Biological Conservation 191 (2015) 282–290

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Are artificial burrows efficient conservation tools for seabirds? A case study of two sympatric shearwaters on neighbouring islands and guidelines for improvement

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ARTICLE INFO

Article history:
Received 19 February 2015
Received in revised form 29 June 2015
Accepted 4 July 2015
Available online xxxx

Keywords:
Artificial burrows
Calonectris diomedea
Nesting habitat stability
Occupancy rate
Puffinus yelkouan
Reproductive success

ABSTRACT

Seabirds are one of the most threatened animal taxa worldwide as they have to deal with threats both at sea and on their breeding grounds. One of these threats is the loss and deterioration of their nesting habitat. Here, we evaluated the long-term effectiveness of providing artificial burrows for the conservation of Yelkouan (*Puffinus yelkouan*) and Scopoli's (*Calonectris diomedea*) shearwaters on two islands of the Hyères archipelago (Mediterranean, France). We estimated and compared the longevity, occupancy of and breeding success in artificial burrows and natural cavities. We also analysed factors affecting these three parameters in artificial burrows to optimize their installation for the conservation of our study species. Although their efficacy depended on the species and the island considered, artificial burrows provided more stable and persistent breeding habitat (12-years persistence: 80% vs. 72%), allowed the recruitment of new breeders and good reproductive success (49–76%), and probably reduced inter-specific competition for nesting cavities, across the two islands. The characteristics of both artificial burrows and the areas where they were installed affected artificial burrow efficacy in terms of longevity and occupancy by shearwaters. Thus, artificial burrows were successful tools for the conservation of these two Mediterranean species of shearwaters, particularly when their design and installation were optimized by limiting the risk of their destruction and by selecting burrow and habitat characteristics that enhance their occupancy by the target species. The evaluation of such conservation measures should be performed for every species and site to help managers design and implement effective conservation plans.

1. Introduction

Seabirds are among the most threatened animal taxa and are becoming globally threatened at a faster rate than any other bird taxon (Butchart et al., 2004; Croxall et al., 2012). Among Procellariiformes (albatrosses, shearwaters and petrels), over 45% of species are currently threatened and more than half of these species exhibit declining populations (IUCN, 2014). Competition with commercial fisheries, mortality by fishing gear, marine pollution, predation by alien mammals, human disturbance and the loss or deterioration of breeding habitat are their most critical threats (Butchart et al., 2004; Croxall et al., 2012). Because conservation actions are generally easier and less expensive to implement on land than at sea (Wilcox and Donland, 2007), those developed to allow Procellariiform populations to recover are usually carried out on the breeding grounds and include predator eradication and nesting habitat improvement by installing artificial nests for instance (Carlile et al., 2003; Bried et al., 2009; Jones et al., 2011; Jones and Kress, 2012).

Artificial nests (nest boxes or artificial burrows) have been used successfully in the study and management of several burrow- or cavity-nesting seabirds. They can be used to supplement available suitable breeding habitat (Priddel and Carlile, 1995; Lalas et al., 1999; De León and Mínguez, 2003; Bried et al., 2009; Madeiros et al., 2012; Sherley et al., 2012), increase breeding success and adult survival (Byrd et al., 1983; Priddel and Carlile, 1995; De León and Mínguez, 2003; Bolton et al., 2004; Libois et al., 2012; Sherley et al., 2012), decrease inter-specific competition for nesting habitat (Wingate, 1977; Ramos et al., 1997; Sullivan and Wilson, 2001; Bolton et al., 2004; Gummer et al., 2015), establish new breeding sites when coupled with chick translocation and/or vocal attraction (Podolsky and Kress, 1989; Bell et al., 2005; Miskelly and Taylor, 2004; Priddel et al., 2006; Miskelly et al., 2009; Carlile et al., 2012; Gummer et al., 2015), and make the study of breeding biology and habits easier and less disturbing

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http://dx.doi.org/10.1016/j.biocon.2015.07.002
0006-3207/

