Chapter 5

Keys to a Successful Project: Associated Data and Planning

Introduction

Once the research question, target species, and general regions for investigation have been determined, details relating to site selection, logistics, and sampling protocols must be refined. As part of this process, it is important to consider factors that are related to the inventory or monitoring study, but are not a primary focus of it, about which data should be taken. In this chapter, we review types of associated data that we believe merit special attention.

Because amphibian activity and reproductive biology are so closely tied to local weather patterns, we recommend that several kinds of weather data be collected, and we suggest appropriate instruments that can be used to obtain them. We discuss the importance of well-documented collections and recommend minimum standards for associated data. We also provide guidelines for describing habitats, localities, and sampling sites and for recording observations during the fieldwork. We advocate the recording of microhabitat data for all specimens encountered and present lists of sample descriptors that may be used. Finally, we discuss the importance of voucher specimens to inventory projects and make recommendations concerning their identification and deposition.

Attention to these several points before beginning a project should facilitate the work, provide a better-documented and hence more complete sample, and increase the overall quality of the study. Because inventory and monitoring projects demand major commitments of time and personnel and frequently are significant logistical undertakings, well-conceived projects and amply prepared staff are keys to success. We encourage investigators contemplating a monitoring or inventory project to contact local residents near potential study sites. Such contact is particularly important on private land where access to ponds and streams used by amphibians often is possible only with the help of landowners. In addition, because amphibians are obvious components of wetlands and similar aquatic environments, they often are known to local residents. Persons living in the area can be extremely knowledgeable about the biota and can contribute immensely to a project. Likewise, local scientists and other persons may be familiar with the organisms and areas to be inventoried and can provide scientific expertise and guidance. Contacts made before beginning an inventory or monitoring study can be beneficial to the project and in certain instances may be essential to its success. Collaboration on inventory projects can result in rewarding friendships and better science.

Climate and environment

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Weather data are especially critical for interpretation of results in amphibian studies because amphibians are so dependent on moisture. Although different species have different ranges of tolerance, all amphibians exchange gases and lose water through the skin and are, therefore, vulnerable to drying conditions. Temperature, precipitation, and other climatic factors influence the geographic and ecological distributions of amphibians and the timing and intensity of feeding, reproduction, and migration. Climatic conditions also affect population densities and assemblage-wide interactions.

Another rationale for collecting weather data concerns the apparent decline of amphibian populations around the world, even in remote and protected areas (Barinaga 1990; Blaustein and Wake 1990). Possible explanations for the declines include air and water pollution, acidified precipitation, habitat destruction or modification, introduced predators, and changes in global climatic conditions, such as increased temperature and decreased rainfall. Thus, it is critical to document environmental conditions with the hope that the factors responsible for amphibian declines can be identified.

The following example underscores the importance of factoring weather conditions into a study of biological diversity. Imagine that the goal of a study is to compare amphibian species richness between two seasons (2 weeks in the warmer, wetter season and 2 weeks in the cooler, drier season) within 2 types of forest in a region. Ten persons spend 1 week in forest A and a second week in forest B. Heavy thunderstorms occur every day during the first sampling week of the wet season, but no rain falls during the second week. During the dry-season surveys, week 1 is warm whereas week 2 is approximately 10° C cooler than week 1. In the wet-season inventories, 18 species are recorded in forest A, and 5 species in forest B. During the dry season, 13 species are found in forest A, and 2 in forest B. Based on the number of species found, the investigator concludes that the amphibian assemblage in forest A is considerably larger than the assemblage in forest B during both seasons. Actually, they may be equal, or the assemblage in B may be larger. The data may not reflect the true species richness, because of uncontrolled weather variables. Most amphibians are more active during wet periods than during dry periods, and they are more active during warm periods than during cold periods. If the weather data are not recorded, the amphibian data obtained cannot be properly evaluated.

The effect of weather can be minimized in several ways, depending on time and personnel constraints. In the above example, a better design would have been to have 5 persons work in forest A at the same time that 5 persons surveyed forest B. If personnel were limited (e.g., a field crew of 3 persons), one option would be to carry out half-day inventories using all personnel, thus surveying both sites each day (alternating sampling times for each site) for 2 weeks. If the sites were too far apart to reach within one day and still have time to survey both areas, inventories in the two sites could be done on alternate days. (This design does not solve the problem entirely, but alternating days would be preferable to surveying for 7 days at one site followed by 7 days at the other.) If time were not a constraint (i.e., if the survey could be done over several months each season), investigators might do many replicate inventories in the two sites; the increased samples should minimize effects caused by differences in weather.

Basic Weather Data

In order to interpret inventory or monitoring data, baseline weather data are needed not only during the survey but also for some time prior to the survey. Whenever possible, weather data should be collected for several weeks preceding the survey because these data often provide insights for the interpretation of the inventory or monitoring results.

Maximum and minimum temperatures and precipitation are essential data for every inventory or monitoring project and should be recorded continuously or daily at the same time at each site. If a standard weather station is located near the study site (often available at airports or universities), it can provide information on general weather patterns and long-term climatic data. Often, however, the only way to obtain such information is to gather the data oneself.

TEMPERATURE

Temperature is critical to measure because it significantly influences amphibian development and growth, and it often controls reproductive cycles and behavior (particularly for temperate zone species). Temperature changes can affect predation, parasitism, and an amphibian's susceptibility to disease. Cooling or warming trends can initiate migrations and thus influence distribution and activity patterns. Changes in water temperature can affect oxygen concentration and primary production essential to larval stages, thus influencing growth, development, and survivorship. Depending on the goals of the study, any or all of the following temperatures may be relevant: animal body, air, water, soil, leaf litter, or substrate.

For a general inventory, one should record the maximum and minimum temperatures continuously or at regular times each day. Often, recording temperature at the beginning and end of a sampling period will provide information useful in evaluating amphibian activity. If time permits, additional information can be gained if air and substrate temperatures are recorded for each animal encountered during the inventory. However, if recording temperatures for each animal decreases the habitat area sampled, the data may not be worth the effort. Before any temperature data are recorded, the investigator must consider the exact questions to be answered, the statistical analyses to be done, and the cost-benefit ratio of recording various types of weather data.

Instruments for measuring temperature range from standard mercury thermometers to elaborate recording devices. Hand-held thermocouples are often preferable to standard thermometers for measuring air temperature because thermocouples are more durable. Maximum-minimum thermometers provide the high and low temperature for any time interval (usually 24 hr is used). Thermometers can be placed at any height above the ground and thus can yield information relevant to terrestrial or arboreal amphibians. Two meters above ground is a standard reference height for meteorological stations. Thermometers also can be attached to a stake underwater to record high and low water temperatures at any desired depth. Accurate temperatures for microhabitats such as soil and leaf litter can be obtained with resistance thermometers or with thermistors and microprobes buried in the substrate. Continuous recordings of temperature can be made with recording thermographs or with sensors interfaced to data loggers (see "Automated Data Acquisition," below).

PRECIPITATION

Precipitation, likewise, strongly influences amphibian activity, distribution and dispersion patterns, reproductive cycles, and rates of growth and development. Many species remain underground or in aboveground retreats except during wet periods. Therefore, the best time to survey an area is often during the wet season or following rain. Because the seasonal distribution of rainfall is more relevant than average annual precipitation, daily precipitation should be recorded.

The simplest way to measure rainfall is with a rain gauge. If the data desired are measures of the actual amounts of precipitation, the gauge should be set in an open area. On the other hand, if one wishes to know how much water falls through the canopy onto the forest floor or into a forest pond, the rain gauge should be installed so that through-fall precipitation is measured. Gauges range from simple plastic devices that must be manually emptied, to automatic electronic rain gauges that measure rainfall, forward the information to a remote recorder, and then empty themselves. Automatic gauges can accumulate the total amount of rainfall over any specified period of time and have the obvious advantage of never needing to be checked or emptied.

Additional Environmental Data

Depending on the goals of the study and on available resources and personnel, specific microhabitat data for each animal encountered may be desirable. Following are some relevant factors that are known to influence distribution and activity of amphibians.

RELATIVE HUMIDITY

The combination of temperature and humidity determines the rate of water loss from an amphibian's surface. For this reason, the amount of moisture in the air strongly affects distribution and activity patterns. The simplest method of obtaining humidity measurements in the field is with a sling psychrometer or battery-operated hand-held thermohygrometer (the latter is convenient because it provides a digital readout of both temperature and humidity). Air temperatures should always be recorded in conjunction with measurements of relative humidity. A hygrothermograph continuously records both temperature and humidity.

SUBSTRATE MOISTURE

Moisture levels of substrates such as soil, leaves, and leaf litter likewise can affect distribution and activity patterns. Soil moisture measurements can be taken with a tensiometer, and leaf wetness sensors are available that give both temperature and wetness readings for leaf surfaces. For continuous readings, moisture sensors can be interfaced to data loggers.

BAROMETRIC PRESSURE

The environmental factors that trigger calling behavior of male anurans and that stimulate changes in hormone levels preparatory for breeding activity are not clearly understood. Moisture and temperature are important, and they doubtlessly have synergistic effects. Another factor that may be important is change in barometric pressure. Whenever field conditions permit, barometric pressures should be recorded and analyzed in conjunction with patterns of amphibian activity. Barometric pressure can be measured with hand-held barometers or with automatic recording devices (see "Automated Data Acquisition," below).

WIND SPEED AND DIRECTION

Because amphibians are sensitive to water loss, they are strongly influenced by wind currents. Wind speed can be determined easily by hand-held anemometers. If data are recorded at the site of observation for each amphibian found, correlations between wind speed and occurrence of individuals and their activity patterns can be determined. If general trends are desired, daily mean wind velocity and direction can be obtained from a standard weather station if one is located nearby.

WATER LEVEL OF THE BREEDING SITE

For amphibians that oviposit in water, the amount of water present in the breeding site may determine distribution and activity patterns. Whether the study is a one-time inventory or a long-term monitoring program, water depth of the breeding site should be measured. In an inventory, perhaps the only points of interest are maximum and minimum depths. On the other hand, in a monitoring study, changing profiles of water depth in the lake, pond, or stream may be useful. The number of points at which water depth should be measured depends upon the size of the habitat. In a puddle, 5 points may be sufficient; in a large lake 50 or more points may be useful. In a monitoring study, water depth should be measured at these same points each time the habitat is sampled or read from previously located depth markers. Water depths are easy to obtain with a collapsible meter stick. For continuous readings, mechanical recorders are available, or sensors can be connected to data loggers.

pH

Because excessive acidification of water has detrimental effects on amphibian growth, development, and survivorship (Pierce 1985) and has been suggested as a cause of amphibian declines, I encourage investigators doing inventories and long-term monitoring around the world to document pH conditions at their study sites. Relevant sites to measure range from water-filled bromeliad tanks and tree cavities (developmental sites for arboreal tadpoles), and water-filled roadside ditches and shallow ponds, to larger bodies of water such as lakes and streams; measuring the pH of rainwater is also encouraged. Most experts agree that pH indicator paper gives unreliable and misleading results that often are worse than no data at all. Many types of portable pH meters appropriate for field use are available.

Measuring Weather Variables

Whenever possible, weather and microhabitat data should be collected automatically with recording instruments; such instruments increase accuracy of the data collected and provide daily or weekly records of changes. A record of the overall variation in an environmental factor is preferable to individual measurements taken at predetermined times. Another advantage is that recording instruments reduce the field time required to collect the data. If recording equipment cannot be used, manual instruments can be employed successfully, given sufficient time and personnel.

Data should always be recorded in the field with actual numbers rather than codes. The reasons for this are many and include minimization of confusion when multiple persons are involved in data collection, difficulty of remembering the codes used, and ease of making mistakes under adverse field conditions.

