Amphibian Phenology and Climate Change

The effects of climatic warming on the seasonal timing of animal and plant activities are receiving increasing attention in the scientific literature. However, Blaustein et al. (2001) recently highlighted the risks of generalizing about phenological changes with respect to amphibian breeding times. Four North American anurans with long-term time series of breeding observations have shown no significant trends toward early breeding over the past few decades, and the authors warn that suggestions of climate-change effects on amphibian breeding times may be premature. Although I agree that there has been a wide range of responses to climate change among amphibian species, as indeed there has been among other groups such as birds, signals of the effects of climate change from some amphibians are very clear, so there is nothing premature about the proposition. I have observed significant trends toward earlier breeding for two species of anurans and four urodeles in Britain (Beebee 1995*a*, 1995*b*), and these trends correlate with mean seasonal temperature increases since the 1970s. I have also found, however, that one species (the anuran *Rana temporaria*) shows no significant trend of change, and Reading (1998) also found no change in another British anuran, *Bufo bufo*. For both of these species, however, slow trends were apparent that if continued could eventually become significant. Blaustein et al. (2001) do not mention, presumably because the study was in press at the time of their submission, the observations of Gibbs and Breisch (2001), who found that four out of six anuran species in New York State were breeding earlier at the end of the twentieth century than at its start. These changes were also significantly correlated with climatic warming, so it is evident that amphibian phenological responses have not been confined to Britain.

It is not surprising that amphibians are responding to different degrees, or in some cases not at all, to global climate change. First, it is not evident that the climate is changing at all the sites that have been studied. Blaustein et al. (2001) make no comment about this with respect to the locations of the species they observed but did demonstrate correlations between breeding onset and temperature at three of their four study sites, perhaps implying that if climate had changed over time the amphibians would have shown trended responses.

Second, interspecific differences in reproductive biology could also be important. In Britain it is the two "explosive" breeders that spawn very early in the year, *R. temporaria* and *B. bufo,* that have shown minimal signs of response to climate change. By contrast the later, protracted breeders (*B. calamita, R. esculenta*, and all the urodeles) have bred progressively earlier over the past 20–30 years. These asynchronous responses could have significant long-term consequences for community structures. Earlier arrival of urodeles, for example, could increase predation rates on *R. temporaria* spawn. *Rana esculenta* is an alien species in Britain, with introductions documented since the early 1800s. Almost all of the *R. esculenta* introduced in the nineteenth and early twentieth centuries died out after a few years (Smith 1951), but in the late twentieth century populations of this frog have increased and spread dramatically in southeastern England (Wycherley & Anstis 2001). Success of this frog depends on the length of time available for larval development in summer because larvae do not survive overwintering in ponds. Early breeding has transformed breeding success (autumn metamorphosis) from a rare event to one that happens most years, thus facilitating the spread of water frogs in Britain. Evidently there is a need for more observations on more species before we understand the pattern of amphibian responses to climate change in temperate countries and are in a position to assess their possible implications for the conservation of amphibian biodiversity.

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Trevor Beebee (2002) argues that climate change is affecting breeding times in some amphibian species, citing his own study (Beebee 1995) and a recent study by Gibbs and Breisch (2001). He states that it is

not surprising that different amphibian species are responding to global climate changes in different ways. He also reports that climate change may not be evident at all sites where amphibian breeding has been studied. We agree with all of these statements. We certainly can see the evidence that amphibian breeding is occurring earlier in some regions and that global warming is likely the driving factor.

We also agree with Beebee that changes in breeding patterns may affect community structure. Statistical tests indicate that exactly half of the 20 species examined by Beebee (1995), Reading (1998), Gibbs and Breisch (2001), and Blaustein et al. (2001) are breeding earlier. Moreover, some of the remaining species are showing biologically important trends toward breeding earlier that, if continued, will likely become statistically significant (Beebee 2002). When taken together, these important data suggest that global warming is indeed affecting amphibian breeding patterns in many (but not all) species.

These observations, however, also demonstrate the unevenness of climate-change effects. For example, *Bufo fowleri*, a late breeder, has bred progressively later in spring over the past 15 years on the north shore of Lake Erie (Blaustein et al. 2001; D.M. Green, personal observations). Clearly, continued monitoring of amphibian breeding is needed across the globe if a more complete picture, in all its complexity, is to emerge.

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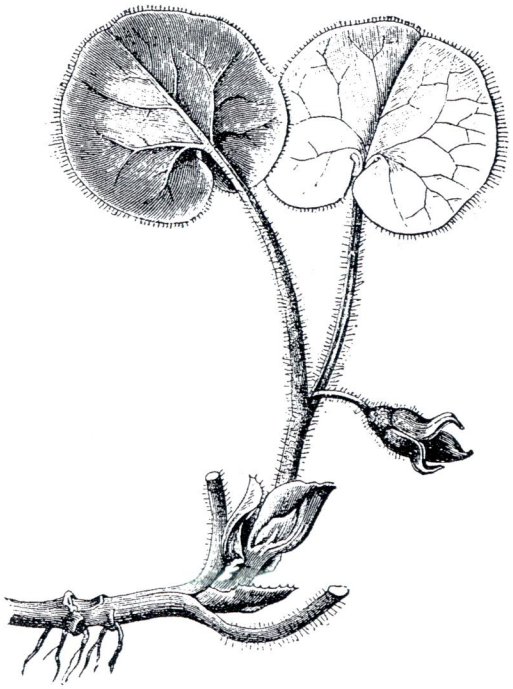

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