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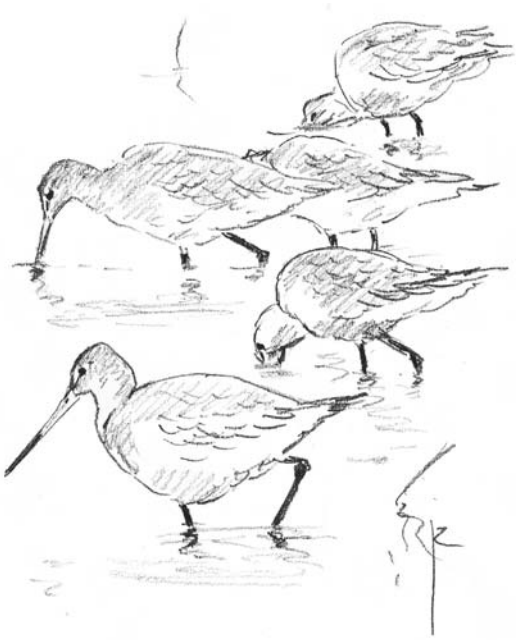
Phenology, stopover dynamics and population size of migrating Black-tailed Godwits *Limosa limosa limosa* in Portuguese rice plantations

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Between 2005/06 and 2008/09 we studied Black-tailed Godwits *Limosa l. limosa* staging in the rice fields surrounding the Tejo and Sado estuaries, Portugal. Godwits were counted weekly and flocks were scanned for colour-ringed individuals. We analysed phenology, dynamics of the stopover, and estimated the size of the Portuguese staging population as well as the total western *limosa* population. Godwits started arriving in January. Numbers peaked in the second half of February, after which they quickly departed from the area. Comparison with previous records suggested that numbers have decreased since the early 1990s, and that godwits currently peak later than some 15 years ago. Individual staging durations averaged 22.6 days in 2007 and 25.3 days in 2009, and increased towards the end of the staging period. We estimated that a total 59 200 birds used the area in 2007 and 53 100 in 2009. Using estimates for the proportion of colour-ringed birds in the flocks, we estimated the population size of the western part of the *L. l. limosa* population at 133 151–140 722 birds. This is higher than previous estimates based on inventories of the breeding population, but accounts for the non-breeding segment of the population. Thus, we estimate that 38–44% of the NW European Black-tailed Godwit population stage in Portugal. It is argued that processes in Iberia are not likely to have contributed to the population decline as the area for rice cultivation has increased. Nevertheless, as godwits staging in Iberia are totally dependent on human-made habitats, changes in rice farming practices could have great impact on the total population size.

Key words: *Limosa limosa*, phenology, population estimate, rice fields, staging area, stopover duration



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Staging episodes are considered critical in the annual life cycle of migratory birds (Piersma & Baker 2000, Chernetsov 2006, Buehler & Piersma 2008) and can have consequences on survival and breeding success (Newton 2006). Important aspects of the staging period are timing and duration, and knowledge of the turnover rate of individuals is crucial to understanding the importance of staging sites for the conservation of migratory species (Chernetsov 2006). Despite this, stopover ecology remained one of the least studied aspects of avian migration (Lindström 1995).

Continental Black-tailed Godwits *Limosa limosa limosa* mostly breed in the agricultural grasslands of northern Europe. Their breeding range extends from the UK and The Netherlands in the west to near Russia in the east (Thorup 2006, Gill *et al.* 2007). The western part of the population is believed to be relatively isolated (Höglund *et al.* 2008), both during the breeding season (breeding mostly in The Netherlands, but also in Germany, Belgium, France, Denmark, Sweden, Norway and the UK) and in winter (when using coastal sites in West Africa). This sub-population has undergone serious population declines over the last decades, probably by as much as 50% since the 1980s (Piersma 1986, SOVON 1987, SOVON 2002, Teunissen & Soldaat 2005). Much of this decline has been associated with agricultural intensification in the breeding areas (Beintema *et al.* 1995, Schekkerman & Müskens 2000, Schekkerman *et al.* 2008).

