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POPULATION COLLAPSE OF *RANA TEMPORARIA* IN A HIGH ALTITUDE ENVIRONMENT? AN OCCUPANCY STUDY

SUMMARY

Alpine areas represent one of the richest biodiversity hotspots of Europe. They are threatened by the combining effect of climate change and land-use modifications. In this study, we used visual encounter surveys along transects to investigate occupancy and detection probability of *Rana temporaria* in Paneveggio-Pale di San Martino Nature Park, Trentino (IT). Multi-season occupancy models revealed that the species occurrence depended on environmental characteristics, namely distance from water and ground vegetation height, while extinction/colonization rates were determined by a combination of weather and microhabitat conditions. Moreover, occupancy and detectability values abruptly collapsed over the study period, indicating a possible population decline issue. Since no main landscape modifications or pathogens have been observed, we hypothesized that the main cause of this decline could be due to the climate. In particular, the reduction affected the juvenile subfraction of the population and we argue that, even if these drops could be considered as stochastic fluctuations, they pose a serious threat to the viability of the population.

Key words. Alps, Amphibian conservation, habitat change, mountain biodiversity.

RIASSUNTO

Crollo di una popolazione d'alta quota di Rana temporaria? *Uno studio sull'*occupancy. Le aree alpine costituiscono alcune delle regioni con la più elevata biodiversità d'Europa. Ciononostante, queste sono minacciate dall'azione combinate dei cambiamenti climatici e della riconversione del suolo. Con questo studio abbiamo utilizzato la tecnica della ricerca visiva lungo transetti per valutare lo status della popolazione di *Rana temporaria* nonché i suoi valori di *occupancy* nel Parco Naturale di Paneveggio-Pale di San Martino, Trentino (I). I modelli multi-stagionali di *occupancy* hanno dimostrato come la presenza della specie dipenda da caratteristiche ambientali quali la distanza da una fonte d'acqua o l'altezza della vegetazione erbosa laddove i processi di estinzione/colonizzazione sono legati ad una combinazione di condizioni meteorologiche e micro-ambientali. Inoltre, tra il

2018 ed il 2020 si è osservata una drastica riduzione nei valori di *occupancy* e *detectability* della specie, indicando un possibile declino della popolazione. Poiché nell'area non sono stati registrati patogeni né vi sono stati cambiamenti improvvisi del paesaggio, suggeriamo una causa climatica come origine di questo trend. Particolarmente colpita è stata la fascia giovanile della popolazione e asseriamo che, anche qualora siano da considerarsi come naturali fluttuazioni stocastiche, queste possano porre un serio pericolo per la persistenza della popolazione.

Parole chiave. Alpi, biodiversità alpina, cambiamento degli habitat, conservazione degli Anfibi.

INTRODUCTION

Mountain regions represent some of the areas with the richest biodiversity of the European continent (CHEMINI & RIZZOLI, 2003). Yet, like most ecosystems, they are threatened by the synergistic effect of land-use conversion and climate change (CHEMINI & RIZZOLI, 2003; DIRNBÖCK *et al.*, 2011).

Because of their extreme adaptations, montane and alpine species are particularly susceptible to environmental changes (VITERBI *et al.*, 2013). This is especially true in the case of species with limited dispersal abilities, such as reptiles and amphibians, for which relatively short distances can be insuperable barriers preventing recolonization in the case of local extinction (URSENBACHER *et al.*, 2009).

Nevertheless, alpine amphibians represent an important part of trophic chains (SZTATECSNY *et al.*, 2013) as well as a highly diversified gene-pool (SAVAGE *et al.*, 2010). Despite mass disappearances of amphibians in high-altitude environments having been predicted both as a direct and indirect consequence of climate change and habitat fragmentation (MCCAIN & COLWELL, 2011; SHELDON *et al.*, 2011), alpine herpetofauna is still largely neglected in conservations studies (CORN, 2005).

Here, we report the results of an amphibian monitoring projects conducted between 2018 and 2020 in Paneveggio-Pale di San Martino Nature Park. By analysing the occupancy rates of *Rana temporaria*, we highlight the potential causes that might trigger such trends and stress the importance of investigating changes in widespread species abundance for the potential implications they might have on the ecosystem.

