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Douglas H. Johnson
USGS Northern Prairie Wildlife Research Center, Douglas_H_Johnson@usgs.gov

Ronald D. Batie
USGS Northern Prairie Wildlife Research Center

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Surveys of Calling Amphibians in North Dakota

DOUGLAS H. JOHNSON and RONALD D. BATIE[1]

U.S. Geological Survey
Northern Prairie Wildlife Research Center
Jamestown, North Dakota

ABSTRACT --Amphibians have received increased attention in recent years from the scientific community and general public alike. Many populations throughout the world have declined or have been extirpated, often without an apparent cause. Concern about the status of amphibians has translated into a growing interest in systematic and statistically sound monitoring programs. Several extensive efforts to monitor populations of calling amphibians are in place, and more are under development. Necessary for the design of appropriate surveys is an understanding of the behavior, especially vocalization, of the various species, and how it varies by geographic location and environmental conditions. In 1995 we conducted roadside surveys of calling amphibians along 44 routes in North Dakota. We describe results of that survey, with special attention given to variables that influence detectability of calling amphibians. Unlike similar studies, we accounted for the amount of time observers spent listening for amphibians under different conditions. We found that the optimal conditions for a single survey for North Dakota in that year would be in early June, between the hours of 2300 and 0130, with ambient temperatures above 13° C, and with no rain and little or no wind or moonlight. Multiple surveys in a year would yield better results, of course, especially for the wood frog (*Rana sylvatica*), which is most active earlier in the season. Studies such as ours should be replicated in space and time to ensure a well-designed survey.

Key words: amphibians, anurans, calling surveys, frogs, North Dakota, toads.

Concern about the status of amphibian populations has heightened in the past several years, due in part to the realization that many populations throughout the world

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[1] Current address: 12948 Mueller Drive, Groveland CA 95321.

have declined, or even have been extirpated, often without an apparent, proximate cause (Barinaga 1990, Blaustein and Wake 1990, Phillips 1990, Wyman 1990, Wake 1991). In light of population declines in many species of amphibians, we need to gain a better understanding of their status. However, the wide natural fluctuations in numbers of many amphibians complicate the detection of long-term trends and identification of causes of population change (Pechmann et al. 1991). Amphibians may display metapopulation dynamics, with decreases in some local population units coinciding with increases in others, which complicates the detection of true long-term population declines (Gill 1978, Hayes and Jennings 1986, Sjögren 1991, Johnson and Larson 1994, Pechmann and Wilbur 1994).

Clearly, we need widespread, systematic, and statistically sound monitoring programs (Wake 1991, Blaustein 1994, Heyer et al. 1994). Monitoring methods need to be standardized in order to ascertain population trends reliably. Development of a reliable and extensive monitoring program will require, in addition to adherence to statistical principles of survey design, an understanding of the biology of the species. Information on the behavior of the various species of calling amphibians, and how it varies by geographic location and environmental conditions, is necessary for broad-scale surveys such as the North American Amphibian Monitoring Program (Weir and Mossman, in press).

The most extensive monitoring has been attempted in eastern North America, beginning with the pioneering effort in Wisconsin (Mossman et al. 1998). Amphibian populations in the northern Great Plains have received relatively little attention, population monitoring or otherwise. An early monograph (Wheeler and Wheeler 1966) provided keys and distributional information on North Dakota populations. Hoberg and Gause (1992) presented a popular guide, indicating counties where each species had been collected or was considered probable.

In 1995 we conducted roadside surveys of calling amphibians (Zimmerman 1994). These are somewhat analogous to the Breeding Bird Survey (Robbins et al. 1986), which has proven very effective for monitoring populations of many avian species over large areas. Our objective was to understand better some of the variables that influence the detectability of calling amphibians in the northern Great Plains.

Other studies that evaluated effects of certain explanatory variables on calling activities of anurans typically did not fully account for differences in amounts of time spent monitoring under different conditions. We overcame that deficiency by reporting the frequency of detections relative to the monitoring effort expended under specified conditions.

STUDY AREAS

We used a systematic sample of areas in North Dakota east and north of the

Missouri River (Fig. 1). That region contains a large number of depressions, called prairie potholes, which contain water for various lengths of time in most years and support a diversity of wetland-dependent wildlife (Johnson 1996). The sample areas had been chosen for other studies, which were designed to develop and test methods of monitoring environmental quality in the Prairie Pothole Region (Peterson et al. 1996). The sample areas were 44 hexagons, each 40 km^2 in size (Fig. 1).

Within each hexagon, we selected a route consisting of secondary or tertiary roads, to avoid interference from traffic on more heavily traveled roads. We endeavored to sample from throughout the hexagon. Stations were located at 0.8-km (0.5-mile) intervals along the route, usually at section lines or half-section lines. We tried to make routes continuous and at least 16 km long, but limited road networks in some areas precluded meeting these criteria. Actual route lengths ranged from 11 to 23 km. Because of heavy precipitation preceding and during the survey period, roads were frequently washed out, which necessitated altering routes to reach certain stations.

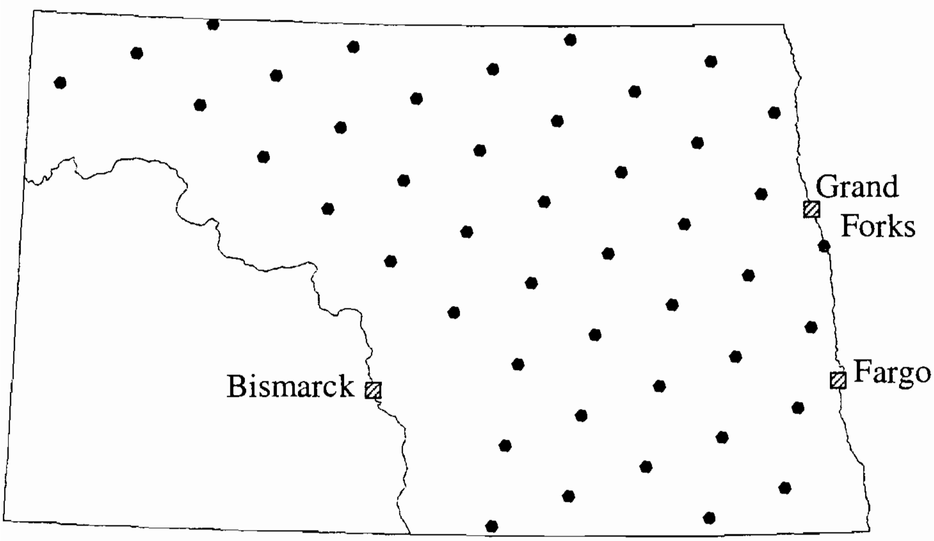

Figure 1. Study areas in which roadside surveys of calling amphibians were conducted during 1995 in North Dakota.