(Wilson, 1986, 1993; Bolton, 1995; Gaston, 1996; Gummer et al., 2015). Occupancy rates of artificial burrows generally increase over time and high rates (>20%) have been reported for many seabird species either from the first breeding season after artificial burrow installation (Wilson, 1986, 1993; Bolton, 1995; Ramos et al., 1997; Lalas et al., 1999; Sullivan et al., 2000; Bried et al., 2009), or from 2 to 4 breeding seasons after installation, as occupancy rates can take years to build up (Priddel and Carlile, 1995; Gaston, 1996; De León and Mínguez, 2003; Bolton et al., 2004; Libois et al., 2012). Several studies have thus shown an increase in the breeding population following the provision of artificial burrows (De León and Mínguez, 2003; Bried et al., 2009; Libois et al., 2012; Madeiros et al., 2012). However, artificial burrow occupancy rates have remained low (<6%) in some petrel species, even after 3 or more years of artificial burrow provision (Podolsky and Kress, 1989; Cruz and Cruz, 1996; Miskelly and Taylor, 2004). Productivity of seabirds using artificial burrows has been shown to be as high as or higher than that of those breeding in natural burrows from the first year of breeding, mainly due to protection from predators and adverse weather conditions, stabilisation of fragile sites, reduction in egg damage and in inter- or intra-specific interferences (Byrd et al., 1983; Wilson, 1986; Bolton, 1995; Priddel and Carlile, 1995; De León and Mínguez, 2003; Bolton et al., 2004; Bried et al., 2009; Libois et al., 2012; Gummer et al., 2015). However, the productivity has been lower in some petrels using artificial burrows because of predator control failure or unidentified causes (Podolsky and Kress, 1989; Cruz and Cruz, 1996).

The occupancy rate of artificial burrows can vary between colonies located on the same small island or on different islands because of variations in habitat quality/optimality (Bolton, 1995; Priddel and Carlile, 1995), in conspecific vocal activity (Podolsky and Kress, 1989), in natural burrow availability (De León and Mínguez, 2003) and in predation pressure (Libois et al., 2012). Occupancy can also be accelerated and increased when artificial burrows are used to directly replace natural ones (De León and Mínguez, 2003). Because the characteristics of natural burrows (dimensions, shape, nearby environment such as slope, vegetation and substrate covers, elevation, and density of conspecifics) affect their occupancy and the breeding success in seabirds (e.g. Byrd et al., 1983; Ramos et al., 1997; Bourgeois and Vidal, 2007), it is likely that similar characteristics would affect these parameters in artificial burrows as well. In addition, materials used for their construction can affect temperature inside artificial burrows (Carlile et al., 2012). For instance, heat stress in artificial plastic burrows placed under a section of forest exposed to long periods of warm is thought to have caused the deaths of a third of translocated grey-faced petrel (*Pterodroma macroptera*) chicks in New Zealand (Miskelly et al., 2009). Thus, locality (e.g. island) and the characteristics of both artificial burrows (e.g. dimensions, construction materials) and the areas where they are installed (e.g. vegetation and substrate covers, slope) are likely to affect artificial burrow efficacy.

