5.3. Amphibians and global change in Sierra Nevada

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Abstract

Amphibians, for their physiological and ecological particularities, constitute one of the groups most sensitive to global change. Between the years 2009 and 2013, different aspects of their ecology related to temperature and water availability in Sierra Nevada were studied. The resulting data indicated changes in amphibian communities in Sierra Nevada, notably: a movement of amphibians in elevation, greater competition among species that reproduce in permanent water bodies, changes in size of the metamorphic stages, and the expansion of emerging diseases.

Aims and methodology

A literature review of the distribution of the amphibians in Sierra Nevada was carried out. All references were grouped into two periods: old citations (prior to 2005) and current ones (after 2008). The elevational distribution was compared for different species detected in the two periods considered.

Also, the breeding dates of three amphibians were studied in 60 bodies of water distributed throughout the elevational gradient. Of the species studied, two reproduced in permanent water bodies (betic midwife toad *Alytes dickhilleni* and common toad *Bufo spinosus*) and another in temporary bodies of water (natterjack toad *Bufo calamita*).

The metamorphic individuals of the Betic midwife toad were weighed and measured along an elevational gradient. Also, the water temperature was continuously measured using data loggers at 13 reproduction sites distributed throughout the gradient. The data were collected from June to October, at regular intervals of 30 min and compared with the optimal growth temperature in order to establish the margin of thermal safety and warming tolerance.

Also, 15 temporary ponds situated along 3 elevational gradients were monitored. The hydroperiod length and the reproduction success for each species were recorded. In the case of the Betic midwife toad, the success in metamorphosis was registered in 18 areas subjected to different degrees of management, with the aim of creating an early-alert network for chytridiomycosis. Finally, for this species, 40-50% of the larvae were marked in 5 streams (with elastomeres visible). These were marked with different colours to determine the movements between ponds.

Results

In the last 30 years, 5 species have ascended elevationally. This trend was significant for the common frog *Pelophylax perezi*, for the common toad, and for the spanish painted frog *Discoglossus galganoi jeanneae* (Table 1 and Figure 1).

The Betic midwife toad and the common toad showed a clear phenological lag as they ascended in elevation (Figure 2), this being clearly related to temperature. These 2 species, which often reproduce in the same places, are currently phenologically uncoupled, possibly reducing interspecific competition [10].

The larvae of most betic midwife toad populations tolerate low water temperatures in relation to their physiological optimum, this being especially evident in the case of those that reproduce in streams. The artificial media studied present a more appropriate temperature for the development of amphibians. Although the development in cold places was slower, the size and final weight of the metamorphic forms was greater (Figure 3).

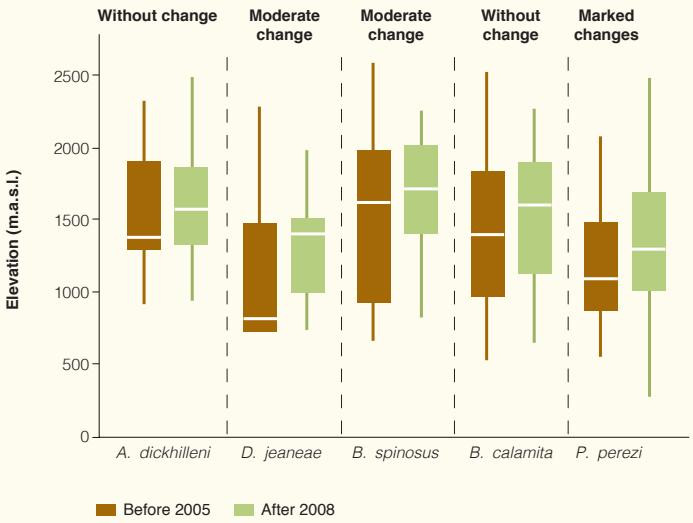
To date, no case of chytridiomycosis has been detected in Sierra Nevada. However growing prevalence of this disease at nearby sites and the conditions of Sierra Nevada suggest a high risk of this pathology appearing.

