

THEORETICAL FLIGHT RANGES OF WADERS RESTING IN THE EBRO DELTA DURING AUTUMN MIGRATION

J.FIGUEROLA AND A.BERTOLERO

*Departament de Biologia Animal (Vertebrats), Facultat de Biologia, Universitat de Barcelona,
Auda Diagonal 645. E-08028 Barcelona*

The Ebro Delta is an important stopover site and wintering area for many species of waders (Figuerola et al. 1993, Velasco and Alberto 1993). Despite the large amount of ringing carried out at this site since 1990,

recoveries which determine the most southern areas used by migrant birds have been scarce. This lack of information may be due to the scarcity of ringers working in southern Europe and Africa, and to the low percentage of recoveries from the African continent (Bernis 1966). In order to know the range of possible destination of birds using a stopover area in SW Europe we calculated theoretical flight distances of individuals captured during post-nuptial migration. We analysed the data of the four most commonly ringed species in the study area: Kentish Plover (*Charadrius alexandrinus*), Little Stint (*Calidris minuta*), Dunlin (*Calidris alpina*) and Curlew Sandpiper (*Calidris ferruginea*). Since larger species are capable of undertaking longer flights than smaller species with the same level of reserves (Davidson 1984), we also investigated the effect of sexual dimorphism in size on the theoretical flight ranges estimated for Curlew Sandpipers.

MATERIAL AND METHODS

Birds were captured with mist-nets and walk-in-traps during post-nuptial migration from 1991 to 1993 at "Les Salines de la Trinitat", Ebro Delta (40.37N 00.35E). The loss of weight during ringing was corrected according to Zwarts et al. (1990). Body mass was standardized for the average bill length for the species (Table 1) using the formula:

$$\text{std. body mass} = \text{body mass} * \frac{(\text{culmen})^a}{(\text{mean culmen})^a}$$

where a was the slope of the lineal regression of the logarithm of body mass on the logarithm of bill length. This transformation eliminates the effects of body size on mass and allows the comparison of body mass for different individuals, (Summers 1988).

TABLE 1

Mean wing and bill length, coefficient used to standardize body mass (a), number of captures used in the analysis (n), arrival and departure masses and estimated flight range. The number of male and female Curlew Sandpipers analysed do not correspond to the total for the species because a small number of birds could not be sexed.

Longitud media del ala y del pico, coeficiente usado para estandarizar el peso (a), número de capturas utilizadas en el análisis (n), pesos de llegada y abandono del área y distancia teórica de vuelo. La suma del número de machos y hembras de Correlimos zarapitín es menor que el total de esta especie porque no se pudo determinar el sexo de algunos individuos.

	\bar{x} wing (mm)	\bar{x} bill (mm)	std.coef. a	n	estimated		
					body mass (g) arrival	body mass (g) departure	flight range (km)
<i>Charadrius alexandrinus</i>	109.7±0.31	15.5±0.05	0.24	265	34.6±0.31	50.9±0.54	2439
<i>Calidris alpina</i>	117.5±0.20	33.7±0.13	0.85	394	41.9±0.25	58.0±0.40	2129
<i>Calidris minuta</i>	97.4±0.14	18.3±0.05	0.25	433	20.8±0.19	34.7±0.36	3285
<i>Calidris ferruginea</i>	131.1±0.09	38.2±0.08	0.33	1099	51.9±0.24	83.2±0.39	3340
males	130.0±0.12	36.3±0.07	0.17	581	51.2±0.29	81.6±0.48	3171
females	132.4±0.13	40.5±0.07	0.43	474	52.8±0.29	85.3±0.58	3288

For Curlew Sandpiper we calculated a second standardized body mass using the average bill length for the sex of each individual. Castro and Myers's (1989) formula was used to calculate the theoretical flight distances for each of the four species studied. For these calculations only birds over one year old were used given that first-year birds tend to accumulate different levels of reserves from adults (Davidson 1981). Departure mass was estimated from the mean body mass of the heaviest 10% of individuals (see Davidson 1984). Arrival mass at the new area was estimated from the mean of the leanest 10% of individuals. In the calculations of flight range a flight speed of 60 km/h was used (Zwarts et al. 1990), however, differences with the estimates of flight speed reported by other authors exist (e.g. McNeil and Cadieux 1972, Welham 1994). For this reason we have enclosed in this paper all the information necessary to recalculate flight range estimates if more accurate measurements of flight speed become available.

RESULTS

The levels of reserves accumulated by each species varied greatly. Thus, the theoretical flight distances ranged from 2129 km in the case of Dunlins to 3340 in Curlew Sandpipers (Table 1, Figure 1). Arrival and departure masses of male Curlew Sandpipers were smaller than female ones (Table 1; arrival: $t = -3.8$, 105 d.f., $p < 0.001$; departure: $t = -5.0$, 105 d.f., $p < 0.001$), but sex-related differences in flight range only reached 100 km.

