M	A
15524 8	ENES	A	4	103	50	32	M	A
15524 9	ENES	C	6	98	54	31	M	A
15525 0	ENES	E	5		19	2		J

* Right column is tenths
Trap Night: Number of nights since traps were opened
Sex: Male, Female (if unknown, leave blank)
Age: Adult, Subadult, Juvenile
PLVE: Plethodon vehiculum
ENES: Ensatina eschscholtzii

Figure 13. A sample data sheet used to record amphibians collected from a pitfall grid. Note that species are identified by a four-letter abbreviation using the first two letters of the genus followed by the first two letters of the species. Data are from an inventory of forest vertebrates in Oregon (Corn and Bury 1991).

cleaned and identified, up to 10% of the field identifications were shown to be wrong, even though they had been made by experienced biologists familiar with the vertebrate fauna of the Pacific Northwest. This finding threw into question the identifications of most of the discarded specimens and severely limited the data analyses.

Species richness of ground-dwelling forms is the minimum information obtained by pitfall trapping. Numbers of animals trapped most often are converted to rate values by dividing by the trapping effort, either trap-nights (i.e., 1 trap-night is 1 trap open for 1 night; a grid of 36 pitfall traps open for 30 nights is 1,080 trap-nights) or array-nights (the array is treated as the trapping unit, and individual traps are ignored). These values can then be used as a measure of relative abundance. Grids of pitfall traps can provide data for estimates of density of selected species if used with mark-recapture. A computer program for estimating density from trapping grid data, CAPTURE (Rexstad and Burnham 1991), is available, but to my knowledge, it has not been used for amphibians.

Data can be used to generate simple species lists, or they can be analyzed with complex

multivariate ordinations. Various measures of species diversity and association are reviewed in Chapter 9. Gauch (1982) and Pielou (1984) described classification and ordination techniques and the use of multivariate statistics. Relative abundance can be compared among habitat types with analysis of variance (e.g., Corn and Bury 1991), but proper application of parametric statistics requires rigor (e.g., randomization) in selection of study sites and placement of arrays.

Diversity measures that include abundance (or anything but species richness) should be used with caution, because of species-specific capture rates. The numbers of each species trapped may bear little relation to real population sizes. The diversity index or abundance curves, therefore, are peculiar to the sampling scheme employed and may have quite limited biological meaning. Comparisons among habitat types (e.g., Stockwell and Hunter 1989) are probably not appropriate if the amphibian species assemblages differ. Determination of species richness can be enhanced by combining results from pitfall trapping with those from other techniques (Corn and Bury 1990; Bury et al. 1991), but abundance values are not comparable among different sampling methods.

SPECIAL CONSIDERATIONS

After collecting the required voucher specimens (see Chapter 5 and Appendix 4), the investigator must decide whether to collect or release the remaining animals captured. Release requires that all animals trapped be positively identified. Identification in the field may be impractical, particularly in areas where the fauna is poorly known. Collection of all animals trapped requires that arrangements be made for verification of identifications and deposition of specimens in a museum. Also, permits may be required for collecting.

In some habitats, large numbers of small mammals, especially shrews, die in pitfall traps (Bury and Corn 1987). These specimens are an important resource and should be saved. If project personnel are unable to process mammals, arrangements for outside help should be made. All applicable data should be recorded for mammals as well as amphibians. Pitfall traps also capture invertebrates, another important scientific resource. Generally, the collection of mammals, but not of invertebrates, is regulated by law.

Each time a trap is checked, debris and excess water must be removed. A small amount of water should be placed in traps when they are opened, but in wet weather, most traps accumulate more water than is desired. Previous workers (Raphael and Barrett 1981; Williams and Braun 1983) have recommended that water be placed in pitfall traps, as the quickest and most humane way to kill small mammals. Current guidelines for trapping small mammals with pitfall traps (American Society of Mammalogists 1987) specify drowning as the only acceptable method of kill-trapping. However, drowning is a slow and inhumane way to kill amphibians, and it is prohibited in the current guidelines for field methods for amphibians and reptiles (Committee 1987). A compromise between these apparently incompatible recommendations is to keep a small amount of water (2–5 cm) in the traps and to check the traps frequently. Small mammals, particularly shrews, will become hypothermic and drown in this amount of water, but most amphibians should survive. Daoust (1991) placed a 10 × 5 × 7 cm piece of saturated sponge in funnel traps and improved survival of trapped *Rana sylvatica*. Dodd and Scott (technique 9, below) recommend using synthetic foam rather than sponge, which disintegrates rapidly.

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