Journal for Nature Conservation 20 (2012) 242–246

Contents lists available at SciVerse ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.de/jnc

Short communication

Do systematic daily counts reflect the total number of birds using stopover sites during migration? A test with Eurasian Spoonbill

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ARTICLE INFO

Article history:
Received 4 October 2011
Received in revised form 21 March 2012
Accepted 27 March 2012

Keywords:
Connectivity
Counting methods
Flagship species
Staging sites
Stopover
Waterbirds
Wetland conservation

ABSTRACT

Many migratory waterbird populations are declining and wetland connectivity is a major conservation challenge. The importance of stopover sites has been typically assessed by peak counts of birds, which underestimate the total number of individuals using the site over a migratory season, especially in small wetlands. We analysed the accuracy of different daily count schemes to estimate the total number of Eurasian Spoonbill that stop over at two tidal wetlands during their autumn migration and compared them with the birds observed leaving the area each day. Total number of birds was obtained by combining numbers of each flock of birds leaving during the season. We obtained different accurate predictors for birds departing daily from each stopover area. Daily low-tide counts were the best predictor of the daily number of birds that stopover in a tidal wetland mainly used to refuel (staging site), whereas daily high-tide counts were best at a wetland mainly used to rest (stopover site). Each measure also accurately predicted annual trends for each area, respectively. Daily low-tide counts could be used as an easy census method to estimate the daily number of individuals using a staging site consistently during the entire migratory season, as well as indicating trends, without the necessity of estimating turnover rates. By contrast, daily high-tide counts would be especially suitable for determining the minimum relevance and the population trends of other tidal wetlands (especially the smaller ones), which regularly support moderate numbers of spoonbills during migration where birds use to stop over for less than one day. This method developed for the spoonbill, a flagship and umbrella species, could represent a first step in improving the conservation of other endangered migratory waterbird populations.

Introduction

The most recent reviews of the population status of migratory waterbirds confirm that many of them are in decline (Wetlands International 2006). Although there are many factors that might be impacting negatively on these populations, loss and/or alteration of natural wetlands are probably the main causes (Morrison et al. 2001). Recently, many efforts have been made to clarify the importance of stopover sites in the regulation of populations of migratory waterbirds (reviewed in Newton 2006), since their key role has been demonstrated for some of the most well-known endangered species. For example, an increasing proportion of Red Knot (*Calidris canutus rufa*, Wilson, 1813) failed to reach threshold departure masses during their stopover at Delaware Bay during the period 1997–2002, which had severe fitness consequences for adult survival and recruitment of young in subsequent years (Baker et al. 2004).

To date, the assessment of the importance of stopover sites for waterbirds has typically been based on peak counts of any species, which underestimate the total number of birds using the site over a season because of the turnover of individuals (Frederiksen et al. 2001). This method highlighted the importance of conserving large wetlands that commonly support big flocks of a species during migration, whereas it underestimated the importance of small wetland areas that do not support large numbers of migratory birds. Furthermore, the conservation of many waterbird populations relies on wetland connectivity (Haig et al. 1998), including moderate to small wetland areas where birds can refuel and/or rest before resuming migration. Areas located before an ecological or geographical barrier are particularly important (Åkesson & Hedenström 2007). These stopover sites are essential for long-distance migrants that employ a 'jumping' strategy (i.e. long displacements between breeding and wintering grounds using a few stopover areas), and have been recently renamed staging sites (i.e. sites with abundant, predictable food resources where birds prepare for an energetic challenge; Warnock 2010).

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http://dx.doi.org/10.1016/j.jnc.2012.03.004

Therefore, there is an urgent need to identify and evaluate the total number of birds that stopover in single wetlands in order to assess their conservation value for many endangered migratory waterbird populations.

Although the total number of migrating birds is difficult to calculate for any species, an estimation of the rate at which the individuals present are changing (turnover rate) is possible. Special techniques, such as direct observation of migratory flocks (e.g. Alonso et al. 1990; Frederiksen et al. 2001; Navedo et al. 2010a), or indirect observation through studies of marked (ringed) individuals (e.g. Gillings et al. 2009; Meissner 2007), are required to calculate the turnover rate using specific software for analysis of capture–mark–recapture data (reviewed by Lindberg, in press). Thus, to fulfill international, national and regional governmental requirements, site managers have often simply combined non-systematic records of each species in a certain period to estimate the total number of birds using a wetland, which is an erroneous assumption (Brouwer et al. 2003; Frederiksen et al. 2001).