Digital recorders (data acquisition systems and data loggers) are generally more accurate and reliable than are mechanical, battery-powered, or electrical recording devices (see "Automated Data Acquisition," below). A drawback to use of data acquisition systems in the field is that typically they must interface directly with a computer. In contrast, field data loggers can operate in a stand-alone mode because they typically have internal memories; data loggers can collect the data as integrated, averaged, or point values over logging periods ranging from 1 minute to 24 hours. Data stored in the memory can then be transferred to a compatible computer or printer. In recent years, rapid advances have been made in the development of portable data acquisition systems and data loggers suitable for use in the field, with new models continually being introduced (Pearcy 1989). Investigators should consult with manufacturers (see Appendix 6) prior to purchase regarding suitability of a particular digital recorder for use in connection with environmental monitoring systems.

Weather recording equipment will not be an option for all field studies because of cost (recording equipment, especially an automated device, is expensive), security considerations (in many instances the risk of theft precludes the use of expensive instruments), and risk of equipment failure (a serious consideration if the study site is a long way from the nearest repair shop). Backup, manually operated instruments should always be available in case recording devices fail or are stolen during a study.

The following are merely examples of the sorts of instruments available from scientific suppliers. Anyone seriously contemplating purchase of equipment is advised to search through catalogues for the prices and specifications best suited to the study (see Appendix 6). The estimated prices (all in U.S. dollars = U.S.$) indicated below are from scientific equipment catalogues for 1991, from companies in the United States.

The most efficient field method of obtaining baseline weather data is to set up a portable weather station at each survey site. Machines that measure maximum-minimum temperature, precipitation, relative humidity, barometric pressure, wind speed, and wind direction can be purchased for U.S. $1,000–$1,300. These units run on size D batteries and thus are convenient for field use. More-restrictive recording units include spring-wound, 7-day recording thermometers (U.S. $220–$250), automatic electronic rain gauges (U.S. $70–$100), spring-wound and battery-run hygrothermographs for 1-, 7-, 31-, or 62-day continuous recording (U.S. $550–$1,500), electric-powered anemometers for continuous 30-day recording of wind velocity (U.S. $600), and 7-day electric-powered barometers for continuous recording of data (U.S. $310–$350). Data acquisition systems cost about U.S. $500 or more, and data loggers about U.S. $1,300 or more.

Numerous nonrecording instruments are available: maximum-minimum thermometers (U.S. $25–$40); digital thermocouple thermometers (U.S. $150–$200); standard rain gauges (U.S. $7–$25); sling psychrometers (U.S. $30–$65); battery-operated, hand-held thermohygrometers (U.S. $100–$400); anemometers (U.S. $12 for hand-held portable wind meters); tensiometers (U.S. $50–$250); soil moisture and leaf wetness sensors (U.S. $40–$80); barometers (U.S. $25 to $250 or more); and battery-powered pH meters (U.S. $200–$300).

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Automated data acquisition

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In this section we describe methods for automatically measuring variation in the physical environment and in the behavior, particularly calling, of amphibians. Data quantifying the relationship between environmental variation and amphibian activity can be used as a basis for optimizing sampling procedures for inventory and monitoring programs and for interpreting population changes (Peterson and Dorcas 1992).

We have restricted the scope of this section to continuous, automated measurements rather than single, manual measurements. Because many factors vary through time, it is important to sample regularly over hours, days, and even seasons. For example, the pH of pond water may vary by more than one unit during the course of a day (James T. Brock, pers. comm.) and may change dramatically at certain times of the year (e.g., following the spring snowmelt; Pierce 1985). Automated sampling systems make it possible to measure a wide variety of variables continuously, accurately, and easily at one or more sites.

Data loggers, environmental sensors, automated recording of anuran calls, and automated radiotelemetry are discussed in this section. Most of the information concerning data loggers and environmental sensors was obtained from Pearcy et al. (1989), Campbell (1990), and Tanner (1990). We include the names of various manufacturers, especially for the equipment and materials that we use (Appendix 6). However, our experience with different brands is limited, and the listing of a particular vendor does not indicate our endorsement. Furthermore, technical aspects of instrumentation are advancing rapidly, and many of our specific comments will soon be out of date.

Data Loggers

Within the past 10 years, the task of gathering continuous data has been greatly facilitated by the development of microprocessor-based data loggers that receive, process, and store data from environmental sensors. They can be programmed to record the variables at stipulated time intervals for periods of varying duration.

Important characteristics of field data loggers include portability, battery power, programmability, and the ability to read input from several types of sensors at user-selected intervals (Campbell 1990). Data loggers have numerous advantages over devices such as mechanical recorders and strip chart recorders, including a wider range of operating temperatures, increased sensor compatibility, higher accuracy, greater data storage capacity, and easy transfer of data to computers (Pearcy et al. 1989).

Factors to consider when selecting a data logger include cost, reliability, the range of operating conditions (temperature and humidity), accuracy, resolution, number of channels, sensor compatibility, processing power, data storage and retrieval options, and power requirements (Tanner 1990). Costs range from approximately U.S. $500 to more than U.S. $5,000. Small, inexpensive, single-channel data loggers have recently been introduced (Hobo-Temp or Hobo-RH, Onset Computer Corp.). Although these data loggers are dedicated to a single sensor and have a limited storage capacity (1,800 values), they should be adequate for many studies. The ability to record data from several temperature sensors and to control a device such as a tape recorder automatically can be achieved now, even with relatively low-cost systems. Powerful, versatile systems, capable of reading most sensors and recording the data, are available for less than U.S. $1,700 (including the interface and software for downloading data). Features to look for in this price range include 12-bit or greater resolution, the ability to measure microvolts (e.g., thermocouples), switch or pulse counting capability (for cup anemometers and tipping-bucket rain gauges), the ability to provide excitation voltages (for thermistors and electrical resistance humidity sensors), and digital outputs for controlling devices such as tape recorders, radiotelemetry systems, and fans in ventilated psychrometers. A more expensive data logger, capable of resolving nanovolts, is required for measurements of some variables (e.g., soil water potentials using thermocouple psychrometers).

If funds are not available for purchase of a data logger, it may be possible to borrow one or simply to add sensors to one already in use at or near the study site. As costs decline, data loggers are becoming more common, and many universities, field stations, government agencies, parks, and other institutions make such equipment available to scientists.

For many users, learning to program data loggers is difficult. Becoming comfortable with the more powerful systems may take several days. To minimize learning time, we recommend working with someone already familiar with the equipment. Some manufacturers offer training sessions. Initially, modifying an existing program to suit a given situation may be easier than writing a new one. We have included sample programs for a Campbell Scientific CR10 data logger that direct it to record temperature, radiation, wind speed, and humidity and to operate a tape recorder to record frog calls (Tables 2 and 3). Data loggers need to be enclosed to protect them from weather conditions and vandals. Some manufacturers offer enclosures. A less expensive alternative is a small ice chest or cooler. For electrical equipment, we have also used metal boxes, which can be obtained locally from an electrical supply house. In areas exposed to direct sunlight, it may be necessary to paint the enclosure white or to shade it to prevent overheating. The use of a desiccant (e.g., silica gel) may be required in humid environments to keep conditions in the

Table 2. Sample Computer Program for Operating an Automated Weather Station with a Campbell Scientific CR10 Data Logger[a]

```
  01: 1         Execution Interval (in seconds)

01:  P11        Temp 107 Probe
  01: 1         Rep
  02: 1         IN Chan
  03: 3         Excite all reps w/EX Chan 3
  04: 28        Loc :
  05: 1         Mult
  06: 0.0000    Offset

02:  P10        Battery Voltage
  01: 27        Loc :

03:  P13        Thermocouple Temp (SE)
  01: 6         Reps
  02: 1         2.5 mV slow range
  03: 2         IN Chan
  04: 1         Type T (Copper-Constantan)
  05: 28        Ref Temp Loc
  06: 1         Loc :
  07: 1         Mult
  08: 0.0000    Offset

04:  P2         Volt (DIFF)
  01: 1         Rep
  02: 3         2.5 mV slow range
  03: 5         IN Chan
  04: 7         Loc :
  05: 100       Mult
  06: 0         Offset

05:  P3         Pulse
  01: 1         Rep
  02: 1         Pulse Input Chan
  03: 2         Switch closure
  04: 8         Loc :
  05: 0.6521    Mult
  06: 0.2303    Offset

06:  P11        Temp 107 Probe
  01: 1         Rep
  02: 11        IN Chan
  03: 1         Excite all reps w/Exchan 1
  04: 26        Loc :
  05: 1         Mult
  06: 0.0000    Offset
```

Table 2. ***(Continued)***

07: P12	RH 207 Probe
01: 1	Rep
02: 12	IN Chan
03: 1	Excite all reps w/Exchan 1
04: 26	Temperature Loc
05: 9	Loc :
06: 1	Mult
07:0.0000	Offset
08: P92	If time is
01: 0000	minutes into a
02: 5	minute interval
03: 10	Set high Flag 0 (output)
09: P77	Real Time
01: 0110	Day,Hour-Minute
10: P71	Average
01: 9	Reps
02: 1	Loc:

[a] The execution interval of the data logger is set to 1 second. The first P11 command measures the temperature of the panel thermistor, which is then used as a reference temperature for thermocouple measurements. The next command (P10) reads the voltage of the battery used to power the data logger. This measurement is not output to final memory but is used to examine battery voltage in the field. The P13 command is used to make six single-ended readings of copper-constantan thermocouples (e.g., soil, water, and air temperatures). The P2 command reads the voltage of a pyranometer. A multiplier of 100 and an offset of 0 convert the measurements to watts/m^2. The P3 command reads the pulses of a cup anemometer. A multiplier of 0.6521 and an offset of 0.2303 convert the measurements to m/sec. The multiplier and offset used with cup anemometers vary with the execution intervals used. In general, the multiplier and offset values are used to convert the output from specific sensors into engineering units and often vary among individual instruments. The second P11 command reads the temperature of the thermistor in a relative humidity probe. This temperature is then used as a reference for the P12 command, which measures the relative humidity. The P92 command sets the output interval to 5 minutes. The P77 command outputs the Julian day, hour, and minute. The P71 command averages the measurements of all sensors and outputs that average to final memory. See the Campbell Scientific (1990) CR10 manual for detailed explanations of commands.

Table 3. Computer Program for Turning a Cassette Tape Recorder On and Off with a Campbell Scientific CR10 Data Logger[a]

01: 1	Execution Interval (in seconds)
01: P92	If time is
01: 0000	minutes into a
02: 5	minute interval
03: 30	Then Do
02: P20	Set Port(s)
01: 0000	C8,C7,C6,C5 options
02: 0001	C4..C1=low/low/low/high
03: P22	Excitation with Delay
01: 1	EX Chan
02: 0000	Delay w/EX (units = 0.01 sec)
03: 1000	Delay after EX (units = 0.01 sec)
04: 0.0000	mV Excitation
04: P20	Set Port(s)
01: 0000	C8,C7,C6,C5 options
02: 0000	C4..C1=low/low/low/low
05: P95	End

[a] This program instructs the data logger to turn the tape recorder on for 10 seconds every 5 minutes. The execution interval is 1 second. The program begins with a P92 command, which sets the 5-minute recording interval. The first P20 command sets the control port at high, providing the 5-volt signal required to toggle the relay switch and turn the tape recorder on. The P22 command usually is used to control the excitation ports of the data logger. In this case, zero voltage is specified, and the command is used only to provide a 10-second delay until the port is set low with another P20 command, which turns the tape recorder off. The End command (P95) terminates the program.

enclosure within the operating range of the data logger. Sometimes, we have buried enclosures to hide them from vandals. Burial also reduces the range of temperatures to which the data logger is exposed.

