Northwestern Naturalist

A JOURNAL OF VERTEBRATE BIOLOGY

VOLUME 81 NUMBER ONE SPRING 2000

A COMPARISON IN COLORADO OF THREE METHODS TO MONITOR BREEDING AMPHIBIANS

PAUL STEPHEN CORN
USGS Midcontinent Ecological Science Center, Aldo Leopold Wilderness Research Institute, P. O. Box 8089, Missoula, Montana 59807 USA

ERIN MUTHS AND WILLIAM M. IKO
USGS Midcontinent Ecological Science Center, 4512 McMurry Avenue, Fort Collins, Colorado 80525 USA

ABSTRACT—We surveyed amphibians at 4 montane and 2 plains lentic sites in northern Colorado using 3 techniques: standardized call surveys, automated recording devices (frog-loggers), and intensive surveys including capture-recapture techniques. Amphibians were observed at 5 sites. Species richness varied from 0 to 4 species at each site. Richness scores, the sums of species richness among sites, were similar among methods: 8 for call surveys, 10 for frog-loggers, and 11 for intensive surveys (9 if the non-vocal salamander *Ambystoma tigrinum* is excluded). The frog-logger at 1 site recorded *Spea bombifrons* which was not active during the times when call and intensive surveys were conducted. Relative abundance scores from call surveys failed to reflect a relatively large population of *Bufo woodhousii* at 1 site and only weakly differentiated among different-sized populations of *Pseudacris maculata* at 3 other sites. For extensive applications, call surveys have the lowest costs and fewest requirements for highly trained personnel. However, for a variety of reasons, call surveys cannot be used with equal effectiveness in all parts of North America.

Key words: amphibians, automated call surveys, call surveys, capture-recapture, PIT tags, monitoring, boreal chorus frog, *Pseudacris maculata*, northern leopard frog, *Rana pipiens*, wood frog, *Rana sylvatica*, Woodhouse's toad, *Bufo woodhousii*

The causes of many amphibian declines remain undiscovered. Still controversial is the contribution of natural variation in distribution and abundance to perceived declines (Blaustein 1994; Pechmann and Wilbur 1994). Long-term data sets are necessary to evaluate population dynamics (Meyer and others 1998), but these are relatively scarce for amphibians (Pechmann and others 1991; Blaustein and others 1994). Moreover, the statistical power, the ability to detect a significant trend, of most existing long-term data sets is low (Reed and Blaustein 1995; Hayes and Steidl 1997; but see Thomas 1997), particularly for anurans (PWRC 1998). In response to this problem, international efforts, including the Declining Amphibian Populations Task Force, are attempting to track trends in amphibian populations. The North American Amphibian Monitoring Program (NAAMP) has been organized specifically to establish a network of long-term amphibian population monitoring sites.

The NAAMP is loosely patterned after the North American Breeding Bird Survey (Peterjohn 1994) and has a goal to "Provide a statistically defensible program to monitor the distributions and relative abundance of amphibians in North America, with applicability at the state, provincial, ecoregional, and continental scales" (NAAMP 1996a). Because many anurans have well-defined breeding seasons and males produce loud advertisement calls, surveys of breeding choruses may provide a relatively simple means of monitoring trends in populations (Scott and Woodward 1994).

It is expected that road-based surveys of calling males conducted by volunteers (Bishop and others 1997; Lepage and others 1997; Shirose and others 1997; Hemesath 1998; Mossman and others 1998) will be an important method of collecting data, particularly in northeastern and central North America (NAAMP 1997). However, there are a number of potential problems and biases associated with call surveys, including variation in detectability among species; extended breeding seasons in the southeastern United States; lack of roads, wetlands, and species with audible calls in western North America; inter-observer bias; and problems associated with recruiting and training a large pool of volunteers.

Some of these problems might be solved by automating the monitoring process. Peterson and Dorcas (1994) described a relatively inexpensive (about $200 US for parts; Varhegyi and others 1998), timer-based recording system that can be left unattended at a site and set to record specific lengths of time at specified intervals until the tape needs to be changed. This method samples the acoustic environment throughout the day and night, and therefore has the ability to detect rare species that infrequent manual surveys may miss (Anonymous 1995; Varhegyi and others 1998).

We conducted a study in 1995 to compare 3 methods for monitoring breeding amphibians: automated recorders (frog-loggers; Anonymous 1995); manual call surveys, as they would be implemented in a large monitoring program; and intensive (capture-recapture) surveys. In this paper, we compare our ability to detect presence of breeding amphibians at lentic sites by using each survey technique, correlations between relative abundance and estimated population size, and costs associated with each technique.

