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The relationships between habitat suitability, population size and body condition in a pond-breeding amphibian

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Abstract

The ecological niche of a species determines whether a species can persist and reproduce in a patch or not. The niche of a species is often described using habitat suitability models and indices. Accordingly, one may expect tight links between demography, phenotypes of individuals, population size, and habitat suitability. However, such links are not always found. Here, we study the relationship between a habitat suitability index that is commonly used for conservation assessments and metrics describing the performance at the level of populations and individuals. Using data from a metapopulation of a pond-breeding amphibian, the Great Crested Newt (*Triturus cristatus*), we show that habitat suitability predicts population size but not body condition. Ponds with higher suitability had a higher population size of newts, whereas population size correlated negatively with body condition of individuals. Our results are in line with previous studies showing no straightforward relationship between habitat suitability and body condition (a measure of individual performance) and the performance of populations. We suggest that a population size-dependent reduction of body condition may be a regulatory mechanism in newt populations.

Keywords: *Triturus cristatus*; Phenotypic trait; Ecological niche; Demography

Introduction

The Hutchinsonian population-persistence niche determines whether or not a species can occur and persist in a habitat patch because its population growth rate is either positive or negative (Chase 2011; Hooper et al. 2008; Schoener 2009). The ecological niche of a species is often described

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using statistical models linking data on species presence or abundance to environmental data (known as habitat suitability models, species distribution models or ecological niche models; Guisan & Zimmermann 2000; Guisan & Thuiller 2005; Guillera-Arroita et al. 2015). The output of these models is a habitat suitability score. A natural assumption is that individuals and populations fare better where the habitat is more suitable for the species. This can be seen in Van Horne's (1983) definition of habitat suitability which is "the product of density, mean individual survival probability and mean expectation of future offspring". The relationship between habitat suitability and abundance and demography matters, for example, when estimates of habitat suitability are used to inform conservation decisions (Guisan et al. 2013). As Guisan et al. (2013) note, habitat suitability based on the modelled relationship between occurrence records and the environment may not always correlate with population state variables (e.g. population size, demography and phenotypes) necessary for population persistence. This might result from the fact that species can be found in unsuitable habitat patches (e.g., population sinks; Pulliam 2000) or species may be absent from suitable patches in metapopulations (Hanski 1998). Unsurprisingly, some previous studies found a correlation between habitat suitability and population state variables whereas others did not (Bean et al., 2014; Boiffin, Badeau, & Bréda 2017; Diez, Giladi, Warren, & Pulliam 2014; Thuiller, Albert, Dubuis, Randin, & Guisan 2010; Unglaub, Drechsler, Steinfartz, & Schmidt 2015; Whitman & Ackerman 2015; Wright, Davies, Lau, McCall, & McKay 2006). We believe that it is of fundamental importance for basic and applied ecology to understand the relationships between niche, habitat suitability and population and individual state variables (Matthiopoulos et al. 2015; Schurr et al. 2012; Thuiller et al. 2010; Thuiller et al. 2014).

Using a pond-breeding amphibian as a model, Unglaub et al. (2015) showed that a commonly used habitat suitability index predicted neither pond occupancy nor individual survival. Instead, habitat suitability could be used to predict the ponds where reproduction occurred. Here, we study the relationship between habitat suitability, population size and body condition (i.e., a measure of individual performance) in a metapopulation of the Great Crested Newt (*Triturus cristatus*), a threatened pond-breeding amphibian. We argue that it is important to use both individual-level and population-level metrics to assess and understand habitat suitability because effects on individuals will not necessarily have an effect at the population level (McPeek & Peckarsky 1998; Vonesh & De la Cruz 2002). Moreover, habitat suitability may affect abundance and phenotypic traits differently (Ousterhout et al. 2015), and phenotypic traits of individuals can affect population dynamics and vice versa (Ozgul et al. 2010). Linking abundance rather than occurrence to habitat suitability may be of greater interest to ecologists and conservation biologists because spatial variation in abundance contains more information than occurrence data (Royle, Nichols, & Kéry 2005). However, population size should not be used as the sole metric to describe habitat suitability (Van Horne 1983). We decided to use body condition as an individual-level metric to assess habitat suitability (Bean et al. 2014; Johnson 2007) because a negative relationship between abundance and body size has been reported in previous studies (Green & Middleton 2013; Ousterhout, Anderson, Drake, Peterman, & Semlitsch 2015; White, Ernest, Kerkhoff, & Enquist 2007). In amphibians in general and in newts in particular, body condition is an important phenotypic trait that is related to environmental variation, habitat quality, individual survival, and sexual selection (Green 1991; Janin, Léna, & Joly 2011; Reading & Clarke 1995; Reading 2007; Scheele et al. 2014).

We tested whether habitat suitability has positive effects on both population size (as originally suggested by Oldham, Keeble, Swan, & Jeffcote 2000) and body condition. Alternatively, there may be a positive effect of habitat suitability on population size only, and a negative effect on body condition because increased population size may lead to lower per-capita resource availability. Testing which pattern holds true appears crucial for our understanding of habitat suitability.

Materials and methods

Study species

Great Crested Newts (*Triturus cristatus*) are among the most prominent pond-breeding amphibian species in Europe. They reach up to 20 cm in total body length, with females being generally larger than males. Males display a high dorsal crest as part of the species' sexual dimorphism during the time of reproduction (Jehle, Thiesmeier, & Foster 2011). Adult, juvenile, and larval Crested Newts can easily be captured with traps in ponds during the breeding season (March to July; Jehle et al. 2011). Great Crested Newts are listed in Annexes II and IV of the European Habitats Directive (92/43/EEC). EU member states are required to monitor the conservation status of this species. Great Crested Newts are on the Red Lists of many European countries (Dufresnes & Perrin 2015).

Study area and sampling procedure

We conducted a capture-mark-recapture study in 41 lentic water bodies within the adjacent nature reserve areas Höltigbaum and Stellmoorer Tunneltal which are located in the north of Hamburg, Germany (53° 37′ 32″ N, 10° 12′ 18″ E; Fig. 1). The study area covers 743 hectares. The main habitat and land use types are pasture, riparian forests, reeds, fallows, dry meadows, broadleaf forests, and a variety of small water bodies.

In 2012, we captured newts during two sessions, one early (April/May) and one late (June/July) in the breeding season. Each capture session consisted of three consecutive days of capturing newts, giving us a total of six capture events for each pond in a "robust design" format (Williams, Nichols, &