Environmental Sensors

The following sections describe sensors that are most often used in conjunction with data loggers to measure important environmental variables. It also is possible to use a data logger to measure the signals from manual, stand-alone instruments with millivolt outputs that normally would go to strip chart recorders. Sensors usually are mounted on an instrument tripod, which can be purchased from a supplier or constructed. Data loggers receive input from sensors, which can be plotted against time (e.g., Fig. 2). We do not have firsthand experience with using sensors for some variables (e.g., ultraviolet radiation) and have had to rely on the literature or advice from engineers or other scientists to prepare some of the following material. Publications by Flowers (1978), Fritschen and Gay (1979), World Meteorological Organization (1983), Marshall and Woodward (1985), Finklestein et al. (1986), Bingham and Long (1988), Pearcy et al. (1989), Skaar et al. (1989), Campbell (1990), and Tanner (1990) provide additional information on instrumentation. Information on manufacturers and suppliers of sensors can be found in Appendix 6.

TEMPERATURE

Thermocouples are the preferred sensors for use in most field studies requiring automated temperature measurements. They are relatively accurate and inexpensive, come in a wide range of sizes, respond quickly, and can be used over long distances without a change in the signal (Pearcy et al. 1989). For temperature measurements in the range of biological interest (–70° to 100°C), Type T (copper-constantan) thermocouples are most appropriate. This combination of metals produces a relatively large voltage that changes linearly with temperature (approximately 40 μv/°C) within the range of interest. Thermocouples made from 24-gauge (0.5-mm diameter) wire are commonly used for measuring water, soil, and air temperatures. Thermocouple wire is relatively inexpensive (< U.S. $1 per m) depending on type, size, and quality. Thermocouples can be purchased or easily made by stripping the ends of the wire and then twisting the exposed ends together and soldering them; the other wire ends are installed in the wiring panel of the data logger (Pearcy et al. 1989). The actual site of temperature measurement lies at the first junction of the twisted wires (i.e., the thermocouple). Thermocouples usually do not have to be calibrated individually. Potential problems with thermocouples include heat conduction via the thermocouple wire and inaccurate measurements of the reference temperature (usually taken where the thermocouple wire attaches to the data logger).

Thermistors (temperature sensitive resistors) are another device commonly used for measuring temperature. Advantages include high sensitivity, accuracy, and fast response time. However, thermistors are more expensive and less rugged, cannot be used easily over long distances, and require individual calibration. Some data loggers can read both thermocouples and thermistors easily, whereas other data loggers may be unable to read, or have difficulty reading, one or the other sensor accurately.

We usually measure air temperatures at animal height (e.g., 1 cm) and at 2 m (a standard reference height for meteorological stations), water temperatures on the bottom and 1 cm below the surface, and soil temperatures from at least two depths (e.g., 1 and 20 cm), if we are interested in burrow temperatures. Thermocouples used to measure air temperatures should be shaded unless they are small and highly reflective (e.g., painted white).

HUMIDITY

Electrical resistance humidity sensors (e.g., Physical Chemical Scientific Corporation) or capacitance humidity sensors (e.g., Vaisalia) provide a convenient way of measuring atmospheric water vapor automatically (Tanner 1990). Costs range from U.S. $200 to $800. Some of these sensors require an AC excitation voltage from the data logger. Some electrical

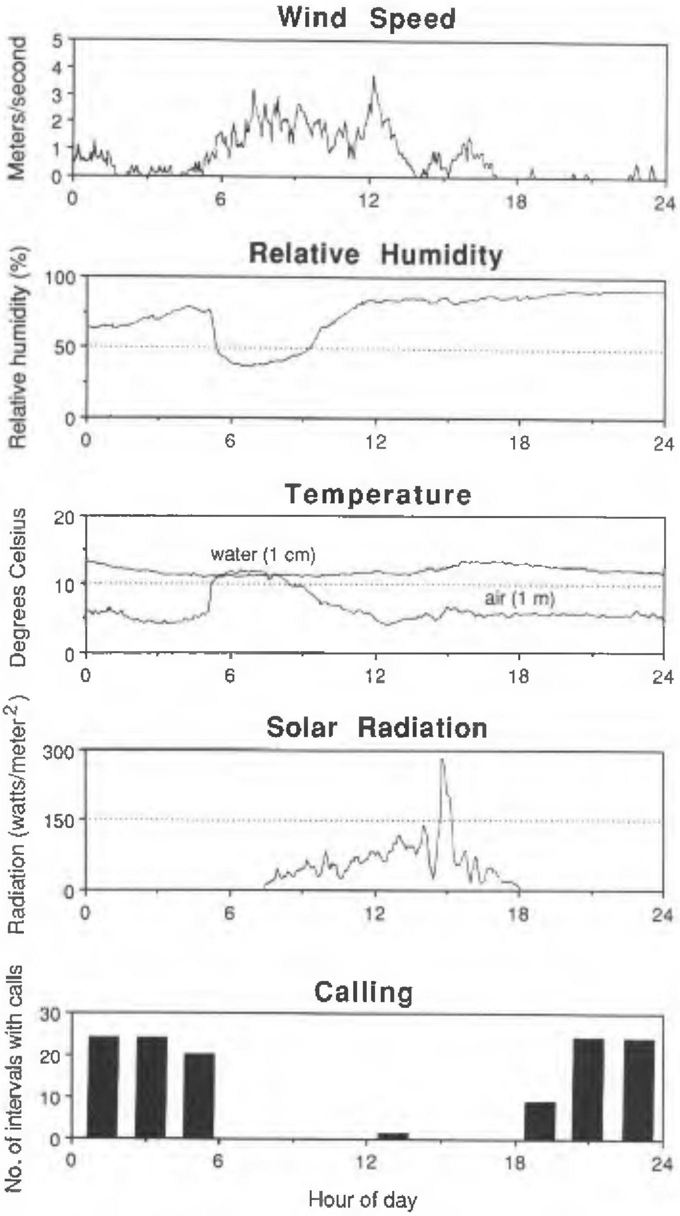


Figure 2. Measurements of the calling activity of southwestern toads (*Bufo microscaphus*), solar radiation, water and air temperatures, relative humidity, and wind speed at Lytle Ranch in southwestern Utah, 18 March 1991. Calling was recorded for 10 seconds every 5 minutes using a cassette tape recorder controlled by a Campbell Scientific CR10 data logger. The same data logger was used to sample environmental variables at 1-second intervals and to provide average values every 5 minutes.

humidity sensors may be damaged by condensation or air contaminants (Campbell 1990). Sensor elements need to be calibrated individually at least annually and may need to be replaced periodically. Skaar et al. (1989) compared commercial hygrometers. Ventilated wet-bulb, dry-bulb psychrometers are more accurate than electrical resistance humidity sensors but usually are more expensive, require power to run a fan, require attention to keep the water reservoir filled, and will not read accurately below 0° C (Tanner 1990).

PRECIPITATION

Precipitation can be measured automatically with a tipping-bucket rain gauge (e.g., Texas Electronics) connected to a pulse-counting channel on a data logger (Tanner 1990). When a specified depth of water has collected, the bucket tips and empties. The number of tips is counted with the data logger. Resolution in the range of 0.1 to 0.2 mm is possible (World Meteorological Organization 1983). To measure precipitation in the winter, tipping buckets can be heated so that snow will melt and the water will drain from the bucket. Weighing-bucket rain gauges are a more accurate, but more expensive, way to measure precipitation (Tanner 1990).

RADIATION

Solar radiation sensors (pyranometers) that are commonly used with data loggers are silicon photocells (e.g., LI-COR LI200SZ) and thermopile devices (e.g., Eppley model PSP, Kipp and Zonen model CM11). The silicon cells are considerably less expensive than the thermopile devices (about U.S. $200 vs. $1,300–$3,000). However, because their spectral response is limited to between 400 nm and 1,100 nm, silicon cells should not be placed under vegetation or used to measure reflected radiation (Tanner 1990).

Measurement of ultraviolet radiation is of particular interest to herpetologists because of possible adverse effects on amphibians (especially in the 290–320 nm wavelength band known as ultraviolet B [UVB]). Ideally, an investigator would like to know the irradiance (watts/m^2) at specific wavelengths and the response of amphibians to UVB. Unfortunately, the spectral radiometer required to make these measurements is very expensive (> U.S. $60,000) and requires considerable expertise to use. Useful UVB data may be obtained from sensors with spectral responses that approximately parallel the sunburn response of human skin. These sensors are available from Solar Light Company and Yankee Environmental Systems (YES) at U.S. $3,500 and $4,000, respectively. The Solar Light sensor reads in units of minimum erythemal dose (MED), and the YES sensor reads in watts/m^2, which can be converted into MED units. These sensors can be easily connected to a data logger, but their output needs to be corrected for temperature variation. A program for reading a UVB meter with a data logger is available from Campbell Scientific. Approximately 18 stations in the United States use these sensors as part of the National Oceanic and Atmospheric Administration RB Meter UV Network (John De Luisi, pers. comm.); about 20 stations elsewhere in the world use them as well.

WIND SPEED

Wind speed can be measured automatically with a cup anemometer and the pulse-counting channel of a data logger. Cup anemometers are omnidirectional, have linear responses, and are reasonably precise (Campbell 1990). Factors to consider when selecting an anemometer include size, the range of wind speeds over which the sensor operates (especially the starting and stopping thresholds), cost, and durability. Propeller anemometers have lower thresholds and can be used to measure wind direction, but they are more expensive (Campbell 1990). We usually mount our anemometer at a height of 2 m. If more than one anemometer is available, wind profiles can be determined so that the 2-m wind speed can be used to calculate wind speeds at other heights.

pH AND CONDUCTIVITY

Continuous monitoring of pH with a data logger presents a variety of problems, including matching the input impedance from the pH electrode to the data logger, isolation of the electrode from the data logger to prevent ground loops, temperature compensation of the sensor output, and maintenance of the pH electrode in operating condition. An example of an equipment configuration (Omega Engineering) for measuring pH includes a submersible, industrial-grade, flat-sensing-surface pH probe (U.S. $95), a two-wire pH transmitter (U.S. $225), a 24-volt battery (or two 12-volt batteries wired in series), and a loop-powered isolator (U.S. $125). Alternatively, a pH probe can be read with a pH 220 Probe Amplifier (Campbell Scientific). The data logger can be used to measure sensor temperature and make the temperature compensation calculation. Electrodes need to be checked, cleaned, and recalibrated regularly to ensure proper operation. Freezing will damage electrodes. For short-term monitoring of pH (several days or less), we are experimenting with feeding the analog output of a manual pH meter to a data logger.

Water conductivity can be measured automatically with a similar system but with a conductivity sensor (U.S. $130) and conductivity transmitter (U.S. $230). If the conductivity transmitter does not have an isolator, one should be added. Conductivity sensors also need to be cleaned periodically.

Thermal Environment

Temperature is one of the most important factors influencing the activity of amphibians (especially in the temperate zone) and, thus, our ability to determine their presence and abundance (Peterson and Dorcas 1992). For this reason, it is important to describe accurately the thermal environments of amphibians. The thermal environment of submerged, aquatic amphibians (e.g., larval salamanders) can be characterized relatively easily by measuring the temperature of the surrounding water. Describing the thermal environments of terrestrial amphibians is more complex because a variety of factors interact to determine body temperatures. These factors include air temperature, substrate temperature, radiation, humidity, soil moisture, wind speed, and animal properties such as size, shape, reflectivity, and permeability of the skin to water (Tracy 1976).

