The Use of Automated Data-Acquisition Techniques in Monitoring Amphibian and Reptile Populations

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THE USE OF AUTOMATED DATA-ACQUISITION TECHNIQUES IN MONITORING AMPHIBIAN AND REPTILE POPULATIONS

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Abstract. A major problem associated with herpetological surveys and monitoring programs is that environmental variation affects animal activity and, thus, our ability to determine the presence and abundance of amphibians and reptiles. This paper discusses how automated data-acquisition techniques can be used to quantify the relationships between environmental variation and animal activity and thereby improve surveys and monitoring programs. Two major issues are addressed: (1) how to describe temporal and spatial variation in the physical environment, and (2) how to measure the activity patterns of free-ranging animals. We use an automated weather station to gather environmental data and techniques such as radiotelemetry and audio recording to determine activity patterns. Combining environmental and activity data helps optimize where, when, and under what conditions to sample. We illustrate our approach with data on the effects of environmental variation on the activity patterns of rubber boas (*Charina bottae*) and on the calling activity of southwestern toads (*Bufo microscaphus*).

INTRODUCTION

To manage populations of amphibians and reptiles properly requires information on the species that are present and their abundances. Most surveying and monitoring techniques (e.g., time-constrained searches, trapping, and road cruising) are most effective when animals are active at the surface. However, variation in environmental conditions greatly affects the activity of animals and, thus, our ability to observe or capture them (Fig. 1). This problem is more pronounced with amphibians and reptiles because ectothermic animals are more closely coupled to variation in the physical environment than are endotherms (Pough et al. 1989). Additionally, the relatively low energetic requirements of ectotherms allow them to be inactive for long periods of time during unfavorable conditions (Pough 1983, Scott and Seigel, this volume). In fact, most amphibians and reptiles spend the majority of their time under cover (e.g., resting, aestivating, hibernating; Huey 1982, Peterson 1987, Huey et al. 1989). Consequently, studies that do not take into account the effects of environmental variation on animal

activity may fail to detect the presence of a species, may underestimate the number of individuals, and may overestimate population fluctuations.

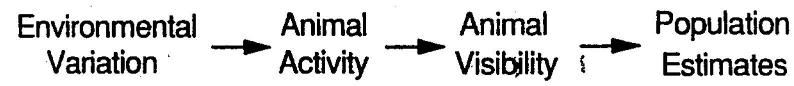

Fig. 1. Flow diagram indicating how environmental variation influences population estimates. Variation in the physical environment (e.g., temperature, radiation, precipitation, and humidity) affects animal activity. Techniques for estimating activity levels include radiotelemetry (changes in location, body temperature patterns, and movements) and the audio recording of frog calls. Variation in animal activity influences animal visibility (i.e., detectability) and, thus, the effectiveness of techniques commonly used to find amphibians and reptiles (e.g., road cruising, time-constrained searches, and trapping).

The objective of this paper is to describe how automated data-acquisition techniques developed for physiological and behavioral ecology studies can be used to refine surveying and monitoring procedures for amphibians and reptiles. We address two key issues: (1) describing temporal and spatial variation in the physical environment, and (2) measuring the activity patterns of individual animals. Our approach consists of using an automated weather station to gather environmental data while using techniques such as telemetry and audio recording to determine activity patterns. The techniques we describe are intended to improve the effectiveness of traditional methods (e.g., trapping and time-constrained searches) for determining the presence and abundance of amphibians and reptiles. We illustrate our approach with data on the effects of environmental variation on the activity patterns of rubber boas, and on the calling activity of southwestern toads.

Automated data-acquisition techniques can help researchers improve surveying and monitoring programs in several ways. First, they should help optimize where, when, and under what conditions to sample. This will maximize the chances of encountering animals and minimize variation among samples due to activity differences. Second, clarifying the relationships between environmental variation and activity could also aid in the evaluation of data collected under different environmental conditions (e.g., adjusting for the effect of temperature on capture rates). Finally, if gathered over a sufficiently long period of time, such data may prove useful in testing hypotheses concerning the causes of population fluctuations (e.g., the effects of changes in pH or ultraviolet radiation on anuran populations; Wyman 1990).