The Yelkouan (*Puffinus yelkouan*) and the Scopoli's (*Calonectris diomedea*) shearwaters are two medium-sized Procellariiformes endemic to the Mediterranean Basin which breed sympatrically (Warham, 1990). The Yelkouan shearwater has been considered as a distinct species from both the Manx (*Puffinus puffinus*) and the Balearic (*Puffinus mauretanicus*) shearwaters for over 10 years (Sangster et al., 2002). The Scopoli's shearwater has just been separated from the Cory's shearwater (*Calonectris borealis*) which breeds mainly in the Atlantic, though the separation is still debated (Sangster et al., 2012; Genovart et al., 2013). The Yelkouan shearwater has recently been uplisted to the Vulnerable category in the IUCN redlist because of rapid population decline (Derhé, 2012a; BirdLife International, 2014; IUCN, 2014). The newly split Scopoli's shearwater is considered Least Concern, but there is evidence that the species could be slowly declining (Derhé, 2012b). Major threats to these Mediterranean shearwaters at their current breeding colonies are predation of adults and/or eggs and chicks by introduced mammalian predators such as black rats (*Rattus rattus*) and feral cats (*Felis catus*) (Igual et al., 2006; Pascal et al., 2008; Baccetti et al., 2009; Bonnaud et al., 2009, 2012; Ruffino et al., 2009), and habitat deterioration (Bourgeois and Vidal, 2008; Bourgeois et al., 2014). While breeding habitat does not seem to be limiting (Bourgeois and Vidal, 2007; Bourgeois et al., 2008), it has been shown that breeding success is higher in deep cavities with a winding tunnel and that breeding habitat can be unstable and prone to disappearance (Bourgeois and Vidal, 2007; Bourgeois et al., 2014). In addition, there is evidence of inter-specific competition for suitable nesting cavities in some mixed Procellariiform species colonies (Harris, 1969; Ramos et al., 1997; Gardner and Wilson, 1999). The smaller species are likely at considerable competitive disadvantage in disputes over nest ownership. As Scopoli's shearwaters (505–795 g) are larger than Yelkouan shearwaters (320–530 g) and their close relatives, Cory's shearwaters, are known to out-compete small burrowing Procellariiformes (Ramos et al., 1997), they are potentially stronger competitors than Yelkouan shearwaters. This is supported by recent observations of Yelkouan shearwaters being evicted from their nests by Scopoli's shearwaters (K. Bourgeois, unpubl. data).

The aim of this study was to evaluate the long-term (>10 years) effectiveness of providing artificial burrows for the conservation of Yelkouan and Scopoli's shearwaters on Hyères islands (France). The main purposes of artificial burrow provision were to offer more stable and persistent breeding habitat, to increase breeding population size, to improve breeding success and to reduce inter-specific competition for nesting cavities. We thus estimated and compared the longevity, occupancy of and breeding success in artificial burrows and natural cavities. We also analysed factors affecting these three parameters in artificial burrows in order to optimize their installation and their use for conservation, not only for our study species but also for burrow-nesting Procellariiformes in general.

2. Methods

2.1. Study site and species

This study was conducted from 2003 to 2014 on Porquerolles (43°00′00″N 6°12′00″E), and Port-Cros (43°00′20″N 6°23′47″E) islands in the Hyères archipelago, off south-eastern France. These two islands are about 9 km apart. Both islands are hilly, culminating at 141 m and 196 m, respectively. Port-Cros Island (640 ha) is 15 km away from the mainland and has been a National Park since 1963. Porquerolles Island (1,254 ha) is 3 km away from the mainland and the National Park manages 80% of its area. Both islands are sub-humid temperate Mediterranean in climate and principally covered by a mixed forest (holly oak [*Quercus ilex*] and Aleppo pine [*Pinus halepensis*]).

Porquerolles and Port-Cros islands host 66–121 and 143–235 Yelkouan and 100–180 and 43–82 Scopoli's shearwater breeding pairs respectively (Bourgeois and Vidal, 2009). Shearwater colonies are situated along the coasts of both islands, on indented cliffs and fallen boulders, with varying extents of vegetation cover (Bourgeois et al., 2008). Birds generally nest in natural rock cavities (e.g., among fallen boulders), pre-existing crevices or burrows they excavate (Bourgeois and Vidal, 2007; Bourgeois et al., 2014). Breeding habitat is less stable on Porquerolles Island where landslips and rockslides can quickly destroy nest-cavities and burrows (Bourgeois et al., 2014). The two species select different types of nest-cavities for breeding, as Yelkouan shearwaters occupy the deepest cavities available, preferably with winding tunnels, and Scopoli's shearwaters use cavities located at a higher elevation and with a greater gravel cover and higher entrances (Bourgeois and Vidal, 2007). Based on these results and because they did not observe unusual behaviours suggesting inter-specific competition, these authors conclude that there is no competition for nest-cavities between the two species. However, we have since then