METHODS

Surveys were conducted by a single observer (RDB) between 4 May and 30 June 1995. He typically began each survey at about sunset and continued until early morning. Again, weather conditions often required some deviations from planned schedules.

At each station along a route, the observer spent 10 minutes and recorded both birds and calling amphibians. Abundances of calling amphibians were categorized, from a single individual calling to full chorus at high intensity, but in our analysis we considered only presence/absence. Shirose et al. (1997) found that most anuran species were detected during the first two minutes of 30- or 60-minute survey periods. At the beginning and end of each route, the observer recorded temperature, relative humidity, wind speed, cloud cover, precipitation, and moonlight. For analysis by station, estimates of those variables at a station were made by linear interpolation in time from the recordings at the first and last stations. For the categorical variables, wind speed, and cloud cover, we first converted coded values to their midpoints of intervals (Table 1), then interpolated, and finally converted back to nearest coded values.

We compared the proportion of observations that were made under specified conditions (e.g., temperature and time of day) to the proportion of time spent by the observer conducting surveys under those conditions. This latter quantity would equal the proportion of observations expected under the specified conditions, if detections occurred independently of those conditions. For each species, we excluded from analysis routes outside the geographical ranges presented by Hoberg and Gause (1992), unless we detected the species in a hexagon outside that range. In that case, we also included that hexagon.

We compared our results to those from five other sources. Bowers (1998; also see Bowers et al. 1998) conducted similar surveys in 21 of the same sample units in North Dakota in 1995 and 1996, by using both roadside transects and survey points adjacent to wetlands. Blasus (1997) presented a timetable for amphibians in Minnesota, which indicated when individual species called most frequently. Mossman et al. (1998) described results from the Wisconsin frog and toad survey. Sargent (1997) presented results, including phenological information, from the Michigan frog and toad survey. For our purposes, we compared her results for the Upper Peninsula, which is similar in latitude to North Dakota. Bishop et al. (1997) reported on results of extensive monitoring of anurans in Ontario. They provided some comments on seasonal phenologies of the species encountered and variation in detections according to time of night, air temperature, wind speed, and precipitation.

Table 1. Codes used for explanatory variables.

Wind speed: Beaufort scale	
0	Smoke rises vertically (<1.6 km/h)
1	Wind direction shown by smoke drift (1.6- 4.8 km/h)
2	Wind felt on face, leaves rustle (4.9-11 km/h)
3	Leaves and small twigs in constant motion; light flag extended (12-19 km/h)
4	Raises dust and loose paper; small branches are moved (20-29 km/h)
Cloud Cover	
0	Clear or a few clouds (<10% cover)
1	Partly cloudy (10-25% cover)
2	26-50% cover
3	51-75% cover
4	Mostly cloudy, fog, or mist (>75% cover)
Precipitation	
0	None
1	Drizzle
2	Light rain
3	Showers
Moonlight	
0	None, new moon, or blocked by cloud cover; difficulty in seeing directly in front of you without a light
1	Some light from waxing or waning moon; not enough to comfortably navigate in the dark
2	Reasonably bright, near full moon, or light reflecting off clouds; able to navigate, but not able to differentiate objects well
3	Bright, full moon; able to see shapes of objects well
4	Dusk; still enough daylight to see objects at station

RESULTS and DISCUSSION

In our survey we encountered eight of the nine anurans known to occur in North Dakota: plains spadefoot (*Spea bombifrons*), Canadian toad (*Bufo hemiophrys*), Woodhouse's toad (*B. woodhousii*), Great Plains toad (*B. cognatus*), gray treefrog (*Hyla versicolor*), boreal chorus frog (*Pseudacris maculata*), northern leopard frog (*Rana pipiens*), and wood frog (*R. sylvatica*). We did not record the American toad (*B. americanus*), which occurs uncommonly in the eastern third of North Dakota (Hoberg and Gause 1992)

For analyses of features that might influence the detection of calling amphibians, we concentrated on the five species that were recorded at more than 10 stations (Table 2), but describe conditions under which the three uncommon species were recorded (Table 3).

Seasonal effect

Plains spadefoots were documented mostly in late May, and once in mid June (Table 3). We recorded Canadian toads in both early and late June (Fig. 2). In contrast, Blasus (1997) indicated that calling of Canadian toads in Minnesota terminates in mid June. We recorded Woodhouse's toads and Great Plains toads more frequently than expected in late May through early June (Fig. 2). Bowers (1998) showed calling activity of Woodhouse's toads varied irregularly from mid May until the beginning of July. She detected Great Plains toads most commonly from late May through June. Blasus (1997) noted the calling period of Great Plains toads to be mid May to mid July, a period that encompasses all of our records.

Boreal chorus frogs were heard more often than expected in our surveys throughout May, and less often in June. Bowers (1998) detected them throughout her surveys. For Minnesota, Blasus (1997) indicated the calling period of chorus frogs (boreal and western, *P. triseriata*, combined) to be March to early May. Western chorus frogs (*P. triseriata*) were recorded more frequently in Wisconsin during the early survey period (15 - 30 April; Mossman et al. 1998). In northern Michigan, western chorus frogs were most frequently detected in May (Sargent 1997).

