Estuarine, Coastal and Shelf Science 181 (2016) 266–276

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

An obligate beach bird selects sub-, inter- and supra-tidal habitat elements

Glenn Ehmke [a, *], Grainne S. Maguire [a], Tomas Bird [b], Daniel Ierodiaconou [b], Michael A. Weston [c]

[a] BirdLife Australia, Suite 2-05, The Green Building, 60 Leicester Street, Carlton, Victoria, 3053, Australia
[b] Deakin University, Centre for Integrative Ecology, School of Life and Environmental Sciences, Warrnambool Campus, Geelong, Victoria, 3280, Australia
[c] Deakin University, Centre for Integrative Ecology, School of Life and Environmental Sciences, Burwood Campus, 221 Burwood Hwy, Geelong, Victoria, 3125, Australia

A R T I C L E I N F O

Article history:
Received 15 February 2016
Received in revised form
27 July 2016
Accepted 29 August 2016
Available online 1 September 2016

Keywords:
Beach
Citizen science
Coastal
Habitat selection
Hooded plover
LiDAR
Reef
Shorebird

A B S T R A C T

Few habitat models are available for widespread, obligate, high-energy sandy shore vertebrates, such as the Eastern Hooded Plover *Thinornis cucullatus cucullatus*. We examined habitat attributes which determined the difference between sites where plovers breed and randomly-selected absence sites (determined from long-term systematic monitoring). A variety of habitat variables were derived from aerial photography and bathymetric and terrestrial Light Detection And Ranging (LiDAR) data. Logistic regression against eight candidate variables, in a model selection framework, revealed considerable support for four variables with respect to explaining the presence of breeding territories. In particular, the amount of unvegetated dune and foredune which was unvegetated, and the amount of intertidal and sub-tidal reef were positively associated with the presence of breeding territories. Thus, plovers apparently select certain habitat in which to breed, involving sub-tidal, intertidal and supra-tidal habitat elements. The model also helps explain the virtual absence of breeding plovers from long sections of superficially suitable habitat, such as the fourth longest continuous beach in the world.

1. Introduction

Ocean shores represent the most distinct ecological interface, between marine and terrestrial ecosystems, on the planet (Schlacher et al., 2008). Sandy shores differ from marine or terrestrial habitats in that there is little primary productivity on beaches, rather ecological subsidies occur from marine and terrestrial environments (Huijbers et al., 2013). Coastal wildlife dependent on beaches directly exploit these energy flows through scavenging on beach-cast carrion or preying upon infauna, which themselves depend on energetic subsidies (Spiller et al., 2010; Huijbers et al., 2013). While sandy shores are extensive, they are highly varied, in terms of geomorphology, sand grain size, and biodiversity (McLachlan and Brown, 2006). For example, benthic infauna is patchily distributed, being influenced by a range of factors including sediment grain size, wave action, and anthropogenic stressors such as beach nourishment (Schlacher et al., 2008).

Few vertebrates can be considered high-energy, sandy-shore obligates; those that are, are not well studied. A classification of niche specialisation of coastal wildlife is currently unavailable, although it is clear there are differences in the way wildlife uses beaches, and we provisionally suggest a classification here (Fig. 1). Sandy coast obligate species may exploit resources in near-shore hinterlands (e.g. dunes), from the beach itself, and from the intertidal zones. Thus, their habitat includes marine and terrestrial elements. They rely on these areas to provide resources for foraging, shelter (from weather and predators) and breeding (McLachlan and Brown, 2006).

One prominent group of sandy shore obligate vertebrates includes populations of particular coastal shorebirds. Many of these species are under conservation stress, and are the subject of ongoing conservation efforts (e.g. Piping Plover *Charadrius melodus*, Wemmer et al., 2001, Shore Plover *Thinornis novaeseelandiae*, Marchant and Higgins, 1993, Hooded Plover *Thinornis cucullatus*, Maguire et al., 2013, Chatham Island Oystercatcher *Haematopus chathamensis*, Department of Conservation, (2001)). Shorebirds

* Corresponding author.
E-mail address: glenn.ehmke@birdlife.org.au (G. Ehmke).

