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Research Article

Extrinsic and intrinsic factors affecting the daily rhythms of a semiaquatic carnivore in a mediterranean environment

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Abstract

Field research assessing the effects of both intrinsic and extrinsic factors on animal daily rhythms has been rare, particularly in carnivores and other medium-to-large mammals in hot environments (e.g., Mediterranean regions). This is a crucial knowledge gap, hindering the accurate prediction of how animals might react to widely-anticipated global environmental changes. To assess the behavioral plasticity of Mediterranean semiaquatic mammals in coping with harsh climatic conditions, we investigated the effects of intrinsic and extrinsic factors on the daily rhythms of a Mediterranean population of radio-tracked Eurasian otters (*Lutra lutra*). Multiple components cosinor population models revealed markedly nocturnal activity, affected by seasonality and air temperature. In particular, otters lowered their daylight activity and increased their nighttime activity during the dry season, being generally less active under higher air temperatures. Other extrinsic factors affecting otters' daily rhythms were moon phase, habitat type and wind, whereas differences in activity patterns according to intrinsic factors were mainly related to males' ranging behavior and females' reproductive status. This study provided detailed and population-mean data on *Lutra lutra* daily rhythms, including some insights into inter-individual variation. More importantly, it showed that otters are well adapted to the dry and wet season-cycle typical of Mediterranean regions, while highlighting their potential vulnerability to increasing air temperatures.

Introduction

The Earth's rotation and orbit around the sun cause noticeable periodicity at certain latitudes, which is manifested by obvious effects on both the light-dark cycle and seasonality. These periodic environmental cues (also called "zeitgebers") lead to the insurgence of endogenous circadian rhythms that synchronize ("entrain") animal activities with factors in the environment (Aschoff, 1981). Understanding the dynamics that make an organism adapt its functions to its surrounding photoperiod, season, or other extrinsic (e.g., moon, rain, air temperature) or intrinsic (e.g., gender, age, reproductive status) factors is a key concept in ecology. It has, in fact, implications in several fields of study that include morphology, physiology, evolution, ethology (Enright, 1970; Daan and Aschoff, 1982; Halle and Stenseth, 2000; Kronfeld-Schor and Dayan, 2003; Hut et al., 2013), and conservation biology (Daan, 1981; Macdonald, 2016). This being said, there is still no comprehensive understanding regarding how intrinsic and extrinsic factors influence animal activity rhythms and their inter- and intra-individual variability (Refinetti, 2012). Field research addressing questions related to animal activity rhythms has been rare, especially pertaining to medium-to-large wild mammals. Existing chronobiology literature instead mostly focuses on laboratory experiments and small mammals, which limits its applicability and predictive power in natural environments (Halle and Stenseth, 2000; Fernández-Duque, 2003).

Particularly little has been investigated, to date, on the influence of seasonality and air temperature on the daily rhythms of free-ranging mammals living in Mediterranean regions (Pita et al., 2011). Research on small mammals by Pita et al. (2011) is a notable exception. However, the publication of similar studies on medium-to-large mammals, and especially carnivores, lags far behind. Moreover, those studies that have been published generally have been limited in sample size, thereby restricting any inferences on individual and seasonal variability (e.g., Beltrán and Delibes, 1994; Palomares and Delibes, 2000). Particularly overlooked so far have been assessments on whether or how air temperature and other climatic variables influence wild mammals' activity and other behaviors in present times (Helm et al., 2013; Bennie et al., 2014). Research addressing climate-related effects on animal ecology, in fact, has generally focused upon modeling the geographic distribution of animals (e.g., Araújo et al., 2011; Cianfrani et al., 2011; Pacifici et al., 2015). Changes in biogeographical distributions, however, arise secondary to individual behavioral responses to varying weather conditions (Helm et al., 2013; Bennie et al., 2014; Macdonald, 2016). Neglecting contemporary thermal constraints on animal behavior thus

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