MATERIALS AND METHODS

The study was conducted in Paneveggio-Pale di San Martino Nature Park (46°17'54"N, 11°47'20"E), in Trentino Region, Italy. We surveyed a total of 16 plots in an altitudinal range spanning from 1890 to 2100 m a.s.l., in an area consisting of open habitats dominated by grass and shrub vegetation, alternating with coniferous forests. Each plot was at least 250 m away from the next closest one, consisted of two parallel 100-m transects and was surveyed for nine consecutive days with no time constraints. All animals encountered were captured and measured, dividing them in three age classes (MIAUD *et al.*, 1999): juveniles (SVL ≤ 3.5 cm), sub-adults (3.5 cm < SVL ≤ 5 cm) and adults (SVL > 5 cm).

In each plot, we collected macro-scale environmental variables measured from the centre of the plot. These include distance from ski-lift, distance from ecotone, and distance from a permanent water source. We further took habitat variables every 10 meters along transects and then averaged them for the whole area. These include percentages of rocks, bush and log ground covers, and ground vegetation height. In addition, for every survey day we noted the Julian date, the survey starting hour, the number of days since the last rain, the intensity of wind, and measured air temperature every 10-m using a probe thermometer. We also gathered average monthly temperatures and total precipitation amount from the local weather station (station number T0103, www.meteotrentino.it).

We analyzed presence/absence data of *Rana temporaria* using multi-season occupancy models (MACKENZIE *et al.*, 2003). As potential detection predictors, we used the daily weather variables, vegetation height and log, bush and rock covers, while as potential occupancy predictors, we used all the environmental and habitat variables. Because of collinearity between the variables, we did not use air temperature and wind intensity in the model selection. Finally, as potential extinction and colonization covariates we used those parameters that were changing yearly, namely bush and log covers, ground vegetation height, previous summer (June-August) total precipitation and current spring (March-May) average temperature. Model selection was performed ranking the models using Aikake's Information Criterion (AIC; BURNHAM & ANDERSON, 2002). The importance of each covariate was calculated by summing up AIC weights (ωAIC) for each test predictor across models.

RESULTS

Overall, we conducted 153 days of surveys evenly distributed among years, and registered a total of 141 observations of *Rana temporaria*. For 96 of these, identification was performed at the individual level. The numbers have been declining steadily, with a 40% reduction from 2018 to 2019 and of 46.7% between 2019 and 2020 (Fig. 1). The proportion of individuals captured to those observed remained constant throughout the whole study. In

