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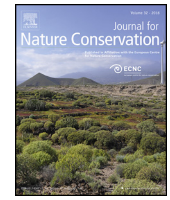

Short communication

Reducing light-induced mortality of seabirds: High pressure sodium lights decrease the fatal attraction of shearwaters

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ABSTRACT

The use of artificial light at night and its ecological consequences are increasing around the world. Light pollution can lead to massive mortality episodes for nocturnally active petrels, one of the most threatened avian groups. Some fledglings can be attracted or disoriented by artificial light on their first flights. Studies testing the effect of artificial light characteristics on attractiveness to seabirds have not provided conclusive results and there is some urgency as some endangered petrel species experience high light-induced mortality. We designed a field experiment to test the effect of three common outdoor lighting systems with different light spectra (high pressure sodium, metal halide and light emitting diode) on the number and the body condition of grounded fledglings of the short-tailed shearwater *Ardenna tenuirostris*. A total of 235 birds was grounded during 99 experimental hours (33 h for each treatment). 47% of birds was grounded when metal halide lights were on, while light emitting diode and high pressure sodium lights showed lower percentages of attraction (29% and 24%). Metal halide multiplied the mortality risk by a factor of 1.6 and 1.9 respectively in comparison with light emitting diode and high pressure sodium lights. No differences in body condition were detected among the birds grounded by the different lighting systems. We recommend the adoption of high pressure sodium lights (or with similar spectra) into petrel-friendly lighting designs together with other light mitigation measures such as light attenuation, lateral shielding to reduce spill and appropriate orientation.

1. Introduction

The increasing use of artificial light at night is causing a loss of the natural nightscapes worldwide (Falchi et al., 2016). Light pollution is an emerging threat to biodiversity conservation by disrupting circadian rhythms, affecting natural behaviours, reproduction, animal movement or endocrine systems, and finally, influencing the ecosystem functioning by cascading effects (Gaston, Duffy, Gaston, Bennie, & Davies, 2014; Hölker, Wolter, Perkin, & Tockner, 2010; Longcore & Rich, 2004). Although marine environments are mostly free of artificial light, most coastal areas are affected by light pollution at night (Davies, Duffy, Bennie, & Gaston, 2014). Artificial lights along the coast can cause direct and incidental mass mortality events in endangered marine taxa, e.g. turtles or seabirds (Rich & Longcore, 2006; Rodríguez, Holmes et al., 2017). Despite the multiple effects on human health and biodiversity, artificial light is steadily proliferating in the night environment led by improvements in luminous efficiency (Kyba, Hänel, & Hölker, 2014). Thus, the determination of the impact of the different artificial lighting systems on biodiversity should be a priority for developing appropriate lighting policies to enable better coastal planning and conservation practices.

Fledglings of nocturnal petrel species (including shearwaters and storm-petrels) are attracted to artificial lights during their first flights from nest-burrows to the ocean, often colliding with human structures or the ground. If they survive the collision, they are grounded in artificially lit areas and susceptible to being killed by incidental threats (vehicle collision, predation, starvation or dehydration) (Ainley, Podolsky, Deforest, & Spencer, 2001; Le Corre, Ollivier, Ribes, & Jouventin, 2002; Rodríguez, Rodríguez, Curbelo et al., 2012; Rodríguez et al., 2014). To mitigate light-induced mortality of petrels, rescue programs have been implemented in several locations around the world (Rodríguez, Holmes et al., 2017). However, pre-emptive measures, that reduce the attractiveness of artificial lighting to seabirds, would be much more effective at the population level. To our knowledge, there is no published information on whether seabird attraction to artificial lights is related to the type of lights or individual traits of the seabirds. Here, we test the effect of three commonly used lighting systems with different

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light spectra (metal halide – MH, high pressure sodium – HPS – and light emitting diode – LED) on the attraction of short-tailed shearwater (*Ardenna tenuirostris*) fledglings, a species severely affected by light pollution (Rodríguez et al., 2014). We also test if body condition of grounded fledglings differs among lighting systems. Why petrels are attracted to lights is not entirely understood, but it may be related to food as petrels could confuse lights with natural bioluminescent prey or associate light with food during the nestling period at their nest-burrows (see Rodríguez, Holmes et al., 2017). Although short-tailed shearwater fledglings attracted by artificial lights do not seem handicapped, as their body condition is similar to those of adults (Rodríguez, Moffett et al., 2017), degree of attraction to lighting systems could be mediated by body condition. Body condition at fledging is a proxy to greater likelihood of survival and recruitment in long-lived seabirds (Becker & Bradley, 2007; Maness & Anderson, 2013). Thus, attraction of birds in good condition, i.e. those with higher survival and recruitment probabilities, to a particular lighting system would worsen the impact of such light for petrel populations. Apart from lighting systems, other factors appear to play a role in the number of seabirds attracted to lights. First, birds tend to fledge early in the night (Reed, Sincock, & Hailman, 1985; Rodríguez, Rodríguez, & Negro, 2015), and therefore, it was expected that the number of grounded birds would increase during the first nocturnal hours. Second, fledging is a synchronous process leading to high number of birds fledging around a peak date (27–28 April for the short-tailed shearwater; Rodríguez et al., 2014). Third, fledging date is favoured by strong winds which give a lift to flight-inexperienced fledglings (Rodríguez et al., 2014; Skira, 1991). Fourth, the number of grounded birds is reduced during full moon nights (Le Corre et al., 2002; Rodríguez & Rodríguez, 2009; Telfer, Sincock, Byrd, & Reed, 1987). Fifth, the number of attracted birds in a year is related to the number of fledglings produced by the population in that particular year, i.e. the higher breeding success the higher the numbers of grounded birds (Day, Cooper, & Telfer, 2003; Rodríguez, Rodríguez, & Lucas, 2012).

