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Original Investigation

Effects of a drought episode on the reproductive success of European free-tailed bats (*Tadarida teniotis*)

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ABSTRACT

Increases in the frequency and severity of droughts are expected in the Mediterranean region under ongoing climatic change, but their potential effects on bat populations still remain largely unstudied. Here we address this issue, by using data from a monitoring program of *Tadarida teniotis* to assess the reproductive consequences of a severe drought event. Unusually dry conditions occurred in the first of the 2 years under study (2012–2013), when the annual precipitation was the lowest on record during three decades, and the normalized difference vegetation index (NDVI) was well below the long term median, particularly during the pre-breeding season. A total of 1304 individuals were captured between May–October 2012 and 2013, and their body condition index (BCI), gender, age, and reproductive status were assessed. In both years, the BCI of adults increased throughout the year, reaching its maximum in October. BCI in May was significantly lower in 2012 than 2013, but converged thereafter to similar values. The sex-ratio varied throughout the year, but the proportion of females was consistently higher in both years. The number of pregnant or lactating females and the proportion of juveniles were significantly lower in 2012 than in 2013. Overall, our results suggest that the drought event largely impaired the reproduction of *T. teniotis*, though it only affected body condition early in the pre-breeding season. Possibly, dry conditions in 2012 resulted in reduced food resources during pre-breeding, limiting individuals' ability to restore their body condition after the winter and before breeding season. As a consequence, most individuals did not produce offspring, probably using the food resources available during the dry breeding season to restore body condition before winter. This is in line with the view that long-lived species reduce investment in reproduction to maximize adult survival during stressful periods, and suggest that multiyear droughts may result in population declines due to recurrent reproductive failure.

Introduction

There is currently a global anthropogenic decline in biological diversity, and in the goods and services it provides to humankind (Tittensor et al., 2014; Russo and Jones, 2015). A factor likely to become one of the major threats to biodiversity is climate change and the associated increases in the frequency of extreme events such as hurricanes, floods, heat waves and droughts (IPCC, 2012). Droughts may be particularly relevant because they contribute to decrease ecosystem productivity, increase mortality and reduce fecundity rates at the population level (Archaux and Wolters, 2006), thereby affecting a wide range of taxa (Ledger et al., 2012).

Given its pervasive effects, droughts are considered a major threat to conservation in biodiversity hotspots worldwide (Myers et al., 2000; Milly et al., 2005), with Mediterranean areas featuring at the top of the most vulnerable (Dai, 2011). This might be regarded as unexpected, however, because Mediterranean climates are naturally characterized by predictably dry and hot summer periods (Blondel et al., 2010). It might thus be assumed that species associated to this biogeographical region should be adapted to cope with the occurrence of droughts. Notwithstanding, there is evidence that the frequency of severe droughts is increasing in the Mediterranean basin, with 10 out of the 12 driest winters since 1902 occurring during the last 20 years (Hoerling et al., 2012). This new and more severe drought regime may have negative

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consequences, as suggested for Mediterranean stream fish (Magalhães et al., 2007).

Information on the effects of droughts is lacking for Mediterranean bats. This information is needed, because the Mediterranean basin harbors a particularly speciose bat fauna in the European context, including some endemics (Dietz et al., 2009). Moreover, some of these species will likely suffer major range shifts due to climate change (Rebelo et al., 2010), which will result in species losses at the regional level (Amorim et al., 2014). Droughts may exacerbate these negative effects, because peak dry conditions occur in summer during the periods of pregnancy and lactation of many species, when females experience greater metabolic requirements, and thus have a high demand for water and food (Kunz et al., 1995; Mclean and Speakman, 1999; Adams and Hayes, 2008; Frick et al., 2010). As a consequence, the reproductive output of Mediterranean bats may strongly decline during unusually dry years, as suggested for a few other bat species studied in arid and temperate regions elsewhere (Adams and Hayes, 2008; Adams, 2010; Frick et al., 2010).

Here we aimed to assess the consequences of a severe drought event on Mediterranean bat reproduction, using data from a monitoring program of the European free-tailed bat, *Tadarida teniotis* (Rafinesque, 1814). *T. teniotis* is a medium-large crevice-dweller that mainly occurs in the Palearctic (Dietz et al., 2009), where it is strongly associated with the Mediterranean region (Horáček et al., 2000; Rebelo et al., 2010). It is locally abundant, naturally roosting in cliffs, but often occurring also in man-made structures such as bridges, which somehow mimic the rupicolous environment (Amorim et al., 2013; Russo and Ancillotto, 2015). A monitoring program of the species started in northeast Portugal in 2012, corresponding to an unusually dry year that provided the opportunity to assess the short term effects of a severe drought on a Mediterranean adapted species. Based on comparisons between the dry (2012) and an average year (2013), we aimed to assess the effects of this drought on (a) the body condition of individuals, (b) the age structure and sex-ratio, and (c) the reproductive output of the population. The results highlight the need for long-term monitoring and will help to calibrate monitoring programs to detect and measure potential fluctuations on the breeding success of natural populations.