STUDY SITES AND METHODS

We installed frog-loggers and conducted manual call and intensive surveys at 6 small (<0.5 ha), discrete sites in northern Colorado (Fig. 1): Pawnee, a pool in an intermittent tributary of Owl Creek on the Pawnee National Grassland (elevation 1575 m); First Creek, an impoundment on an intermittent stream at the Rocky Mountain Arsenal National Wildlife Refuge (elevation 1615 m); Prospect Canyon, an abandoned beaver pond (elevation 2707 m), and Horseshoe Park pond (elevation 2606 m), both in Rocky Mountain National Park; and Matthews Pond (elevation 2805 m) and Lily Pond (elevation 2900 m), both vernal ponds in the Arapaho-Roosevelt National Forest (see Vertucci and Corn 1996). Pawnee and First Creek are in short-grass prairie, and the other 4 are montane sites in lodgepole pine (*Pinus contorta*) forests. Study sites were selected to represent an elevational gradient, to be typical of size and habitat character of amphibian habitats in these landscapes, to be reasonably protected from vandalism, and to have confirmed or suspected amphibian populations.

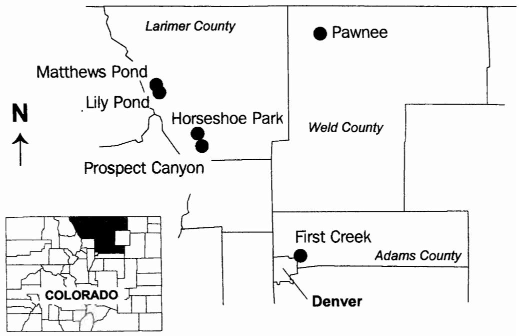

FIGURE 1. Locations of study sites in northern Colorado.

Study sites were close to roads and were affected by a variety of historic and current human activities. The Pawnee site is on an active grazing allotment, although no cattle were present during this study. The First Creek site is located in the uncontaminated, peripheral buffer area of the Rocky Mountain Arsenal, where stream flows were regulated, leading to rapid increases in the size of the impoundment. The forest surrounding Lily Pond was clear cut about 40 yr ago. Horseshoe Park, Matthews Pond, and Prospect Canyon are in relatively undisturbed habitat.

Frog-loggers (purchased assembled for $350 each) were placed at each site. These included a voice clock that generated a time stamp at the beginning of each recorded segment. Each frog-logger was placed inside a large (44 L) cooler for protection from low temperatures. The microphone was located about 0.5 to 1.5 m above the surface at the edge of standing water. The systems recorded on normal bias 90-min cassette tapes for 12 sec every ½ hr, 24 hr per day. Recording length and interval were chosen to allow tapes to be changed every 5 days. Each frog-logger was accompanied by a small weather station containing a rain gauge and single-channel data loggers (Peterson and Dorcas 1994) that recorded air and water temperatures. Frog-loggers were placed in season-long operation at each site before any species initiated calling and were left until after breeding activity ceased.

Frog-logger tapes were processed by paid staff after the field season. Calling intensity for each species heard was recorded for each recorded segment using the following categories: 1 = single calls, not overlapping; 2 = overlapping, but discernible calls; and 3 = continuous calling, individual calls not discernible (Bishop and others 1997; Lepage and others 1997).

We conducted 3 to 4 manual call surveys at each site between 2000 and 2200 hr. Intervals between surveys averaged 7 days (Table 1). Surveys began after amphibian breeding activity began regionally. We spent 3 min at the edge of each site with observers recording the calling intensity for each species using the same scale as for frog-loggers. Notes were taken independently by observers. We also recorded air and water temperature, percent cloud cover, wind speed with a portable anemometer, and moon phase. Observers were zoologists working for the National Biological Service or student volunteers. All observers were trained using frog call tapes and amphibian identification books in the laboratory and by observation and call identification in the field.

Intensive surveys were in conjunction with capture-recapture efforts and were conducted after the manual call surveys. Searches required 2 to 6 hr, including time used in tagging animals. Formal search patterns (for example, Thoms and others 1997) were not used, but all areas of each site <1 m deep were examined at least once during each survey. Individual chorus frogs, *Pseudacris* sp.[1] were marked with a unique toe-clip (Donnelly and others 1994), and Woodhouse's toads (*Bufo woodhousii*) were injected with a PIT tag (passive integrated transponder; Camper and Dixon 1988; Christy 1996, Corn and others 1997) dorsally parallel to the urostyle.