Table 2. Number of transects and stations at which calling amphibians were recorded in surveys in North Dakota during 1995, and number of transects and stations that lie within ranges of species.

	Transects		Stations	
Species	Recorded	In range	Recorded	In range
Plains spadefoot	3	17	6	345
Woodhouse's toad	6	17	42	332
Great Plains toad	12	35	126	706
Canadian toad	4	44	11	896
Gray treefrog	1	10	2	204
Northern leopard frog	6	44	14	896
Wood frog	1	44	1	896
Boreal chorus frog	38	44	587	896

Table 3. Conditions under which the three uncommon species of calling amphibians were recorded in North Dakota surveys during 1995. See Table 1 for codes.

Species	Wind	Cloud	Humidity (%)	Precipitation	Moon	Temperature (°C)	Time	Date
Plains spadefoot	4	2	90	2	2	10	0030	23 May
Plains spadefoot	0	3	80	0	1	16	2330	29 May
Plains spadefoot	0	2	80	0	0	13	2400	29 May
Plains spadefoot	0	2	80	0	0	13	0030	29 May
Plains spadefoot	0	1	90	0	0	10	0200	29 May
Plains spadefoot	0	4	70	0	4	24	0030	15 June
Gray treefrog	1	4	90	0	0	18	2330	26 June
Gray treefrog	1	3	90	0	0	18	2400	26 June
Wood frog	0	2	90	0	0	4	0130	22 May

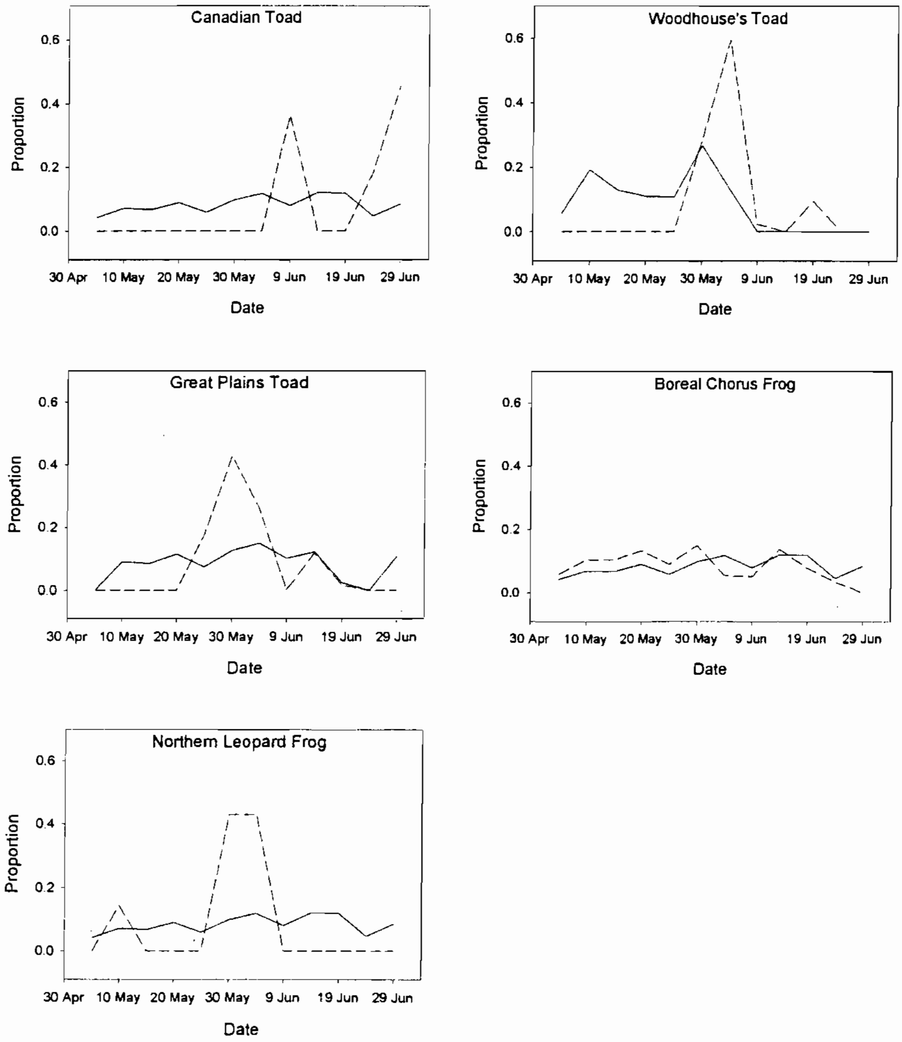

Figure 2. Proportion of all detections of calling amphibians (dashed line) and proportion of time spent surveying in species' range (solid line) plotted against date within season.

We recorded northern leopard frogs more frequently than expected in late May through early June. Bowers (1998) found northern leopard frogs irregularly from mid April through May, and rarely in late June and early July. Blasus (1997) noted the calling period of northern leopard frogs in Minnesota to be late April to mid June. In Wisconsin, northern leopard frogs were recorded more frequently in late April surveys than in surveys in late May or later (Mossman et al. 1998). In northern Michigan, northern leopard frogs in one year were heard most commonly in early May, and in another year were detected infrequently but steadily from early May through mid July. Bishop et al. (1997) indicated that the peak period for northern leopard frogs in Ontario was from 1 April or earlier to 31 May.

The only occurrence of wood frogs in our survey was on 22 May. Bowers (1998) found wood frogs only in late April and early May. Records from our study and Bowers (1998) are later than the interval of late March to late April given for Minnesota (Blasus 1997). In Wisconsin, wood frogs were detected in late-April surveys (Mossman et al. 1998). For northern Michigan, the species was most common in early surveys (late April) and declined steadily through mid to late May (Sargent 1997). Bishop et al. (1997) listed peak calling period as 1 April to 17 May for wood frogs in Ontario.