A single-number representation of the thermal environment that incorporates these factors is the operative temperature (Bakken and Gates 1975; Bakken 1992). Operative temperatures can be calculated using computer models of heat transfer, but this approach may be difficult to apply at small spatial scales and requires considerable instrumentation and expertise. A simpler and less expensive approach for measuring operative temperatures involves the use of physical models that incorporate animal properties such as size, shape, and reflectivity (Bakken and Gates 1975). This approach has been applied with considerable success to dry-skinned ectothermic vertebrates, that is, reptiles (Crawford et al. 1983; Peterson 1987; Grant and Dunham 1988). It is more difficult to make models of most amphibians, because the models must be kept wet to incorporate the effect of evaporation. Consequently, most amphibian models have been used for short periods. Although the use of physical models has proven valuable in studies of temperature and water relationships of amphibians, the usefulness of such studies to inventory and monitoring studies remains to be demonstrated. Numerous articles provide information on the construction and use of different model types: agar (Spotila and Berman 1976; Wygoda 1984); plaster of Paris (Tracy 1976;

O'Connor 1989; Wygoda and Williams 1991); metal casts (Bakken and Gates 1975; Bradford 1984); copper tubing (C. R. Peterson and M. E. Dorcas, unpubl. data). All models require further validation through comparison of the temperatures they record with those of live amphibians.

Recording Frog Calls

The automated recording of anuran vocalizations is a relatively simple but effective way not only to determine the presence or absence of anuran species, but also to establish their temporal calling patterns (see "Acoustic Monitoring at Fixed Sites," in Chapter 7). Automated sampling has several advantages when compared with manual sampling procedures: (1) It allows continuous 24-hour sampling; (2) it can be used to monitor several sites simultaneously; and (3) it frees the investigator for other tasks. We describe two types of systems that can be used to record anuran vocalizations automatically. The first type is data logger-based and allows the simultaneous measurement of environmental variables. The second type is timer-based and less expensive, but it cannot be used to monitor environmental variables.

Data logger-based systems periodically activate a tape recorder via a relay switch. For example, the control port on a Campbell Scientific CR10 data logger (Fig. 3) can be used to send a 5-volt impulse to a relay switch at regular intervals (e.g., 5 min). The relay switch turns the battery power to the tape recorder on and off. The relay switch design is described in the CR10 instruction manual (Campbell Scientific 1990: sect. 14.9; Fig. 3). Cost of construction is approximately U.S. $20. A comparable relay can

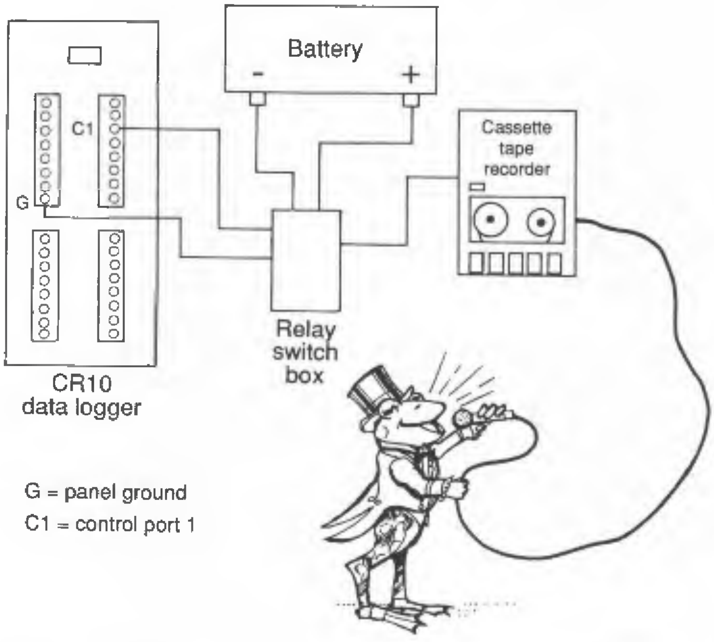


Figure 3. Diagram of a data logger-based system for automatically recording anuran vocalizations. This system consists of a Campbell Scientific CR10 data logger, a cassette tape recorder, a microphone, a relay switch box, and a battery. The data logger is programmed (Table 3) to turn the cassette tape player on and off (via the relay switch box) at designated intervals (e.g., 5 min). The data logger also can be programmed (Table 2) for simultaneous monitoring of various environmental sensors, such as thermocouples, pyranometers, anemometers, and relative humidity probes.

be purchased (e.g., Hexfet relay #44F7743, Newark Electronics, U.S. $38) and modified slightly by inserting a 1N4001 diode (#610, Campbell Scientific) into the circuit. When analyzing the tape recordings, the starting and ending times and the number of recorded intervals must be noted, so that the times of calling activity can be determined accurately.

Data logger-based systems have several advantages, including (1) accurate, precisely timed intervals; (2) capability to monitor environmental variables or to control an automated telemetry system (see "Recording Radiotelemetry Signals," below); and (3) efficient use of tape. For example, if anurans are calling only at night, the data logger can be programmed to record only at night, thus conserving both cassette tape and battery power. Disadvantages include the cost of the data logger (about U.S. $1,700) and the time involved in learning how to program it. A less expensive data logger (e.g., Tattletale Lite, Onset Computer Corp., about U.S. $500) can be used in place of a CR10, but measurement capabilities are more limited (e.g., 5 channels, thermistors only, without additional signal conditioning circuitry).

A data logger-based system was used to study the effects of environmental variation on calling activity of the southwestern toad (*Bufo microscaphus*) in southwestern Utah in March (Dorcas and Foltz 1991). Calling was sampled for 10 seconds every 5 minutes using a Tandy TRS-80, CCR-82 computer cassette tape recorder controlled by a Campbell Scientific CR10 data logger. A 2-liter plastic soda bottle, with the bottom removed, was placed over the microphone to protect it from precipitation. When tape recordings were played back, the authors were able to determine times of precipitation from the sound of the rain hitting the microphone cover. Solar radiation was measured with a LI-COR LI200SZ pyranometer; relative humidity was measured using a Campbell Scientific model 207 relative humidity probe; wind speed was measured using a Qualimetrics Micro Response Contact Anemometer; and temperatures were measured using 24-gauge copper-constantan thermocouples. All instruments were read every second, and 5-minute average values were calculated and recorded using the CR10 data logger. Results of this study (Fig. 2) indicate that sampling for southwestern toads would be most successful at night, at high humidities, and when water temperatures are 10–18°C.

An alternative system for periodically recording anuran vocalizations uses a solid state timer to control a cassette tape recorder. In this system, a timer is connected to a 12-volt battery and tape recorder (Fig. 4). Because the timer requires 12 volts and most tape recorders require only 6 volts, several inexpensive electrical parts are needed to reduce the voltage to the tape recorder and avoid damaging the timer. Figure 4 includes a circuit diagram, and part numbers are provided in the caption. All of these parts can be purchased at local electronics stores and cost less than a total of U.S. $10. The timer can be set to activate the tape recorder for a specified period (0.1–102.3 sec) at specified intervals (0.1–102.3 min). Timers with different ranges also can be purchased. The advantages of this system are low cost (U.S. $100) and simplicity. Little expertise is needed to assemble the system. Because of the low cost, several systems can be used simultaneously to monitor numerous sites. This system does not have the ability to make synchronous environmental measurements as does the data logger-based system. However, an inexpensive single-channel data logger can be used to monitor environmental temperatures.

Recording Radiotelemetry Signals

We have used automated telemetry systems to monitor the body temperatures and activity pat-

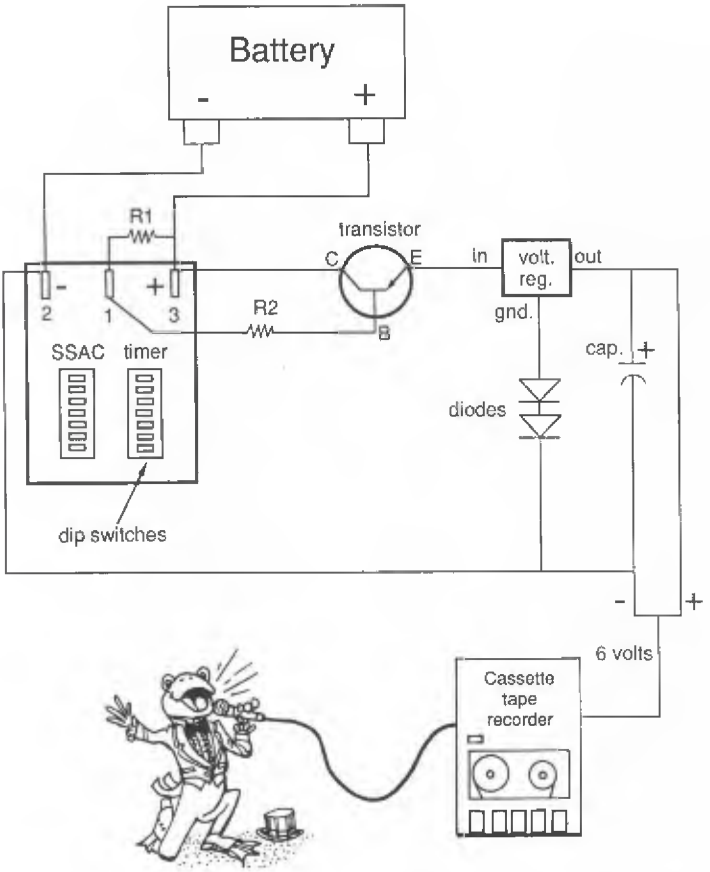


Figure 4. Diagram of a relatively inexpensive, timer-based system for automatically recording anuran vocalizations. This system consists of an SSAC timer (Radio Shack [RS] #1A12), a 6-volt cassette tape recorder, a microphone, a 12-volt battery, and several electronic parts that cost less than U.S. $10: one PNP plastic power transistor TIP42 (RS #276–29027), one 5-volt 7805 voltage regulator (RS #276–1770; *volt. reg.* in figure), two 1N4001 diodes (RS #276–1101), one 4.7 MFD electrolytic capacitor (RS #272–1012; *cap.* in figure), one 1,000-ohm resistor (RS #271–153; *R1* in figure), and one 100-ohm resistor (RS #271–152; *R2* in figure). The proper polarity must be observed when connecting the tape recorder to the external power source (many recorders have a negative center pin). In figure, *gnd.* = ground wire.

terns of snakes (Peterson 1987; Peterson and Cobb 1991), and we believe that this technique could be applied successfully to amphibians that are large enough to carry radio transmitters (see "Radio Tracking" under "Tracking," in Chapter 7). Tracking transmitters weighing less than 1.0 g and temperature-sensitive transmitters weighing less than 2.0 g are now commercially available (AVM Instrument Company; Holohil Systems). Multiple animals can be continuously sampled by interfacing a data logger with a scanner, a radio receiver, and a signal processor (Petron et al. 1987; C. R. Peterson and M. J. McDonald, unpubl. data). Such systems can be used in several ways; for example, the times of arrival and departure at a breeding site of amphibians with radio transmitters can be determined. If temperature-sensitive transmitters are used, considerable information about an ectotherm's behavior, such as emergence times, retreat times, and microhabitat selection, can often be inferred from body temperature patterns, especially if operative temperature measurements are recorded simultaneously (Peterson 1987; Huey et al. 1989). It also may be possible to use variation in signal strength to infer the activity patterns of animals (e.g., Chappell and Bartholomew 1981; Nams 1989; Stanner and Farhi 1989). Information derived from telemetry complements data from mark-recapture studies and also can aid in the location of animals without radio transmitters.

Two key problems associated with radiotelemetry are the need to replace batteries periodically and the minimum size of animals that can be studied. In the future, passive integrated transponders (PIT tags—small, glass-encapsulated diodes that, when activated by a detector, transmit a unique code back to a receiver) may offer a solution to this problem because they are small (e.g., 0.1 g) and do not require batteries (Camper and Dixon 1988). Unfortunately, transponder systems that allow identification of individual animals also have a very short range. Nevertheless, it should be possible to interface data loggers with transceiver units to monitor activity in certain situations (e.g., salamanders passing through a gate in a drift fence). This approach should become more effective as the range of these systems improves.