A significant portion of this sub-population stages on the rice fields of the Iberian Peninsula during northward migration (Kuijper *et al.* 2006, Lourenço & Piersma 2008a), where they forage on rice kernels to accumulate energy for the subsequent flights (Lourenço & Piersma 2008b). Although these areas seem important to the godwits, little is known about when and in which numbers they occur in these areas. In this study we capitalized on the large number of Black-tailed Godwits colour-ringed at Dutch breeding sites in recent years (e.g. van den Brink *et al.* 2008), which mix with birds from other breeding areas, allowing for a robust estimation of size of the source population (White 1996, Gunnarsson *et al.* 2005).

In order to better understand the staging processes of the declining population of continental Black-tailed Godwit and to substantiate the importance of the rice fields in central Portugal (surrounding the estuaries of the Tejo and Sado rivers, see Lourenço *et al.* in press) we aimed to collect the following information. (1) Describe the current phenology in comparison with the situation in the early 1990s, (2) estimate staging duration of individual godwits and the total number of godwits using this staging area, and (3) estimate the size of the western *L. l. limosa* population.

METHODS

Phenology

Field work took place in the winters 2005/06 through 2008/09. The main rice field areas around the Tejo (38°57'N, 8°54'W) and Sado (38°24'N, 8°38'W) river estuaries were surveyed for godwit presence in each winter during the period that Black-tailed Godwits migrate through the area (Kuijper *et al.* 2006), from early December to mid-March. For information on the study area see Lourenço & Piersma (2008b). Each site was visited at least three times per week, and weekly counts were made for the total area. The observed phenology was compared with data for 1991/92 and 1992/93 (R. Rufino, unpubl. data) to check for possible changes in the timing of stopover.

Staging duration

Since 2004, continental Black-tailed Godwits received individual combinations of four colour rings and one leg-flag at breeding sites in The Netherlands (van den Brink *et al.* 2008). Icelandic Black-tailed Godwits were colour-ringed in different parts of their range since the 1990s (Gunnarsson *et al.* 2005). In Portugal, flocks were checked for the presence of colour-marked individuals. We found 16 (2005/06), 66 (2006/07), 71 (2007/08) and 127 (2008/09) different Dutch individuals. However, only in 2006/07 and 2008/09 we achieved a stable resighting effort throughout the study period. Therefore, to estimate staging duration we used only the data sets from these years.

To analyse the mark–recapture data, we used the program MARK (Cooch & White 2006). Week was the temporal unit as daily resighting rates were too low. Model selection was based on Akaike's information criterion corrected for small sample size (AIC_c). All models used the logit link function. We assessed goodness-of-fit for the most general model in each set by the bootstrapping method included in MARK. We calculated the deviances from 100 simulations of data that are not over-dispersed. We accepted a general model if its deviance ranked over 90 of the 100 rank-ordered simulated deviances. We also tested for overdispersion: the median $\hat{c}$ was 0.95 for 2006/07 and 0.92 for 2008/09, which indicates a slight underdispersion of the data. In MARK we constructed two types of models, the first to estimate the 'survival' *phi* parameter (for emigration = 1–*phi*) and the second to estimate the 'seniority'

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gamma parameter (for immigration = 1–*gamma*). The first parameter predicts the chance that an individual present just after time *t* will still be present just before time *t+1*, while the second parameter predicts the chance that an individual present just before time t was already present just after time *t–1* (Pradel 1996).

To calculate the stopover duration, we used the most parsimonious models to estimate *phi* and *gamma* and applied these in software SODA (Schaub *et al.* 2001), which provided a stopover duration estimate (± SD) for each week. In the first winter we had eight staging duration estimates. In the second winter, when resightings of colour ringed birds started two weeks earlier, we had 10.

Number of Black-tailed Godwits staging in Portugal and size of source population

We used *gamma* to estimate how many birds arrived at the site just before time *t* as the number of birds counted each week (*t*) multiplied by 1–*gamma* calculated for that week. Also, by adding all new birds from each week we obtain an estimate of the total number of birds staging in the sites. Total numbers of birds were corrected for the numbers of the Icelandic subspecies *L. l. islandica* that also occurred in the same rice fields (Gunnarsson *et al.* 2005). Based on the proportion of ringed birds of each subspecies in each week, only 5–8% were *L. l. islandica* (Alves *et al.*, unpubl. data).

Past ring recoveries have shown that the *limosa* Black-tailed Godwits visiting Iberia come exclusively from north-western Europe (Haverschmidt 1963, Beintema & Drost 1986). During our field work we observed birds from four different breeding areas: two from The Netherlands, one from Germany and one from the UK. This indicates that there is mixing of birds from different breeding areas at the staging sites. We therefore assumed that birds seen in Iberia are a random sample of birds from the western population, and used the density of ringed birds in our samples to estimate population size.

To estimate the density of ringed birds (number of colour-ringed birds on total number), we sampled 81 (in 2007), 67 (in 2008) and 76 (in 2009) godwit flocks, considering a different flock per site and per sampling day. In each flock, we checked all visible legs, starting at one end of the flock and counting until either the end of the flock or until the flock flew up. We checked an average of 691 (SE 49) birds per flock. Only birds ringed within the University of Groningen ringing scheme (van den Brink *et al.* 2008) were considered to be ringed, as only for these birds we had a reliable estimate of how many were alive in each winter (see below).

Furthermore, we used data on the density of ringed birds collected following the same methodology in the Extremadura rice fields located along the Guadiana river near Mérida, Spain (38°58'N, 5°59'W) (Sánchez-Guzmán *et al.* 2007). In total 75 (2007), 111 (2008) and 200 (2009) godwit flocks were sampled, with an average of 151 (SE 11) birds per flock.

To estimate the number of ringed birds alive (University of Groningen ringing scheme only) at the time of the observations in each year, we used the best available annual survival estimates for the ringed population, 0.91 for adults and 0.53 for first calendar year birds (R. Kentie, unpubl. data). This may slightly underestimate the number of ringed birds alive, as birds had been ringed in the breeding areas in May and the observations were made in January and February, so not a full year had passed. Since the godwits had already undergone a southbound migration, a summer and autumn in Africa and a large part of the northbound migratory flight, the remaining mortality until the following breeding season is likely to be low. All samples of the density of ringed birds, separated by year and country were input in program NOREMARK (White 1996, Gunnarsson *et al.* 2005) in which we used JHE closed population model estimation to calculate population estimates with 95% confidence intervals.

RESULTS

Phenological pattern

Over the four studied winters we found a similar phenology in the Tejo and Sado rice fields. Although some birds were already present in December, godwits mostly started to arrive in early January, reaching peak numbers in the second half of February. The birds left the area in the beginning of March (Fig. 1). In 2006, the pattern was somewhat different, with two separate peaks. The dip was probably caused by missing birds that had gone to a location that was not yet counted. Data available for 1992 and 1993 suggests that the migration peak occurred on average three weeks earlier than what was found in 2006–09. Peak numbers were similar among the four recent years (mean 44 185 birds, SD 2768), while in the 1990s there was much more variation. The current peak numbers were 46% lower than the maximum peak in the 1990s (Fig. 1).

Stopover dynamics

The most parsimonious emigration models were those that estimated a constant *phi* during the first weeks,

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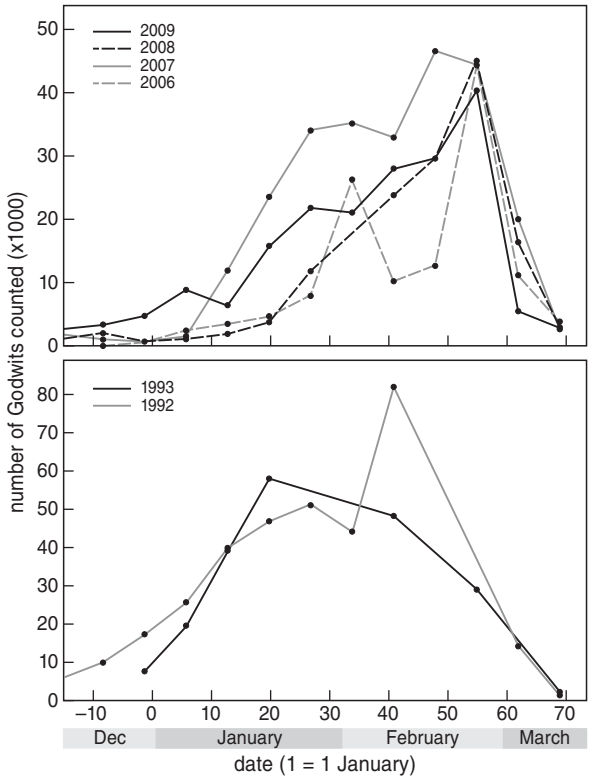


Figure 1. Total counts of Black-tailed Godwits in Portuguese rice fields in 2006–09. For comparison, data are given for two winters in the 1990s (1992 and 1993).

Table 1. Modelling 'survival' probabilities (to estimate emigration rate) of Black-tailed Godwit in Portugal in 2007 and 2009. Phi = survival probability, p = resighting probability, weight = Akaike weight, NP = number of parameters, t = temporal variation (by week), c = constant. Notations like 5c+2t mean that the parameter is constant in the first five periods and varies in the last two. Models with lowest AIC_c are the most parsimonious. Other candidate models were less parsimonious and are not shown here.

Model	AIC_c	ΔAIC_c	AIC_c weight	NP	Deviance
2007					
Phi(5c+2t). p(c)	261.51	0.00	0.41	2	56.28
Phi(4c+3t).p(c)	262.58	1.07	0.24	3	55.25
Phi(c).p(t)	263.60	2.10	0.14	8	45.21
Phi(6c+t).p(c)	263.71	2.20	0.14	2	58.48
Phi(c).p(c)	265.04	3.54	0.07	2	59.82
Phi(t).p(c)	273.67	12.17	0.00	8	55.28
Phi(t).p(t)	273.91	12.41	0.00	13	43.42
2009					
Phi(8c+t). p(t)	521.00	0.00	0.47	10	148.72
Phi(7c+2t).p(t)	521.86	0.86	0.31	11	147.33
Phi(c).p(t)	523.77	2.77	0.12	10	151.24
Phi(6c+3t).p(t)	523.97	2.97	0.11	12	147.16
Phi(t).p(t)	534.89	13.89	0.00	17	145.90
Phi(c).p(c)	535.25	14.25	0.00	2	182.27

and a varying *phi* in the final weeks (Table 1). In 2007 the top-ranking models estimated a constant resighting probability during the stopover period, averaged at 29% (SE 6). In 2009 the top-raking models estimated a temporal resighting probability, which averaged 28% (SE 3).

The top-ranking seniority models estimated a fully temporal *gamma*. In 2007, there was equal support for models that estimated a constant resighting probability and a temporal resighting probability (Table 2). Model averaging provided an estimate of 35% (SE 2) for the resighting probability over the stopover period. In 2009 the top-ranking model estimated a fully temporal resighting probability, which averaged 32% (SE 3).

In both years the staging duration seemed to vary with time, becoming longer closer to the end (Fig. 2). Staging duration was similar in the two years, averaging 22.6 days (SD 7.2 days) in 2007 and 25.3 days (SD 3.6) in 2009.

Table 2. Modelling 'seniority' probabilities (to estimate immigration rate) of Black-tailed Godwit in Portugal in 2007 and 2009. Gamma = seniority probability, p = resighting probability, Weight = Akaike weight, NP = number of parameters, t = temporal variation (by week), c = constant. Models with lowest AIC_c are the most parsimonious. Other candidate models were less parsimonious and are not shown here.

Model	AIC_c	ΔAIC_c	AIC_c Weight	NP	Deviance
2007					
Gamma(t).p(c)	272.13	0.00	0.54	8	48.7
Gamma(t).p(t)	273.34	1.20	0.30	12	46.9
Gamma(c).p(t)	274.53	2.40	0.16	8	51.7
Gamma(c).p(c)	296.81	24.68	0.00	2	67.9
2009					
Gamma(t).p(t)	575.04	0.00	0.98	17	193.25
Gamma(c).p(t)	583.98	8.95	0.02	10	206.97
Gamma(t).p(c)	595.91	20.87	0.00	10	216.98
Gamma(c).p(c)	602.78	27.74	0.00	2	229.87

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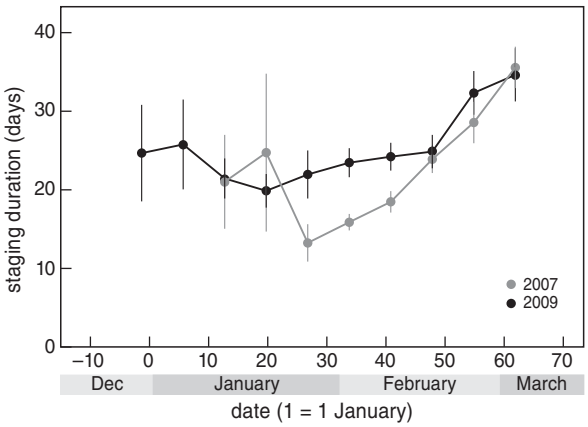


Figure 2. Average staging duration ± SE for individual Black-tailed Godwits present in the study area in each week.

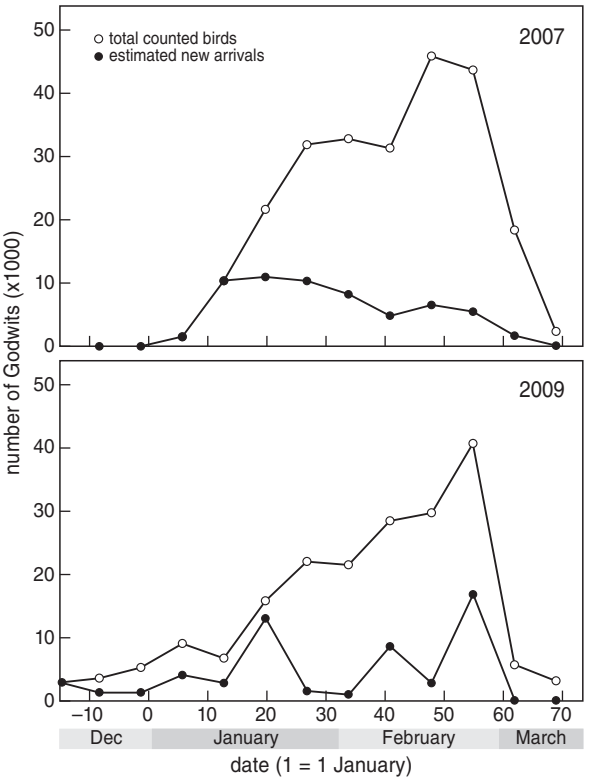


Figure 3. Comparison between the total numbers of Black-tailed Godwits counted and estimated new arrivals in each week of the staging periods in 2007 and 2009.

Number of Black-tailed Godwits staging in Portugal and a new population estimate

During the first three weeks in 2007 Black-tailed Godwits arrived at a constant rate of about 10 000 birds/week, after which the rate of new arrivals dropped to almost zero by the end of February (Fig. 3). In 2009 godwits arrived in three distinct peaks, one in January and two in February (Fig. 3). We estimated the total number of birds migrating through the area at 59 200 ± 2900 for 2007 and at 53 100 ± 4600 for 2009.

From 2007 to 2009 the density of ringed birds in the flocks increased, and the variation between samples decreased. These trends corresponded with an increasing number of birds ringed in the Dutch breeding population. Based on the density of ringed birds and number of ringed birds alive in the population, the population estimates ranged from 133 151 to 140 722 birds (Table 3).

We thus conclude that 38–44% of the western population of *Limosa l. limosa* used the rice fields in Portugal during the period of our study.

