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Short Communication

Rapid response of a long-lived species to improved water and grazing management: The case of the European pond turtle (*Emys orbicularis*) in the Camargue, France

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ABSTRACT

Among human activities, the effect of habitat management by grazing on population viability is ambiguous. Indeed, beneficial effects of grazing are expected by maintaining open meadows, but overgrazing is supposed to increase mortality by trampling. Grazing has been shown to negatively impact the survival of European pond turtle (*Emys orbicularis*) in the Camargue. Consequently, a new management plan was defined. We investigated the consequences of this management using capture–recapture methods to estimate variations of population sizes in this managed site and a control site over a 17 years period. Results show an increase of the number of adults and juveniles on the managed site after the management change. Our results suggest that improved water management with flooding in autumn provided better hibernation conditions, and that reduced grazing intensity in autumn/winter likely decreased the risk of trampling. Population size significantly increased in less than 4 years following the management change, probably by the relaxation of density-dependence. It is an original result for a long lived-species supposed to have an important time of resilience to perturbations.

Introduction

One third of the reptiles inhabiting marine and freshwater environments are threatened of extinction (Böhm et al., 2013). Higher level of threats to freshwater and marine habitats compared with terrestrial ones are likely responsible for this figure. In particular, 46–57% of the freshwater turtle species are threatened by habitat degradation (Böhm et al., 2013; World Commission on Dams, 2000). Many of these species are particularly affected by home range reduction due to the loss of favourable habitats, competition with invasive species and landscape fragmentation (Williams & Osentoski, 2007).

The European pond turtle (*Emys orbicularis*) is the reptile which has shown the most important range reduction in Europe (>2%) between 1970 and 1990 with increasing fragmentation of populations and the extinction of several relict populations in Eastern Europe (Servan, 1999). Poaching (especially capture with fishtraps), road mortality, invasive species, habitat loss and transformation (Rogner, 2009) are the main causes of this negative trend. In particular, drainage, channel constructions, water regulation and dike management generally cause strong habitat homogenization and population fragmentation (Rogner, 2009). Furthermore, the conversion of wetlands to croplands generates additional threats for European pond turtles by exposing them to water pollution.

European pond turtles require both good quality freshwater habitat for foraging and terrestrial habitat with open areas and low plant cover for successful nesting (Ficetola et al., 2004). In this context, cattle grazing may provide open meadows offering favourable nesting sites, essential for the breeding dynamics of the species as was shown in the bog turtle *Glyptemys muhlenbergii* (Tesauro & Ehrenfeld, 2007). However, the benefits of grazing remain controversial: some authors argue that intensive grazing negatively affects the survival of herpeto-fauna by changing the macrohabitat (vegetation structure) or microhabitat (ground temperature),

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decreasing prey abundances (Wilgers et al., 2006), or increasing the numbers of injured animals by trampling (Olivier et al., 2010).

Olivier et al. (2010) compared the dynamics of two European pond turtle populations of the Camargue (south of France) facing different managements, the Esquineau population face intense grazing and a variable water management while the Faïsses site has constant conditions of management characterized by moderate grazing intensity and stable water levels. The Esquineau population was found to be declining and individuals were found to present shell damaged by cattle trampling. It was thus hypothesized that trampling increased turtle mortality and consequently reduced the numbers of individuals (Fig. 1). In parallel, we suspected that natural winter flooding was too late to offer optimal hibernation conditions since overwintering starts as soon as autumn (Rogner, 2009). Therefore, sites offering better conditions for hibernation due to the dense vegetation (that allows stable conditions to be maintained during the winter; Thienpont et al., 2004) were unavailable, forcing European pond turtles to take refuge in areas less favourable, which may have increased mortality during the hibernation period. Based on these hypotheses, in 2007, a new management plan was implemented at the Esquineau so that flooding started in autumn and the timing and stocking rates of cattle were changed with moderate grazing intensity outside the active period of turtles (Fig. 1). In an adaptive management perspective, monitoring the change of turtle population size following this management change should allow evaluating the effect of grazing and water management on this species. Adaptive management is a conservation strategy that aims to "learn by experimenting" (McLain & Lee, 1996; Walters, 1986). The principle is to establish a management policy based on assumptions and models of the functioning of the system, and to assess their effectiveness *a posteriori* (Berkes et al., 2000; Maris & Béchet, 2010). Hence, 7 years after management change we evaluated the effectiveness of the conservation measure taken to prevent the decrease of the *E. orbicularis* population to validate the hypotheses made on the functioning of the system. In particular, we expected that mitigating the grazing pressure and changing water management would allow population size to return to the first period state.

