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Short communication

Landscape influences the morphology of male common toads (*Bufo bufo*)

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ABSTRACT

In Europe, the recent agricultural intensification has strongly homogenised the landscape. This loss in habitat diversity and the use of agrochemicals are considered as major causes of the global erosion of biodiversity. Landscape changes may also favour phenotypic variation with divergences between populations even at a small spatial scale. We investigated this notion in the common toad (*Bufo bufo*), a species that inhabits a wide variety of rural habitats. Specifically, we compared the morphology of male adult toads from three contrasting landscapes: forests, traditional farming landscape and intensive farmlands. Overall, individuals from open landscapes were larger and heavier, had longer hind legs and larger parotoid glands than their forest counterparts; suggesting that open landscapes positively influence body size in this species. However, toads from intensive farmland were less symmetrical, suggesting that these individuals may have experienced environmental stress during larval and/or post-metamorphic development. Overall, our results suggest that landscape-specific traits can influence the morphology of male toads in complex ways. Further studies are required to comprehensively assess the impacts of environmental and anthropogenic pressures on amphibians in agroecosystems.

1. Introduction

During the last century, strong changes in land-use priorities have provoked a shift from natural or ancestral rural landscapes to large scale agricultural and urban systems (Chapin et al., 2000; Foley et al., 2005). In Europe, the revolution in agricultural practices that occurred after World War II led to land consolidation, which has strongly homogenised the landscape, from a complex matrix of small fields and meadows bordered by hedges, to very large fields hosting monocultures (intensive farmland; Benton et al., 2003; Tscharntke et al., 2005). In addition, agricultural intensification is also characterised by considerable use of agrochemical substances (Geiger et al., 2010). Overall, these changes in land-use and landscape structure are considered as driving forces in the global biological diversity loss that affects most taxonomic groups at a global scale (Vitousek et al., 1997; Fischer and Lindenmayer, 2007).

Although biodiversity and population trends (declines or outbreaks) seem to be influenced by landscape heterogeneity (Van Burskirk and Arioli, 2004), changes in landscape structure might also bear other consequences on organisms. For instance, the locomotor capacities required to live in a forest may strongly diverge from those required to successfully forage in an extended monoculture. Similarly, the strategy adopted by an individual to evade predation should vary depending on landscape structure (Murdoch et al., 1996; Krivan, 1998). Finally, in agricultural environment, species must face the presence of many agrochemical substances (Berger et al., 2012), which have been suggested to induce trait changes in nontarget species (Lawrence and Isioma, 2010; Relyea, 2012). Taken together, these elements suggest that landscape changes should be responsible for new pressures that could lead to phenotypic divergence between populations from different habitats (Van Burskirk and Arioli, 2004; Phillips et al., 2006; Janin et al., 2011).

We investigated this notion using the common toad (*Bufo bufo*) for several reasons. First this widespread species can live in a variety of habitats and persist even in highly modified agricultural areas, thereby allowing comparisons between landscapes. Second, as most amphibians, it displays a high level of phenotypic plasticity, thereby allowing to investigate the impact of landscapes on phenotype (Newman, 1992; Brady and Grifiths, 2000). Third, it is an explosive breeder which allows sampling individuals in large

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numbers (Janin et al., 2011). Importantly, the terrestrial part of the life cycle occurs within 2 km from the breeding sites, which allow straightforward classification of the surrounding landscapes (Janin et al., 2011).

We compared the morphology of adult male toads from forest, traditional farming landscape and intensive farmland. We predicted that 1) Body condition should be lower in altered intensive agricultural landscapes where trophic resources are expected to be poorer and scarcer, 2) locomotion-related traits (body size, relative limb size) should be more developed in intensive farmland, because toads should travel more to forage successfully or to evade predation, 3) defensive attributes (parotoid glands which secrete an alkaloid substance to deter predators) should be larger in altered agricultural landscapes where the refuges needed to evade predation are scarcer, and 4) asymmetry should be greater in intensive farmlands, because of altered developmental conditions (i.e., suboptimal habitats).

2. Materials and methods

2.1. Study species

The common toad, *Bufo bufo*, is one of the most common anuran species in Europe. Toads emerge from hibernation in early spring (March) and massively migrate towards aquatic breeding sites (Reading and Clarke, 1983). Breeding toads usually come back to the sites at which they were spawned (Reading, 1991). Males remain at the breeding site for several weeks, while females leave shortly after mating and egg-laying (Reading and Clarke, 1983). The remaining part of the annual cycle occurs in various terrestrial environments usually within 2 km from the breeding site (Janin et al., 2011). Because males can be captured in larger numbers at breeding sites, we restricted our sampling to adult males.

