21

Monitoring Long-term Trends in Wisconsin Frog and Toad Populations

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Recent, possibly widespread declines in amphibian populations (Blaustein and Wake 1990) are disturbing because of the important roles of amphibians in many ecosystems. Moreover, their complex life cycles, insectivorous habits, permeable skin, and sensitivity to water chemistry in the egg and larval stages probably make them good bioindicators of environmental stress. There is little geographic or taxonomic pattern to the reported declines, some of which are from sites free from local anthropogenic disturbance. Causative factors are usually unknown and may be various, including habitat destruction, chemical contamination, introduction of predators, global climatic changes, acidic precipitation, or synergistic combinations of these factors (Blaustein and Wake 1990; Phillips 1990; Wyman 1990). Recent discoveries of malformed anurans, including at least seven species in fourteen Wisconsin counties (Dubois 1996), have heightened concern over amphibian populations.

Determining the nature, extent, and causes of amphibian population declines is hampered by a dearth of long-term population data. In fact, many reported declines have been based on local, short-term, or anecdotal evidence and may not reflect important or widespread problems. There is clearly a need for a coordinated system of research and monitoring that will determine and characterize significant population trends and identify causes (Blaustein and Wake 1990; Pechmann et al. 1991). This includes long-term population monitoring for a large number of species over wide areas that will identify changes in geographic ranges and distinguish regional and long-term trends from those that are local or short-term. Such a monitoring system could alert researchers and managers to species and regions in need of attention and suggest patterns or causes of declines. The North American Amphibian Monitoring Program (NAAMP) was initiated in 1994 (Mac 1996; NAAMP 1996) to investigate monitoring needs and methodologies and to suggest standards. For anurans, which advertise their presence during the breeding season with species-specific vocalizations, volunteer-based auditory surveys have been recommended by the NAAMP as the best monitoring method for most of the continent. Suggested standards for these surveys are still being modified, but the basic methodology is based on the long-running Wisconsin Frog and Toad Survey (WFTS).

The WFTS was initiated in 1981 in response to known and suspected declines in several frog species, especially bullfrogs (*Rana catesbeiana*), northern leopard frogs (*Rana pipiens*), pickerel frogs (*Rana palustris*), and Blanchard's cricket frogs (*Acris crepitans blanchardi*). Annual statewide coverage began in 1984. The primary purpose of the WFTS is to determine the status, distribution, and long-term population trends of the state's twelve species. Its secondary purpose is educational. In this chapter, we describe the WFTS and its analytical methods, sample adequacy, and results. We discuss logistical considerations for initiating and maintaining such a program, some of its values and limitations, and possible modifications.

Methods and Study Area

Survey Methodology

The WFTS, begun in 1981 by Ruth Hine of the Wisconsin Department of Natural Resources (WDNR), was based on the initial recommendations and audio instructional tape of Jansen and Anderson (1981). After three years of experimenting and gathering phenological data with the help and comments of several volunteers, Mossman and Hine (1984) standardized the criteria and procedures for the survey. The survey was patterned after the successful North American Breeding Bird Survey (BBS) (Robbins et al. 1986; Peterjohn et al. 1994) and relies on cooperators identifying each of the state's twelve anuran species by their characteristic breeding calls. Cooperators were enlisted through word of mouth, notices in newsletters and magazines, presentations at nature centers and meetings, and contact with reliable observers from other cooperative programs, such as the statewide black tern survey and the natural areas breeding bird survey. In subsequent years, cooperators were added from various sources, and beginning in 1992 WDNR wildlife managers routinely ran surveys or enlisted new cooperators. Initially, routes were established wherever cooperators were available, although poorly sampled areas of the state were increasingly targeted. In the early 1990s, WDNR biologists set a goal with the WFTS of establishing at least two routes in each county. Our current goal is to stratify coverage geographically according to ecoregions and sections established by the U.S. Forest Service (USFS).