Table 1

Species	Water bodies	Number of records before 2005	Number of records after 2008	Mean elevation before 2005	Sd	Mean elevation after 2008	Sd	W	t	g.l.	P
A. dickhilleni	Permanent	18	32	1,548.72	413.83	1,629.03	416.82		0.74	17	0.47
B. spinosus	Permanent	62	80	1,519.39	605.18	1,692.20	376.49		2.11	61	0.03*
B. calamita	Temporary	23	26	1,445.65	556.15	1,497.38	501.66		1.21	22	0.24
P. perezi	Permanent	85	130	1,215.36	426.90	1,306.63	487.47		9.23	84	0.00**
D. galganoi jeanneae	Temporary	22	8	1,180.27	539.27	1,322.12	422.38	28	-----	-----	0.02*
P. ibericus	Temporary	2	-	1,482.00		------			-----	-----	-----
H. meridionalis	Temporary	7	-	764,.00		------			-----	-----	-----

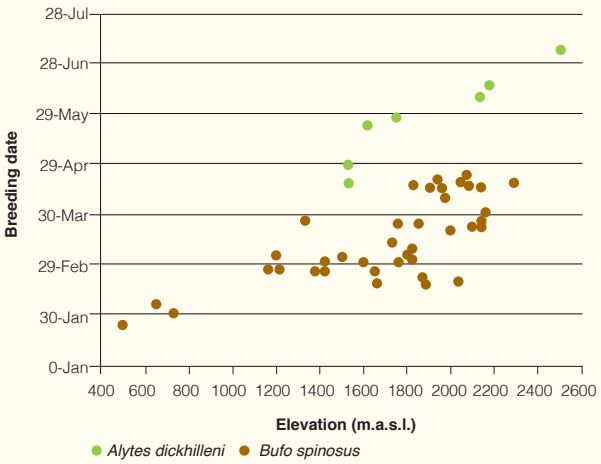
Number of citations and mean elevation of the amphibians found prior to 2005 and after 2008, and the results of the parametric Student's t-test for species with a distribution of citations fit to normality (Shapiro-Wilk test), except for *D. jeanneae*, for which the non-parametric *Wilcoxon-Mann-Whitney* test was applied. Asterisks indicate species with significant differences.

Figure 1



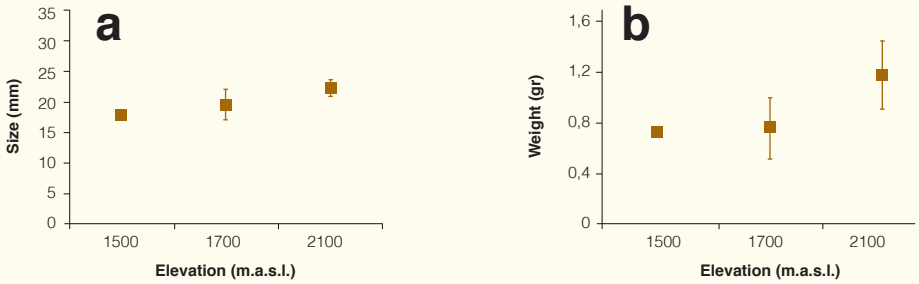
Comparison by box diagrams of the mean elevational distribution of the previous citations before 2005 and after 2008 of 5 species of amphibians in Sierra Nevada.

Figure 2



Breeding date in relation to elevation for the Betic midwife toad and common toad.

Figure 3



Size and mean weight of the metamorphic forms of the Betic midwife toad. With ascending elevation, the size and weight of the metamorphic forms are larger, both variables being significant. Kruskal-Wallis Test for size (X^2=7.092; g.l.=2; p<0.05) and weight (X^2=7.409; g.l.=2; p< 0.05).

Discussion and conclusions

The results show that the amphibians in Sierra Nevada have ascended in elevation a mean of 107.8 m in the period 2008-2011 in relation to the period 1980-2005. From the 7 species studied, 3 showed a clear ascending pattern (the Iberian painted frog, common toad, and common frog), 2 showed no definite pattern (Betic midwife toad, and natterjack toad), and another 2 tended to become rare and disappear (*Hyla meridionalis* the mediterranean tree frog and *Pelodytes ibericus* the iberian parsley frog).

Forecasts for temperature rises imply major changes in the amphibian communities of Sierra Nevada. The main changes for the amphibians are diagrammed in Figure 4.

In general, high-mountain populations may benefit from a temperature rise, while those of the low and middle mountains face a serious risk of disappearing, especially those of temporary media [11]. In high-mountain populations, an increase in water temperature would involve early physiological development and a reduction in the larval period, which would spur the rate of population growth and reduce the risk of contracting chytridiomycosis. At sites located in streams, the frequency of overflows and other extreme phenomena is expected to grow in frequency. Furthermore, the changes predicted in phenology of breeding date due to climate change may spur changes in the assemblages of amphibian communities.

The populations in low and medium mountains are currently closer to optimal physiological conditions, but they risk undergoing greater physiological stress and disappearance in the event of excessive increases in water temperature. In this scenario, a decline would occur in the quantity of dissolved oxygen in the water, which may hamper the development of embryos and larvae.