Here we analyse the accuracy of different daily counts to quantify the total number of birds of a waterbird species, the Eurasian Spoonbill (*Platalea leucorodia leucorodia*, L. 1758), using two different stopover sites during fall migration. This species is charismatic and easy to detect, and accordingly has been monitored in many wetlands over several years and throughout its life cycle (Triplet et al. 2008). Most of these monitoring schemes were based on peak counts, thus potentially including a significant bias when estimating the total number of spoonbills using a given stopover. Furthermore, its current position as a functional top predator in estuaries makes it a suitable umbrella as well as a flagship species (Jin et al. 2008; Lorenz et al. 2009) for ecosystem-level conservation of wetland areas (Sergio et al. 2006; Sergio et al. 2008).

Supported by a continuous daily monitoring program allowing direct estimation of the total number of spoonbills at two important stopover sites during their autumn migration (Del Villar et al. 2007; Navedo 2006), the aim of this study was to evaluate whether there was an accurate indirect method that could be used to assess the total number of spoonbills at tidal wetlands during migration as a basis of systematic daily counts of birds. As spoonbills are restricted to foraging at low tide at both areas studied (Navedo 2006, R. Garaita, *pers. obs.*) we expected that the tidal cycle would have a great influence on the daily counts of spoonbills.

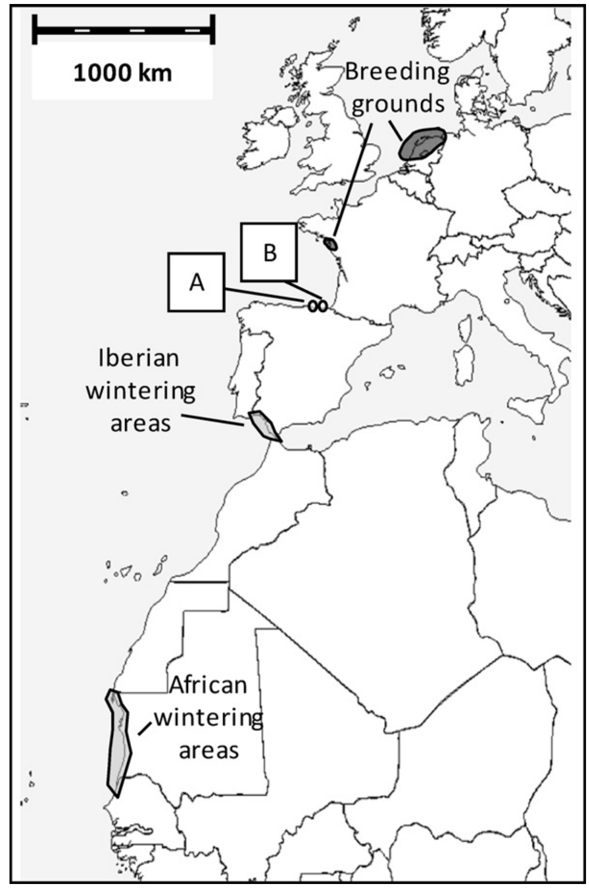

Fig. 1. Location of Santoña Marshes (A) and Urdaibai rivermouth (B) within the autumn migration route of the Atlantic population of Eurasian Spoonbill.

Methods

Santoña Marshes Natural Park (43°25′N, 3°30′W) and Urdaibai Biosphere Reserve (43°22′N, 2°40′W), designated as Ramsar sites and Special Protection Areas (SW Europe, 65 km distance between both sites; Fig. 1), are similar estuarine wetlands covering nearly 1250 ha and 250 ha of effective intertidal areas (estimated following Stillman et al. 2001), respectively. Both are strategically located between breeding (mainly the Netherlands and France) and wintering areas (SW Iberia and NW Africa) for the 'Atlantic' population of the species (Triplet et al. 2008). Since 30–40% of this breeding population stop over at Santoña to refuel during the autumn migration (Navedo 2006), it has been identified as a key stopover site for the species (Navedo 2006; Triplet et al. 2008). On the other hand, Urdaibai has been identified as another important stopover site during the autumn migration (Triplet et al. 2008), as it supports hundreds of birds throughout this period, thus accounting for ca. 3–10% of the population (Del Villar et al. 2007).