By 1995, the survey included approximately 120 permanent roadside routes throughout the state. Each route comprises ten listening stations selected subjectively by a volunteer observer to be within hearing distance of wetlands that represent the range of local anuran breeding habitats, such as ephemeral ponds, lakes, meadows, marshes, and wooded swamps. Stations were located far enough apart that individual frogs could not be heard from more than one station. Depending on the local topography and vegetation characteristics, interstation distances were as close as about 400 meters, but were generally greater, usually on the order of 0.8 to 3 kilometers. Routes were run after sunset under favorable conditions (i.e., relatively warm air temperature, wind less than 13 kilometers, and preferably humid or after recent rains). Most routes were 15 to 40 kilometers long and took two to three hours to complete. At each station the observer listened for five minutes (or up to ten minutes if necessary due to noise interference) and recorded one of the following call index values for each species heard:

1 = individuals can be counted; there is space between calls
2 = calls of individuals are distinguishable, but some calls overlap
3 = full chorus; calls are constant, continuous, and overlapping

Because the annual calling period of each species is usually short and is different from the calling periods of other species, cooperators were asked to run each route a total of three times every year, once each during the following sampling periods:

Early spring = 8–30 April and when pond temperatures have reached 10°C
Late spring = 20 May–5 June and when pond temperatures have reached 15.5°C
Summer = 1–15 July and when pond temperatures have reached 21°C

Water temperatures were recorded where feasible and where they appeared to represent the conditions in which frogs call. Air temperature, wind speed (Beaufort scale), and sky condition were recorded at the beginning and end of each route. Cooperators were asked to comment on such things as changes in wetland conditions and problems with background noise and were encouraged to invite along at least one other reliable observer who could run the survey alone if the primary cooperator was unable to do so at some future time.

To avoid overlap with other routes, when a new route was established we sent the interested cooperator county maps of the area indicating the locations of previously established stations. We suggested that the cooperator run eleven or twelve stations during the first year and then select as permanent stations the ten with the least noise interference or access limitations—problems that were not always initially apparent. The cooperator then returned a county road map with the stations indicated, and we sent back photocopies of the appropriate 7.5' topographic maps on which to mark the exact locations. These photocopies were returned to us along with narrative and legal descriptions of each station location and a general description of nearby wetlands. We checked these for accuracy and clarity and made three clear sets of the route description and of the appropriate topographic and county maps with the station locations marked on them. New cooperators were asked to purchase (at cost) a copy of Jansen and Anderson's (1981) instructional audio cassette tape of anuran breeding calls from the Madison Audubon Society. There were no formal training sessions. People interested in initiating a new route were usually asked first to go along on a previously established route with an experienced cooperator.

Every year in late March we sent each cooperator the appropriate route description and a set of topographic and county route maps, along with standard instructions and information on the natural history, distribution, and identification of each species (including range dot maps from Vogt 1981); two data sheets (Fig. 21-1); a form letter that included news on the survey and other amphibian matters (e.g., discussing a common problem that cooperators had noted or that we had in interpreting data, with recommended solutions); a report on coverage and trends through the previous year (sometimes this was not sent until later in the year); a self-addressed, stamped return envelope; and often photocopies of recent popular or semipopular articles on amphibians. Sometimes we included a personal note or made contact via telephone or e-mail in response to a cooperator's question or problem. The instructional materials, route maps and descriptions, and a completed data sheet were returned to us at the end of the season. A postcard was sent to all cooperators in the fall as a reminder to return data. For a more complete description of the survey methods and sample instructional materials and route description, see Mossman and Hine (1984).

Returned data were checked for accuracy and entered into an SAS computer databank. Records of state-endangered Blanchard's cricket frogs were accepted only with documentation, such as photographs, recordings, or specimens, and documentation was requested for records that were extralimital according to Vogt's (1981) maps. Dubious records or those from far outside the recommended survey periods and temperature ranges were flagged and not used in most analyses; during seasons with a particularly early or late phenology, and based on observer comments, some exceptions were made. In fact, in 1989 we lengthened the first survey period, shifting the starting date from 15 April to 8 April (and allowing even earlier surveys when necessary), because several observers in southern counties believed they were missing wood frogs (*Rana sylvatica*) during years when spring arrived early. For most of the dubious records, we tried to contact the observer to verify that a mistake was not made in entering data onto the data sheet, to ask for verification for that or future records of the same species, or to encourage the cooperator to take special care in recording the species in the future.

All routes are considered permanent. Changes have been allowed only during the first few years of a route's history (in which case the earlier years' data were not used in trend analyses) or on rare occasions when an insurmountable access problem developed or background noise at a particular station increased to the point that results were not comparable with earlier years. These cases were resolved by one of three options: the cooperator replaced the station with another one as similar as possible to the original, the route was abandoned, or the route was changed without regard to similarity to the original and treated as a new route.

During the first few years of the WFTS, we used survey data to examine geographic distributions and to investigate the relationships among call index values, water and air temperatures, and dates. To help with the latter issue, several cooperators conducted surveys at frequent (one-to-ten-day) intervals throughout one or more seasons and years at a single station close to their home. Cooperator Ron Eckstein did this at one site every year during 1983 through 1996. We include his data for 1996 (although we report on trend analysis only through 1995) because phenologically it was instructive as an extremely late year.

Analysis

We used several regression techniques to measure population trends for individual species. Analyses from four techniques are reported here. Three of these techniques were developed recently with the support of the U.S. Geological Survey's Biological Research Division (BRD; formerly known as the National Biological Service), based on their procedures for determining trend "estimating equations" for BBS data (Link and Sauer 1994). In these techniques, a particular route was considered completed for a particular species in a particular year only if it was run during the seasonal sampling period that corresponded to the species' peak calling period (Table 21-1). That is, data from the early spring sampling period were used only for wood frogs, northern spring peepers (*Pseudacris crucifer crucifer*), western and boreal chorus frogs (*Pseudacris triseriata triseriata* and *P. t. maculata*, respectively), leopard frogs, and pickerel frogs. If this was the only period in which a particular route was run during a particular year, then the data were used for computing only these trends. Likewise, data from the late spring period were used to calculate trends for American toads (*Bufo americanus americanus*) and both species of treefrogs (eastern [*Hyla versicolor*] and Cope's [*Hyla chrysoscelis*]), and data from the sum-

WISCONSIN FROG AND TOAD SURVEY -- Field Data Sheet
Bureau of Endangered Resources
Department of Natural Resources
Box 7921, Madison, WI 53707

Observer name(s), RUN 1 ________________ Route No. ________
(Add address and phone on back.) RUN 2 ________________ Year ________
RUN 3 ________________ County ________

INSTRUCTIONS: Use this form for new or established survey routes. Each route consists of 10 listening sites, and is repeated 3 times during the breeding season, according to the minimum water temperatures and approximate range of dates given below for each survey period. Run surveys after dark, when wind velocity is less than 8 mph. Listen 5-10 minutes at each site and record a call index value of 1,2, or 3 (see below) for each species calling. See back of sheet for wind and sky codes and additional comments. Return to above address by 15 August.

FIRST RUN Water 50°F; 15-30 April
BEGIN: Date / Time: / Wind: Sky: / Air temp. (F): — END: Time: / Wind: Sky: / Air temp. (F):

SITE NAME	Site Number	Water Temp (F)	Wood frog	Chorus frog	Spring peeper	Leopard frog	Pickerel frog	Am. toad	E. gray tree frog	C. gray tree frog	Cricket frog	Mink frog	Green frog	Bullfrog
1.	1.													
2.	2.													
3.	3.													
4.	4.													
5.	5.													
6.	6.													
7.	7.													
8.	8.													
9.	9.													
10.	10.													
For office use only — Mean														
For office use only — Freq.														

