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Diversionary feeding as a means of reducing raptor predation at seabird breeding colonies

Jennifer Smart[a,b,*], Arjun Amar[a,1]

[a] RSPB Centre for Conservation Science, The Lodge, Sandy, Bedfordshire, SG19 2DL, UK
[b] School of Biological Science, University of East Anglia, Norwich, Norfolk, NR4 7TJ, UK

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ABSTRACT

Predation can limit bird populations, especially in ground-nesting and colonial species. Solutions are usually available to reduce the impacts of predation if the predator is non-native or not legally protected (e.g. predator control or exclusion). However, when the predator is protected by law (e.g. raptors) potential solutions are limited. If predator and prey are both species of conservation concern this can bring the conservation of these species into conflict. Diversionary feeding (DF) is a potential solution, whereby predators are provided with food to reduce their motivation to hunt. The efficacy of DF has rarely been tested thus, in this paper, we test the efficacy of DF to reduce predation by kestrels, *Falco tinninculus,* a protected and declining raptor, on little tern chicks, *Sternula albifrons*, a protected seabird, within an internationally important colony in eastern England. We used a 17-year dataset of annual estimates of little tern productivity and counts of kestrel predation events to compare years with and without DF (DF = 6 years). During a four-year period of more intensive monitoring efforts, where we employed DF at focal kestrel nests in alternate years, we quantified the rates of kestrel predation at the colony and prey provisioning rates at kestrel nests. Predation rates were 47% lower and productivity of little terns doubled in years when kestrels were fed. Intensive monitoring showed that predation rates by kestrels at the colony were 88% lower in the two years when kestrels were fed. Provisioning rates of all wild prey and little tern prey, was 3.4 and 6.2 times lower in DF years and the likelihood of little tern chicks being provisioned at nests was lower when alternative wild prey were provisioned. DF is an effective tool to reduce predation and increase productivity of little tern colonies threatened by kestrel predation. The magnitude of these effects on little tern productivity was sufficient to promote population increases. Raptor conservation has resulted in increasing populations of many species and it is expected that predator-prey conflicts are likely to increase. DF could be an important tool to manage these conservation issues, but further tests of the efficacy in different predator-prey systems will be needed.

1. Introduction

In human modified landscapes, conservation conflicts are becoming increasingly common (Kubasiewicz, Bunnefeld, Tulloch, Quine, & Park, 2016; Redpath et al., 2013) and can occur when a predator of conservation concern preys on another species of conservation concern, with consequent detrimental effects on the survival or breeding success of the prey species (Smart & Ratcliffe, 2000; Summers, Willi, & Selvidge, 2009). Predation can limit populations of some species, in particular those that are ground-nesting, colonial, range-restricted because of severe population declines and those that are long lived with slow reproductive rates (Newton, 1998; Roos, Smart, Wilson, & Gibbons, 2018). When the main predator is non-native and/or not protected by law, predator removal can be effective at increasing hatching success, fledging success and breeding populations of the prey species (Smith, Pullin, Stewart, & Sutherland, 2010). When the predator is mammalian, predator exclusion can lead to increases in hatching success (Smith, Pullin, Stewart, & Sutherland, 2011). However, where the predators themselves are protected (e.g. raptors or protected mammals), the range of potential solutions to reduce their predatory effects on species of conservation concern is extremely limited and rarely tested. Methods to reduce predation have produced mixed results which are often short-lived and have small-scale application e.g. visual, physical or sonic deterrents, chemical repellents or conditioned taste aversion (Smith, Linnell, Odden, & Swenson, 2000).

Effective raptor conservation, through decreased persecution,

* Corresponding author at: RSPB Centre for Conservation Science, The Lodge, Sandy, Bedfordshire, SG19 2DL, UK.
E-mail addresses: Jennifer.smart@rspb.org.uk (J. Smart), arjundevamar@gmail.com (A. Amar).
[1] Present address: Fitzpatrick Institute of African Ornithology, University of Cape Town, Rondebosch 7701, Cape Town, South Africa.

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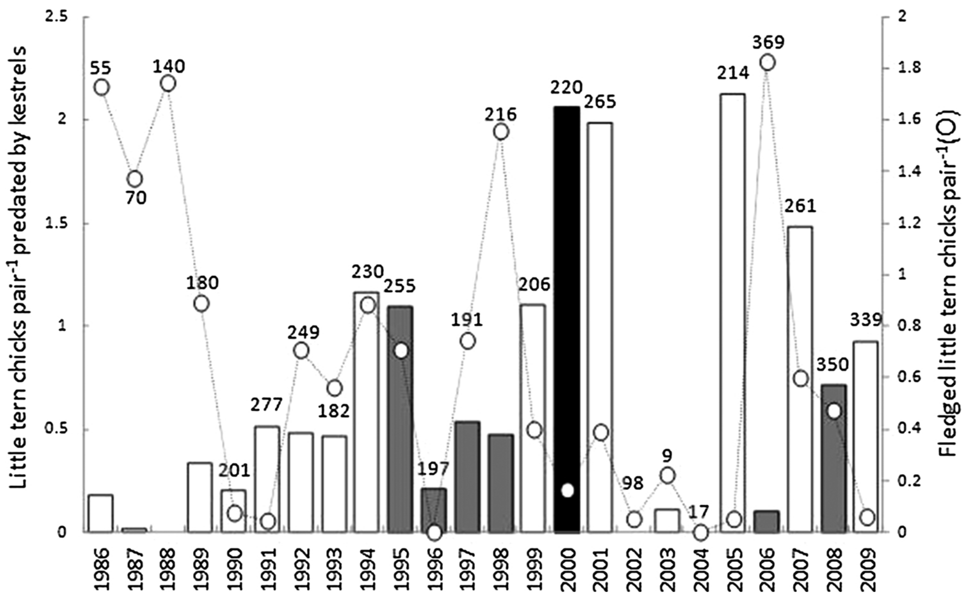