Manual call and intensive surveys were conducted coincident with changing tapes in the frog-loggers and included 2 to 4 (usually 3) observers. Because of logistic constraints (time required to reach sites and staff hours involved), we conducted surveys without regard to recommended environmental constraints (air temperature ≥8° and wind speed ≤5.6 m/sec; Bishop and others 1997; Shirose and others 1997). We considered effects of weather on the observations as part of our analysis.

We compared the potential of each technique to detect species by summing species richness across all sites (total detections). For species with enough captures, we attempted to calibrate relative abundance scores to estimated abundance. We calculated the mode of all manual call survey scores for a species at a site and the modal and mean non-zero frog-logger score for that species both for the week (Sun to Sat) with the greatest calling activity (greatest percentage of observations with calling recorded) and for the entire season. We estimated numbers of males ($\hat{N}$) from capture-recapture data using the closed population estimation program CAPTURE (Otis and others 1978). We used model M_t (capture probabilities vary with time, Darroch procedure), because ability to catch frogs varied from night to night, depending on environmental conditions. We then compared ($\hat{N}$) to auditory and frog-logger relative abundance values.

RESULTS

Combining all 3 methods, we observed 6 to 7 species of amphibians: tiger salamander (*Ambystoma tigrinum*), plains spadefoot (*Spea bombifrons*), *B. woodhousii*, *P. maculata*, *P. triseriata* (?), *Rana pipiens*, and wood frog (*R. sylvatica*). Because of uncertain identification, chorus frogs from Pawnee and First Creek will be referred to hereafter as *Pseudacris* sp. We found 2 to 4 species at each site (Table 2), except Prospect Canyon, where amphibians were not found.

No single method registered all species, but species richness scores summed across sites were similar among methods: 10 for frog-loggers, 8 for manual call surveys, and 11 for intensive surveys (9 if salamanders are excluded). Frog-loggers recorded vocalizing species at 5 sites but could not detect the non-vocal *A. tigrinum*. Intensive searches observed *A. tigrinum* at 2 sites (Table 2). At 4 of 5 sites with calling amphibians, manual call surveys and intensive surveys identified the same vocalizing species recorded by the frog-loggers. At the Pawnee site, manual call surveys detected only 1 species and intensive surveys found 2 of 3

[1] Boreal chorus frogs, *P. maculata*, occurred at mountain sites, but the identity of chorus frogs, either *P. maculata* or western chorus frogs, *P. triseriata*, occurring at lower elevations in eastern Colorado is uncertain (Platz 1989).

TABLE 1. Dates of frog-logger operation and manual call and intensive surveys of breeding amphibians at 6 sites in northern Colorado, 1995. Frog-loggers recorded 12 sec every half-hour during peak dates of breeding activity and 12 sec/hr at other times. Days recorded are the number of days with successful recordings (days down are the number of days without data resulting from malfunction or operator error).

Site	Frog-logger Start date	Frog-logger End date	Frog-logger Days recorded (days down)	Frog-logger Number of recordings	Manual call and intensive survey dates
Pawnee	17 March	30 May	63 (10)	2793	30 April; 4, 9 May
First Creek	12 April	3 July	71 (10)	3716	5, 10, 20 May
Horseshoe Park	20 April	6 July	57 (19)	2202	18, 23 May; 2, 7 June
Prospect Canyon	20 April	1 July	35 (36)	1450	18 May, 2 June
Matthews Pond	19 April	3 July	74 (0)	2541	17 May; 1, 6, 15 June
Lily Pond	1 June	8 July	37 (0)	1438	15, 20, 23 June

species recorded by the frog-logger (Table 2). Cold and windy conditions on survey nights may have affected detection. Recommended limits for manual call surveys were exceeded twice. Air temperature was 5°C during the 30 April survey, and wind speed was gusting to 6.8 m/sec on 9 May. All 3 species also were relatively rare. Calls of *Pseudacris* sp. and *R. pipiens* occurred only 3 and 9 times, respectively, out of 2793 recordings on the frog-logger tapes. *Spea bombifrons* was recorded 30 times, but not until 17 May, 6 days after the last call survey (Table 1).