CALL INDEX*

SECOND RUN Water 60°F; 20 May - 5 June
BEGIN: Date / Time. / Wind: Sky: / Air temp. (F): — END: Time: / Wind: Sky: / Air temp. (F):

SITE NAME	Site Number	Water Temp (F)	Wood frog	Chorus frog	Spring peeper	Leopard frog	Pickerel frog	Am. toad	E. gray tree frog	C. gray tree frog	Cricket frog	Mink frog	Green frog	Bullfrog
1.	1.													
2.	2.													
3.	3.													
4.	4.													
5.	5.													
6.	6.													
7.	7.													
8.	8.													
9.	9.													
10.	10.													
For office use only — Mean														
For office use only — Freq.														

CALL INDEX*

THIRD RUN Water 70°F; 1-15 July
BEGIN: Date / Time: / Wind: Sky: / Air temp. (F): — END: Time: / Wind: Sky: / Air temp. (F):

SITE NAME	Site Number	Water Temp (F)	Wood frog	Chorus frog	Spring peeper	Leopard frog	Pickerel frog	Am. toad	E. gray tree frog	C. gray tree frog	Cricket frog	Mink frog	Green frog	Bullfrog
1.	1.													
2.	2.													
3.	3.													
4.	4.													
5.	5.													
6.	6.													
7.	7.													
8.	8.													
9.	9.													
10.	10.													
For office use only — Mean														
For office use only — Freq.														

*The call index is a rough estimate of the numbers of calling males of a particular species, according to the following index values:

1 Individuals can be counted; there is space between calls.
2 Calls of individuals can be distinguished but there is some overlapping of calls (intermediate between "1," and "3").
3 Full chorus. Calls are constant, continuous and overlapping.

Figure 21-1. Data sheet for Wisconsin Frog and Toad Survey.

Table 21-1. Sampling periods required for each species in Wisconsin Frog and Toad Survey analyses. I = early spring, II = late spring, III = summer.

	Trend Analysis Technique	
Species	Route Regressions (single period)	Percent Occurrence (combined period)
Wood frog (*Rana sylvatica*)	I	I
Chorus frog (*Pseudacris triseriata*)	I	I and II
Northern spring peeper (*Pseudacris crucifer crucifer*)	I	I and II
Northern leopard frog (*Rana pipiens*)	I	I and II
Pickerel frog (*Rana palustris*)	I	I and II
American toad (*Bufo americanus americanus*)	II	II
Eastern gray treefrog (*Hyla versicolor*)	II	II
Cope's gray treefrog (*Hyla chrysoscelis*)	II	II
Blanchard's cricket frog (*Acris crepitans blanchardi*)	III	II and III
Mink frog (*Rana septentrionalis*)	III	III
Green frog (*Rana clamitans melanota*)	III	III
Bullfrog (*Rana catesbeiana*)	III	III

mer period were used for Blanchard's cricket frogs, mink frogs (*Rana septentrionalis*), green frogs (*Rana clamitans melanota*), and bullfrogs. For each route an index to abundance was computed for each species in each year. In the route frequency regression technique, the number of stations of occurrence was added (range = 0 to 10). The route index regression technique summed the index values from each station (range = 0 to 30). In the route adjusted-index regression technique, we arbitrarily assigned to each call index value a number that we believed better estimated the relative abundance of animals represented by that value (call index 1 equals three calling males, call index 2 equals twenty-five calling males, call index 3 equals fifty calling males); these values were then summed for each route as in the preceding technique (range = 0 to 500).

Trends for each route were then computed by using estimating equations, regressing the appropriate dependent variable (frequency, summed index values, or summed adjusted index values) on year, and these trends were averaged for all routes in each ecoregion, expressed as mean annual percent change for that ecoregion. Before averaging, however, the trend for each species on each route was weighted according to the relative abundance of the species on that route (routes with a high average frequency of occurrence or high mean index value contributed more to the estimated ecoregional trend than did routes in which the species was less common) and an estimate of the variance in the trend estimate (routes in which the trend was precisely estimated contributed more than routes in which the trend was imprecise). The mean trend for each ecoregion was then weighted according to the area of that ecoregion, and these weighted means were averaged to produce a standard trend (Geissler and Sauer 1990).