Fig. 1. The number of nesting pairs and breeding success of little terns (pairs = numbers, chicks fledged pair^{-1} = open circles) and the predation pressure from kestrels (little tern chicks pair^{-1} predated by kestrels = bars) between 1986, the first year of protection by the RSPB and 2009, the last year that little terns nested at the colony. Shading of the bars indicates whether diversionary feeding was used all season (grey bars), part season (black bar) or not (white bars).

recovery from deleterious effects of pesticides and reintroductions (Evans et al., 2009; Newton, 1998; Smart et al., 2010), has led to increases in populations of many raptor species in the UK. For example, buzzards *Buteo buteo* and red kites *Milvus milvus* increased by 84 and 1231% respectively between 1995 and 2015 (Harris et al., 2017). The combined effect of increasing predator populations alongside a decline in the abundance and distribution of their key prey species increases the likelihood of negative effects on prey species that are themselves of conservation concern. It is thus increasingly important that effective, legal and ethical solutions are developed and tested which can reduce predation pressures in circumstances where predator and prey species are both of conservation concern.

Diversionary feeding (DF) is one potential solution to such conservation conflicts. DF is defined as "the use of food to divert the activity or behaviour of a target species from an action that causes a negative impact, without the intention of increasing the density of the target population" (Kubasiewicz et al., 2016). DF might work because it is likely to reduce the motivation of the predator to hunt natural prey. In a review of the effectiveness of DF as a strategy to reduce conflicts involving wildlife (including both human-wildlife and conservation conflict), Kubasiewicz et al. (2016) found there were relatively few studies (n = 30), that success varied between studies and that only 13 studies were sufficiently detailed to allow quantification of effectiveness. Furthermore, only three of the studies related to reducing predatory effects on prey species of conservation concern and only one of these quantified effectiveness (Smart & Ratcliffe, 2000).

In the UK, there is now a growing range of conservation conflicts where DF may provide a solution e.g. pine martens *Martes martes* preying on capercaillie *Tetrao urogallus* nests (Summers et al., 2009), raptors preying on grey partridges *Perdix perdix* (Watson, Aebischer, & Cresswell, 2007; Watson, Aebischer, Potts, & Ewald, 2007) and Eurasian kestrels *Falco tinninculus* preying on little tern chicks, *Sternula albifrons* (Smart & Ratcliffe, 2000). Given the growing range of conservation conflicts and the paucity of scientific evidence for the efficacy of this technique, there is an urgent need to test the efficacy of DF across a range of predator-prey systems, in order to understand the success and generality of this approach. Each example is likely to have specific practical limitations, in terms of the ability to target food at the individuals in a population causing the conflict, while at the same time limiting possible negative side-effects of DF, such as increased productivity, survival and potentially population size of the target predator species (e.g. Dijkstra, Vuursteen, Daan, & Masman, 1982; Hansen, 1987; Wiehn, Ilmonen, Korpimaki, Pahkala, & Wiebe, 2000) or food being taken by non-target species (Redpath, Thirgood, & Leckie, 2001).

In this paper, we focus on the Eurasian kestrel (hereafter kestrel) and little tern conservation conflict. The little tern is Britain's second rarest seabird and is protected under Schedule 1 of the Wildlife and Countryside Act 1981 and listed under Annex I of the EC birds directive (Batten, Bibby, Clement, Eliot, & Porter, 1990). Little terns are 'Amber' listed in the Birds of Conservation Concern (Eaton et al., 2015). The species is a colonial beach-nesting seabird that has declined by 25% between the mid-1980s and the late-1990s (Mitchell, Newton, Ratcliffe, & Dunn, 2004), with further declines recorded from 2153 pairs (1998–2000) to 1417 pairs (2006; Mavor, Heubeck, Schmitt, & Parsons, 2008). Declines in this species are thought to be due to successive years of poor productivity, which have been influenced, in order of apparent importance, by predation, tidal flooding, weather, disturbance and poor food availability (Ratcliffe, 2003). It is a species which largely depends upon conservation action and a combination of 24-hour protection from wardens and/or electric fencing can be extremely effective at reducing effects of predatory mammals (largely red fox *Vulpes vulpes*, hedgehogs *Erinaceus europaeus* and domestic cats *Felis silvestris*) and human disturbance (Smart, 2003). However, predation of little tern chicks by kestrels, a protected and declining raptor species in the UK (−38% 1995–2015; Harris et al., 2017), has limited the success of little terns at a number of important colonies, including one of the UK's largest, at Great Yarmouth (Thompson, Brindley, & Heubeck, 1997). In 2006, 369 pairs nested within this colony, which was 26% of the UK population (1417 prs; Mavor et al., 2008) and 0.7–1.1% of the European population (35–55,000 prs; BirdLife International, 2004). DF of kestrels has been employed at this site periodically since 1995 (Fig. 1). With the increasing importance of this colony in a UK and EU context, and the increasing numbers of other colonies reporting kestrel predation issues, it became critical to examine DF as a tool to reduce the effects of kestrel predation on little terns.

In this paper, we report on analyses of a 17-year dataset of annual estimates of little tern productivity and counts of kestrel predation events, to compare between years with and without DF (DF = 6 years), coupled with a four-year period of a more formal experiment when we employed DF at focal kestrel nests in alternate years (2006 and 2008) and quantified the kestrel predation rates at the colony and prey provisioning rates at kestrel nests. Our main hypothesis was that kestrels would predate or provision fewer little tern chicks in years when they were provided with DF and that this would lead to higher little tern productivity. This hypothesis was tested by addressing the following questions: