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Selecting umbrella species for conservation: A test of habitat models and niche overlap for beach-nesting birds

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ABSTRACT

Umbrella species are rarely selected systematically from a range of candidate species. On sandy beaches, birds that nest on the upper beach or in dunes are threatened globally and hence are prime candidates for conservation intervention and putative umbrella species status. Here we use a maximum-likelihood, multi-species distribution modeling approach to select an appropriate conservation umbrella from a group of candidate species occupying similar habitats. We identify overlap in spatial extent and niche characteristics among four beach-nesting bird species of conservation concern, American oystercatchers (*Haematopus palliatus*), black skimmers (*Rynchops niger*), least terns (*Sterna antillarum*) and piping plovers (*Charadrius melodus*), across their entire breeding range in New Jersey, USA. We quantify the benefit and efficiency of using each species as a candidate umbrella on the remaining group. Piping plover nesting habitat encompassed 86% of the least tern habitat but only 15% and 13% of the black skimmer and American oystercatcher habitat, respectively. However, plovers co-occur with all three species across 66% of their total nesting habitat extent (~649 ha), suggesting their value as an umbrella at the local scale. American oystercatcher nesting habitat covers 100%, 99% and 47% of piping plover, least tern and black skimmer habitat, making this species more appropriate conservation umbrellas at a regional scale. Our results demonstrate that the choice of umbrella species requires explicit consideration of spatial scale and an understanding of the habitat attributes that an umbrella species represents and to which extent it encompasses other species of conservation interest. Notwithstanding the attractiveness of the umbrella species concept, local conservation interventions especially for breeding individuals in small populations may still be needed.

1. Introduction

The use of umbrella species is attractive in conservation because comprehensive data on all (or the majority of) species are rarely available (Caro and O'Doherty, 1999). Commonly, umbrella species are defined as those whose conservation benefits a group of co-occurring ('target') species and the ecosystem they inhabit (Roberge and Angelstam, 2004; Seddon and Leech, 2008). Effective umbrellas should have a wide enough habitat breadth to encompass a substantial amount of each target's habitat within its range (high degree of spatial overlap) and should share similar habitat criteria across the target group (niche overlap) (Favreau et al., 2006; Suter et al., 2002). Theoretically umbrella species can be an effective management tool, especially with respect to implementing strategies that can benefit several species or ecosystems simultaneously.

Despite its potential utility, the approach is not without criticism (e.g., Andelman and Fagan, 2000; Lindenmayer et al., 2002; Murphy et al., 2011). Much of the debate surrounding the effectiveness of conservation umbrellas stems from a lack of consensus on the objectives and outcomes in using them (Hunter et al., 2016). Reasons for the choice of a particular umbrella species are not always well known or articulated and can be based on anecdotal rather than scientific evidence (Pullin et al., 2004; Sutherland et al., 2004). Many purported umbrella species are actually flagship species (e.g., charismatic megafauna; Arponen, 2012), which are not primarily intended to function as an umbrella (although some do), but rather are used as a means of garnering public support and funding, or enacting legislation (Caro and O'Doherty, 1999; Home et al., 2009). Umbrella species also are often chosen from a list of threatened species (Possingham et al., 2002), likely because those species already carry regulatory protection (Fleishman et al., 2000), which greatly facilitates conservation intervention. Indeed, threat status is increasingly used to assign legislative priorities (Arponen et al., 2005; Marsh et al., 2007), and conservation targets are often policy-driven (Svancara et al., 2005). These decisions reflect

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differences in objectives and expectations rather than a failure of a given species itself to represent a broader range of conservation targets.

Conservation organizations and management authorities have differing ideas regarding the role particular species fill in a conservation context (Hunter et al., 2016). A growing body of literature shows that umbrella species can protect target groups or habitats provided they are carefully chosen using quantitative and standardized methods and explicit criteria (Carroll et al., 2001; Favreau et al., 2006). Umbrella species should also be chosen at the appropriate scale, represent ecologically-linked taxa that share similar habitats (Caro, 2003; Caro et al., 2004; Favreau et al., 2006; Fleishman et al., 2000), and in some cases should have similar life history traits or management requirements as the target group (Báldi, 2003; Lovell et al., 2007).

Proper choice of umbrella species, using transparent methods and explicit criteria, is important to meet conservation goals. Even in the absence of adequate datasets for all species in a target group (i.e. the group of species to be conserved; Roberge and Angelstam, 2004), advanced approaches for delineating species' distributions can help to elucidate the degree of distributional concordance among species, as well as identify species with the appropriate characteristics (Caro and O'Doherty, 1999; Seddon and Leech, 2008). In this paper, we use a maximum-likelihood, multi-species distribution modeling approach to select an appropriate conservation umbrella from a group of candidate species occupying similar habitats. We examine which of these species could, theoretically, offer the largest conservation benefit for other species (i.e., be the most effective and efficient candidate for an umbrella species) by quantifying both the degree of spatial co-occurrence, as well as the niche overlap among each potential umbrella and the residual target species group.