Acknowledgments. We thank the following persons and companies for providing information: George Bakken, Art Beaubian (YES), Dan Berger and Saul Berger (Solar Light), Andrew Blaustein, Dave Bradford, Jim Brock, Gaylon Campbell, John De Luisi, Jeff Foster, Joel Green (Campbell Scientific), Joanne Jerolman, Mark Kallgren (Solomat), Leslie Long, Dave Meek (Campbell Scientific), Michael O'Connor, Warren Porter, Bert Tanner (Campbell Scientific), and Dave Waitman. Dave Bradford lent us electroformed frog models. Scott Grothe helped with the illustrations. Jeff Foster reviewed the manuscript.

Data standards

ROY W. McDIARMID

The many individual salamanders, frogs, caecilians, and their larvae encountered during the course of an inventory or monitoring project will have to be identified to species. Depending on the goals and sampling method(s) used, some individuals will be identified from a distance by their calls; others will be handled. At the same time, some will be marked for recapture, and others will be sampled as vouchers. For each, certain minimum data should be recorded. In this section, data pertaining to locality and sampling methodology are considered; information on microhabitats and specimen vouchers is covered in sections that follow. I feel strongly that the data outlined here should be the minimum for any project. Investigators with specific goals may require additional types of data as well.

Standardized, printed sheets containing the required data categories provide a convenient, inexpensive, and effective way to ensure that all the desired information is recorded in a consistent format. Data sheets should be well organized, printed on good-quality paper (75%–100% cotton content) and include extra space (e.g., other side of sheet) for notes that do not fit preestablished categories.

Data should be recorded in the field with permanent (waterproof) ink as simply and directly as possible. I strongly recommend against the use of data codes in the field; it is too easy to forget codes or to enter the wrong code. Original data sheets can be photocopied for security, but they should not be copied by hand. If data are to be coded for computer analysis, the original or photocopied sheets should be used for data entry to minimize transcription errors. Some workers prefer recording information on small tape recorders; this also works well if a list of the standard data categories is checked during taping to ensure that all required information is recorded.

Information recorded on tapes should be transcribed to data sheets or into a computer within 24 hours of the sample.

Geographic Characterization

Specific information about the locality should include geographic and political characterizations of the study site and descriptions of the habitats sampled. The geographic and political descriptions of the locality minimally should include the following information:

1. *Country or island group.* The country name is normally equivalent to the political unit, but substituting island names for country may be of value in some instances.
2. *State or province.* A secondary political unit should be part of every locality record.
3. *County, district, or other tertiary division.* For specimens collected in the United States and certain other countries, a tertiary political unit should be included. In countries in which tertiary divisions exist but are infrequently used or rarely mapped, this category may not be useful.
4. *Drainage system and other geographic data.* Some reference to the closest river system is important, especially in remote areas for which detailed maps are not readily available. Inclusion of other geographic names may also be extremely helpful (e.g., mountain range, savannas, zoogeographic region), but the case for including them in these minimal data elements is less compelling than for drainage.
5. *Specific locality.* The locality should be as detailed and specific as possible. Distances and compass directions from easily located places (e.g., towns, mouths of rivers, mountain peaks) are essential. Whether the distances are by road or straight-line on a map should be specified. Inclusion of a map or gazetteer reference often is helpful.
6. *Latitude and longitude.* This geographic attribute is independent of political units. It is the only generally recognized locator that allows universal retrieval of data from any geographic area, and electronic mapping. Workers should include coordinates for each locality as specifically as possible. However, approximate coordinates, clearly identified as such, are also of value if specific coordinates cannot be obtained. Latitude and longitude are reported with the standard notation of degree, minute, and second, rather than with a decimal. Portable global positioning devices that provide accurate measures of latitude and longitude are available for field use (about U.S. $3,000, see Appendix 6).
7. *Elevation.* When available, elevation should be noted. Approximate elevation, clearly indicated as such, is better than none. Elevations and distances should be given in standard metric units.

Habitat

Amphibians occupy both terrestrial and freshwater aquatic habitats. Habitat descriptions should include the following information.

TERRESTRIAL HABITATS

1. Moderately detailed description of the kind(s) of vegetation (e.g., evergreen lowland tropical forest, temperate deciduous forest, thorn scrub, savanna-woodland) at each site. For forests, some mention of canopy cover, epiphyte load and type, nature of other water-holding structures (tree holes), etc. For savannah-woodland habitats, designation as natural, agricultural, or fire-maintained; indication of extent and regularity of seasonal flooding. For other terrestrial sites, some indication of plant type and cover. If plant species are known, a list of

some of the dominant forms is useful. Published references to vegetation at the site should be noted.

Descriptive lists of vegetation types exist for most regions of the world (e.g., Walter 1973) and can be used as a foundation for specific site descriptions. Representative vegetation types for tropical and subtropical forests in Southeast Asia might include the following: primary rain forest, hilly; primary rain forest, flat; evergreen oak/chestnut montane forest; mossy montane forest; coniferous forest; deciduous forest; gallery forest; selectively logged forest; rubber plantation; secondary growth; large clearing; camp.

2. Description of the climate at each site, including details of weather with distribution and abundance of rainfall and annual and diel variations in temperature.
3. Some indication of the degree of disturbance. For forests, designation as primary, secondary, or plantation may be adequate. For grasslands, some mention of the influence of grazing, agricultural use, or frequency of fire or flooding may be important. Sampling done near or through a forest edge should be indicated.
4. Brief mention of other habitat factors (e.g., soil type and water-holding capacity, frequency of flooding) potentially important to amphibians is helpful.

AQUATIC HABITATS

Details of surrounding vegetation (see item 1 under "Terrestrial Habitats," above) and climate (item 2 above), water temperature and water clarity, and information for the type of water body sampled.

LENTIC—PONDS AND LAKES

1. Habitat type (e.g., lake, pond, swamp, ditch, rain puddle), size (surface area in ha or length × width), and depth (minimum, maximum, and average); percentages of the water surface that are open or occupied by emergent or surface vegetation; notation of whether the site is open above or covered by forest canopy.
2. Some indication of the relative duration of the habitat (e.g., is permanent, has water most years, fills in a good rain, results from flooding, lasts 2–4 weeks).
3. Nature of any shoreline or emergent aquatic vegetation; species or types of vegetation (e.g., reeds, water lilies), if known.
4. Bottom type (e.g., silt, sand, leaf pack).

LOTIC—STREAMS AND RIVERS

1. Habitat type (e.g., river, stream, spring, creek, seep), width, and depth (e.g., pools and shallows, riffles); some indication of the flow rate (e.g., cascades and falls, white water-high gradient, moderate current, slow and meandering, meters per second).
2. Some indication of the relative duration (life) of the habitat (e.g., flows all year, only in the wet season, or only after a good rain).
3. Nature of any bordering vegetation (e.g., trees, small bushes, broad-leaf plants); plant types and species, if available.
4. Substrate types (e.g., rocks, boulders, gravel, sand, mud, leaf pack).

WATER IN PLANTS (PHYTOTELMATA) AND ARTIFICIAL STRUCTURES

1. Nature of the water-holding structure (e.g.,bromeliad, leaf axil, tree hole, bucket, bowl), size (surface area), depth, water volume, location (open forest, clearing, canopy), height above ground, and distance from natural (larger) bodies of water.
2. Relative age and duration of the habitat (is permanent, has water most years, is 2 weeks old).
3. Identification and description of the water-holding plant.
4. Substrate in the structure (e.g., bare, detritus, sand, leaf pack).

Sampling Methodology

Information pertinent to sampling procedures should be recorded, with reference to the specific method (or methods) used (see Chapter 6). In addition, the following information should be taken for each specimen encountered during an inventory or monitoring project (see also "Microhabitat Description" and "Voucher Specimens," below):

1. Date and time of encounter.
2. Identification of specimen (e.g., *Rana pipiens*, *Bufo* sp., brown salamander of type A).
3. Size of specimen. Total length probably is the most reliable indicator of size (snout–vent for frogs and snout–tail tip for salamanders, caecilians, and anuran larvae; broken tails are indicated with a + after the measurement). Normally one would not disturb individuals identified by their calls. Adult, juvenile, and metamorph may be convenient size categories for use in monitoring studies of well-known species, but the use of these terms can present problems (e.g., adult-size frogs are not necessarily mature nor are juvenile-size frogs necessarily immature, as the names imply). For larvae, only representatives of each (distinctive) size class are measured.
4. Sex. Recorded only if the determination is confirmed or the specimen is not collected. Presence of nuptial pads, vocal sacs, and coloration can be useful, but positive determinations may require dissection or observation of egg laying or of calling (usually males only). If in doubt, a voucher should be collected.
5. Position in environment, that is, the horizontal and vertical position of each individual, in as much detail as possible.
6. Activity of individual, that is, the behavior of the individual at the time it was encountered. Typical descriptors include calling, sitting, moving, swimming, hopping, coiled around eggs.

Microhabitat description

ROBERT F. INGER

Amphibians typically are irregularly, often patchily, distributed in a habitat, particularly in complex habitats. Individual species occur in microhabitats, that is, limited subsets of habitats at each site. Microhabitats, as used here, are the precise places where individual amphibians occur within the general environment. Although simple species richness at a site can be determined without knowing the microhabitats used by the amphibians living there, I advocate recording microhabitat data for each individual amphibian observed. The resulting data are scientifically richer by orders of magnitude. For example, differential microhabitat use by the same species at different sites can be determined, as can seasonal differences of microhabitat use at a given site. Knowing that certain amphibian species are restricted to given microhabitats can have profound conservation implications (Zimmermann and Bierregaard 1986).

Recording microhabitat data requires advance planning, especially in the design of an appropriate checklist for registering microhabitat features. Taking such data can be time-consuming and may result in a decrease in the number of specimens captured and preserved. However, the general utility of specimen records that include microhabitat data is so superior to those without them that the trade-off in reduced numbers of specimens preserved overwhelmingly favors collection of the data. Microhabitat information is essential for determining ecological distributions in a manner that is repeatable from site to site and that yields data easily subjected to statistical analysis. By combining all data from a microhabitat classification scheme, it should be possible to describe the ecological distribution of each species at a site and to compare distributions across sites.

Each major biome type has its unique environmental features and will, therefore, require a distinct descriptive checklist, with two important caveats. First, no paper scheme can duplicate the actual complexity of the real world; consequently, investigators must expect to amplify certain records with supplementary notes. Second, the use of a microhabitat checklist does not obviate the need to record gross aspects of the environment, such as vegetation type, elevation, general topography, weather, and so forth. Nevertheless, it should be possible to create a microhabitat classification scheme for every major environment in which amphibians occur. A microhabitat checklist will have both unique and general characteristics and will vary in complexity depending on the habitats sampled. For example, tropical wet forest sites presumably will require a more complex microhabitat classification scheme than temperate grassland sites. Such a scheme has been used successfully for tropical rain forest sites in several parts of the world.

Whatever checklist is assembled must balance detail and generality. The goal is to achieve generality without undue loss of information. Another important characteristic of a good microhabitat checklist is expandability; it should be possible to add elements as local situations demand. For example, an investigator should be able to add vegetation or habitat types as amphibians are encountered in them.