2. Material and methods

Our study was conducted on Phillip Island, south-eastern Australia, where natural night skyscapes unpolluted by artificial lights are available adjacent to short-tailed shearwater breeding colonies (Fig. 1*a*). Phillip Island is relatively low with a maximum altitude about 112 m above sea level. It holds around 543,000 breeding pairs of short-tailed shearwaters (Harris, Brown, & Deerson, 1980), which is more than 1% of its global breeding population (BirdLife International, 2017), mainly distributed along the south coast (Fig. 1*a*). The short-tailed shearwater nests in dense colonies generally in sandy soils. Adults start migration before their chicks fledge and consequently fledglings depart the colony in the absence of their parents. Fledglings try to reach the ocean on their first flights.

Our experiment was conducted in the overflow car park at Phillip Island Nature Parks on the Summerland Peninsula (−38.505942°S, 145.149486°E), which is a 13,000 m^2 grassed area surrounded by some unlit buildings and short-tailed shearwater colonies (Fig. 1*b*). At the experiment site, masts held the three types of lamps (MH, HPS and LED) at the same height and orientation at each mast. Five masts of 3–5 m high supported the lamps used during the experiment (Fig. 1*b*, *c*). The three light types employed in our study are commonly used in outdoor facilities (e.g. car parks, sport stadiums and industrial areas) and they emit different spectra (Fig. 2*a*; Table 1). MH and HPS bulbs emit light in 360° in every direction, and for this reason they were housed in similar luminaries. In contrast, LED emits light in one direction.

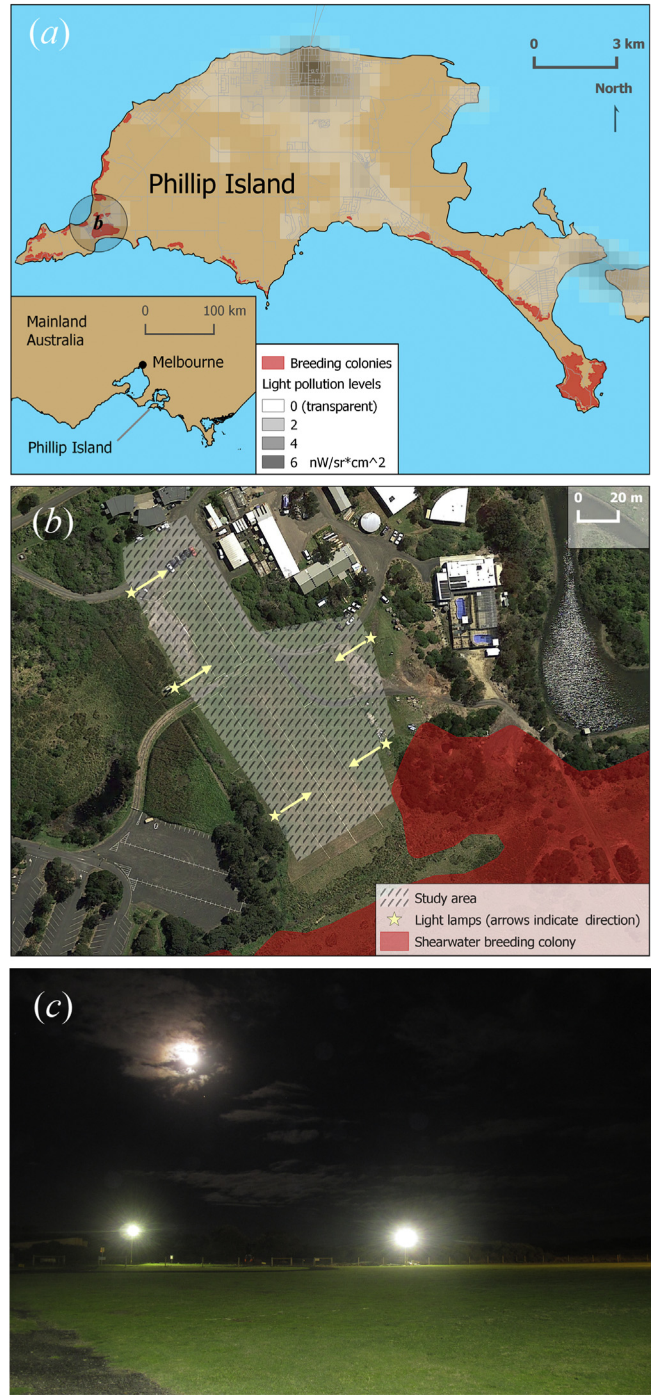

Fig. 1. (*a*) Phillip Island map showing distribution of breeding colonies, study site (grey circle) and light pollution levels taken from a nocturnal satellite imagery; NOAA National Geophysical Data Center; available at http://ngdc.noaa.gov/eog/viirs/download_monthly.html. (*b*) Map of the study area showing the light posts and the lit area. (*c*) Nocturnal picture showing two light-posts and the moon.

To assess the potential attraction of shearwater fledglings to the three lighting types, we designed an experiment in which every treatment (light type) was replicated every night. We lit the area at night during the fledging period and counted the number of grounded birds on the lit field. The experiment was repeated over three fledging seasons (2014: 22 April-4 May; 2015: 19 April-5 May; 2016: 26–29 April). To account for the high variability in number of groundings from night to night, we turned on each lighting type for one hour in a random order each night. The same type