DESCRIBING VARIATION IN THE PHYSICAL ENVIRONMENT

A number of physical variables may influence the occurrence, activity, and abundance of amphibians and reptiles, including temperature, radiation, precipitation, humidity, wind speed, and pH (Fitch 1956, Porter et al. 1973, Pierce 1985, Semlitsch 1985, Duellman and Trueb 1986, Karns 1986, Gibbons and Semlitsch 1987, Pechmann et al. 1991). However, few of these variables other than temperature are routinely measured because of the time and money required to make the measurements. The use of data loggers to automate data collection has helped minimize these problems.

Measuring environmental variation automatically with data loggers has several advantages over making manual measurements. Data loggers allow researchers to measure a wide variety of variables accurately and easily so they can concentrate on studying the animals. Furthermore, data loggers allow measurements to be made at regular intervals at multiple sites even when the researchers are not present. Because many factors vary through time, it is often important to sample regularly over hours, days, and even seasons. For example, pH may vary by over one unit during the course of a day, and may change dramatically at certain times of the year (e.g., following the melting of snow in the spring; Harte and Hoffman 1989). Other advantages of data loggers include the large amount of data that can be stored and the ease of data transfer to a computer. Helpful introductions to automated acquisition of environmental data (general aspects, measurements of climatological variables, and lists of equipment manufacturers) are provided by Tanner (1990) and Peterson and Dorcas (*in press*). Researchers can learn to operate a data logger within a few days. To minimize learning time, we suggest working with someone already familiar with the equipment.

Because temperature is one of the most important factors influencing the activity of amphibians and reptiles, it is important to describe their thermal environments accurately. A particularly useful index is the operative environmental temperature (Bakken and Gates 1975). Operative environmental temperatures incorporate animal properties such as size, shape, and reflectance, as well as environmental variables such as radiation, wind speed, and environmental temperatures. Operative environmental temperatures more accurately describe the thermal environment of an animal than air or substrate temperatures alone, and thus, have more predictive value. Operative temperatures can be measured through the use of physical models of animals. Physical models have been used to measure the operative temperatures of a variety of amphibians and reptiles, including frogs (Bradford 1984), turtles (Crawford et al. 1983), lizards (Grant and Dunham 1988), and snakes (Peterson 1987). A review of model construction and the application of operative temperatures in ecology is provided by Bakken (*in press*). Examples of how operative temperatures for a rubber boa vary spatially and diurnally are shown in Fig. 2.

Although data loggers are relatively expensive, their price is declining and they are becoming more available in agencies, universities, field stations, national parks, etc. Obtaining the desired data may require simply attaching additional sensors to an already functioning data logger system.

DESCRIBING ACTIVITY PATTERNS

Data acquisition systems also can assist surveying and monitoring efforts by increasing our knowledge of animal activity patterns. Most monitoring techniques require animals to be active at the surface, yet amphibians and reptiles generally spend most of their time under cover. Therefore, they may be inaccessible to most monitoring procedures for long periods of time. Some species (e.g., spadefoot toads [*Spea*] and rubber boas) may be common but are visible under conditions that occur only occasionally (Stebbins 1985). The use of automated techniques is particularly appropriate for these animals.

Although it is usually more difficult to measure variation in animal activity than in environmental factors, the activity patterns of many individual animals can be determined by interfacing data loggers with radiotelemetry systems, transponder systems, tape recorders, and videorecorders. In the following sections, we describe how automated telemetry and audio recording systems can be used to measure animal movements and calling activity, respectively.

Telemetry

Radiotelemetry has played an important role in our understanding of the activity patterns of some moderate- to large-sized reptiles (e.g., Christian et al. 1983, Fitch 1987, Brown and Brooks 1991). Most telemetry studies have focussed on habitat selection and movement patterns (Reinert 1984, Shine 1987, Huey et al. 1989) and have helped researchers determine where to sample (e.g., the locations of gravid snakes or den sites). Although in principle it should be possible to develop an automated system for relocating animals, it is not yet practical to do so in most situations.

Activity patterns of animals can be determined automatically by frequently sampling individuals with radiotransmitters. Continuous sampling of multiple animals can be achieved by interfacing a data logger with a scanner, radio receiver, and signal processor (Petron et al. 1987, Peterson and McDonald, *unpublished manuscript*). Such systems can be used to detect if telemetered animals are present within the range of the system (e.g., to determine the time of arrival and departure of telemetered amphibians at a breeding site or the amount of time green sea turtles [*Chelonia mydas*] spend at the surface and submerged [Sharon Manzella, *personal communication*]). More detailed activity data can be obtained if transmitters are equipped with temperature and motion sensors. Considerable information about an ectotherm's behavior, such as emergence times, retreat times, and microhabitat selection, often can be inferred from body temperature patterns, especially if used in conjunction with operative temperature measurements (Peterson 1987, Huey et al. 1989). The use of motion-sensitive switches in transmitters makes it possible to describe quantitatively the activity patterns of free-ranging animals (Peterson et al. 1989). For example, Fig. 2 shows the daily body temperature and activity patterns of free-ranging rubber boas. These data indicate that sampling for rubber boas would be most effective during midday in the fall versus late evening in early summer. It may also be possible to use variation in signal strength to infer the activity patterns of animals (e.g., Chappell and Bartholomew 1981, Nams 1987, Stanner and Farhi 1989). The information derived from telemetry studies also can aid in the location of nontelemetered animals.

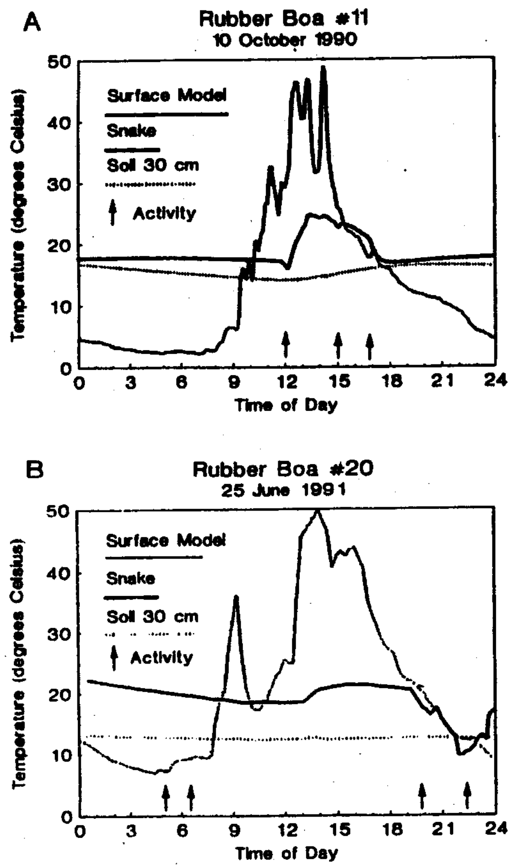

Fig. 2. Telemetered body temperatures from two (A,B) free-ranging, adult female rubber boas, snake model temperatures (i.e., operative environmental temperatures) at the surface (exposed to sun), and 30 cm soil temperatures plotted versus time of day. The relatively flat portions of the body temperature curves indicate when the snakes were under cover. Sharp changes in body temperature indicate movements. Periods of activity are further indicated by the toggling of a transmitter's mercury switch (arrows).

Two key problems with radiotelemetry are the need to replace batteries periodically, and limitations on the minimum size of animals that can be studied. In the future, transponders may be a solution because they are small and do not require batteries (Fagerstone and Johns 1986, Mascanzoni and Wallin 1986, Camper and Dixon 1988). Unfortunately, transponder systems that allow identification of individual animals have a very short range. Nevertheless, it should be feasible to interface data loggers with transceiver units to monitor activity in certain situations (e.g., snakes entering a hibernaculum or salamanders passing through a gate in a drift fence). This approach should become more effective as the range of these systems increases.

Audio recording

Monitoring of anuran advertisement calls can be used to detect the presence of a species and to indicate its relative abundance (Karns 1986, Rand and Drewry, *in press*). A simple, but effective, technique for monitoring the calling activity of anurans involves using a data logger programmed to periodically turn on a tape recorder. Such a system was used to study the effects of environmental variation on calling activity in southwestern toads.

To illustrate our approach for determining optimal sampling times and conditions, we describe a southwestern toad calling study in some detail. It was conducted at Beaver Dam Wash in southwestern Utah, 18-22 March 1991 (Dorcas and Foltz, 1991). Calling was sampled for 10 seconds every 5 min using a cassette tape recorder controlled by a data logger (Campbell Scientific CR10). Solar radiation was measured with a pyranometer (Li-Cor LI-200SZ); relative humidity was measured using a relative humidity probe (Campbell Scientific); wind speed was measured using a micro response contact anemometer (Weathertronics); and temperatures were measured using copper-constantan thermocouples. All instruments were read each second, and 5-min averages were calculated and recorded by the data logger.

Based on the results (Figs. 3 and 4), we predict that calling surveys for this species would be most successful if taken at night when water temperatures are between 12 and 18°C. If this study had been conducted for a longer period of time, we also could predict the best time of year to sample this species.

Automated sampling of anuran calling activity can be easily and inexpensively extended to multiple sites. Sampling systems can be assembled by using a $50 timer (SSAC), a cassette tape recorder, and an external microphone (see Peterson and Dorcas, *in press*, for details). By using an array of units, several sites and species can be sampled simultaneously. This approach would be especially useful when time for sampling is limited or when sampling populations of explosively breeding anurans that call for short periods of time.

Videocameras can be used in a similar fashion to monitor the activity patterns of animals at a specific site. By using videocameras sensitive to near infrared light and an infrared light source, animal activity can be monitored at night or underground with minimal disturbance.

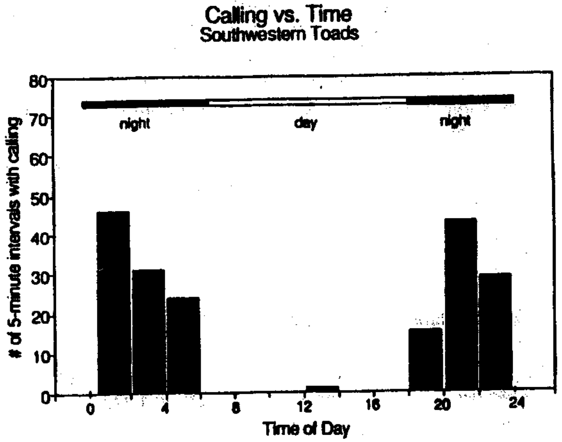

Fig. 3. Calling activity of southwestern toads over a 3-d period in March 1991 at Beaver Dam Wash in southwestern Utah (χ^2 = 264.45, df = 1, $P < 0.001$). The numbers of 5-min intervals during which calling was recorded are plotted versus the hour of day. Note that all but one of the calling intervals occurred at night.

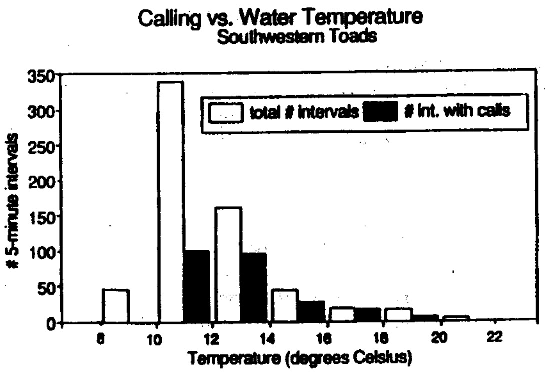

Fig. 4. Calling activity of southwestern toads during four nights (18-21 March 1991) at Beaver Dam Wash in southwestern Utah (χ^2 = 103.45, df = 6, $P < 0.001$). The total number of 5-min intervals and the number of intervals during which calling was recorded, are plotted versus water temperature at a depth of 1 cm. Note that no calling was recorded below 10°C and that the highest proportion of intervals with calls occurred between 12 and 18°C.

CONCLUDING REMARKS

In this paper we explain how to measure variation in the physical environment and in animal activity, and how such information can improve surveying and monitoring amphibian and reptile populations. New technologies will make these capabilities more available and less expensive.

The next step is to combine measurements of environmental variation and animal activity with actual population estimates to quantify relationships among these variables. Once these correlations have been established for a given species, the design of sampling programs and the evaluation of data gathered under different environmental conditions can be refined.

In addition to improving the accuracy and precision of population estimates, automated data-acquisition techniques can contribute to determining the causes of population changes. Long-term data sets from a variety of locations should assist in understanding the reasons for population fluctuations. We believe that networks of monitoring sites should be developed, and that environmental and animal abundance data should be collected systematically.

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