The fourth technique, percent occurrence, was used early in the WFTS program, and although trends are calculated by a much less sophisticated manner than in the route regression techniques, the data selection procedure was more complicated. Even though each species' calling period usually peaks within one of the three sampling periods, some species are also frequently recorded in another period. Thus, a particular species may be more detectable at individual ponds in either period in a given year; this is presumably because of annual and geographic variations in phenological progression, differences in water temperatures between different ponds (even within a given route), and the effects of different environmental conditions on different survey nights. A species whose main calling period often spans two survey periods is treated as follows for each route in each year: the call index at each of the ten stations is compared between the two periods ("combined period" data, Table 21-1), and the largest value is selected for analysis. Data are not used when only one of the required survey periods was sampled. In other techniques of analysis (not described here), these maximum station-index values were used to calculate trends, but in the percent occurrence technique, these are reduced to presence or absence for each station, and the stations of presence are summed and expressed as a percentage of all stations surveyed statewide that year. These annual percentages are regressed on year, and the slope is compared to zero by using a t-test. Trends are expressed as mean annual change in percent occurrence.

We also ran the three route regression analyses on combined-period data.

A power analysis was used to measure the statistical ability of the WFTS to detect population trends at various levels of certainty over various time periods (Mossman et al. 1996). Power analyses consider variables such as number of routes, counts per route, count variance, duration of monitoring, and interval between monitoring events to evaluate the statistical ability (power) of a monitoring program to detect trends in species abundance, given that a trend actually occurs. A power level of 75 percent, for example, indicates that if a nonzero trend actually exists, the trend analysis is expected to detect this trend in at least 75 percent of cases (i.e., a 25 percent chance of committing a type II error but not rejecting a false null hypothesis). Power depends on the alpha level of the test, which sets the probability of falsely rejecting a null hypothesis. An alpha level of $p < 0.1$ means that when the analysis detects a nonzero trend, it will be associated with true zero trend (type I error) about 10 percent of the time. In our power analyses we used eleven years of data (1984 to 1995) and the statistical methodology described by Sauer (1996). That is, given the variability in the WFTS data set for a particular species, we estimated how many routes would be needed to detect, for example, a mean annual change of 3 percent over a period of ten years or a mean annual change of 1 percent over a twenty-year period. The analysis was run on many combinations of precision parameters, including 1, 2, 3, and 5 percent annual mean changes, ten-year and twenty-year periods, and various levels of power and alpha.

To compare population trends with drought conditions that might affect habitat availability or quality, we used the Palmer Drought Severity Index—a monthly index based on soils and on current and previous precipitation and temperatures (Palmer 1965). Data for the nine Wisconsin climatological regions were acquired from the state climatologist.

In 1987, we mailed cooperators a questionnaire requesting information on occupation, age, experience with amphibians prior to joining the WFTS, how they learned about the WFTS, why they joined the WFTS, what has maintained their interest, and comments on techniques, data forms, instructional materials, reports, coordination, and any other topics.

Ecoregions

We stratified our data and report our results according to the six ecoregional sections found in Wisconsin (McNab and Avers 1994; Keys et al. 1995) and additionally separated the Central Sands from the remainder of southeastern Wisconsin. For brevity, we called these "regions" and have abbreviated their names (Fig. 21-2; Table 21-2).

The Northwest Forest region mostly comprises extinct glacial lake beds with sandy or peaty soils and is dominated by pine and oak barrens and woods, some more mesic forest, and relatively nonintensive agriculture. This region has numerous lakes, streams, marshes, and bogs. The large North-central Forest region is mostly forested with northern hardwoods, although nonintensive agricultural land is scattered and more intensive agriculture dominates some southern parts. Much of this region is on Precambrian shield overlain by morainal deposits and sandy outwash; lakes and bogs are common. The Eastern Forest region was historically dominated by mesic maple, beech, and pine forests, with