The only (two) records of gray treefrogs in our surveys were on 26 June (Table 3). Bowers (1998) found gray treefrogs in late May through mid June. Blasus (1997) indicated the calling period for that species in Minnesota to be May through June. In Wisconsin, gray treefrogs were noted from late May through June (Mossman et al. 1998). For northern Michigan, periods of peak calling activity were early to mid June in one year, and late May through late June in another year (Sargent 1997). Bishop et al. (1997) indicated the peak calling period for gray treefrogs as 9 May to 8 July.

Time of night

We noted plains spadefoots between 2330 and 0200 hours (Table 3). Canadian toads had a clear calling peak at about 2400 hours (Fig. 3). Woodhouse's toads were heard more frequently from about 2300 to 0130 hours, after which calling diminished; results of Bowers (1998) were similar. Great Plains toads followed a similar pattern, except they began calling slightly earlier; Bowers (1998) detected them calling regularly between 2130 and 0130 hours.

Gray treefrogs were heard only at 2400 hours or just before (Table 3). Conversely, Bowers (1998) detected them from sunset until four hours later. Boreal chorus frogs called independently of time of night; observations closely matched the proportion of time spent doing the survey (Fig. 3). Bowers (1998) recorded boreal chorus frogs calling during all time periods. Northern leopard frogs were detected somewhat more frequently than expected from 0030 to 0130 hours, after which time they were not detected. Bowers (1998) noted them from sunset for about 3.5 hours. We heard wood frogs only once, at 0130 hours (Table 3), which was later than when

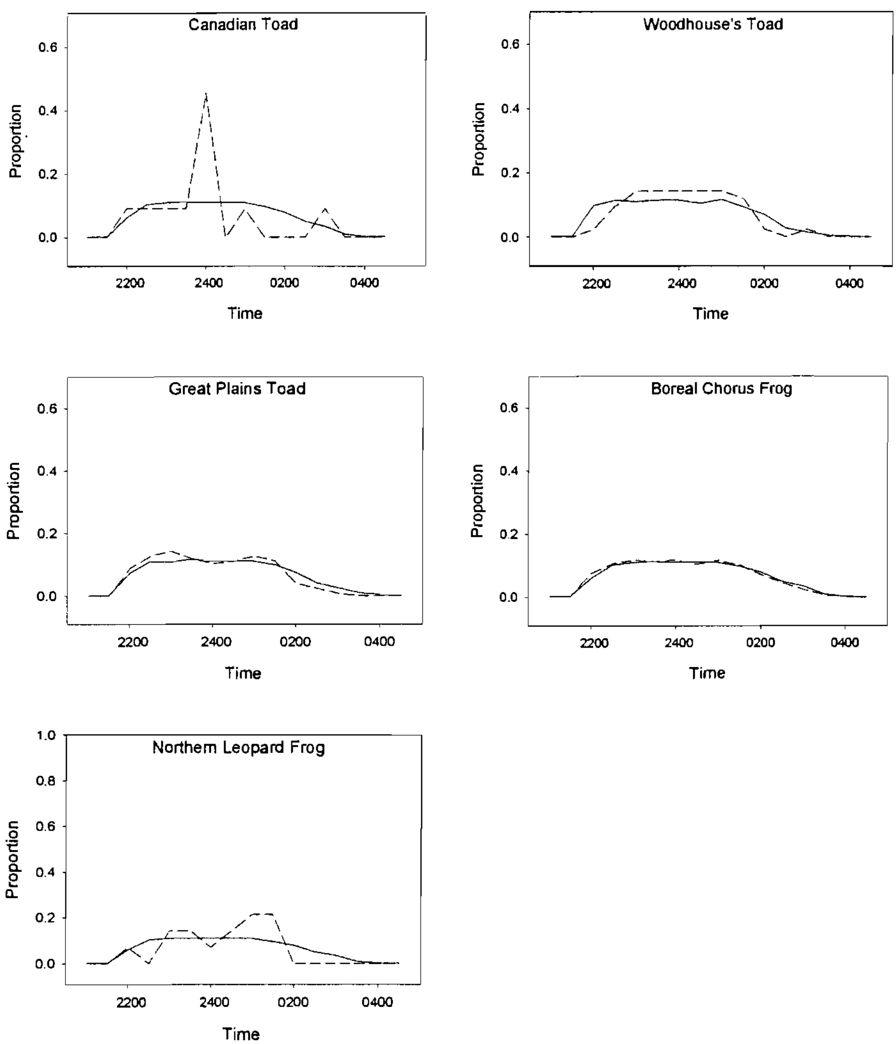

Figure 3. Proportion of all detections of calling amphibians (dashed line) and proportion of time spent surveying in species' range (solid line) plotted against time of night.

Bowers (1998) detected them.

Temperature

Plains spadefoots were detected calling at a variety of temperatures (10° - 24° C; Table 3). Farrar and Hay (1998) noted that in Iowa their breeding periods were linked to rainfall and temperature, with the breeding periods following locally heavy rains and temperatures about 21° C. The only departure from expected for Canadian toads was that they seemed most active at temperatures near 20° C (Fig. 4). Woodhouse's toads also seemed more active at temperatures of about 18° to 21° C. Bowers (1998) found that Woodhouse's toads called at cooler temperatures in 1995 than in 1996. Great Plains toads called more than expected when temperatures were 15° C or above, and less than expected at lower temperatures. In contrast, Bowers (1998) indicated that Great Plains toads called more actively when temperatures were between 12° and 23°C.

Gray treefrogs were recorded when temperatures were near 18° C (Table 3). Bowers (1998) indicated that gray treefrogs called more frequently at temperatures 18° C and above. Shirose et al. (1997) noted that a hot, dry period in June interrupted the breeding activity of gray treefrogs in Ontario. We recorded boreal chorus frogs slightly more frequently when temperatures were below 12° C, but they were heard at all temperatures encountered; Bowers (1998) suggested that activity declined uniformly with temperatures above about 15° C. Northern leopard frogs were detected more commonly at temperatures of about 15° to 20° C. Bowers (1998) found them when temperatures were between 5° and 20° C. Wood frogs were heard when the temperature was only 4° C; Bowers (1998) also noted more calling at lower temperatures (1° - 10° C).

Humidity

No effect of humidity was apparent for Woodhouse's toads, Great Plains toads, boreal chorus frogs, or northern leopard frogs (Fig. 5). Canadian toads were heard more frequently than expected when the relative humidity exceeded 85%, and gray treefrogs and wood frogs were encountered only when the humidity was 90% or above. Bowers (1998) indicated that Woodhouse's toads and northern leopard frogs called more frequently when humidity was below 65%, Canadian toads and chorus frogs seemed unaffected by humidity in her study, and the other two species' calling activities peaked between 45 and 60% humidity.

Precipitation

Precipitation seemed not to influence markedly detections of any species (Fig. 6), but calling by all species was slightly more frequent than expected when rain was absent. Bishop et al. (1997) had some limited evidence that gray treefrogs were detected more often during rain.

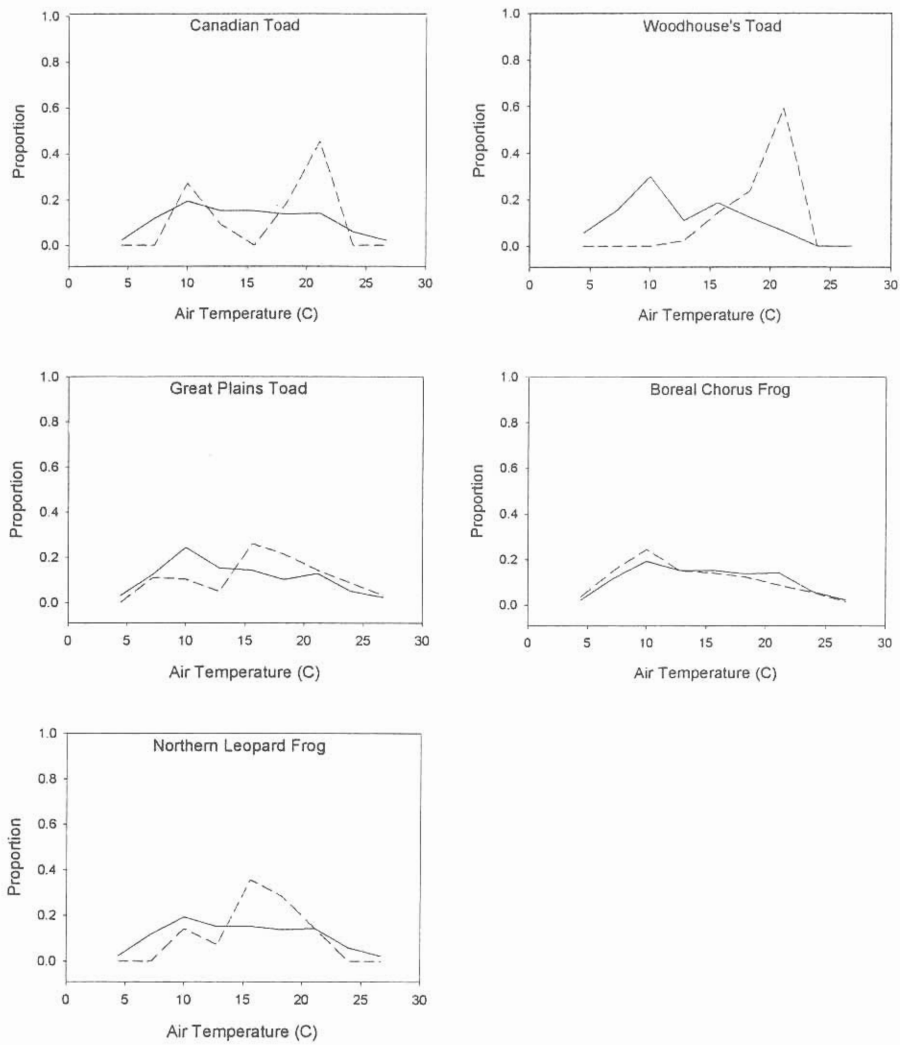

Figure 4. Proportion of all detections of calling amphibians (dashed line) and proportion of time spent surveying in species' range (solid line) plotted against air temperature.

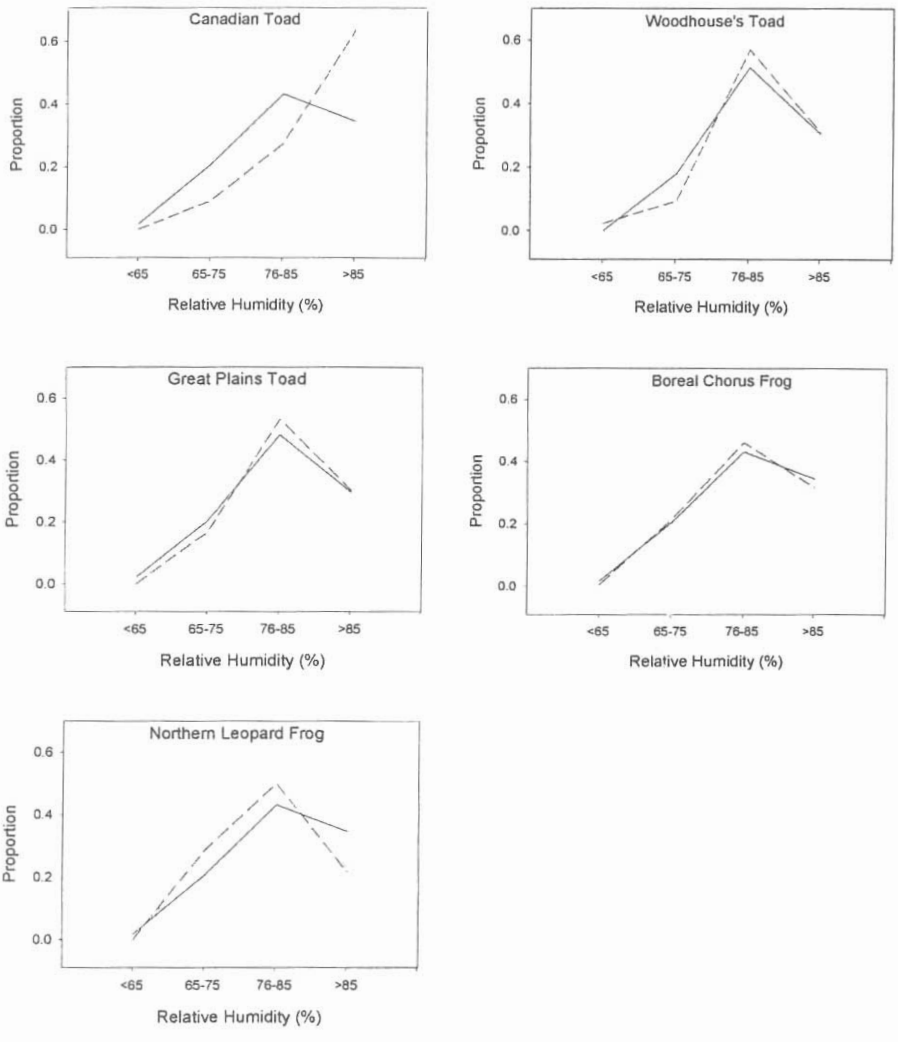

Figure 5. Proportion of all detections of calling amphibians (dashed line) and proportion of time spent surveying in species' range (solid line) plotted against relative humidity.

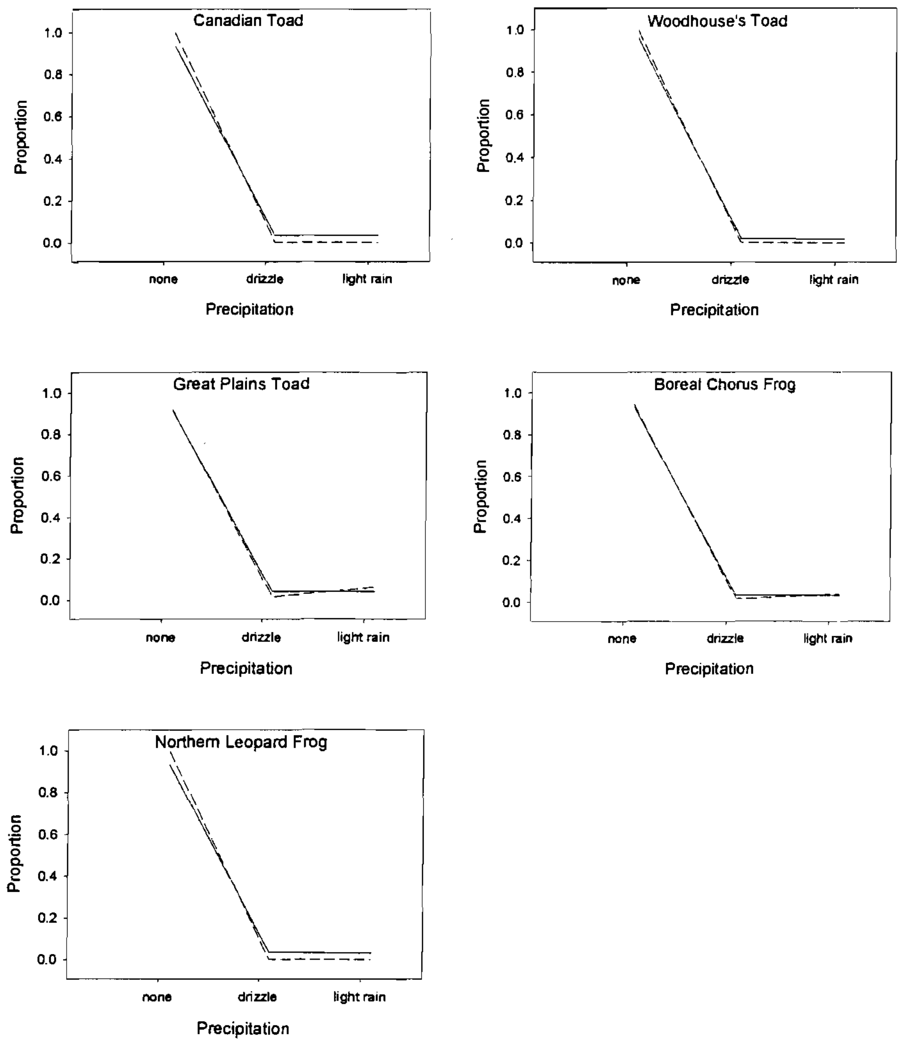

Figure 6. Proportion of all detections of calling amphibians (dashed line) and proportion of time spent surveying in species' range (solid line) plotted against precipitation.

Wind speed

Plains spadefoots were recorded mostly under calm conditions, but were detected once when the Beaufort value was 4 (Table 3). Calling of Canadian toads and Woodhouse's toads was not correlated clearly with wind speed (Fig. 7). Great Plains toads were detected more frequently when winds were still, and less frequently when the Beaufort scale reading exceeded 1. Gray treefrogs were detected only at a Beaufort reading of 1 (Table 3). Boreal chorus frogs generally were not influenced by wind speed, except for a minor drop-off at Beaufort 4; Bishop et al. (1997) detected a similar pattern for spring peepers (*Pseudacris crucifer*). Northern leopard frogs and wood frogs were recorded only under still conditions.