With regard to temporary *vs*. permanent media, species that reproduce in temporary media are in clear decline. Despite that the sampling effort after 2008 was greater than before 2005, the number of records of this species was lower, and some had even apparently disappeared from the Sierra Nevada Protected Areas (iberian parsley frog and the Mediterranean tree frog). In fact, the data available indicate that temporary ponds are the water bodies in the poorest state of conservation, although they have the highest diversity. Many of them have sharply reduced water periods, a situation that may be aggravated by global warming [12].

The Iberian painted frog is one of the species that has undergone an elevational ascent of the greatest magnitude in Sierra Nevada.

Figure 4

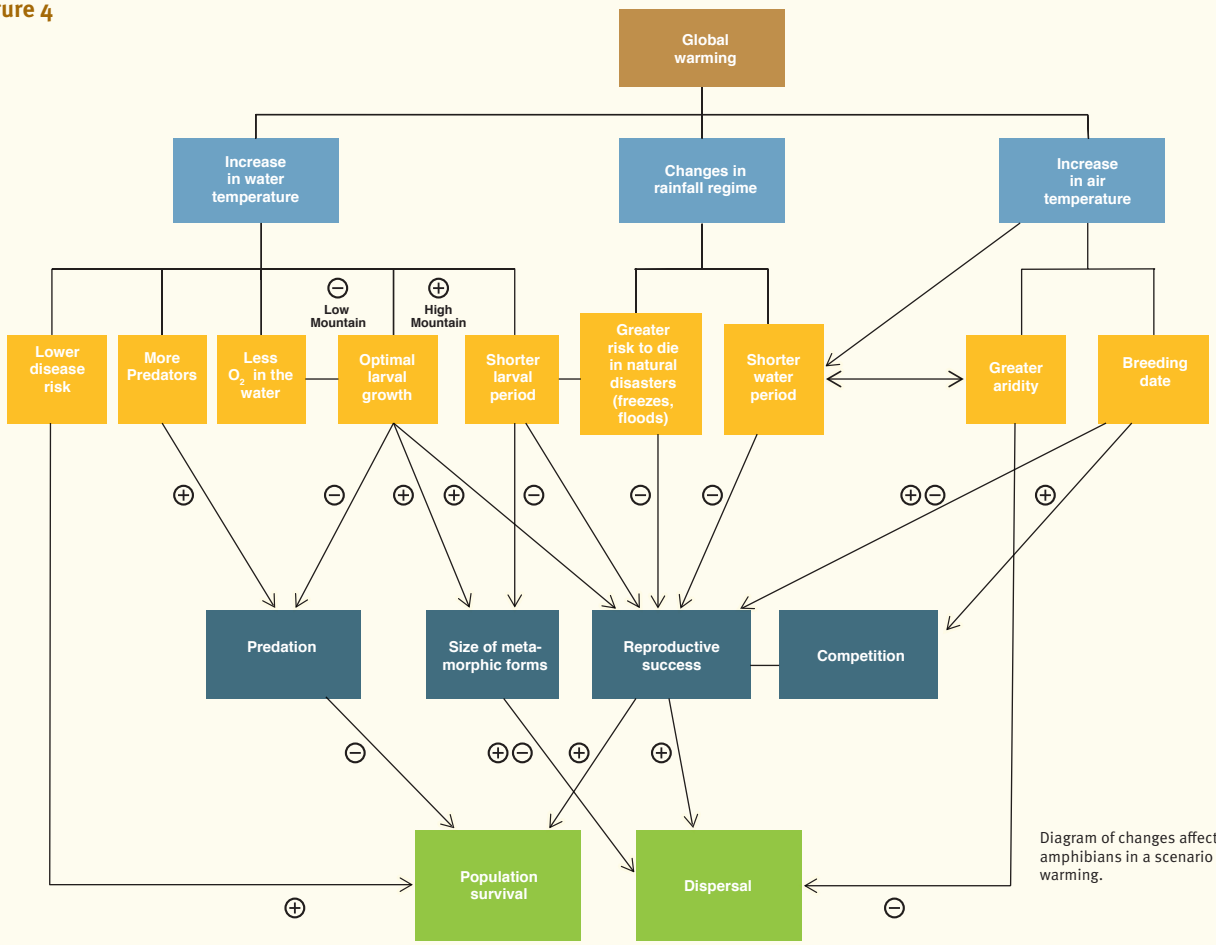


Diagram of changes affecting amphibians in a scenario of global warming.

Temporary ponds and species that reproduce in them, such as the Iberian painted frog, are strongly affected by climate warming in Sierra Nevada.