A census of the number of spoonbills using both tidal areas was undertaken by experienced ornithologists (JGN at Santoña and RG at Urdaibai) on a continuous basis from 09:00 to 20:00 h during (at least) 28 consecutive days in September in four consecutive years (2002–2005) (for more details see Del Villar et al. 2007; Navedo et al. 2010a). Spoonbills were surveyed from hills overlooking the entire estuaries. At both study areas we were able to directly observe each flock of birds leaving the estuary (see Navedo et al. 2010a, R. Garaita, *pers. obs.*). Therefore, we had an accurate measure of the daily number of birds leaving both estuaries (*n*OUT) and, following Navedo (2006) the total number of birds was then obtained by combining numbers for each flock of birds leaving during the study period. Despite a comparable daily observation effort, only six PVC-ringed spoonbills registered at Santoña during this 4-year period (2% of all birds; $n = 323$; data from Navedo et al. 2010b) were previously registered at Urdaibai. Therefore, there is a generally low connectivity between areas.

We systematically registered the hourly presence of spoonbills from 09:00 (n0) to 20:00 (*n*END) at both areas. Tidal stage has a strong influence on spoonbill departure decisions at Santoña, since the majority leave the stopover area after foraging during the low tide (Navedo et al. 2010a). Thus, we further estimated the number of spoonbills in relation to tidal cycle, at the low- (*n*LOW) and high-tide peaks (*n*HIGH) at both areas. We finally selected four daily periods (*n0*, *n*END, *n*LOW and *n*HIGH) instead of any other period, because numbers of spoonbills at any period during daylight strongly depended on how many individuals were there at sunrise, and the tidal stage governed foraging and resting activities, as well as departure decisions at Santoña (Navedo et al. 2010a), during their stopover at both areas (Navedo 2006; Del Villar et al. 2007). All censuses were log transformed before analysis to meet normality and homocedasticity in data.

As expected (see above), the four potential predictors were highly correlated between them at both study areas (Santoña: Spearman $r > 0.41$; $p < 0.00001$ in all cases; Urdaibai: Spearman

Table 1
Multiple regression models used to select the best set of predictors (log transformed) of daily number of spoonbills departing from Santoña marshes and Urdaibai rivermouth during September (2002–2005). *n*0 = num birds after sunrise (09:00); *n*END = num birds before sunset (20:00); *n*LOW = num birds at low tide peak; *n*HIGH = num birds at high tide peak.

Area	*n*0	*n*LOW	*n*HIGH	*n*END	AICc	ΔAICc
	x	x			208.21	0.00
Santoña	x	x	x		208.80	0.59
	x	x		x	210.09	1.88
	x	x	x	x	184.02	[a]
Urdaibai	x	x	x		190.83	0.00
		x	x		192.34	1.51

[a] *n*END at Urdaibai were finally removed since its relationship with the number of spoonbills departing at this area was negative, thus non-meaningful as a predictor (see text for more details).

$r > 0.61$; $p < 0.00001$). Despite this drawback, we included all of them in multiple regression models, one for each study site, with *n*OUT as the response variable. All possible models (i.e. all possible combinations of explanatory variables) were ranked according to Akaike's Information Criteria with small sample size correction (AICc; Burnham and Anderson 2002). The model with the smallest number of explanatory variables within the subset of models with an increase of AICc smaller than 2 (i.e. equiprobable models) was selected as the best. The explanatory variables included in the selected model were used in a new multiple regression model to test for the consistency of the variable effects among the studied years. For this purpose, these models (one per study site) included the year and the interaction with the previously selected explanatory variables as predictors.

Statistical analyses were performed using Statistica v6.1 (Statsoft Inc. 2002). Values are presented as means ± SE.

Results

A mean number of 58 ± 7 (Santoña) and 11 ± 2 (Urdaibai) spoonbills departed daily from both areas during September ($n = 116$ at both areas), giving an average annual total (means ± SD) of 1685 ± 278 and 312 ± 140 birds that stop over at each area, respectively.

At Santoña, daily counts at low tide and after sunrise were included into the best model explaining the number of spoonbills leaving the area each day, with models also including counts at high tide or counts before sunset (but not both) being equivalent (Table 1). Every measure was positively correlated with the number of birds departing from this area each day. On the other hand, the four daily counts were included in the best model explaining the daily number of birds departing from Urdaibai. However, counts before sunset were negatively correlated with daily departing birds from Urdaibai, in contrast to the other predictors that were positively correlated. Therefore, since we were interested in a proxy measure of birds departing daily (i.e. an indirect measure positively correlated with daily departing birds), we repeated the analysis removing this predictor. The three remaining predictors were all included into the best model explaining the number of birds leaving Urdaibai each day, but a simplified model comprising counts at low and high tide was equivalent (Table 1).