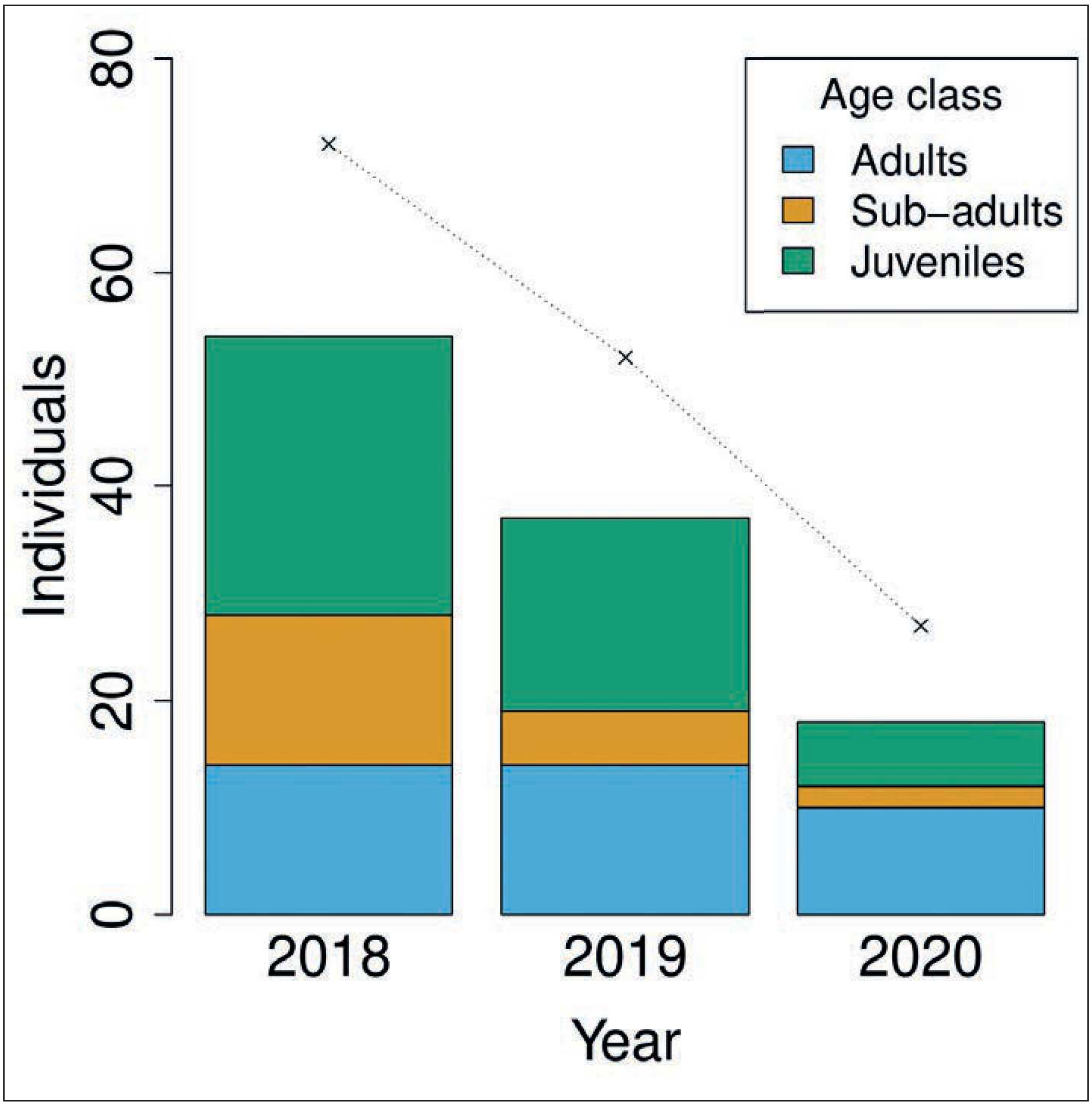

Fig. 1 — Number of individuals of *Rana temporaria* in the different years. The dotted line refers to the total number of individuals including those for which individual identification was not possible.

adjunct to our focal species, we also observed individuals of *Bufo bufo*, *Ichthyosaura alpestris*, *Zootoca vivipara* and *Vipera berus*.

The numbers of individuals were not evenly distributed among age classes, with the adults remaining constant through the three years. Of the other two groups, we recorded a significant loss in the number of sub-adults between 2018 and 2019, which passed from 14 individuals observed in 2018 to only four in 2019. Similarly, juveniles had a similar drop in the next year, with six individuals caught in 2020 compared to the 18 of 2019 and 26 of 2018.

In total, *Rana temporaria* was found in 10 of the 16 plots (62.5 %). However, the mean occupancy probability plummeted between 2019 and 2020 after two years of stability (0.56, 0.56, and 0.37, respectively). The most important parameter in determining detectability was the year ($\omega_i = 0.89$), followed by vegetation height ($\omega_i = 0.49$), date ($\omega_i = 0.42$), and bush and rock covers ($\omega_i = 0.37$ and 0.32, respectively). As expected, detectability decreased with increasing vegetation height and ground covers as well as with the passing years (Fig. 2).

On the other hand, the most important predictors for occupancy were distance from water ($\omega_i = 1$), logs, bushes and rock covers ($\omega_i = 0.88$, 0.69 and 0.60, respectively), and vegetation height ($\omega_i = 0.51$). Increasing rock, bush and log covers as well as vegetation height increased the occupancy rate, while an increasing distance to water decreased it (Fig. 2). Finally, a higher vegetation height favored colonization ($\omega_i = 0.96$) while extinction was mostly predicted by decreasing spring precipitations ($\omega_i = 0.60$) and by a decrease in logs cover ($\omega_i = 0.53$).

