Journal of Sea Research 104 (2015) 33–40

Contents lists available at ScienceDirect

Journal of Sea Research

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

Foraging ecology of sanderlings *Calidris alba* wintering in estuarine and non-estuarine intertidal areas

Pedro M. Lourenço [a,*], José A. Alves [b,c], Teresa Catry [a], José P. Granadeiro [d]

[a] Centro de Estudos do Ambiente e do Mar (CESAM)/Museu Nacional de História Natural e da Ciência, Universidade de Lisboa, Rua da Escola Politécnica 58, 1250-102 Lisboa, Portugal
[b] Centro de Estudos do Ambiente e do Mar (CESAM), Universidade de Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
[c] University of Iceland, South Iceland Research Centre, Fjolheimar, IS-800 Selfoss, Iceland
[d] Centro de Estudos do Ambiente e do Mar (CESAM)/Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal

ARTICLE INFO

Article history:
Received 12 March 2015
Received in revised form 9 June 2015
Accepted 22 June 2015
Available online 30 June 2015

Keywords:
Diet
Intake rate
Macroinvertebrates
Prey availability
Substrate
Shorebirds

ABSTRACT

Outside the breeding season, most shorebirds use either estuarine or non-estuarine intertidal areas as foraging grounds. The sanderling *Calidris alba* is mostly associated with coastal sandy beaches, a habitat which is currently at risk worldwide due to increasing coastal erosion, but may also use estuarine sites as alternative foraging areas. We aimed to compare the trophic conditions for sanderlings wintering in estuarine and non-estuarine sites within and around the Tejo estuary, Portugal, where these two alternative wintering options are available within a relatively small spatial scale. To achieve this, we analysed sanderling diet, prey availability, foraging behaviour, and time and energy budgets in the different substrates available in estuarine and non-estuarine sites.
In terms of biomass, the most important sanderling prey in the estuarine sites were siphons of the bivalve *Scrobicularia plana*, polychaetes, staphylinids and the gastropod *Hydrobia ulvae*. In non-estuarine sites the main prey were polychaetes, the bivalve *Donax trunculus* and chironomid larvae. Both food availability and energetic intake rates were higher on estuarine sites, and sanderlings spent a higher proportion of time foraging on non-estuarine sites. In the estuary, sanderlings foraged in muddy-sand substrate whenever it was available, achieving higher intake rates than in sandy substrates. In the non-estuarine sites they used both sandy and rocky substrates throughout the tidal cycle but had higher intakes rates in sandy substrate.
Estuarine sites seem to offer better foraging conditions for wintering sanderlings than non-estuarine sites. However, sanderlings only use muddy-sand and sandy substrates, which represent a small proportion of the intertidal area of the estuary. The extent of these substrates and the current sanderling density in the estuary suggest it is unlikely that the estuary could provide alternative wintering habitat for sanderlings if they face habitat loss and degradation in coastal sites.

1. Introduction

Outside the breeding season, migrants often have to cope with strong competition for food, due to increased population densities in wintering areas (Cox, 1985), and those that elect wintering in temperate areas also face considerable energy demands due to high costs of thermoregulation (Wiersma and Piersma, 1994). Therefore, habitat quality in the wintering grounds is often of paramount importance for migratory animals, affecting their survival and also producing effects that may extend to subsequent breeding events (Gunnarsson et al., 2005; Harrison et al., 2011).

During winter, migratory shorebirds (Aves: Charadrii) are mainly restricted to a few suitable habitats, which comprise only a very small area of each continent. Many species are key predators in intertidal communities worldwide, particularly in sheltered and highly productive estuaries, where prey abundance and availability (Piersma et al., 1993), sediment characteristics (Granadeiro et al., 2007; Mouritsen and Jensen, 1992), predation risk (van den Hout et al., 2008), human disturbance (Gill et al., 2001) and microhabitat characteristics (Lourenço et al., 2005) explain their distribution and habitat preferences at several spatial scales. Unlike tidal flats, non-estuarine coasts under tidal regimes are generally much less extensive, being mostly composed of strips of either rocky or coarse sandy substrates. Also, the open coast is much more hydrodynamic and this characteristic may limit its availability for birds during low tide, but conversely, often supports a rich intertidal fauna and flora providing abundant food resources for shorebirds (Dierschke, 1993; Wootton, 1997). In fact, important numbers of several shorebird species are found in non-estuarine coastal areas during winter (Burton et al., 2008; Lecoq et al., 2013), their abundance being influenced by human disturbance, urbanization, substrate type, exposure to waves and predation risk (Lourenço et al., 2013; Summers et al., 2002).

* Corresponding author.
E-mail address: p.m.g.lourenco@gmail.com (P.M. Lourenço).

http://dx.doi.org/10.1016/j.seares.2015.06.013
1385-1101/

At present, coastal sandy beaches worldwide face escalating anthropogenic pressures, chiefly from rapacious coastal development, sediment starvation due to river damming and dredging, direct human uses, and rising sea levels (Komar, 1998; Schlacher et al., 2007; Zhang et al., 2004). This problem is particularly severe in more urbanized coasts (Brown and McLachlan, 2002) where rates of shoreline retreat can reach several metres per year (e.g. Pranzini and Williams, 2013), and human interventions to combat coastal erosion, such as shoreline armouring and beach nourishment, can result in severe ecological impacts and loss of biodiversity at both local and global scales (Schlacher et al., 2007).