Both low tide and post-sunrise counts (Fig. 2A and C, respectively) retain a significant and positive effect explaining the number of spoonbills departing daily from Santoña when analysed in the final model including the year and its interaction (Table 2). There were no differences in the number of birds departing daily from this area between years, but its correlation with the count of birds after sunrise varied significantly between years (Table 2). Nevertheless, the relationship was always positive and only the gradient of the slope changed between years. This final model accounted for 35.54% of the observed variance. At Urdaibai, low- and high-tide counts (Fig. 2B and D, respectively) retained their significant and

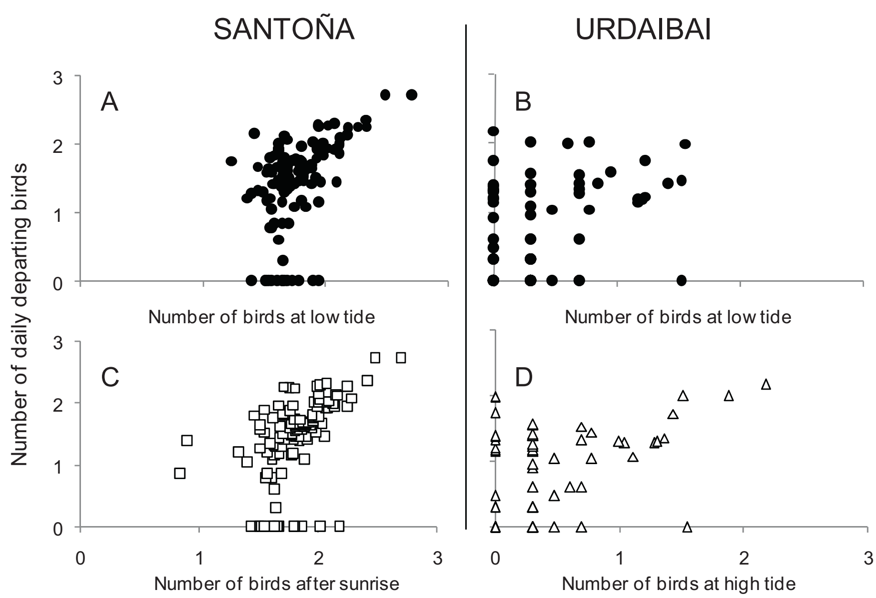

Fig. 2. Relationships between departing Eurasian Spoonbill and number of birds counted during low tide at (A) Santoña marshes ($N = 116$) and (B) Urdaibai rivermouth ($N = 116$); and number of birds counted at Santoña after sunrise (C) and at Urdaibai during high tide (D). All data are log transformed. Note that a given point in the graphic could represent more than one register, especially in B and D.

Table 2
Multiple regression models to test for the inter-annual consistency of predictors on the daily departing spoonbills during September from Santoña marshes and Urdaibai rivermouth between years (2002–2005). *n*0 = num birds after sunrise (09:00); *n*END = num birds before sunset (20:00); *n*LOW = num birds at low tide peak; *n*HIGH = num birds at high tide peak.

Area	Source	*F*	*df*	*p*
Santoña	Year	1.94	3	0.128
	*n*0	17.74	1	<0.001
	*n*LOW	8.20	1	<0.001
	Year * *n*0	2.73	3	0.048
	Year * *n*LOW	0.33	3	0.801
Urdaibai	Year	0.70	3	0.556
	*n*LOW	12.70	1	<0.001
	*n*HIGH	15.29	1	<0.001
	Year * *n*LOW	0.65	3	0.587
	Year * *n*HIGH	1.23	3	0.303

positive effect on spoonbills departing daily from this area when analysed between years, and neither the year nor its interaction had any significant effect (Table 2). This final model explained 34.16% of the observed variance.

Discussion

Without the need to measure turnover rate (Frederiksen et al. 2001; Gillings et al. 2009; Meissner 2007), different systematic and continuous daily counts at each area provided accurate indirect measures to estimate daily numbers of spoonbills using both stopover areas during fall migration.

As expected, tidal cycle had a decisive influence on spoonbill abundance at both areas. Like many other waterbird species, spoonbills spread out to forage during the low-tide period, whereas they gather in a couple of roosts during high tide (Van De Kam et al. 2004), and are thus easier to count during this later period (Smit & Piersma 1989). In fact, counts to calculate the total number of spoonbills using a wetland are normally carried out during high tide (reviewed in Triplet et al. 2008). However, the majority of spoonbills, as well as other migratory waterbirds (Piersma & Jukema 1990), especially those that have developed a fly-and-forage migratory pattern (Alerstam 2009) usually depart from a tidal stopover after foraging during the low-tide period. Therefore, individuals that stop over for less than one day would not be taken into account in those daily high-tide counts. Accordingly, daily low-tide counts are an accurate predictor of daily departing spoonbills that use both stopover areas during fall migration as well as annual trends but, interestingly, high-tide counts were also a good predictor of both parameters at Urdaibai.