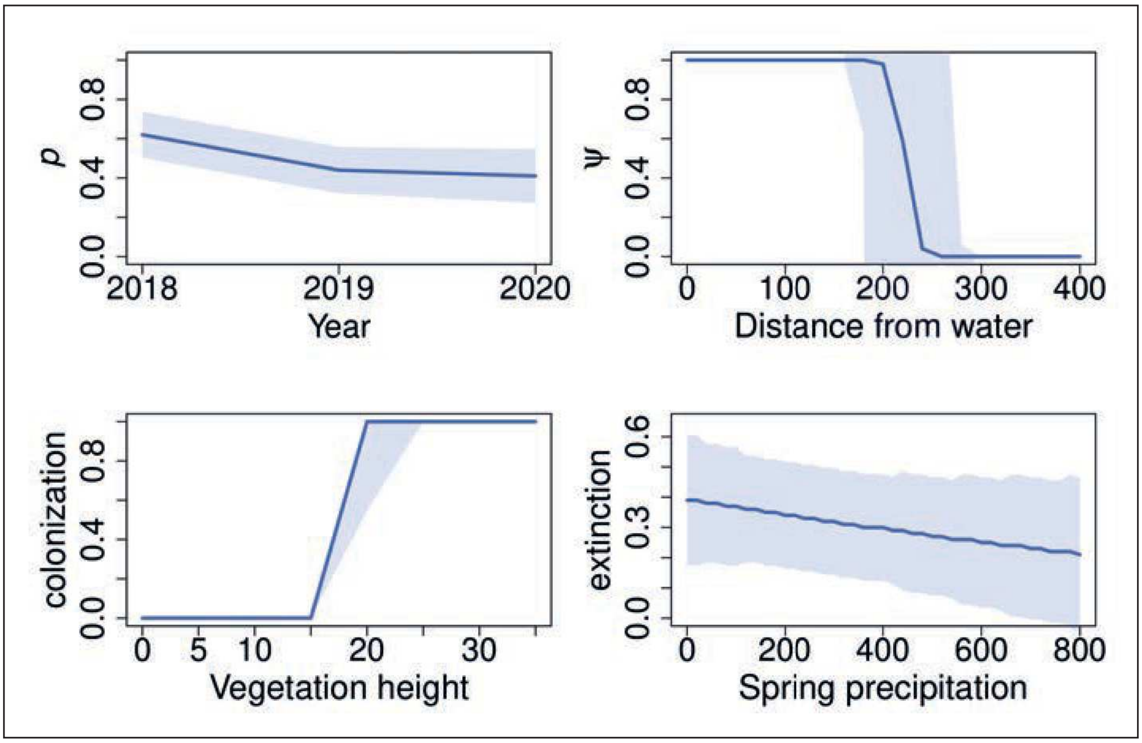

Fig. 2 — Estimates of detection probability (p), site occupancy ( ), and colonization and extinction rate with 95% confidence intervals (CIs) plotted against the most important variable as in the first-selected model.

Discussion

With this study, we provide a short-term population assessment of *Rana temporaria*. The species, generally abundant, is showing marked signs of decline in different areas of its range, especially in its southern regions (Guar-

INO *et al.*, 2008; KYEK *et al.*, 2017), yet showing some evidence of local adaptation (TIBERTI *et al.*, 2021).

As expected, the species' distribution within the landscape is strongly determined by environmental characteristics such as distance from water. Occupancy was also determined by vegetation heights and availability of microhabitats, which are all frequently removed during the construction and management of ski-runs (NEGRO *et al.*, 2009). However, this is also true for meadows that are not strictly used for winter tourism activities such as those where the grazing pressure is too strong and prevent a sufficient vegetation regrowth.

Since no pathogens or sudden landscape modifications have hit the areas, we attribute the decline to direct and indirect effects of declining precipitations. Amphibians in fact, due to their physiological and phenological characteristics, are considered to be particularly vulnerable to climate change (BLAUSTEIN *et al.*, 2011), especially because of the modifications in the precipitation regime that is associated with climatic shifts (LAWLER *et al.*, 2009). These climatic abnormalities can seriously imperil aquatic species as they can reduce the water availability in the whole landscape and the persistence of ponds that amphibians use for reproduction (GRIFFITHS *et al.*, 2010), but also as they affect terrestrial behaviors like migration and thermoregulation (DERVO *et al.*, 2016), and individual survivability (FICETOLA & MAIORANO, 2016).

Amphibians are known to show marked annual stochastic variability (MARSH, 2001; GREEN, 2003), and there is the chance for these drops to be natural fluctuations in an otherwise stable population. However, even if they are to be considered as stochastic, their continuative repetition in time due to climate change can undermine population stability and increase extinction risks even in widespread species (GREENBERG *et al.*, 2017). The extinction risk further increases if such instability increases the mortality rate in the juveniles (SCHMIDT, 2011; COLE *et al.*, 2016). Moreover, if such oscillations are caused by changes in rainfall patterns, these trends probably reflect a geographically wider condition as the reduced precipitation will likely reflect the regional condition, hence resulting in an overall water reduction across most water bodies of a region (GRIFFITHS *et al.*, 2010).

Further monitoring actions are therefore needed to confirm or reject these hypotheses. Moreover, the monitoring of common and widespread species is of particular importance as it can detect changes in community parameters that might otherwise go unnoticed and thus allows a more prompt intervention with beneficial cascading effect on the whole ecosystem.

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