Sufficient numbers of *B. woodhousii* at First Creek and *P. maculata* at Horseshoe Park, Matthews Pond, and Lily Pond were captured and marked to allow estimates of population size (Table 3). Relative abundance scores from manual call surveys and frog-loggers did a poor job of identifying a relatively large population of *B. woodhousii* at First Creek. The low score from the frog-logger may have been because most calling toads were located 100 m or more from the microphone and the recorded calls were generally faint. Also, environmental noise (mainly wind and jet noise from Denver International Airport) made detecting amphibian calls on the tapes difficult at times. Conversely, the calls of *P. maculata* were loud and the frog-logger tapes were often saturated, regardless of the population size (Table 3). Manual call surveys identified the smallest population of *P. maculata* (Matthews Pond, $\hat{N}$ = 20), but did not distinguish between the chorus at Lily Pond ($\hat{N}$

TABLE 2. Summary of species recorded by automated call surveys (frog-logger), manual call surveys (call counts), and intensive surveys at 6 locations in northern Colorado.

Location	Method	Number of species	Species
Pawnee	frog-logger	3	*Pseudacris* sp., *Rana pipiens, Spea bombifrons*
	call counts	1	*Pseudacris* sp.
	intensive	3	*Pseudacris* sp., *R. pipiens, Ambystoma tigrinum*
First Creek	frog-logger	2	*Pseudacris* sp., *Bufo woodhousi*
	call counts	2	*Pseudacris* sp., *Bufo woodhousi*
	intensive	2	*Pseudacris* sp., *Bufo woodhousi*
Horseshoe Park	frog-logger	1	*P. maculata*
	call counts	1	*P. maculata*
	intensive	2	*P. maculata, A. tigrinum*
Prospect Canyon	frog-logger	0	
	call counts	0	
	intensive	0	
Matthews Pond	frog-logger	2	*P. maculata, R. sylvatica*
	call counts	2	*P. maculata, R. sylvatica*
	intensive	2	*P. maculata, R. sylvatica*
Lily Pond	frog-logger	2	*P. maculata, R. sylvatica*
	call counts	2	*P. maculata, R. sylvatica*
	intensive	2	*P. maculata, R. sylvatica*

TABLE 3. Measures of relative and absolute abundance of calling amphibians. Statistics on frog-logger relative abundance scores were computed for the week with the greatest calling activity and for the entire season.

	Species			
	Bufo woodhousii	*Pseudacris maculata*		
	Site			
	First Creek	Horseshoe Park	Matthews Pond	Lily Pond
Call surveys				
Modal relative abundance score	2	3	2	3
Frog-logger				
Week with greatest activity	14–20 May	14–20 May	11–17 June	18–24 June
Modal relative abundance score (week)	1	3	3	3
Mean relative abundance score (week)	1.9	2.6	2.6	2.5
Mean relative abundance score (season)	1.8	2.5	2.4	2.3
Intensive surveys				
Number marked	136	64	14	41
Estimated abundance	213	113	20	78
Standard error	19.8	18.2	5.3	17.6

= 78) and the one at Horseshoe Park ($\hat{N}$ = 113) that contained 45% more frogs.

Total costs of using frog-loggers were the highest of any method. Frog-loggers require an initial funding outlay for equipment (>$600 per site the 1st year for the froglogger, cooler, tapes, temperature loggers, and miscellaneous hardware). Frog-loggers also required 9 to 16 visits, depending on the length of the breeding season, to set up and remove the installation and to change tapes every 5 days. Data transcription required about 1.5 hr per hour of tape; for example, about 15 hr for the 10.5 hr of tape from Matthews Pond. Intensive and call surveys, in contrast, had modest equipment needs, required 3 to 4 visits per site, and needed little or no post-processing of data.

Discussion

Amphibians and their habitats in northern Colorado represent a relatively simple system in which amphibian monitoring methods may be tested effectively. The relatively low species diversity allows analysis of methodological advantages and disadvantages that may sometimes be obscured by too much complexity.

Frog-loggers are promising tools for detecting rare species, and they provide data on phenology and behavior related to environmental conditions (Fig. 2; Peterson and Dorcas 1994; Varhegyi and others 1998) that are difficult to obtain by other means. In addition, the audio tapes provide a permanent record against which questionable data can be checked (Varhegyi and others 1998). However, the equipment is expensive relative to the other techniques tested here. The reliability of the frog-loggers was variable. Both equipment and operator failures produced gaps in the data record. Missing data for the weeks beginning 23 April at First Creek and 30 April at Horseshoe Park (Fig. 2) were particularly inconvenient because data on the initiation of breeding activity were lost at both sites. Bowers and others (1998) also experienced technical problems with automated equipment in a study of prairie potholes in North Dakota. The equipment also is vulnerable to theft, vandalism, and damage from wildlife (something we experienced).