Cloud cover

Plains spadefoots were recorded somewhat more often under moderately cloudy conditions (Table 3). Canadian toad calling was more frequent under heavy cloud cover than expected (Fig. 8). Woodhouse's toads and Great Plains toads showed a reverse pattern, being detected somewhat more often when cloud cover was less than 50%. The two detections of gray treefrogs occurred under cloudy conditions (Table 3). Calling by boreal chorus frogs was unaffected by cloud cover. Northern leopard frogs were recorded somewhat more often under moderately cloudy conditions. The only detection of wood frogs was under conditions of medium cloud cover.

Moonlight

Canadian toads, Great Plains toads, and northern leopard frogs were heard more often than expected under darker conditions (Fig. 9). Gray treefrogs and wood frogs were detected only under the darkest conditions (Table 3). Plains spadefoots, boreal chorus frogs, and Woodhouse's toads seemed unaffected by moonlight.

CONCLUSIONS and RECOMMENDATIONS

To monitor anurans successfully, we must have a solid understanding of their biology, particularly the features that influence their vocalizations and therefore their detectability. Calling varies not only by species, but also by time of year, time of day, and environmental conditions. These variables may have different effects in different geographic areas, so they need to be evaluated in various locations.

Our results suggest the following criteria for a monitoring program in North Dakota and areas with similar phenologies. If sites are to be surveyed on a single occasion, it should be in early June. That time seems nearly ideal for Canadian toads, Woodhouse's toads, northern leopard frogs, plains spadefoots, and gray treefrogs. Boreal chorus frogs can be detected anytime in May and June, so that species requires no special timing. Early June is too late for the early-breeding wood frog; a survey in

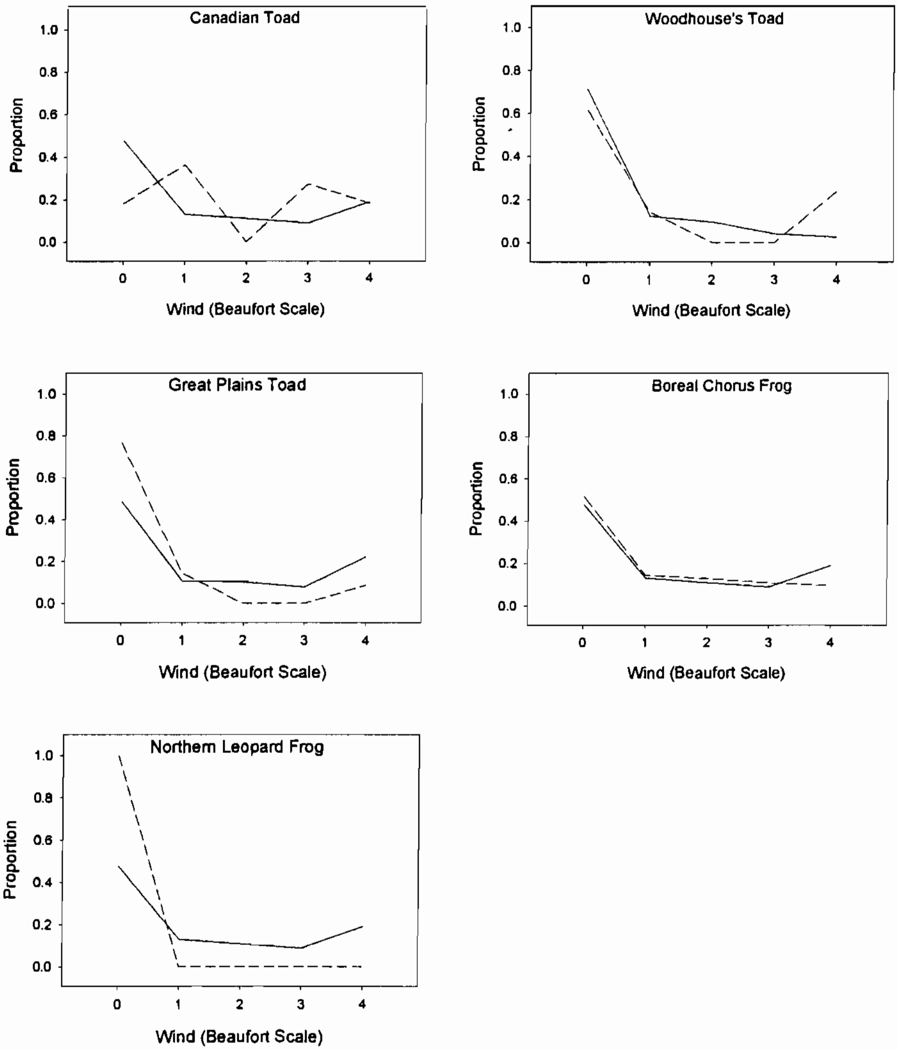

Figure 7. Proportion of all detections of calling amphibians (dashed line) and proportion of time spent surveying in species' range (solid line) plotted against wind speed.