http://dx.doi.org/10.1016/j.ecss.2016.08.050
0272-7714/

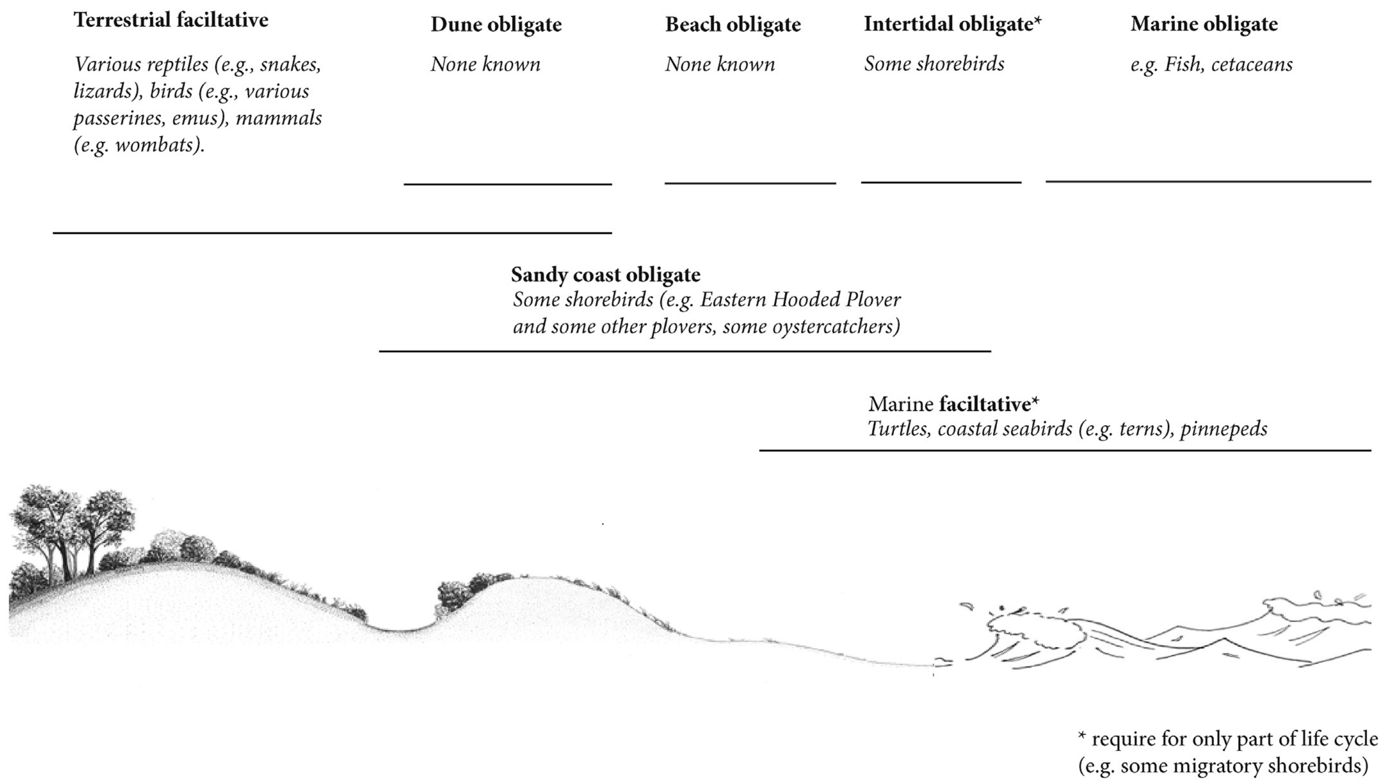

Fig. 1. A proposed classification of niche specialisation for high-energy sandy shore vertebrate fauna (wildlife).

which occupy sandy shorelines are often widespread at low densities when they breed (Page et al., 1983; Marchant and Higgins, 1993; Weston et al., 2009), with breeding territory formation being driven presumably by competition for resources required for producing young (Brown, 1969; Sergio et al., 2009). Because of their widespread distributions, there is a tendency for managers and ecologists to assume that all coastal high energy sandy shorelines (beaches) represent 'habitat' of equivalent suitability or quality for these birds, despite the occurrence of substantial stretches of unoccupied beach (see, for example, Fig. 1 in Weston et al., 2012). This assumption has made it difficult to assess population viability, including determining carrying capacity of coastlines, and to identify priority breeding habitats. Conservation management for coastal obligates has focused largely on improving reproductive success (Weston et al., 2003), however the availability of breeding territories is also likely to be critical for recovery of these taxa (Wemmer et al., 2001). Thus, an improved understanding of which beaches represent habitat, and the factors which influence suitable habitat, is required to improve species management. Additionally, such understanding is required to help predict the impact of rising sea levels on species viability (Convertino et al., 2012). Shorebirds are also considered to be valuable indicators of sandy shore ecosystems, and enjoy substantial public interest and engagement, which assists with the attainment of management objectives (Schlacher et al., 2014, 2015).

Habitat models have become prominent features of species management, especially for species which are widespread, rare or both (e.g., Guisan and Zimmermann, 2000; Klar et al., 2008; Convertino et al., 2011, 2012). They offer insights into the extent of viable habitat for species (Convertino et al., 2011; Gratto-Trevor, 1996; Meager et al., 2012; Schlacher et al., 2013), to model different conservation options (e.g., Wemmer et al., 2001; Murray et al., 2011) and have even been used to help identify stakeholders in species conservation (Weston et al., 2012). The vast majority of models are terrestrial (e.g. Lauver et al., 2002), though some marine seafloor models are also available but are often restricted by geographic extent due to the lack of data availability in coastal zones (Ierodiaconou et al., 2011). Mapping the seafloor is difficult along coastal margins, especially exposed coasts, which present a range of challenging obstacles due to wave action and turbidity (Chust et al., 2010). Habitat models of coastal biodiversity are uncommon (Ozesmi and Mitsch, 1997; Willems et al., 2008), though a few exceptions model the habitat suitability of coastal shorebirds (Convertino et al., 2011, 2012; Meager et al., 2012), and of those, are often restricted to the use of supra-tidal or intertidal data only. One challenge to building habitat models in coastal environments is the feasibility of collecting baseline data on the presence/absence of species, along with descriptions of underlying habitat features both above and below the water over large areas. Fortunately, developments in remote sensing, and especially the application of Light Detection And Ranging (LiDAR) technologies to coasts, hold great promise in mapping habitat of coastal biodiversity (Goodale et al., 2007; Ledee et al., 2008; Zavalas et al., 2014; Jalali et al., 2015). LiDAR can provide high resolution digital elevation models and surface complexity information with seamless mosaics over large geographic extents across the common terrestrial-marine divide that can be used to characterise habitats (Vierling et al., 2008; Kennedy et al., 2014). In addition, the growing use of volunteers, or Citizen Scientists, in the collection of monitoring data provides a means by which presence-absence of species can be confirmed across much larger areas than is possible by individual researchers (Greenwood, 2007; Dunn and Weston, 2008).

In this study, we develop a simple habitat model for an obligate coastal vertebrate, which considers supra-, inter- and sub-tidal variables. We aim to examine whether any habitat preferences exist in the selection of breeding territories by this species, and if so,