Data from frog-loggers were poor at discerning relative abundance of *Pseudacris* and probably also *B. woodhousii*, although only 1 population was sampled providing no basis for comparison. A more complete analysis of the *Pseudacris* data, using several years of observations and so beyond the scope of this paper, is underway.

Use of frog-loggers requires more staff time and higher levels of training than manual call surveys. Time required to set up, maintain (change tapes), and remove the equipment results in more visits to a site than would be necessary for manual call surveys. Significant time, 35 to 40 hr in this study, is required to lis-

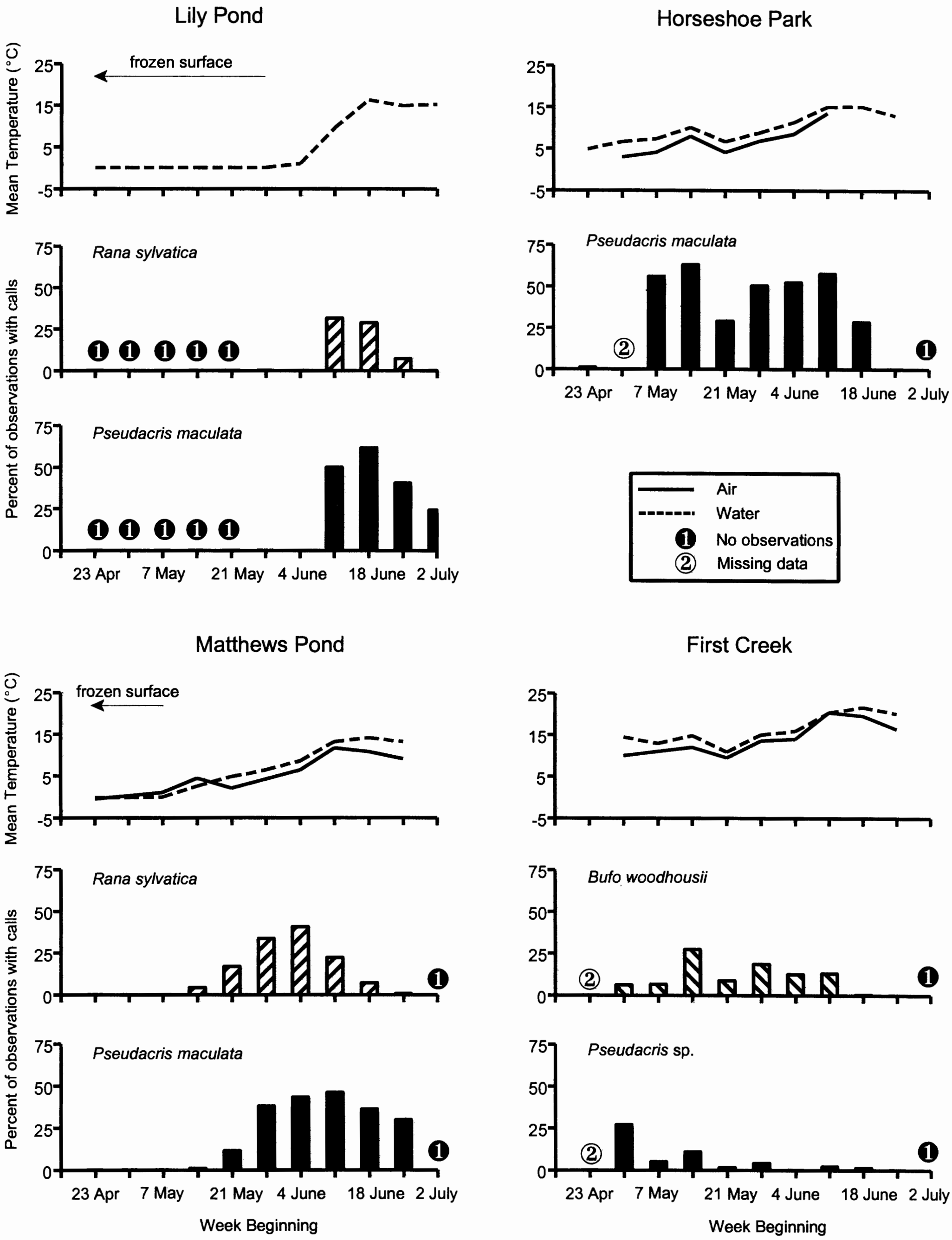

FIGURE 2. Breeding activity of amphibians (percentage of observations with calling recorded) detected by frog-loggers and mean air and water temperatures during 1-wk intervals at 4 sites in 1995. Missing data were due to frog-logger errors; no observations were dates when frog-loggers had been removed or not yet turned on. Data from Pawnee were not included because of the small number of observations.

ten to tapes and transcribe the data. Varhegyi and others (1998) concluded that use of frog-loggers would cost significantly less than manual call surveys, but they based this on each technique collecting the same number of observations. Cost per datum is not a valid comparison, because far fewer manual call surveys are needed to identify most amphibian species present at a given site, and manual surveys would not be used to gather detailed information on phenology and behavior. Also, a monitoring program would include manual call surveys at several sites each night, while use of frog-loggers is restricted by their cost and need for locations safe from theft or vandalism.

Manual call surveys may be capable of distinguishing small and large populations of some species, but call surveys quickly lose the ability to estimate relative abundance as numbers of calling males increase. Shirose and others (1997) found they could estimate numbers of small populations (<30 calling males) of *B. fowleri* and *R. catesbeiana*. Hine and others (1981) found that manual call surveys were unreliable for estimating abundance of *R. pipiens*. In this study, manual call surveys were only able to differentiate between small and larger populations of *P. maculata*.

Manual call surveys detect the presence of common species, but rare species are easily overlooked, as illustrated by *R. pipiens* at Pawnee in this study. Manual call surveys also will fail if they are not conducted during times when the species is present (for example, *S. bombifrons* at Pawnee). Because timing of amphibian breeding varies among species and annually, depending on temperature and precipitation, scheduling is an important consideration and constraint in the design of monitoring programs that use call surveys. Manual call surveys in this study were conducted at smaller intervals than recommended for extensive programs and occasionally during suboptimal weather. Manual call surveys are the least expensive of the methods tested here because inexpensive labor (volunteers) may be used, there is almost no cost for equipment, and there is limited need for transcribing data after they have been collected.

Intensive surveys are effective for determining presence of species, and capture-recapture methods provide data on population size useful for tracking changes in individual populations. For example, the 113 male *P. maculata* estimated present at Horseshoe Park in 1995 is not significantly different than the 136 males estimated at the same pond in 1988 (Corn and others 1997). However, the relatively large error involved in estimating size of *P. maculata* populations (mean CV of these 2 estimates = 15.5%), combined with large year-to-year variation in population size (mean number of males at Lily Pond, 1986 to 1997 = 98, CV = 39.5%; Corn, unpubl. data), means that the statistical power for evaluating small changes in population size is low. Intensive surveys require the greatest amount of expertise, and the time required to capture and mark individual frogs makes population estimation at a large number of sites impractical.

Moreover, population estimation is not the appropriate method for determining trends in the abundance of a species over a large area. Because of the inherent variability and small size of many populations, wide fluctuations and extinctions are normal occurrences (Pechmann and Wilbur 1994; Green 1997). A better indicator of whether a species is declining is the turnover rate of populations (gains minus losses of populations; Green 1997), which can be determined from data on presence and absence.

The goals of a study dictate the methods, and all of the techniques tested here are useful in specific circumstances (Table 4). The objectives of a prospective study will determine which methods are used. A study of individual species might employ a single technique, while a survey of amphibians in a given area (for example, a county or ranger district) might use call surveys and intensive searches to determine presence of all species. As area, time, and number of species increase, no single method can satisfy all requirements of the objectives and a combination of methods will be necessary.

Detecting long-term trends of several species requires an efficient means for determining presence or absence. Despite their limitations, manual call surveys are probably the most effective technique to detect anurans (but not salamanders) in areas such as northeastern and central North America (Shirose and others 1997; Mossman and others 1998). In addition, we suggest that a small network of frog-loggers would be useful to track breeding phenology

TABLE 4. Effectiveness of monitoring methods for collecting specific types of data and suitability for general study designs.

Data or study design	Frog-logger	Manual call survey	Intensive survey
Effectiveness			
Detecting species with audible calls	recommended	acceptable	acceptable
Detecting species with weak or no calls	inappropriate	inappropriate	recommended
Estimating abundance	poor	poor	recommended
Estimating relative abundance	poor	acceptable for some species	acceptable
Behavior and phenology	recommended	poor	poor
Reliability	acceptable	acceptable	recommended
Cost	expensive	affordable	expensive
Suitability			
Single species ecology / natural history	recommended	poor	recommended
Multiple species; small geographic area	recommended	acceptable	acceptable
Multiple species; large area	poor	acceptable	acceptable

(Fig. 2). These data can be used for quality control of each year's surveys to determine if they were conducted at appropriate times (Bishop and others 1997). Other regions pose problems that limit the usefulness of call surveys. In western North America, amphibian habitats are less abundant, road networks are sparse, availability of volunteers is questionable, and many species have weak calls that are not easily detected (NAAMP 1996b). In the southeastern United States, increased diversity of amphibians and extended breeding seasons pose severe complications for organizing a volunteer-based survey. In both cases, intensive methods and increased involvement of professionals and paid staff will likely be necessary for establishing successful long-term monitoring.

ACKNOWLEDGMENTS

This research was funded by the National Biological Service's Global Change Research Program. We thank Rocky Mountain National Park for permits and logistical support, T. Johnson and several Student Conservation Association volunteers who helped considerably in changing tapes, M. Hetrick and the U.S. Fish and Wildlife Service at the Rocky Mountain Arsenal Wildlife Refuge for changing tapes and logistical support, the U.S. Forest Service (Pawnee National Grassland and Arapaho-Roosevelt National Forest), and K. Pirani for data entry. We thank B. Bury, S. Droege, L. Shirose, and anonymous reviewers for comments and suggestions that improved the manuscript.

LITERATURE CITED

ANONYMOUS. 1995. Frog-logger: an automated recording system. Froglog 13:4.

BISHOP CA, PETIT KE, GARTSHORE ME, MACLEOD DA. 1997. Extensive monitoring of anuran populations using call counts and road transects in Ontario (1992–1993). In: Green DM, editor. Amphibians in decline: Canadian studies of a global problem. St. Louis, MO: Society for the Study of Amphibians and Reptiles. Herpetological Conservation 1. p 149–160.

BLAUSTEIN AR. 1994. Chicken little or Nero's fiddle? A perspective on declining amphibian populations. Herpetologica 50:85–97.

BLAUSTEIN AR, WAKE DB, SOUSA WP. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. Conservation Biology 8:60–71.

BOWERS DG, ANDERSEN DE, EULISS NH JR. 1998. Anurans as indicators of wetland condition in the Prairie Pothole region of North Dakota: an environmental monitoring and assessment program pilot project. In: Lannoo MJ, editor. Status and conservation of Midwestern amphibians. Iowa City, IA: University of Iowa Press. p 369–378.

CAMPER JD, DIXON JR. 1988. Evaluation of a microchip marking system for amphibians and reptiles. Austin, TX: Texas Parks and Wildlife Department. Research Publication 7100–159. 22 p.

CHRISTY MT. 1996. The efficacy of using passive integrated transponder (PIT) tags without anesthetic in free-living frogs. Australian Zoologist 30:139–142.

CORN PS, JENNINGS ML, MUTHS E. 1997. Survey and assessment of amphibian populations in Rocky Mountain National Park. Northwestern Naturalist 78:34–55.

DONNELLY MA, GUYER C, JUTERBOCK JE, ALFORD RA. 1994. Appendix 2: Techniques for marking amphibians. In: Heyer WR, Donnelly MA, McDiarmid RW, Hayek LC, Foster MS, editors. Measuring and monitoring biological diversity standard methods for amphibians. Washington, DC: Smithsonian Press. p 277–284.

GREEN DM. 1997. Perspectives on amphibian population declines: defining the problem and searching for answers. In: Green DM, editor. Amphibians in decline: Canadian studies of a global problem. St. Louis, MO: Society for the Study of Amphibians and Reptiles. Herpetological Conservation 1. p 291–308.

HAYES JP, STEIDL RJ. 1997. Statistical power analysis and amphibian population trends. Conservation Biology 11:273–275.

HEMESATH LM. 1998. Iowa's frog and toad survey, 1991–1994. In: Lannoo MJ, editor. Status and conservation of Midwestern amphibians. Iowa City, IA: University of Iowa Press. p 207–216.

HINE RL, LES BL, HELLMICH BF. 1981. Leopard frog populations and mortality in Wisconsin, 1974–1976. Madison, WI: Wisconsin Department of Natural Resources. Technical Bulletin 122. 39 p.

LEPAGE M, COURTOIS R, DAIGLE C, MATTE S. 1997. Surveying calling anurans in Quebec using volunteers. In: Green DM, editor. Amphibians in decline: Canadian studies of a global problem. St. Louis, MO: Society for the Study of Amphibians and Reptiles. Herpetological Conservation 1. p 128–140.