Table 3. Population estimates for the western population of *L. l. limosa*. Given is the number of ringed birds estimated to be alive each winter (ringed population , based on ringing scheme of the University of Groningen), the number of flocks sampled, the total number of birds checked and the population estimates with their 95% confidence intervals (C.I.).

Year	Country	Ringed population	Number of samples	Total birds checked	Population estimate	95% C.I.
2007	Portugal	241	81	45 129	133 151	113 478–157 694
2007	Spain		75	14 882	140 722	98 176–211 985
2008	Portugal	425	67	40 041	139 677	117 697–167 534
2008	Spain		111	15 246	139 914	104 994–192 261
2009	Portugal	552	76	39 711	138 664	117 582–164 694
2009	Spain		200	30 945	135 573	113 456–163 883

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DISCUSSION

We estimated that the total number of birds migrating through the Portuguese rice fields was roughly 25% higher than the peak counts. This clearly underlines the importance of taking into account the turn-over of birds at staging sites to correctly assess the importance of the sites (e.g. Frederiksen *et al.* 2001, Schaub *et al.* 2001). That 38–44% of the western *L. l. limosa*'s use Portugal during northward migration confirms the importance of Portuguese rice fields for this near-threatened population (Kuijper *et al.* 2006; Lourenço *et al.* in press). Despite this, most of the fields are outside local protected areas and no management measures are currently enforced to assure that the favourable staging conditions will remain in the future.

If we exclude the first week of February in 2006, when we probably missed some birds in a rice plantation not yet surveyed at that time, the pattern of occurrence of godwits was basically the same in all years. Numbers peaked at 44 000–45 000 birds in the second half of February, after which the sites were quickly abandoned by the godwits on their way towards their breeding areas. In a nearby stopover area in the Spanish Extremadura, the migratory peak is not quite as constant, ranging between the first and third week of February and being on average earlier than in Portugal (Masero *et al.* 2007).

Peak counts in the 1990s seemed to occur on average three weeks earlier than during our study, but there was large variation between the two years for which data is available. At that time counts were not performed every week, so the data might not be comparable in terms of timing. If we assume the trend towards a later stopover in Iberia is true, this is in accordance with the apparently larger reduction in the numbers stopping over in France than in Iberia (Lourenço & Piersma 2008a). If birds remain longer in Iberia they are likely to overfly France altogether in order to arrive timely at their breeding sites. Indeed, arrival dates of first birds at breeding sites in The Netherlands start in the beginning of March (J.C.E.W. Hooijmeijer *et al.*, unpubl. data), shortly after departure from Portugal.

The maximum count in the early 1990s reached nearly 82 000 birds, which indicates that peak numbers have been reduced by 46%. If the turn-over rate in the 1990s was similar to the present value, and the number of birds passing through the area was 25% more than the average of the two peak counts, then the decline would be similarly around 40%. This figure is close to the decline witnessed in the breeding areas (50% since the early 1980s, Piersma 1986, SOVON 1987, SOVON 2002, Teunissen & Soldaat 2005). Although there are no reliable data on overall population changes in Spain in the last decades (Kuijper *et al.* 2006), numbers have probably declined in the Coto Doñana area, a traditional staging site. In the Extremadura rice fields numbers have increased as this is a novel staging area that has only become available for godwits following the vast irrigation projects in the 1980s (Sánchez-Guzmán *et al.* 2007, Lourenço & Piersma 2008a).

On average, Black-tailed Godwits remained in the area for 22–25 days, although the latest birds seemed to stay longer than early arriving birds. This means that there is a larger turn-over of birds in the beginning of the season, with birds arriving and departing. In February, the turn-over is reduced, the arrivals lead to a build up of birds, culminating in the peak counts, while departures seem to be delayed until most birds depart almost simultaneously in the beginning of March. Such an increase in staging time towards the end of the staging period, coupled with a synchronized group departure might suggest that the birds delay departure to await favourable conditions on the breeding grounds. Maybe leaving too early would imply a risk of facing bad weather and frozen soils that make food unavailable on the breeding areas. Also, staying in Iberia longer instead of making further stopovers in France might be the safest option, as the hunting pressure is much higher in France (Gill *et al.* 2007).