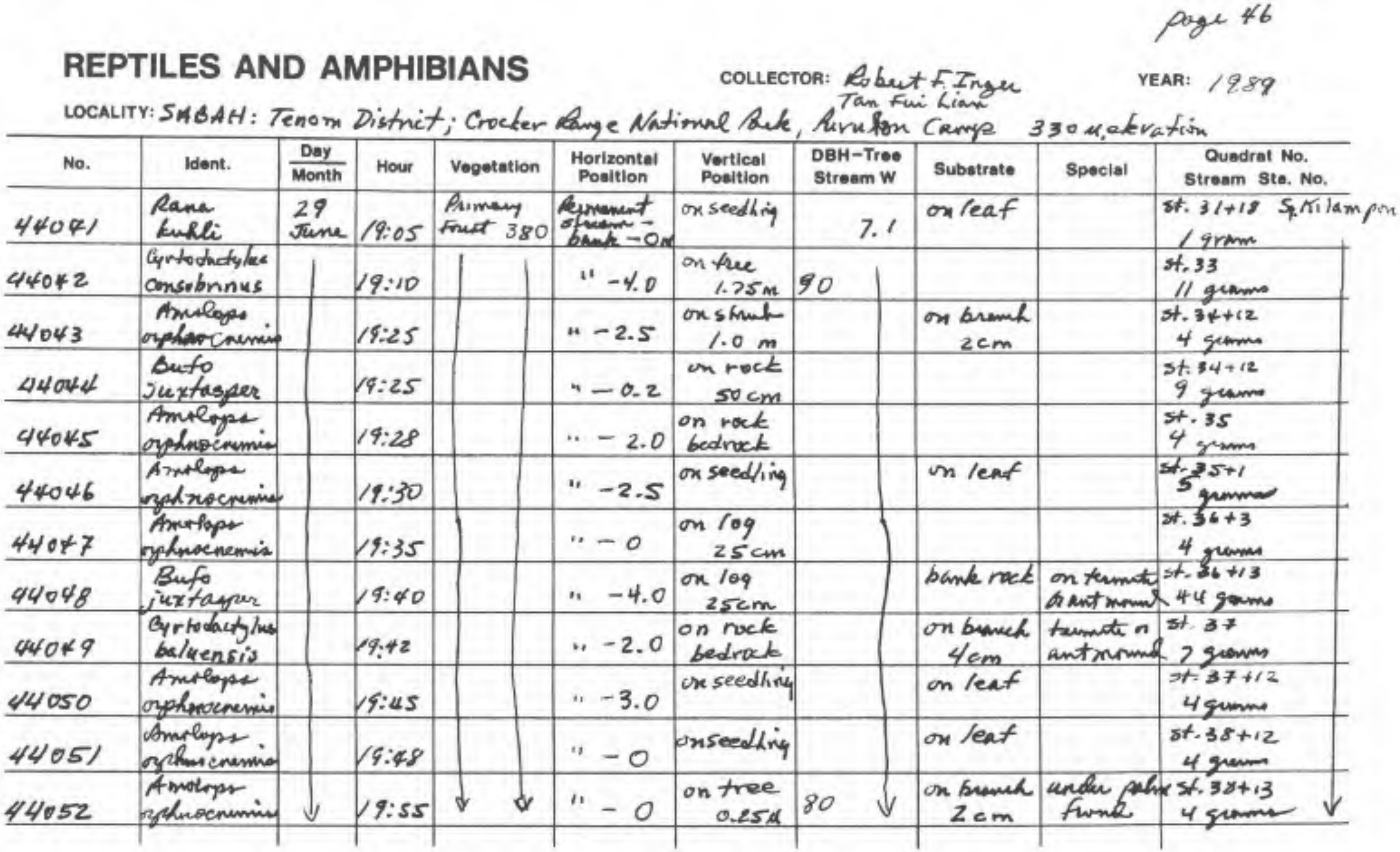
Characteristics of a Microhabitat Checklist

Analysis of the information recorded with each observation leads to an understanding of the ecological distribution and habitat use of amphibian species. Therefore, it is important that the data with each specimen be complete and recorded in a standard way. Generally, six major elements of the microhabitat of each individual observed are described. For each element, there is a checklist of environmental features about which information should be noted, as well as a series of standard descriptions for each feature. The notion is that for every amphibian encountered a single notation for each feature of each element will describe that microhabitat. Use of the checklist of features and the standard descriptors facilitates complete and standard notation of data. Separate checklists are used for adults and larvae.

The six elements to be recorded for each observation are as follows:

1. Date and time of observation (24-hr clock).
2. General location, vegetation type, and elevation (refer to descriptions and standards in the section "Data Standards," above).
3. Horizontal position, with reference to bodies of water, shade-casting vegetation, and, in the case of some lacustrine environments, the shore. Each position needs to be qualified in detail (see checklist below).
4. Vertical position. In terrestrial environments, vertical position is defined as subsurface, at soil surface exposed, at soil surface under shelter, above ground, or in water. In lacustrine environments or in deep rivers, vertical position is defined as depth.
5. Substrate, usually mineral soil, dead leaves, log, rock, or vegetation. Each substrate often requires finer subdivision (see checklist below).
6. Special information that does not fit easily into the preceding categories—for example, limb projecting over water, under exfoliating rock, in termite mound.

A sample field catalogue sheet summarizing microhabitat data for adult amphibians is provided in Figure 5.



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REPTILES AND AMPHIBIANS

COLLECTOR: Robert F. Inger
Tan Fui Lian

YEAR: 1989

LOCALITY: SABAH: Tenom District; Crocker Range National Park, Purulon Camp 330 m, elevation

No.	Ident.	Day/Month	Hour	Vegetation	Horizontal Position	Vertical Position	DBH–Tree Stream W	Substrate	Special	Quadrat No. Stream Sta. No.
44041	Rana kuhli	29 June	19:05	Primary Forest 380	Permanent stream - bank - 0 m	on seedling	7.1	on leaf		st. 31+18 S. Kilampon 1 gram
44042	Cyrtodactylus consobrinus		19:10		" -4.0	on tree 1.75 m	90			st. 33 11 grams
44043	Amolops orphnocnemis		19:25		" -2.5	on shrub 1.0 m		on branch 2 cm		st. 34+12 4 grams
44044	Bufo juxtasper		19:25		" — 0.2	on rock 50 cm				st. 34+12 9 grams
44045	Amolops orphnocnemis		19:28		" – 2.0	on rock bedrock				st. 35 4 grams
44046	Amolops orphnocnemis		19:30		" -2.5	on seedling		on leaf		st. 35+1 5 grams
44047	Amolops orphnocnemis		19:35		" – 0	on log 25 cm				st. 36+3 4 grams
44048	Bufo juxtasper		19:40		" -4.0	on log 25 cm		bank rock	on termite & ant mound	st. 36+13 44 grams
44049	Cyrtodactylus baluensis		19:42		" -2.0	on rock bedrock		on branch 4 cm	termite or ant mound	st. 37 7 grams
44050	Amolops orphnocnemis		19:45		" -3.0	on seedling		on leaf		st. 37+12 4 grams
44051	Amolops orphnocnemis		19:48		" – 0	on seedling		on leaf		st. 38+12 4 grams
44052	Amolops orphnocnemis	↓	19:55	↓ ↓	" – 0	on tree 0.25 m	80 ↓	on branch 2 cm	under palm frond	st. 38+13 4 grams ↓

Figure 5. Field catalogue sheet summarizing microhabitat data for adult amphibians from a primary forest site in Sabah.

Some of the above information categories also are needed for larval microhabitat descriptions: date, hour, general location, and general habitat and vegetation types. In addition, information should be collected on the general type of the aquatic environment, microhabitat type, aspects of the physical environment (see checklist below), vertical and horizontal positions of the larva(e), and kinds of other organisms present. A sample data sheet used to describe the microhabitats of larval amphibians is presented in Figure 6.

Basic Descriptors for a Microhabitat Checklist

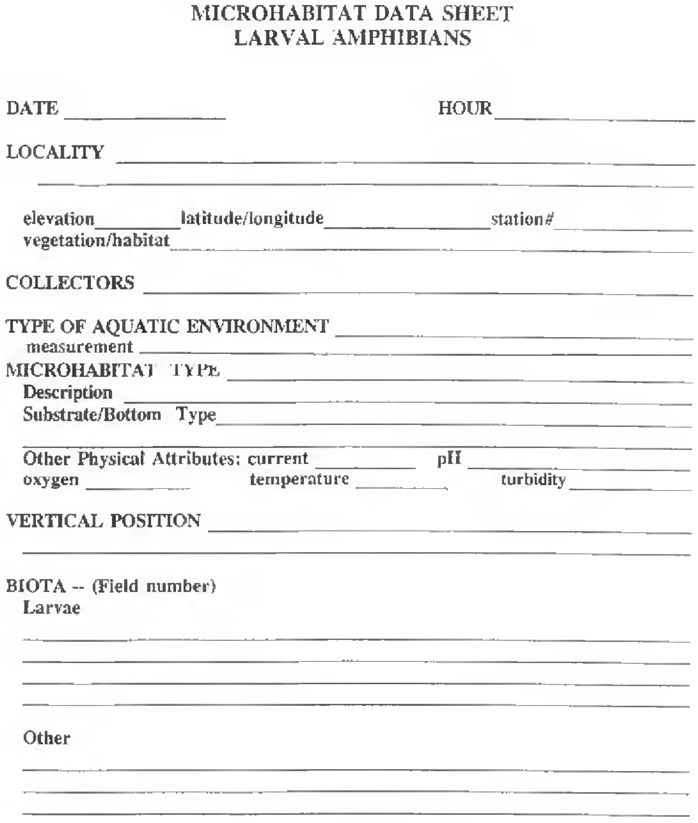
The following descriptive categories were devised for tropical and subtropical forests to illustrate the method. Investigators will need to develop similar descriptors for microhabitat checklists to be used in other biomes such as temperate forest, grassland, and desert.

ADULT AMPHIBIANS IN TROPICAL AND SUBTROPICAL FORESTS

DATE

HOUR (24-hr clock)

VEGETATION (Use separate descriptors for each major vegetation and habitat type at the site. See the section "Habitat" under "Data Standards," above).



MICROHABITAT DATA SHEET
LARVAL AMPHIBIANS

DATE ______________ HOUR ______________

LOCALITY ______________________________

elevation ________ latitude/longitude ______________ station# __________
vegetation/habitat ______________________________

COLLECTORS ______________________________

TYPE OF AQUATIC ENVIRONMENT ______________________________
measurement ______________________________
MICROHABITAT TYPE ______________________________
Description ______________________________
Substrate/Bottom Type ______________________________

Other Physical Attributes: current __________ pH __________
oxygen __________ temperature __________ turbidity __________

VERTICAL POSITION ______________________________

BIOTA -- (Field number)
Larvae

Other

Figure 6. Sample data sheet for information on microhabitats of larval amphibians.