Along the U.S. Atlantic Coast, several beach-nesting bird species are in decline due to habitat loss, beach stabilization and nourishment practices, predation and human disturbance (Andres et al., 2012; LeDee, 2008; Thomas et al., 2006). When anthropogenic activities lower reproductive success in breeding birds, overall population viability may be compromised (e.g., Dowding and Murphy, 2001; Gill et al., 2001). Among these species, the Atlantic Coast population of piping plovers (*Charadrius melodus*) has received significant conservation attention since its federal listing as a threatened species in 1986 (Melvin et al., 1991; Sidle et al., 1991). This small, Nearctic territorial bird occurs sparsely across a wide geographic extent (the North American Atlantic Coast) and breeds from Newfoundland, Canada south to North Carolina, USA (Haig et al., 2005), but local populations can be small. For breeding, the species depends on early successional sandy beach habitats characterized by low-lying dunes, sparse vegetation and access to tidally inundated moist substrates for foraging (Loegering and Fraser, 1995; Maslo et al., 2012; Maslo et al., 2011). Because of its broad geographic distribution, reliance on habitats severely threatened by anthropogenic activities, and its charismatic appeal, the piping plover has been labeled both an umbrella species for coastal species and habitats, as well as a flagship species for coastal conservation more broadly (Gratto-Trevor and Abbott, 2011; Hecker, 2008). The United States Fish and Wildlife Service considers the piping plover a 'representative' species of coastal conservation across its entire U.S. Atlantic Coast range (USFWS, 2014).

Annually, millions of dollars from the budgets of public agencies and non-profit organizations (Hecht and Melvin, 2009) are spent protecting existing piping plover breeding habitat through symbolic fencing, restrictions on recreational activities (i.e. off-road vehicles, dog walking; Melvin et al., 1994; Patterson et al., 1991), nest and brood monitoring (Hecht and Melvin, 2009; MacIvor et al., 1990), and predator management (Maslo and Lockwood, 2009). Coastal habitat restoration projects along the U.S. Atlantic Coast are often conducted explicitly to benefit piping plovers, and the species is often monitored to measure the success or failure of management interventions (McIntyre and Heath, 2011; Smith et al., 2005). These activities are conducted under the assumption that other beach-nesting bird species will benefit as well, implying that piping plovers are an effective and efficient umbrella species (NPS, 2007; USFWS, 2007).

However, several other beach-nesting bird species of conservation concern use habitats that are generally similar to piping plovers and may act as conservation umbrellas. American oystercatchers (*Haematopus palliatus*), black skimmers (*Rynchops niger*) and least terns (*Sterna antillarum*) are all considered representative species of coastal habitat conservation for at least a portion of the north Atlantic coastal region (USFWS, 2014). An evaluation of each species' 'performance' as an umbrella may further increase the efficiency of future conservation efforts, particularly in light of the appreciable investment in management of beach-nesting birds and other coastal species. In this paper, we first ask whether a focus on piping plover conservation benefits other coastal birds in terms of encompassing their habitat. We also evaluate the umbrella species concept more broadly in the context of beach-nesting birds and ask which species (American oystercatcher, black skimmer, least tern, or piping plover) is likely to confer the greatest conservation benefit to other species in this guild by having a distribution that would capture the largest fraction of another species' habitat.

2. Materials and methods

Our study region is the coastal zone of central and southern New Jersey, USA, including the counties of Monmouth, Ocean, Atlantic, and Cape May. To encompass all sites potentially available for nesting by our target species, we designated the specific study area as all land and water within 5 km of the New Jersey coastline from Gateway National Recreation Area – Sandy Hook Unit south to Cape May Point (~1040 km^2; Fig. 1). This area included all beaches, dunes, salt marsh, and tidal flats where our target species could breed. The four beach-nesting bird species – American oystercatchers, black skimmers, least terns and piping plovers - are of high conservation concern in New Jersey and along the North American Atlantic Coast and occur over a significant portion of the study area (Table A.1). While these species have similar habitat requirements, there are important distinctions among habitat needs and life history traits. American oystercatchers and piping plovers breed as solitary pairs, while least terns and black skimmers nest in colonies of up to several hundred pairs (Brunton, 1999; Erwin, 1977). Atlantic coast piping plovers and least terns are obligate beach-nesting birds (Beck et al., 1990; Maslo et al., 2011); rooftop nesting by least terns in not known to occur in northeastern USA (Gochfeld, 1983; Krogh and Schweitzer, 1999). In contrast, black skimmers and American oystercatchers nest in several habitat types, including sand/shell beaches, salt marshes and dredge spoil islands (Burger and Gochfeld, 1990; Simons et al., 2012). Finally, foraging behavior varies widely among species, with piping plovers and American oystercatchers feeding on small marine and terrestrial invertebrates along the intertidal zone and in wrack, and black skimmer and least terns preying upon small fish in surf zone or other nearshore marine habitats (Cuthbert et al., 1999; Gordon et al., 2000; Maslo et al., 2012).

2.1. Modeling the occurrence of breeding beach-nesting birds

To create distribution maps for each species, we used nest or colony occurrence data obtained from the New Jersey Endangered and Nongame Species Program (ENSP). Each year, trained ENSP personnel conduct monitoring of beach-nesting birds in New Jersey from March through September. All beaches are visited at least once, and sites where target species are observed are surveyed repeatedly to monitor all reproductive stages (courting, nesting, chick-rearing, etc.). The GPS coordinates of each nest or colony are recorded. We extracted (from the full ENSP dataset) all documented nest and colony occurrences of our target species for the years 2007–2011. To minimize spatial autocorrelation and remove potential bias from variation in sampling effort, we spatially rarified the points, retaining only points that occurred ≥10 m