At the Extremadura staging areas in Spain, average staging duration was estimated at 21.7 days in 2007 (J.A. Masero *et al.*, unpubl. data). This is similar to what we observed in Portugal and suggests that turn-over rates are similar at both Iberian staging areas.

The lower number of godwits seen in France during migration in recent years (Lourenço & Piersma 2008a) could be explained by the relatively low turn-over in Iberia. The reason for this change in France could be an increase in the available foraging habitat in Iberia, where the hunting pressure is lower. Recent work has shown that the Iberian rice fields provide a very profitable foraging habitat for godwits (Masero *et al.* 2007, Lourenço & Piersma 2008b). However, in Portugal the extent of rice plantations decreased by at least 25% in the last three decades. Over the same period the area used for rice cultivation in Spain increased by 35%. Overall this resulted in a 28% increase of the rice cultivated area in Iberia (FAOSTAT 2008). Even if not all rice fields are usable by godwits, due to the specific habitat requirements (Lourenço & Piersma 2008b), the available high-quality habitat in Iberia seems to have increased. This increase in available habitat suggests that stopover processes in Iberia are not contributing to

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the ongoing population decline. However, the population is now almost exclusively dependent on man-made habitats, making it very sensitive to any future changes in the extent of rice cultivation or in rice farming practices, which can easily fluctuate according to the profitability of planting rice and the economic incentives that rice planters receive from the EU (GPPAA 2006).

The total European population of *limosa* Black-tailed Godwits was estimated at 86 500–120 000 breeding pairs in 2000 (Thorup 2006), and the western segment of this population, migrating through Iberia, would have amounted 53 200–59 600 pairs or c. 110 000 individuals (Thorup 2006). Our estimate of 135 000–140 000 is slightly larger, but includes adults that for some reason skip a breeding season, which can be a substantial proportion in some years and at some breeding sites (P.M. Lourenço *et al.*, unpubl. data) and also some second calendar year birds that venture north. Covering only three years, and considering the uncertainty associated with the estimates, these data do not establish a current rate of population decline. However, a repetition of this study in the next 5 to 10 years could provide robust estimates of population trends.

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SAMENVATTING

De westelijke populatie van de Grutto *Limosa limosa*, die voornamelijk in Nederland broedt, neemt sterk in aantal af. Een belangrijk deel van deze populatie verzamelt zich in de loop van de winter op de rijstvelden van het Iberisch schiereiland. Bij dit onderzoek werden tellingen en observaties van gekleurringde vogels in Portugal gebruikt om een beter inzicht te krijgen in de timing van deze doortrek en het aantal vogels dat van deze gebieden gebruikmaakt. Bovendien is aan de hand van de dichtheid aan gekleurringde vogels een schatting van de totale grootte van de West-Europese populatie gemaakt. De eerste Grutto's komen in januari in Portugal aan. Daarna lopen de aantallen op tot ze een piek in de tweede helft van februari bereiken. Daarna nemen de aantallen weer snel af. Een vergelijking van gegevens uit 1992 en 1993 met die uit recente jaren geeft aan dat de piek tegenwoordig twee weken later wordt bereikt dan destijds. Mogelijk stelt dit de vogels in staat rechtstreeks naar de broedgebieden door te vliegen, zonder in Frankrijk te hoeven stoppen, waar de jachtdruk hoger is dan op het Iberisch schiereiland. Uit de analyse van de observaties aan gekleurringde vogels blijkt dat de vogels gemiddeld zo'n 23–25 dagen in het gebied verblijven. De lengte van het verblijf lijkt echter op te lopen naar het einde van de doortrekperiode. Het totaal aantal Grutto's dat de Portugese rijstvelden aandoet, werd geschat op 53.000–59.000 vogels, een afname van zo'n 40% ten opzichte van de jaren 1990. De totale West-Europese populatie werd geschat op 133.000–141.000 vogels, wat zou betekenen dat 38–44% van de populatie de rijstvelden van Portugal aandoet.

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