HORIZONTAL POSITION

- Permanent stream
  - In water
  - Midstream on bar or snag
  - On bank; distance (m) to water
  - On exposed dry bed; distance (m) to water
  - On overhanging vegetation; height (m) above water
- Intermittent stream
  - Actually in water
  - Midstream on bar or snag
  - On bank; distance (m) to water
  - In dry bed
  - On overhanging vegetation; height (m) above water
- Permanent pond
  - In water
  - On bank; distance (m) to water
  - On overhanging vegetation; height (m) above water
- Temporary pond
  - In water
  - On bank; distance (m) to water
  - On overhanging vegetation; height (m) above water
- Permanent marsh
- Distant from any body of water; approximate distance to nearest water

VERTICAL POSITION

- Under surface of soil; depth (cm)
- In or under dead leaves
- Under rock; maximum dimensions (cm) of rock
- Under log; diameter (cm) of log
- In log; diameter (cm) of log
- On surface of bare mineral soil
- On surface of leaf litter
- On rock; maximum dimensions (cm) of rock
- On log; diameter (cm) of log
- On seedling or herbaceous plant (< 1 m tall)
- On shrub or sapling (1–7 m); height (m) above ground or water
- On tree or large vine (> 7 m); height (m) above ground or water; diameter (cm) at breast height (DBH) for woody plants
- On dead stump; height (m) above ground
- In crown of fallen dead shrub or tree; height (m) above ground or water
- On grass blade; height (m) above ground or water
- In grass

SUBSTRATE

- Leaf of plant; maximum dimensions (cm) of leaf
- Stem or branch of herbaceous plant
- Twig or branch of woody plant; diameter (cm) of perch
- Stem of shrub or tree
- In epiphyte
- Under bark of log, stump, or tree
- Bank of mud, of sand, of small gravel, or of rock

SPECIAL ATTRIBUTES OF MICROHABITAT

- Isolated pool in stream floodplain
- Seepage area
- Tree hole
- Burrow
- Bank: flat (< 20°), moderately sloping (20–45°), or steep (> 45°)
- Between tree buttresses
- On or in floating vegetation
- Among roots of floating vegetation
- On termite or ant mound
- In or under termite or ant mound; distance (cm) to surface
- Under fallen palm fronds
- On fallen palm fronds
- In or on building
- In terrestrial bromeliads
- Other (describe on back of field sheet or elsewhere)
- Stream width or pond diameter (m)

Depending on the nature of the study, the following information also may be appropriate:

PLOT, STREAM STATION, OR LOCAL GRID NUMBER

TYPE OF ACTIVITY
- Quiescent or resting
- Disturbed by investigator
- Active and alert
- Calling
- Uncovered by investigator
- In amplexus
- In nest

DETECTION METHOD
- Observed
- Heard
- Uncovered
- Dug up
- Pitfall trap
- Funnel trap
- Trench
- Seine or other net

LARVAL AMPHIBIANS IN TROPICAL AND SUBTROPICAL FORESTS

DATE

HOUR (24-hr clock)

VEGETATION (Use separate descriptors for each major vegetation and habitat type at the site. See the section "Habitat" under "Data Standards," above.)

TYPE OF AQUATIC ENVIRONMENT
- Temporary pond; length × width × depth (m)
- Permanent pond; length × width × depth (m)
- Perennial stream; width (m)
- Intermittent stream; width (m)
- Phytotelmata (plant-held water)
- Marsh or swamp
- Spring; distance (m) from head
- Seep
- Terrestrial (describe)
- Artificial structure (e.g., barrel, pit)

MICROHABITAT TYPE
- Streams; width (m)
  - Torrent
  - Riffle
  - Open pool, in main flow; length × width × depth (m) of pool
  - Side pool, off main current; length × width × depth (m) of pool
  - Leaf drift or mass of dead leaves and other debris held by eddy or back current; length × width (m) of mass
  - Pothole in bank rock; height (m) above stream flow; dimensions (cm) of pothole
  - Interstitial in gravel or sand; depth (cm)
- Ponds or lakes
  - Open area; area (ha) or length × width × depth (m) of pool
  - Among rotted vegetation
  - Among floating vegetation or algae
- Plant-held water
  - Buttress tank; height (m) above ground; approximate volume (cm^3)
  - Epiphyte tank; height (m) above ground; approximate volume (cm^3); type of plant
  - Log or tree hole; height (m) above ground; approximate volume (cm^3)
  - "Cup" pool (fruit husk, palm spathe, or other natural cup in litter); approximate volume (cm^3)
- Artificial structure or container
  - Describe structure; height (m) above ground; approximate volume (cm^3)
- Other
  - On or in adult frog
- Substrate or bottom type
  - Mud or silt
  - Sand
  - Gravel
  - Large rock
  - Bed rock
  - Dead leaves

    - Wood
    - Other (describe)
  - Other physical attributes
    - Current (cm/sec)
    - Oxygen (ml/l; % saturation)
    - Temperature
    - pH
    - Turbidity

VERTICAL POSITION

- On bottom; depth (cm) below surface
- Midwater; depth (cm) below surface
- At surface

BIOTA

- Odonate naiads, present or absent; approximate sizes
- Dytiscid larvae or adults, present or absent; approximate sizes
- Belostomatid or other predaceous hemipterans, present or absent; approximate sizes
- Fishes, present or absent; approximate sizes
- Other vertebrate predators present

Field Methods

Recording microhabitat information in the field can be simplified greatly with temporary data sheets. Such sheets are ruled into columns corresponding to the major categories of information required by the microhabitat descriptor checklist being used. As animals are observed, appropriate information is entered. Upon return to camp the data are transferred into permanent field catalogues or notebooks. I strongly recommend that the data be transferred within a few hours of collection. A computer should be used in the field only if hard copy can be produced at the site, because total reliance on disk storage in the field can be risky. In either case, original data sheets should be maintained indefinitely.

If animals are collected, each should be placed in a separately numbered bag, and the bag number should be included as part of the temporary field record. A mixture of plastic (mostly) and cloth (for larger specimens) bags are required. Animals should be processed as soon as possible to avoid mixing of data and loss of specimens.

Voucher specimens

ROBERT P. REYNOLDS, RONALD I. CROMBIE, AND ROY W. McDIARMID

Specimens that permanently document data in an archival report are called *vouchers*. Voucher specimens serve to verify the identity of organisms encountered or used in a study and to ensure that the study, which can never be repeated exactly, can be reevaluated accurately. Voucher specimens are the only mechanism for validating the presence of a species in a study and for making historical comparisons. In addition to their importance in systematic studies and as documentation of floral and faunal surveys, vouchers provide irreplaceable data regarding biochemical properties, demographic trends, and geographic distributions for future investigation. Lee et al. (1982) provided a cogent review of voucher specimens and their importance to biological studies, and we have adopted many of their points in this presentation.

Voucher specimens are always needed to provide scientific credibility to an inventory or monitoring project and should be collected unless there is a compelling reason not to do so. Valid reasons for not collecting voucher specimens include protection of the species by law, endangered or threatened status of the species, and serious species survival risk from loss of an individual. If undisputed reasons exist not to collect the animal, a good-quality photograph together with a recording of the call (for anurans), a tissue sample for molecular analysis (even a clipped digit), or some other useful secondary representation of the organism may serve as a voucher. To fulfill its function, a voucher must illustrate the recognized diagnostic traits appropriate for the level of identification required (species), be preserved in good condition by the collector, be documented with appropriate field data, be deposited and maintained in a suitable institution, and be readily accessible (Lee et al. 1982).

Anuran calls should be recorded (Appendix 3) and tissue samples taken (Appendix 5) when possible, although such materials are not strictly required for all inventory and monitoring work. Frog calls provide important behavioral and evolutionary information, and tissues can be used to estimate genetic relatedness. Calls and tissues increase the information available with each voucher and may reduce the need to take additional specimens at a future time. However, recording calls and taking tissue samples require significant amounts of time. The investigator must plan for these activities before the study is initiated; otherwise, the goals of the inventory or monitoring study may be compromised.

Field Identifications

Accurate specific identification of amphibians in the field is rarely possible except in areas for which the fauna has been studied in detail. Even there, diagnostic characters are often subtle and difficult to see without magnification or, sometimes, dissection. Even herpetologists with considerable experience in an area usually provide only generic or tentative specific identifications of specimens in the field. These names serve for bookkeeping purposes rather than for identification, and they facilitate tracking of numbers of species and specimens sampled.

Accurate species identifications are such an integral part of all aspects of comparative biology that studies without voucher specimens violate a basic premise of scientific methodology, that is, the ability of subsequent workers to repeat the study. Correct identifications of organisms are essential to all biological investigation. Only voucher specimens provide a basis for verification of identifications and thereby duplication of a study. The literature is replete with examples of comparative studies in physiology, ecology, behavior, morphology, and systematics for which research results are questionable or even useless because of species misidentifications or failure to recognize that more than one species was involved. Most decisions relating to the management and conservation of species also depend on accurate species identifications. Voucher specimens are the only means to verify or, if necessary, correct specimen identifications and, therefore, are essential to scientific investigation in the above-mentioned disciplines.

All field identifications should be verified by a person with experience with the group, through the use of reliable and authoritative keys, or by comparison with specimens in museum collections. Vouchers should be deposited in appropriate repositories, usually a natural history museum. With erroneous field identifications, specimens of poorly known species may be overlooked, and important data may not be collected because the investigator assumes the species involved is well known. For purposes of sampling in little-studied regions, we recommend that all field identifications be treated as tentative and that all species be considered equally important.

Except for well-studied areas such as North America and Europe, few useful field guides or identification manuals for amphibians exist, and for many countries even lists of the recorded species are not available. Many of the older monographs on amphibian faunas (e.g., Cochran 1955; Taylor 1962; Laurent 1964; Cochran and Goin 1970) were based almost entirely on (often poorly) preserved museum specimens and are of limited utility for field identifications or as sources of general information on geographic and habitat distributions. We suggest, therefore, that investigators become familiar with available primary literature before commencing an inventory and, whenever possible, that they examine preserved specimens of species from the area of interest prior to beginning the fieldwork. Notes on the amphibian fauna of the region with a list of the species and their diagnostic features should allow the worker to identify the more common species, focus on those of specific interest, and recognize any taxa that may be protected (see the section "Permits," below).

Because vouchers serve as the sole means of verifying data collected during investigations of biological diversity and provide critical information for future investigations, the importance of voucher materials should be generally recognized and their preparation considered essential to good science. We acknowledge, however, that the removal and preservation of specimens for scientific purposes can be an emotional issue. Therefore, it is essential that field investigators carefully plan their studies in advance, clearly identify their objectives, and evaluate the need to collect voucher specimens.

Sample Size

What constitutes an adequate or optimal sample for the purposes of identification is not easily determined. For some species, identification is possible from a single specimen (although this is rare); for other species, 20 individuals would not adequately sample the variation in the population, and a larger sample would be necessary. Some species are amazingly polymorphic (see color plate of *Dendrobates pumilio* in Myers and Daly 1983), some have striking sexual, ontogenetic, geographic, and/or individual variation, and others are relatively uniform even across broad geographic areas. Modern systematics takes into account this potential for variation and the significance of ancillary biological data in attempting to determine species limits. Gone are the days of running a single specimen through a key and magically achieving a reliable specific identification. This "cookbook" approach and the idea that a single specimen could be "typical" of a deme or a population, much less an entire species, are scientifically unsound. Keys, if properly constructed, can be useful tools in providing identifications, but these preliminary identifications must be tested by comparisons with descriptions in the literature and with preserved museum specimens.

We agree with Frith (1973:3) that the number of animals sampled "really has no [biological] significance unless it is related to the total number of animals in the population and their rate of replacement." Concerned readers will find a cogent discussion of what many consider an unwarranted preoccupation with survival of individuals, as well as quantitative data on the relative impacts of scientific collecting, natural mortality, habitat destruction, and commercial collecting on amphibian populations in Ehmann and Cogger (1985, esp. table 3). It is revealing that not a single species of animal is known to have been exterminated as a result of scientific collecting during the 250-year history of systematics (Hedges and Thomas 1991). In contrast, hundreds to thousands of species have likely gone extinct as a result of habitat destruction.

With few exceptions, amphibians are prolific, with reproductive potentials sufficient to accommodate increased levels of predation. As predators on amphibians, scientists usually are singularly inefficient compared to snakes, birds, and other organisms. Furthermore, preparing specimens and recording the data associated with them (Appendix 4) are time-consuming tasks and, when done correctly, discourage human collectors from random oversampling (see also Foster 1982:6–7; Ehmann and Cogger 1985:439).

It would be convenient if we could provide an absolute value for, or formula to calculate, the number of vouchers of a given species that should be collected, but science is rarely convenient. Providing a meaningful formula for the more than 4,000 species of amphibians is beyond our capability. For areas where the amphibian fauna is well known, a single representative adult specimen of each population at each site minimally will suffice as a voucher for an inventory or monitoring study. Normally, the first adult of every species encountered during a project is suitable. For monitoring studies, we recommend that a voucher be preserved at the initiation of the study. If additional vouchers are required, they can be taken at the end of the study or from an area adjacent to the study site. As an operational figure, we recommend that 10 to 20 specimens of adults and larvae would better represent the species at each site in well-studied areas.

Because we are in the early discovery phase and do not understand the taxonomic relationships of many tropical forms, and because many areas are poorly known and numerous species are undescribed or inadequately represented in systematic collections, we usually recommend collecting many more than one voucher specimen. Generally speaking (and with an awareness of the frailties of any generalization), we recommend a sample of 25 individuals (ideally 10 adult males, 10 adult females, and 5 immatures) for identification purposes. We strongly encourage additional sampling of polymorphic species and those known to be inadequately understood taxonomically or suspected to include several taxa; for such species, samples of up to 25 males, 25 females, and 25 juveniles may be adequate. A researcher who is interested in assessing genetic diversity within and among sites should prepare tissue samples for biochemical analysis (Appendix 5) and preserve voucher specimens of a minimum of 5 to 10 males and females from each site.

Larval amphibians also should be collected whenever they are encountered. After the adults have finished breeding, the larvae may represent the only accessible specimens of a species during the study period. Because larvae are poorly known and generally underrepresented in natural history collections, we recommend a minimum voucher sample of 20 to 30 larvae of each species from each site. Ideally, subsamples should be preserved at various stages to provide a developmental series. If conditions permit, samples of larvae should be raised through metamorphosis. This approach will ultimately yield larvae that can be positively associated with identifiable adults. This is especially important in areas where the fauna is poorly known.

Factors other than sample size can also affect the potential for accurate identification of specimens. Improperly or carelessly prepared specimens are often difficult or impossible to identify because diagnostic features are obscured or modified. Anyone collecting material for scientific purposes should be intimately familiar with proper techniques for specimen preparation and documentation. Ecological information, notes on color in life (dorsal and ventral color, other pattern elements, hidden portions of limbs and groin, iris color), recordings of calls (preferably with a definitely associated voucher specimen), and confidently associated juveniles and larvae often aid identification. Generally speaking, a small number of carefully prepared specimens with detailed data is preferable to a large, carelessly prepared sample with inadequate biological data. Instructions for preparing and preserving amphibian specimens as vouchers are provided in Appendix 4.

Specimen Data

To fulfill their function as vouchers of monitoring or inventory studies, all specimens must be thoroughly documented with locality and relevant specimen data. Data associated with voucher specimens enhance the value of the vouchers and potentially make identifications easier, but those data must be accurate. Even for critically important information, having no data is better than having inaccurate data.

In addition to full locality data in a standard format and information on sampling procedures and habitat (see the section "Data Standards," above), the minimum information required for each voucher specimen includes the following:

1. *Unique sample designation.* This unique field number is assigned by the collector to a specimen or lot obtained at one place and time during the inventory. The number is noted on a field tag that is tied to juveniles or adults or is associated in a single container with larvae.
2. *Date and time of collection.* The date and time (24-hr clock) that the specimen was collected and the date it was prepared (if different) are essential. The month should be written out (i.e., numeric designations or abbreviations are not used).
3. *Name of collector.* The collector is the person (or persons) making the collection. The collector's name is never abbreviated, and the middle initial is included when available.
4. *Taxonomic identification.* Ideally each specimen should be identified to genus and species. This level of identification often is impossible in the field, especially with larvae; a family or other taxon name (caecilian, tadpole, *Bufo*) can be substituted for the scientific name until the animal is identified.
5. *Number of specimens.* For specimens sampled in small lots (eggs and larvae), exact counts should be given. Counts of large lots (≥ 50 specimens) can be designated as "more than 50," "about 90," or "≥ 200."
6. *Other information.* The existence of an associated special preparation (e.g., tissue sample) or other specimen data (e.g., behavioral observation, color notes, recorded call, or photograph) should be entered in the field notes and associated with the unique field number of the voucher specimen. Maps of the study area and trip itineraries are always useful for identification, cataloguing, and historical or archival purposes.

Call Vouchers

When frog calls are used as part of the sampling methodology, tape recordings of the calls of all species are an integral part of the documentation. Recordings are particularly important in habitats with many poorly known species. To serve as a voucher, any tape-recorded frog call must be accompanied by a well-preserved voucher specimen. In this instance the voucher is the male giving the call and the tape recording. If the calling male eludes capture or escapes, that is noted in the field notes and on the tape. Ambient temperature recorded at the time and site of calling should accompany the tape. Appendix 3 provides additional information regarding call vouchers and tape recordings.

Most institutions require that the original or clear photocopies of a collector's field notes and catalogue accompany any incoming collection. The importance of good field notes to all subsequent use of the collection cannot be overemphasized. Poorly recorded field data can seriously mislead the specialist and reduce the usefulness of specimens. If the data accompanying the collection are a secondary compilation from the original field notes, they should be clearly labeled as such.

Selection of a Specimen Repository

Voucher specimens from faunal surveys that are accompanied by detailed field notes and associated documentation have almost incalculable scientific value. Given the inevitable widespread habitat destruction that may preclude collection of additional material from many areas, and the rapid technological advances that allow for previously unsuspected uses of specimens, we can only guess at the possible significance of such specimens in the future. Consequently, this often irreplaceable "time capsule" of information should be permanently stored in a secure institutional collection with a documented long-term commitment to conserving specimens and making them available for study by qualified researchers.

The amount of time, space, and money required to maintain a museum collection is enormous, and relatively few institutions are able to provide the long-term security necessary for large research collections. Therefore, selection of an appropriate institution for the deposition of field vouchers is of critical importance. Using field collections as an enhancement for employment or to ensure acceptance to graduate school is inappropriate; establishing a private collection unavailable for study by qualified researchers does a disservice to the scientific community and often imperils the long-term survival of the study specimens. Many important collections are lost or destroyed when the collector dies or retires and his or her home institution loses interest or realizes it no longer can provide the space or funds required for their maintenance.

When a researcher from one country collects specimens from another country, it is highly appropriate (and often a requirement of the collecting permit) for representative material to be returned, after identification, to designated institutions in the country of origin for the purpose of establishing functional reference collections. Excessive nationalism or misplaced possessiveness, however, should not obscure the economic realities of establishing and maintaining an extensive natural history collection. The primary concern of all responsible biologists should be the long-term maintenance of specimens and associated data and their availability to qualified scientists for study.

Several variables influence the choice of a deposition site for collections; they are discussed by Lee et al. (1982). If identifications are required, an institution that has a history of research in the geographic area, an appropriate specialist on the staff, and access to extensive library facilities is optimal. The prospective donor should, however, obtain a statement of the museum's policies regarding acquisition, preservation, maintenance, and deaccessioning of collections to determine if the policies meet his or her needs. Most institutions will honor reasonable requests from the donor, but policy is determined by many other factors as well.

The identification, distribution, and cataloguing of voucher collections is a service provided by museums to the scientific community. Many museums are currently suffering from budget cuts and staff shortages. The identification of a large collection often occupies hours of staff time. It may require a curator to borrow specimens or to visit other institutions so that pertinent materials may be compared directly, to lend specimens to specialists for identification, and to search the literature. Altruism, if it exists, has its limits. The donor must keep in mind that few museums can afford to invest the time and energy required to identify a major collection without the complete cooperation of the donor. If assistance with identifications is requested of an institution but the collection is to be deposited elsewhere, the requester should offer at least to deposit representative material in the institution that provides the service. Donors often expect institutions to maintain a voucher collection as a discrete unit, separate from the main collection. This desire is understandable, but most institutions will not be able to accommodate it, because of limited space and curatorial support. Whether a voucher collection should be maintained in a single institution or distributed among several is also debated. Each option has merit. The first obviously simplifies future study of the collection; the latter provides for greater access by researchers in many areas. Donors concerned about this issue should ask about an institution's exchange policy before depositing specimens there.

Permits

ROY W. McDIARMID, ROBERT P. REYNOLDS, AND RONALD I. CROMBIE

During the past few decades, the number of laws regulating the collection, acquisition, study, transport, and disposition of wildlife and wildlife products has increased significantly. These laws have been proposed and promulgated in an effort to control activities that are deemed harmful to animals and plants. Although habitat loss generally is acknowledged to be the primary factor affecting species' distributions, abundances, recruitment, and extinctions, commercial exploitation also has had a detrimental effect on certain species of wildlife. Some species considered to be endangered, threatened, or otherwise in need of protection have been protected by international treaty or various federal, state, and local laws. The laws and regulations contained in the U.S. Endangered Species Act and in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are those of primary concern, but many other foreign, federal, state, and local regulations may also apply to users of this manual. For example, many states require permits for the use of seines or traps in aquatic habitats; permission to use such devices to sample aquatic amphibians should be clarified with the local authority. Other regulations with which travelers should be familiar restrict the transport of liquid nitrogen (see Appendix 5), alcohol, and formalin or the possession and transport of syringes and certain killing agents, drugs, or chemicals used in specimen preparation.

Laws regulating scientific collecting vary widely among states and countries and change constantly. Furthermore, the government agencies responsible for issuing collecting permits sometimes change or are restructured. Current information on most international and federal regulations and responsible agencies can be obtained by writing to or calling the U.S. Fish and Wildlife Service, Office of Management Authority, 4401 N. Fairfax Drive, Arlington, VA 22203 USA (telephone: [703] 358-1708). Information on state and local regulations can be obtained from the appropriate conservation or management agency in the jurisdiction of interest. The variation in requirements often makes obtaining collecting and export permits a trying process. Nevertheless, it is the responsibility of the individual collector to learn about and comply with the appropriate regulations as they apply to amphibians. Although certain provisions of a collecting permit may appear to have little bearing on the conservation of species or protection of habitats and in some instances may even restrict the conduct of scientific research, all of us are obliged to abide by the regulations.

Because obtaining the necessary permits often is a crucial step in ensuring the success of a field study and often is the most difficult part of the preliminary work, it is essential that the investigator present a carefully planned proposal with clearly defined objectives to the permit-granting agency. We recommend that investigators be prepared for delays, which often are inevitable, by allowing a long lead time between the request for permits and the initiation of the field study.

Most institutions cannot or will not accept voucher material unless it is accompanied by documents verifying that the specimens were legally collected and, where appropriate, exported and imported. In many countries, permits for specimen collection and export are issued by different government agencies. In addition, some countries require an animal health permit, issued by a third agency, before specimens can be legally exported. In other countries collection and export are unregulated, at least for noncommercial purposes. In these cases, a letter on official stationery from the most appropriate government agency stating that such permits are not required may suffice for purposes of importation.

Endangered and protected species require special permits beyond the normal collecting and export permits. In addition, in CITES-member countries, export permits for any species covered by CITES must be issued by the designated CITES official. The U.S. Fish and Wildlife Service (see address above) maintains an international directory of CITES Management Authorities, that is, of offices authorized to issue permits or equivalent documentation in accordance with CITES regulations. It is the responsibility of the researcher to ensure that he or she has complied with all laws governing the collection and export of scientific specimens and that the appropriate permits are secured.

For import into the United States a completed U.S. Fish and Wildlife Service form 3-177 (available from a Fish and Wildlife Service agent at a designated port of entry or from the U.S. Fish and Wildlife Service, Division of Law Enforcement, P.O. Box 3247, Arlington, VA 22203-3247 USA) accompanied by the above documents (copies are sufficient) from the country of origin must be presented at the port of entry. It is prudent to notify the agent at the port of entry of your anticipated date and time of arrival. If it is not possible to meet with a Fish and Wildlife agent at the time of arrival, the completed 3-177 form should be left with the customs inspector and a copy sent to the address specified on the form within the specified time. For purposes of declaration, scientific specimens, by definition, have "no commercial value." Importation of specimens into countries other than the United States and shipments through other countries will require other permits. In these instances local agencies should be consulted for information regarding regulations and appropriate procedures.