2.2. Sampling sites and landscape classification

Sampling took place in March 2015 in an area centred on the Centre d'Etudes Biologiques de Chizé (46°09′N, 0°24′W) in France. Reproduction sites (e.g. ponds) were localized using Google Earth, and surveyed during the day to determine accessibility and toad presence. A total of 12 non-overlapping sites were sampled. Study sites were classified into three landscape categories following the main structures of our study area: forest, traditional farming landscape composed by a complex matrix of small fields and meadows bordered by hedges (hereafter hedgerow network, Forman and Baudry, 1984) and intensive farmland composed by extended arable fields (hereafter farmland).

To create landscape categories relevant at the spatial scale used by a toad, for each study site we applied three buffers that span the potential distance travelled by a toad to reach a breeding site (radii of 500 m, 1000 m and 2000 m; Janin et al., 2011). Classification was done using the "BD Ortho" and "BD Topo" vector databases provided by the Institut Géographique National (IGN, available at http://professionnels.ign.fr/bdortho and http://professionnels.ign.fr/bdtopo). Using QGIS (version 2.8.1), we assessed the quantity of hedges ($m\,ha^{-1}$) and the tree cover (%) for each radius. We classified each sampling site according to the dominant surrounding landscape: Sites around which the hedge linear exceeded $40\,m\,ha^{-1}$ were classified as "hedgerow network" (Baudry et al., 2000), sites around which the tree cover exceeded 30% were classified as "forest", and the remaining sites were considered as "farmland" (Appendix A). In practice, no conflicts emerged using these threshold values (e.g., no site was characterized by more than

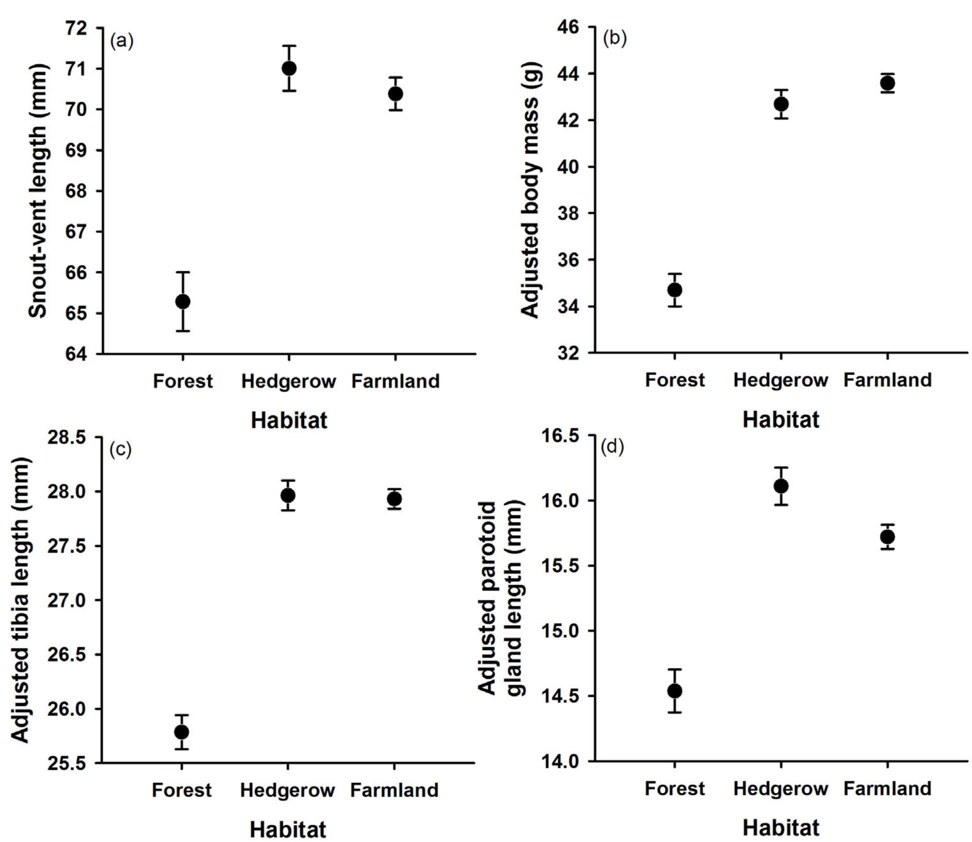

Fig. 1. Morphological traits of toads from three landscapes measured at a spatial scale of 500 m. (a) Snout-vent length, (b) Adjusted body mass, (c) Tibia length and (d) Parotoid gland length. "Hedgerow" stands for hedgerow network. Data are presented as their mean ± S.E.