Material and methods

Study area

The study area was located in north-eastern Portugal (N41°09′–42°00′, W7°15′–6°15′) in the Sabor river valley (Fig. 1). Climate is transitional between meso- and supra-mediterranean, with cold winters (average temperature of the coldest month <6 °C) and dry summers (total annual precipitation <600 mm, of which <5% in July–August), which are particularly hot in some valleys where monthly average temperatures exceed 21 °C (Monteiro-Henriques, 2010). Topography is characterized by plateaus with average altitudes of 700–800 m a.s.l., and the vegetation is mainly meso-mediterranean with evergreen oaks (*Quercus suber*, *Q. rotundifolia*) dominating the native woodlands (Hoelzer, 2003). Valleys are deep and narrow, and watercourses can have steep slopes and a highly variable hydrological regime, with many of them drying out seasonally while others persist year-round. The orography of the area provides optimal conditions for rupicolous fauna and flora.

Monitoring focused on *T. teniotis* roosts found in five bridges (Fig. 1), where the number of individuals was large and captures were much easier than in natural roosts in cliff crevices. These man-made structures offer several roosting possibilities for bats, mainly crevices of different types, but also box girders that mimic cave roosts. All the bridges are of modern construction (the oldest was built in 1992) and are part of the Portuguese main road network. The length of the studied bridges ranged from 60 to 600 m, and height from 10 to 110 m.

Table 1
Number of *Tadarida teniotis* individuals captured in NE Portugal during the years of 2012 and 2013, according to age, gender, and reproductive status.

Age	Gender	Reproductive status	2012	2013	Total
Adult			546	589	1135
	Female		376	446	822
		Pregnant	17	90	107
		Lactating	7	144	151
		Non-reproducing	352	212	564
	Male		170	143	313
		Active	0	5	5
		Not-active	170	138	308
Juvenile			19	150	169
	Female		12	77	89
	Male		7	73	80
Total			565	739	1304

Fieldwork

The study was based on monthly live-trapping of *T. teniotis* throughout the breeding season, from May to October 2012 and 2013. Captures were carried out from dusk till dawn in a total of 57 nights, corresponding to an average of 4.8 ± 1.1 (3–7) nights per month. Captures were made with a trap specifically designed to increase trapping efficiency of *T. teniotis* roosting in bridge crevices, consisting of a steel frame for mist nets that can be secured to the bridge rails or walls (Amorim and Rebelo, 2011). This system can be easily assembled by two persons and the capturing area is adjustable by moving vertically up to two mist-nets. Length is also adjustable and, in our case, up to three sections of 12 m were successfully assembled. An average of 78.1 ± 16.8 m^2 of mist-nets were assembled per night, resulting in the capture of 1034 *T. teniotis* individuals, of which 565 were captured in 2012, and 739 in 2013 (Table 1).

Captured bats were kept in individual cotton bags until they were processed. Individuals were sexed, aged, weighed and measured for forearm length. A digital scale (100 ± 0.01 g) and a caliper (150 ± 0.01 mm) were used to measure weight and forearm length, respectively. Age and reproductive status were assessed following Kunz and Parsons (2009). We used the presence of dried semen around the vulva as an indication of mating in females, while in males we used the size of testes and the presence of a well-developed gular gland, often with visible secretions and lacking hair around it (Appendix A). To the best of our knowledge, this gland has never been described in this species (Ibáñez and Arlettaz, 2013). We did not attempt to determine oestrus due to the difficulty in using morphological evidence (Kunz and Parsons, 2009). Pregnancy was assessed by palpation, distention and size of the abdomen, though early pregnancy was difficult to diagnose. Evidences for lactation included the presence of milk and the enlargement of nipples.

The presence of unfused epiphyses in young bats was used to separate them from adults. All individuals captured before September were considered adults, because young of the year were only observed from that month onwards, and individuals born in the previous year (sub-adults) were no longer distinguishable. During October some individuals could no longer be classified as young solely by epiphyses observation, and so in young males we used as additional characteristics the presence of a small non-secreting gular gland and the smaller size of testes. Young females were usually distinguishable by their small nipples and smaller size.