On the other hand, daily sunrise counts were also an accurate indirect measure of the number of spoonbills departing daily from Santoña marshes, but their correlation significantly changed depending on the year. By contrast, sunset counts were discarded for both areas. Diurnal migratory large waterbird species, such as spoonbills or cranes *Grus* spp., avoid departing during the night (e.g. Alonso et al. 1990). Moreover, these species make extensive use of thermal currents to climb over topographical and/or ecological barriers, especially if they are close to departure sites (Åkesson & Hedenström 2007), so they usually depart some hours after sunrise (Alonso et al. 1990; Navedo et al. 2010a). Therefore, more birds are concentrated at the beginning of the day than the actual number of birds that will depart during that day. In particular, individuals that made long displacements will stay longer at sites used to refuel before crossing a barrier (Navedo et al. 2010b). In summary, systematic daily sunrise counts are also a good basis for estimating the number of spoonbills departing daily from a staging site (*sensu* Warnock 2010) during autumn migration, although they would not be useful in estimating annual trends.

When a stopover is mainly used for stopping (i.e. typically one day or less; a *stopover site*, after Warnock 2010) one should expect that some individuals leave the area before the low-tide period. Spoonbills usually depart from Urdaibai some hours after their arrival (for example 67% of the birds stayed less than 6 h in 2005; Del Villar et al. 2007), while their average stopover duration at Santoña was 2.1 days (data from Navedo et al. 2010b). Thus, low-tide counts, besides being a good predictor of spoonbills departing daily, would be an underestimation when translated into the total number of birds that used Urdaibai as a stopover site.

In the context of wetland connectivity (Haig et al. 1998), managers and/or stakeholders should make use of these proxy measures to assess the daily number of spoonbills that stop over at any site at the coast along its migration routes, promoting systematic daily low-tide counts for staging sites, and daily high-tide counts for other stopover sites (renamed after Warnock 2010). Both counts should be made between 1 h before and 1 h after their respective peaks. The proposed surrogates will ultimately provide a rough underestimation of the total number of birds at stopover sites (i.e. a minimum) but a good estimate at staging sites. More significantly, they accurately predict annual trends in total numbers at both stopover areas. In particular, this method would be easier to implement in several moderate to small tidal wetlands (typically stopover sites, after Warnock 2010) that regularly support numbers of spoonbills during migration (reviewed in Triplet et al. 2008). Moreover, the first objective of the *Waterbird Population Estimates*, even in its first edition (Rose & Scott 1994), was ". . . to assist in the identification of wetlands of international importance using waterbirds as bio-indicators, and especially to provide the basis of the so-called 1% criterion whereby any site which regularly holds 1% or more of a waterbird population qualifies as being internationally important under the Ramsar Convention on Wetlands" (Wetlands International 2006).

Accordingly, given that spoonbills are suitable flagship (Jin et al. 2008) and umbrella species (Sergio et al. 2006, 2008; Simberloff 1998; Steneck & Sala 2005), as well as accurate indicators for estuary restoration (Lorenz et al. 2009), this also represents a first step in improving the conservation of several endangered associated waterbird populations (Wetlands International 2006), including other Eurasian spoonbill populations showing decreasing trends (Triplet et al. 2008). Furthermore, it can be applied to the migratory Black-faced Spoonbill *Platalea minor*, Temminck and Schlegel, 1849, which has similar ecological (Ueta et al. 2002) and trophic requirements (Ueng et al. 2006), and is currently classified as endangered at the global level (Birdlife 2008).

Acknowledgments

M. Mota, J.A. Masero, J.S. Gutiérrez, E. Cervera and two anonymous reviewers made useful comments on an earlier draft of the manuscript. Thanks to several volunteers for their valuable help during the fieldwork at Santoña. JGN was financially supported to carry out the field work by SEO/BirdLife and O.A. Parques Nacionales (belonging to the former Spanish Ministry of the Environment) and currently supported by a postdoctoral fellowship of Plan Regional de Investigación (III PRI + D + I) of Junta de Extremadura. RG was supported by Department of Environment, Territorial Planning, Agriculture and Fisheries of the Basque Government.

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