Materials and methods

Study area and sampling

The two populations of *E. orbicularis* studied are located in the natural reserve of the Tour du Valat in the Camargue (southern France, ~43°30′N, 4°40′E). The first site, the Esquineau, has a total area of 250 ha. The second site, the Faïsses (Moncanard in Olivier et al., 2010) covers a surface area of 100 ha. The studied populations are ~1.5 km apart. At both sites European pond turtles inhabit two kinds of habitats: permanent and semi-permanent marshes managed by man-made irrigation (the majority of the Esquineau) and drainage canals with presence of water all years round (the majority of the Faïsses; Olivier et al., 2010).

From 1997 to 2013, turtles of both populations were captured from April to August with fishtraps and by hand with the same methodology as Olivier et al. (2010). For each capture, the age, sex and shell condition (damaged or not) were recorded. Sex was identified by observing male secondary sexual characteristics: concave breastplate, orange eyes (yellow in females), basic wide tail and cloacae away from the plastron (Zuffi & Gariboldi, 1995). Turtles were classified as adults if they had no visible growth rings (Castanet, 1988). In juveniles, reading these growth rings allows to determine the individual birth year (Olivier, 2002). The juvenile term represents individuals from second year life to maturity phase. The individuals in their first year life are called emergent. Each individual was marked (except emergent) with permanent notches cut into the carapace marginal scutes with a small hacksaw (Cagle, 1939). Turtles were returned within 24 h to the place where they had been collected. A total of 7059 captures corresponding to 963 different individuals was obtained over the 17-years study period. More precisely, the dataset includes 364 adults and 276 juveniles from the Esquineau and 207 adults and 116 juveniles from the Faïsses. For adult individuals, data from Olivier et al. (2010) were used from 1997 to 2006 and new data were supplemented from 2007 to 2013. A new dataset was used for juvenile individuals.

Both horses and cows graze on land and in the marshes. Grazing intensity was calculated as P = (*number of adult livestock* * *number of months of grazing*)/(*grazed area (ha)*). We arbitrarily defined 3 thresholds of grazing intensity: low under a value of 2, high above of 5 and moderate between these two values. The duration of grazing periods varies between years: 1) all year long between 1997 and 2001; 2) in spring and summer between 2002 and 2006; 3) in autumn and winter after 2007 (Fig. 1).

Water levels were measured 2 to 3 times per month and dry period were recorded. Before 2002, water was present in marshes and canals all year long. Since 2002, water levels were modified with a dry period at the end of summer and a natural flooding by rainfall in winter. After 2006, flooding was artificially supplemented by pumping in autumn. Both management changes only affected the Esquineau site so that the Faïsses site can be considered as a control site.

Statistical analysis

We estimated annual variations of the European pond turtle population size at each site separately for each age-class (adult and juvenile) by using close population models. Each year from two to five sampling periods were performed. These sampling periods were used to build the capture histories. Each sampling period length between three to five days was then pooled in our analysis. We first tested for each year whether the population was closed or not by using CLOSE-TEST (Stanley & Burnham, 1999). Then we estimated population size at each of the 17 years with the CAPTURE module (Rexstad & Burnham, 1991) of MARK software (White & Burnham, 1999). CAPTURE allows varying assumptions regarding capture probabilities including: i) inter-individual heterogeneity of capture (M*h*); ii) time variation in capture probability (M*t*); iii) a behavioural response to the first capture (M*b*) and the different possible combinations of effects on capture probabilities. The best model is selected based on the maximum value (between 0 and 1) of a discriminate model selection criteria specific to CAPTURE. We calculated the size of the whole population by adding the number of adults and juveniles estimated each year for each population.

We attempted to explain annual population size variations at the two sites by using Generalized Linear Models (GLM) with a Gaussian distribution for the error term. We included the standard error of the population size as weight to take into account inter-annual variations in the precision of the estimate. We evaluated the fit of models by checking normality, independence and homoscedasticity of residuals. We first tested for a difference of population size between sites. Then we tested for each population the effect of age (juvenile or adult), and of the three periods corresponding to the three management plans: a single period 1997–2013, two periods 1997–2001/2002–2013 and 1997–2006/2007–2013, and three periods 1997–2001/2002–2006/2007–2013. Model selection was achieved using the Akaike Information Criterion corrected for small sample size (AICc; Burnham & Anderson, 2002). Model with the lower AICc value is considered as the best model for the data at hand. Models with an AICc difference less than 2 are considered