The sanderling *Calidris alba* is one of the most widespread shorebirds in the world, migrating south from their Arctic breeding areas to wintering areas along the coastlines of all continents except Antarctica (Delany et al., 2009). Outside the breeding season, they are mostly associated with coastal sandy beaches (Reneerkens et al., 2009; Summers et al., 2002), but also use estuarine areas, including both sandy and muddy-sand substrates (e.g. Burger et al., 1997; Granadeiro et al., 2007). Due to their sheltered nature, estuarine areas are less affected by coastal erosion than exposed oceanic beaches (Ferreira et al., 2008; Pethick, 2001), and could provide suitable alternative foraging areas for sanderlings if wintering habitat is lost due to coastal erosion.

In the central coast of Portugal, around Lisboa, sanderlings are common during the winter (Lecoq et al., 2013) and use both a large estuarine wetland (Tejo estuary) as well as exposed oceanic beaches near the mouth of this estuary. The presence of these two potential wintering areas for sanderlings in the same region led us to establish comparisons in relation to their 1) substrate use, 2) diet, 3) food availability, 4) foraging behaviour, and 5) time and energy budgets in estuarine and non-estuarine tidal areas, ultimately comparing the profitability between these two potential wintering options.

2. Methods

2.1. Study area

Field work took place in five sites, three located within the Tejo estuary (Alcochete, Samouco and Seixal), one of the largest estuarine wetlands in western Europe, and two located on the oceanic coast near the mouth of the river (Oeiras and Caparica; Fig. 1). The minimum distance between estuarine and non-estuarine sites is 14.5 km, and the maximum is 24.8 km, which is within the spatial scale of movements that shorebirds are known to make in reaction to changes in food availability (e.g. Kirby and Lack, 1993; Lourenço et al., 2010; Takekawa et al., 2002). All five sites harbour sanderling flocks throughout the winter, with average counts of 75–126 individuals per area. The three estuarine sites include a sandy beach (silt content: < 5%, Rodrigues et al., 2006) on the upper shore, which is partially submerged during high tide, and muddy-sand flats (silt content: 5–50%, Rodrigues et al., 2006) on the lower shore, only exposed during low tide. In these sites the proportional availability of each intertidal substrate varies markedly throughout the tidal cycle, with only sand being available during or close to high tide periods, while near low tide most of the available area is composed of muddy-sand. The two non-estuarine sites are composed of a mixture of coarse sandy beaches and rocky intertidal areas at all levels of the shore, both only partially submerged during high tide. Here, both substrates are similarly available throughout the tidal cycle, with the exception of the peak of high tide when some beaches become fully submerged and there is a slightly higher proportion of rocky substrate available. The tidal regime is semi-diurnal with amplitudes of 2 to 4 m. All field work took place between November 2012 and March 2013, covering the wintering period of sanderlings in the study area.

2.2. Diet composition and prey availability

We collected a total of 127 sanderling droppings in the two substrate types available in each area: sand and muddy-sand in the estuarine sites, and sand and rock in the non-estuarine sites. In all cases, we followed sanderling flocks during the receding tide and droppings were collected only after a flock was foraging on a particular substrate for over 1 h, ensuring that prey found in droppings have been consumed in that same substrate (Verkuil, 1996).

We also sampled the abundance of potential invertebrate prey, obtaining 30 samples per study site, stratified by substrate type, for a total of 150 samples. On sandy and muddy-sand substrates sampling was carried out by collecting sediment cores, with a diameter of 12 cm and a depth of 15 cm. On rocky substrates sampling was done by carefully scrapping the rock surface in a circular area with a diameter of 12 cm. Samples were taken on random locations in patches were sanderling flocks were observed foraging, and sieved in situ

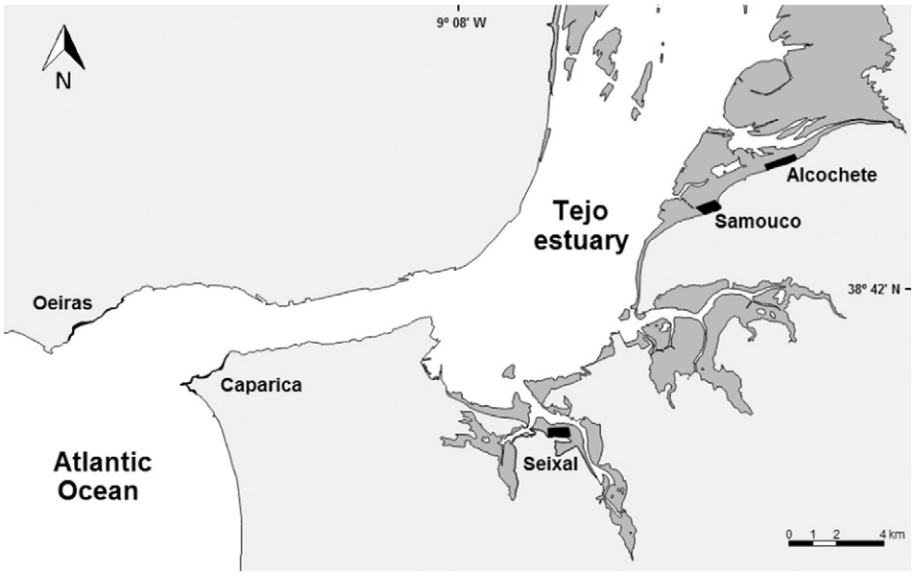

Fig. 1. Map of the five study sites, three located within the Tejo estuary (Alcochete, Samouco and Seixal), and two located on the oceanic coast near the mouth of the river (Oeiras and Caparica). The black areas represent each study site and the darker grey areas represent the intertidal zone of the Tejo estuary. Note that the intertidal is much narrower in the non-estuarine sites.