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Reports of malformed amphibians have been increasing, including external deformities such as missing or extra arms and legs, missing eyes and mandibles, and internal abnormalities involving the bladder, digestive system, and testes. Natural phenomena such as limb amputations during predation attempts by other animals, parasitism, xenobiotic chemicals (herbicides, insecticides, fertilizers and others), and UV-B or other radiation (either directly or indirectly by triggering production of toxicants from nontoxic chemicals) have all been linked to amphibian abnormalities. From 1968–71, I studied the natural history, effective breeding size, and seasonal, annual, and geographic variation in color morph frequencies of cricket frogs (*Acris crepitans*) in Illinois to evaluate the potential adaptive significance of polymorphism in the species. Cricket frogs from seven different populations were marked for later identification and followed for three years. Additionally, cricket frogs from 28 other populations in Illinois were sampled at least once. A detailed review of my field notes showed that 30 years ago the frequency of abnormalities recorded throughout Illinois was 0.39% and that most oddities involved missing arms and legs (0.32%) rather than extra limbs (0.07%). Missing limbs may reflect attempted predation by other animals while extra limbs would indicate developmental errors. Only seven confirmed deformities (extra or deformed arms, deformed digits, underdeveloped mouth) were recorded in almost 10,000 frogs examined.

INDEX DESCRIPTORS: amphibian malformations, Cricket frog, *Acris crepitans*.

Amphibian species are believed to be declining worldwide (Barinaga 1990, Blaustein and Wake 1990, Wyman 1990, Pechmann et al. 1991, Wake 1991). Several amphibian species (e.g., two species of gastric brooding frogs in Australia, the golden toad in Costa Rica) have apparently become extinct in recent decades (McDonald 1990). Along the North American Pacific coast, the red-legged frog (*Rana aurora*) is no longer present in areas where it was previously abundant and common. In the rural Midwest, the cricket frog (*Acris crepitans*) has undergone a dramatic decline in areas such as Illinois where it was once the most abundant amphibian species (Smith 1961). It is on the endangered species list in Wisconsin, and is now believed to be extinct in Minnesota and Ontario, Canada (Oldham 1992, Greenwell et al. 1996).

Concurrent with population declines, reports of malformed amphibians have been increasing (Kaiser 1997, SETAC 1997). However, not until a group of students went on a field trip in Le Sueur County, Minnesota, in August 1995 (Helgen 1998) did the deformity issue achieve its current visibility. The occurrence of malformed leopard frogs (*Rana pipiens*) and other amphibian species is now well documented in the popular press. Reports include external deformities such as missing and extra arms and legs, missing eyes and mandibles, as well as internal abnormalities involving the bladder, digestive system and testes (Greenwell et al. 1996, SETAC 1997).

Amphibians may be considered sentinel species (i.e., the "miner's canary") that can provide early warning of environmental degradation and potential risk to humans. Because of the link to human health, the issue has received extensive media attention and has the potential to become highly politicized. The reported increase in amphibian abnormalities may be real or simply reflect an increase in the number of scientists studying the problem. Deformed frogs were noted as far back as the 1700s.

From 1968–71, I studied the natural history including effective breeding size (Gray 1971a, 1971b, 1983, 1984), and seasonal, annual and geographic variation in color morph frequencies (Gray 1972, 1983, 1995) of cricket frogs, *Acris crepitans,* in Illinois to evaluate the potential adaptive significance of polymorphism in the species. Cricket frogs from seven different populations were marked for later identification and followed for three years. Additionally, cricket frogs from 28 other populations in Illinois were sampled at least once. Throughout the study, I kept detailed records on the condition of each frog sampled (Gray 1972, 1995). However, the incidence of abnormalities was low and I have not previously reported the data. Similarly, authors of other field studies involving *A. crepitans* in Texas and Louisiana (Pyburn 1961), Indiana (Issacs 1971), and Kansas (Burkett 1984) were silent on the incidence of malformations in this species. Because historical data on the nature of malformations in cricket frogs are lacking, I recently conducted a complete review of my field notes to determine the frequency of abnormalities that occurred over 30 years ago.