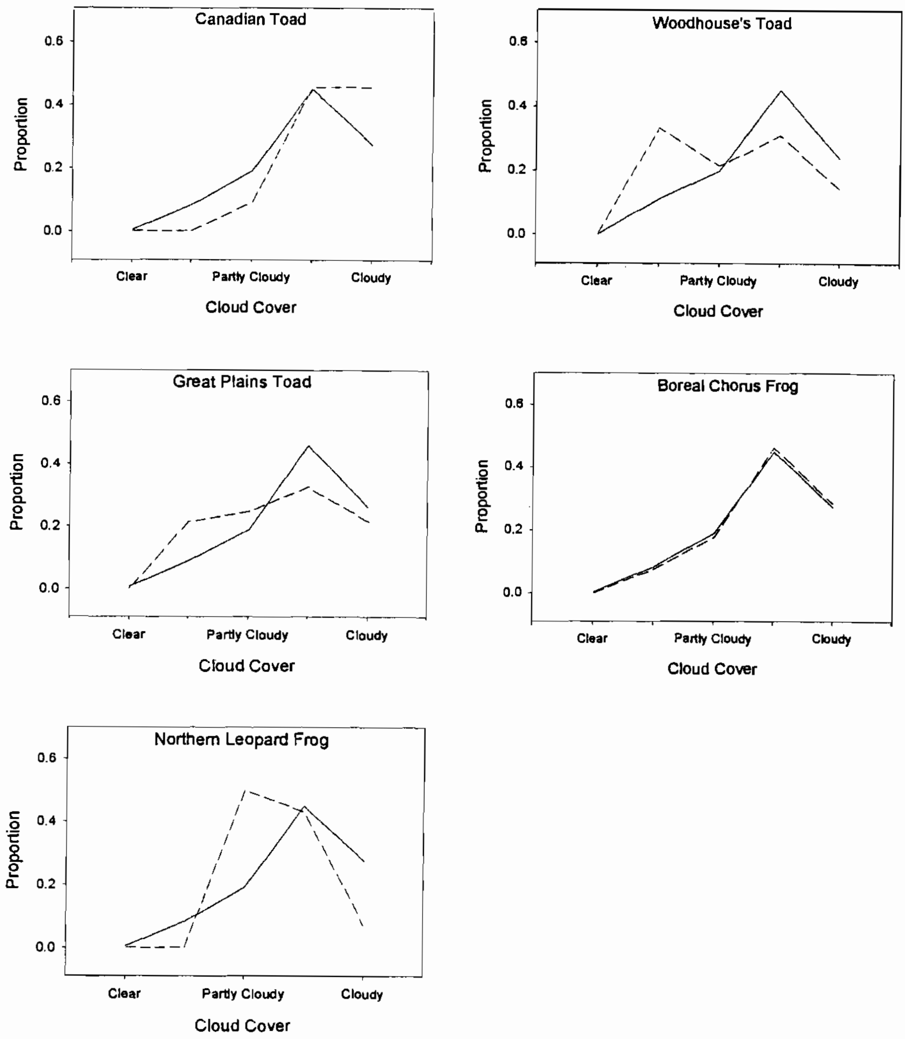

Figure 8. Proportion of all detections of calling amphibians (dashed line) and proportion of time spent surveying in species' range (solid line) plotted against cloud cover.

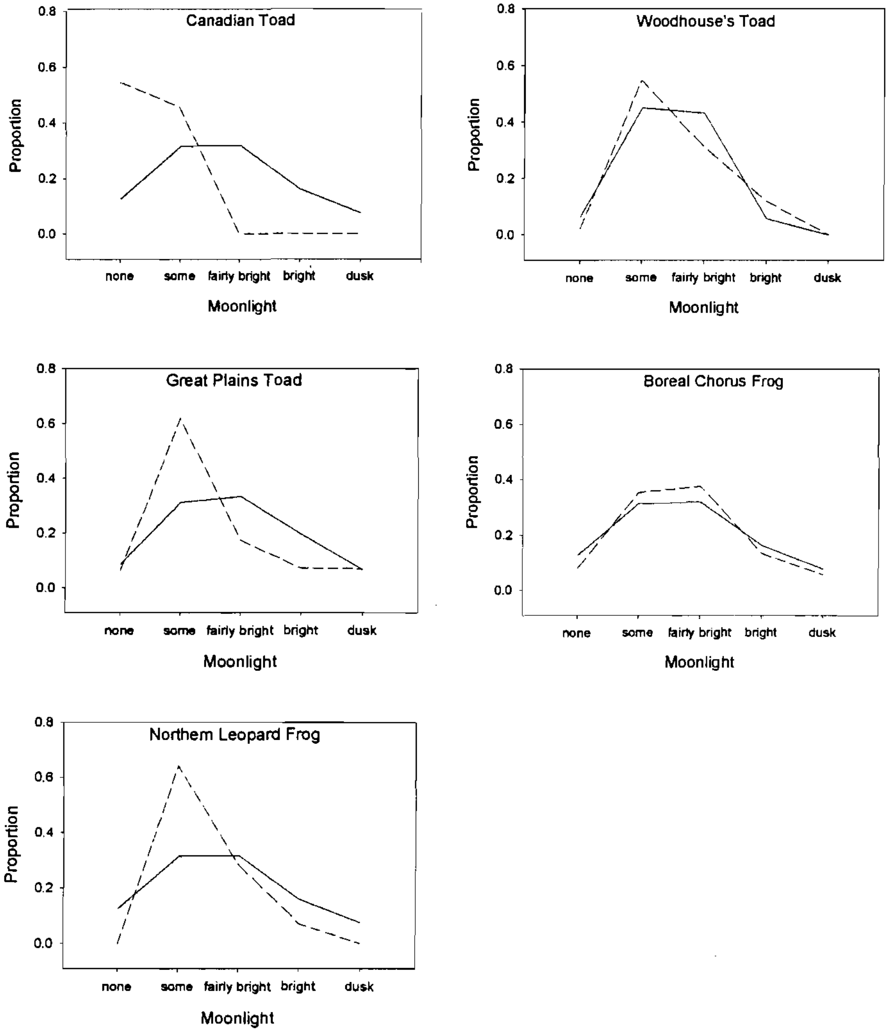

Figure 9. Proportion of all detections of calling amphibians (dashed line) and proportion of time spent surveying in species' range (solid line) plotted against moonlight.

late April would be preferable for that species. More survey occasions during a season would be preferable, of course (an early survey would be more likely to detect wood frogs, in particular). The protocol for the Wisconsin survey, for example, stipulates three survey occasions per year (Mossman et al. 1998)

The preferred hours of the survey would be 2300 to 0130, times that would capture the most active vocalizing of all species we encountered commonly (Fig. 3), as well as most of the detections of the uncommon species (Table 3). Ambient temperatures above 13° C are recommended, although wood frogs are likely to be calling more actively at cooler temperatures. Other conditions deemed favorable include the absence of rain and little if any wind or moonlight.

These recommendations certainly need to be tested and evaluated. Optimal conditions for calling anurans might vary from year to year (Mossman et al. 1998), as well as from one region to another. A well-designed monitoring program will need studies comparable to ours replicated over space and time.

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