MEYER AH, SCHMIDT BR, GROSSENBACHER K. 1998. Analysis of three amphibian populations with quarter-century long time-series. Proceedings of the Royal Society of London B 265:523–528.

MOSSMAN ME, HARTMAN LM, HAY R, SAUER JR, HUEY BJ. 1998. Monitoring long-term population trends in Wisconsin frog and toad populations. In: Lannoo MJ, editor. Status and conservation of Midwestern amphibians. Iowa City, IA: University of Iowa Press. p 169–198.

[NAAMP] NORTH AMERICAN AMPHIBIAN MONITORING PROGRAM. 1996a. Protocols and strategies for monitoring North American amphibians. Internet WWW page at URL: <http://www.im.nbs.gov/amphib/naampintro.html>. Last updated 2 February 1996. Accessed 13 January 1998.

[NAAMP] NORTH AMERICAN AMPHIBIAN MONITORING PROGRAM. 1996b. Amphibian monitoring in western North America. Internet WWW page at URL: <http://www.im.nbs.gov/amphib/naampwest.html>. Last updated 2 February 1996. Accessed 14 January 1998.

[NAAMP] NORTH AMERICAN AMPHIBIAN MONITORING PROGRAM. 1997. Calling-amphibian surveys. Internet WWW page at URL: <http://www.im.nbs.gov/amphib/naampcall.html>. Last updated 21 April 1997. Accessed 13 January 1998.

OTIS DL, BURNHAM KP, WHITE GC, ANDERSON DR. 1978. Statistical inference from capture data on closed animal populations. Wildlife Monographs 62:1–135.

[PWRC] PATUXENT WILDLIFE RESEARCH CENTER. 1998. Variability estimates for local plant and animal populations. Internet WWW page at URL: <http://www.im.nbs.gov/powcase/powvariation.html>. Accessed 6 March 1998.

PECHMANN JHK, SCOTT DE, SEMLITSCH RD, CALDWELL JP, VITT LJ, GIBBONS JW. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892–895.

PECHMANN JHK, WILBUR HM. 1994. Putting amphibian declines into perspective: natural fluctuations and human impacts. Herpetologica 50:65–84.

PETERJOHN BG. 1994. The North American breeding bird survey. Birding 26:386–398.

PETERSON CR, DORCAS ME. 1994. Automated data acquisition. In: Heyer WR, Donnelly MA, McDiarmid RW, Hayek LC, Foster MS, editors. Measuring and monitoring biological diversity standard methods for amphibians. Washington, DC: Smithsonian Press. p 47–57.

PLATZ JE. 1989. Speciation within the chorus frog *Pseudacris triseriata*: morphometric and mating call analyses of the boreal and western subspecies. Copeia 1989:704–712.

REED JM, BLAUSTEIN AR. 1995. Assessment of "nondeclining" amphibian populations using power analysis. Conservation Biology 9:1299–1300.

SCOTT NJ JR., WOODWARD BD. 1994. Surveys at breeding sites. In: Heyer WR, Donnelly MA, McDiarmid RW, Hayek LC, Foster MS, editors. Measuring and monitoring biological diversity: standard methods for amphibians, Washington, D. C.: Smithsonian Press. p 118–125.

SHIROSE LJ, BISHOP CA, GREEN DM, MACDONALD CJ, BROOKS RJ, HELFERTY NJ. 1997. Validation tests of an amphibian call count survey technique in Ontario, Canada. Herpetologica 53:312–320.

THOMAS L. 1997. Retrospective power analysis. Conservation Biology 11:276–280.

THOMS C, CORKRAN, CC, OLSON DH. 1997. Basic amphibian survey for inventory and monitoring in lentic habitats. In: Olson DH, Leonard WP, Bury RB, editors. Sampling amphibians in lentic habitats: methods and approaches for the Pacific Northwest. Northwest Fauna 4:35–54.

VARHEGYI G, MAVROIDIS SM, WALTON BM, CONAWAY CA, GIBSON AR. 1998. Amphibian surveys in the Cuyahoga Valley National Recreation Area. In: Lannoo MJ, editor. Status and conservation of midwestern amphibians. Iowa City, IA: University of Iowa Press. p 137–154.

VERTUCCI FA, CORN PS. 1996. Evaluation of episodic acidification and amphibian declines in the Rocky Mountains. Ecological Applications 6:449–457.

Submitted 24 November 1998; accepted 29 September 1999. Corresponding Editor: D. H. Olson.