STUDY SITES AND METHODS

Seven areas (six in central Illinois, one in southern Illinois) were selected for intensive study from 1968–71. The study areas (Fig. 1) and sampling and marking methods were previously described (Gray 1983). The areas include the Mackinaw River, Dawson Lake Pond, and the English Farm Ponds (A, B, C) in McLean County, Six-mile Creek in Woodford County, and the La Rue Pine Hills Swamp in Union County. Study areas were visited at least monthly. Three study areas (English Farm Ponds) were visited twice monthly. The Dawson Lake Pond was also visited twice monthly during the fall of 1970. Cricket frogs were captured by hand or with a small net and the following information (relevant to this discussion) was recorded: (1) specimen number, (2) vertebral stripe color, (3) snout–vent length, (4) sex, and (5) abnormalities, including malformations. Population sizes were determined by the Lincoln-Peterson Index (Scattergood

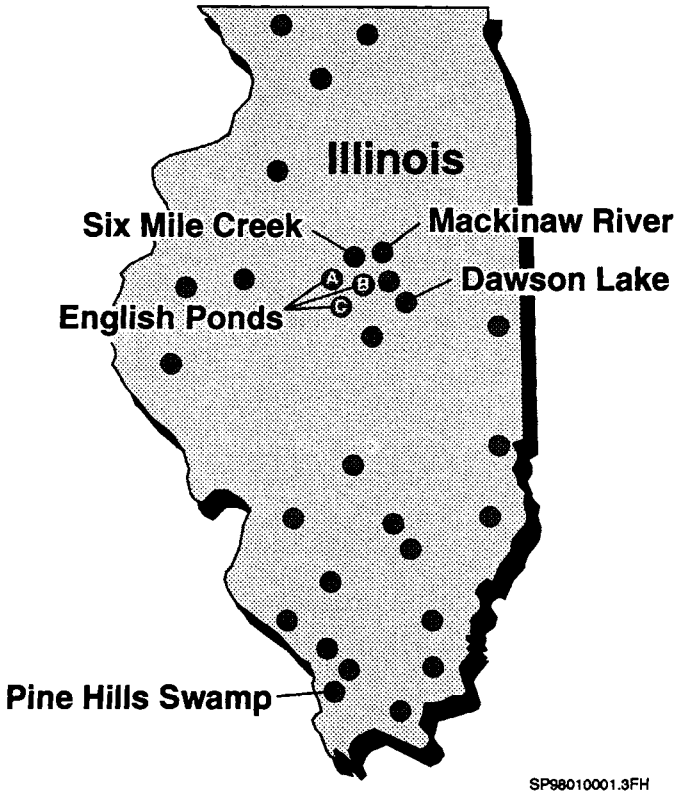

Fig. 1. Study areas sampled in Illinois, 1968–71, for *Acris crepitans*. Main study areas indicated by name.

Table 1. Frequency of cricket frog (*Acris crepitans*) abnormalities in Illinois, 1968–71.

Study Site	Frogs Examined *n*	Abnormalities *n*	Abnormalities %
English Ponds			
Pond A	1022	13	1
Pond B	1988	20	1
Pond C	480	3	1
Macinaw River	345	0	0
Six mile Creek	715	0	0
Dawson Lake	2577	1	0.04
Pine Hills	991	2	0.2
Other Locations (n = 28)	1869	0	0
Total	9987	39	0.39

1954). Other locations in Illinois were also visited during the spring and fall of 1970.

RESULTS AND DISCUSSION

Numbers of frogs examined, and numbers and frequencies of abnormalities recorded in Illinois during 1968–71 are shown by location in Table 1. Overall, only 0.39% of the frogs collected throughout the state were abnormal. The abnormalities occurred in two categories. Deformed frogs were either missing whole or parts of limbs and digits or had deformed or extra limbs, digits and mouth parts (Table 2). Most oddities involved missing arms and legs (0.32%) rather than extra limbs (0.07%). Missing limbs may reflect attempted predation by other animals whereas extra limbs would indicate developmental errors. Only seven confirmed deformities (extra or deformed arms, deformed digits, underdeveloped mouth) were recorded among almost 10,000 frogs examined.

Table 2. Types of cricket frog abnormalities in Illinois.

Number	Description
32	missing limbs/digits (entire leg or below knee, foot, arm, hand, digits)
7	malformed fore limbs, feet, digits, mouth; extra forelimbs

These data show that the incidence of malformations in cricket frogs in Illinois during the years studied was low and generally less than those reported for other species in other areas during other years. Much higher incidences of malformations have been reported for Pacific tree frogs (*Hyla regilla*) in Idaho by Reynolds and Stevens (1984) and spotted salamanders (*Ambystoma maculatum*) by Worthington (1974). In Minnestota, Québec, and Vermont, where abnormalities currently receive much attention, the overall frequency of malformations is 8% but can be as high as 67% in some ponds and lakes (Kaiser 1997). A review of data available on the World Wide Web (http://www.npwrc.org/narcam) from across North America shows that abnormalities can range from 0–100% where the total number of frogs observed is known. However, where incidences of abnormalities are high, sample sizes are always low (<5). In many cases the total number of frogs examined is not reported, and in all cases historic data with which to compare are unavailable.

Most of the abnormalities reported appear to involve missing rather than extra limbs which is consistent with my findings for cricket frogs in Illinois. Missing limbs may reflect unsuccessful predation attempts by other animals. Natural phenomena such as limb amputations during predation attempts and parasitism (Sessions 1997, Sessions and Ruth 1990), agricultural chemicals (herbicides, insecticides, fertilizers) and other xenobiotic contaminants (Ouellet et al. 1997), UV-B radiation either directly (Blaustein et al. 1997) or indirectly by triggering production of toxicants from nontoxic chemicals (Dumont et al. 1997), and radioactivity (Meyer-Ruchow and Koebke 1986) have all been linked to amphibian abnormalities. However, there are very few, if any historical data with which to compare current trends, and the reported increase in amphibian abnormalities may simply reflect increase in number of scientists studying the problem.

Currently, field studies are focused in Minnesota, Wisconsin, Vermont, and Québec, and a centralized reporting mechanism has been established (Johnson et al. 1997, see http://www.npwrc.org/narcam) to collect, manage, and aid in the interpretation of data from across the United States and Canada. The North American Reporting Center for Amphibian Malformations is managed by the Northern Prairie Wildlife Research Center in Jamestown, North Dakota. The Center utilizes the internet and encourages public input. While scientists at several recent workshops appear to agree that the reported decrease in amphibian populations is real, the reported increase in amphibian malformations and their causes are being hotly debated (Reaser and Johnson 1997, SETAC 1997).

Recent surveys of anurans in Minnesota (Hoppe and Mottl 1997)

Table 3. Recaptures of deformed frogs, McClean County, 1969–70.

No. 110 (missing right hand)—Pond A							
Date	10/6/69	11/6/69	4/8/70	6/10/70	7/9/70	8/6/70	9/8/70
Length (mm)	24	24	24	29	29	29	29
Color	gray	gray	gray	gray	gray	gray	gray
Sex	juvenile	juvenile	juvenile	gravid female	gravid female	spent female	spent female
No. 10 (double right arm)—Pond C							
Date	8/21/69	4/28/70	7/9/70				
Length (mm)	15	26	29				
Color	gray	red	red				
Sex	juvenile	male	male				

revealed limb and/or eye malformations in six species: northern leopard frog (*Rana pipiens*), mink frog (*R. septentrionalis*), wood frog (*R. sylvatica*), spring peeper (*Pseudacris crucifer*), gray tree frog (*Hyla versicolor*), and American toad (*Bufo americanus*). The highest frequency and severity of malformations occurred in the most aquatic species (mink frog). Analyses of sediments and water samples are planned from locations where deformed amphibians were found. Because amphibians develop from fertilized eggs in water and have permeable skin, they are at a particular risk from water-based agents.

Ouellet et al. (1997) suggested that conspicuous abnormalities constitute a survival handicap because they interfere with swimming and hopping. Alternatively, Van Valen (1974) speculated that occurrence of extra limbs and digits at relatively high frequencies in some amphibian populations may result in a morphologically and adaptively discontinuous origin for a new taxon. Interestingly, several of the frogs I marked as abnormal, were later recaptured and two survived through the winter and following breeding season.

Table 3 shows the identities, distinguishing characteristics, and capture dates of two frogs from farm ponds in McClean County from 1969–70. Frog No. 110 was originally captured on October 6, 1969 and identified as a 24 mm gray morph with the right hand missing. The animal was subsequently recaptured six times and recorded as a 29 mm gravid female on June 6 and July 9, 1970, and as a 29 mm spent female on August 6 and September 8, 1970.

Frog No. 10 was originally captured on August 21, 1969 and identified as a 15 mm gray morph with an extra right arm. The animal was later recaptured twice and recorded as a 26 mm and 29 mm red male on April 28 and July 9, 1970. Metachrosis of the vertebral stripe involving red and gray morphs occurred about 11% of the time at these ponds (Gray 1972).

In both examples, neither the loss of a hand nor the addition of an arm prevented the animal from overwintering and living through the following breeding season. Whether these animals actually bred is unknown but the female did develop and expel eggs. Given the low incidence of abnormalities observed throughout Illinois, the success of these two frogs is noteworthy.

Future Needs

Other historical databases need to be evaluated to identify areas where resampling could provide valuable information concerning potential changes in frequency of abnormalities over time. Statistically based field surveys must be conducted to establish the true extent and distribution of amphibian malformations. Resurveying the same areas that I studied in 1968–71 would indicate whether the frequency of malformations in Illinois cricket frogs has changed over the last 30 years. Today, this is particularly relevant and urgent because *Acris crepitans,* once the most common amphibian in Illinois (Smith 1961), has experienced a dramatic decline in numbers in the northern Midwest, including the northern third of Illinois (Greenwell et al. 1996). Analytical studies of habitat, sediment, and water quality should then be focused in areas where increases in malformations have been documented to evaluate factors operant in those locals.

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