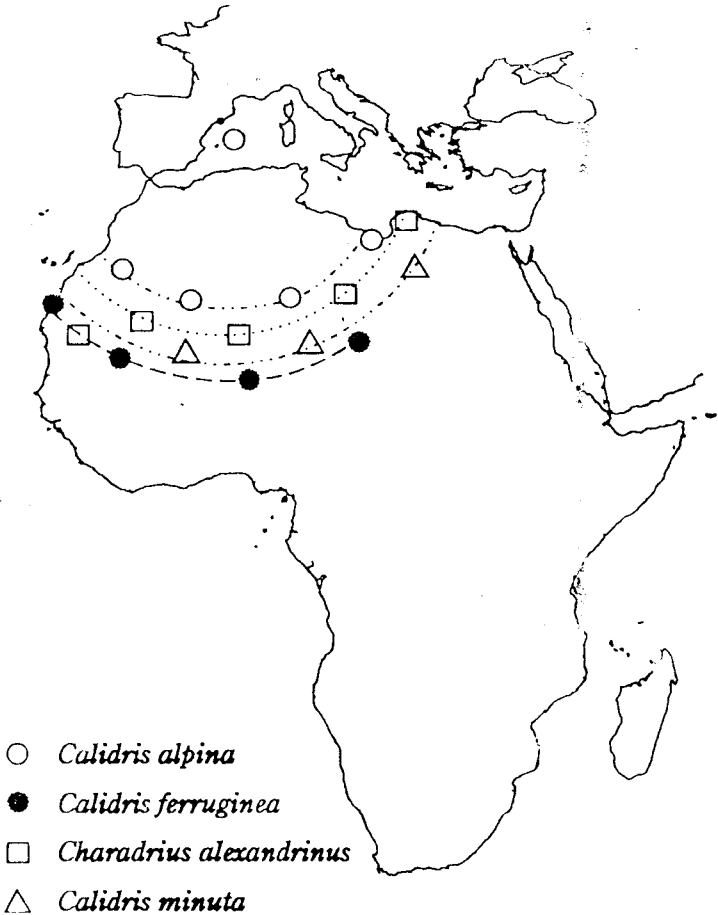


Figure 1. Theoretical flight ranges (lines) and controls (symbols) of waders ringed in the Ebro Delta: Kentish plover (*Charadrius alexandrinus*), Little Stint (*Calidris minuta*), Dunlin (*Calidris alpina*) and Curlew Sandpiper (*Calidris ferruginea*).

Distancias teóricas de vuelo (líneas) y controles (símbolos) de los limícolas anillados en el Delta del Ebro: Chorlitejo patinegro (Charadrius alexandrinus), Correlimos menado (Calidris minuta), Correlimos común (Calidris alpina) y Correlimos zarapitín (Calidris ferruginea).

DISCUSSION

Two main strategies of migration flight have been described: jumping and hopping (Piersma 1987). Migration distance can be covered in a small number of long flights ("jumpers") as Curlew Sandpipers (Wilson et al. 1980), or covered in a great number of stopover localities separated by shorter distances ("hoppers"), as, for example, Dunlins (Pienkowski and Dick 1975). The results reported in this study are only an estimation of maximum flight radius. These estimates will be more accurate for jumper species than for hoppers. Occurrence of overloading have been detected in three other waders (Gudmundson et al. 1991). Apparently, birds accumulate more reserves than necessary to cover flight distances from Iceland to their breeding grounds. However, the occurrence of overloads in the last staging sites before arrival to breeding grounds may be related with a need of bringing body reserves to the breeding areas (Gudmundson et al. 1991). In this case, overloading had a small effect on the estimates of flight range reported here.

Kentish Plovers had sufficient reserves to reach the north of Africa where they can accumulate new reserves which permit them to reach the southern-most limit of their wintering quarters. The only recovery of a Kentish Plover ringed in the Ebro Delta is from this area (Kaolag, Senegal). The estimated flight range suggests that Kentish Plovers use a southern refueling area before arriving at their Senegal wintering grounds.

Dunlins had the shortest estimated flight distances. This figure may be due to the fact that most of the Dunlins which migrate through the western Mediterranean also winter in this area (Fuchs 1973). The lack of recoveries from Africa of birds ringed in Mediterranean Spain (ICONA files) supports this view. The fact that the single winter recovery outside the Ebro Delta has occurred in a wetland at the Balearic islands (247 km out from our ringing area) is also consistent with this hypothesis.

Little Stints showed the highest levels of reserves which would allow them to reach their trans-Saharan refueling or wintering areas in a single flight. However, it is also possible that a large part of the population passing through the Ebro Delta winters in North Africa and South Europe.

Curlew Sandpipers showed the greatest estimated flight range of the four species considered in this study and would have enough reserves to reach their wintering zones in Mauritania and Guinea-Bissau. In this latter area the only two winter recoveries of Curlew Sandpipers ringed in the Ebro Delta (GCA files at 28/11/94) have occurred. Such wintering areas are used by birds migrating through western Europe (Wilson et al. 1980). Nevertheless, autumn observations in southern Spain of three birds colour-

ringed in the Ebro Delta indicate that a portion of the population undertakes shorter flights than those predicted. However, these individuals correspond to birds ringed in the first part of migration, when passage is likely to occur at high speed, with a great number of birds using the area for a very short time (Figuerola et al. 1993). The study of Semipalmated Sandpipers (*Calidris pusilla*) residence patterns at a stopover site have shown that not all individuals reach the same threshold mass before departure (Skagen and Knopf 1994), so different individuals, in a same refueling area, could differ in their flight range.

Although females accumulated more fat reserves than males, the differences found in the estimated flight ranges of each sex (a.100 km) are too small in comparison to the estimated flight range for the species (3340 km), to be considered as biologically significant. However, a more powerful test appears necessary before concluding that no sex-related differences in flight range occur in Curlew Sandpipers.

ACKNOWLEDGEMENTS

This work was funded by the Ebro Delta Natural Park, Diputació de Tarragona and the Grup Català d'Anellament. We thank L.M. Copete and L. Gustamante for his indispensable help in the field work. F.J. Cantos from ICONA and Raul Aymí from GCA, kindly supplied the information for ringing recoveries. We would also like to thank J. Arcos, I. Barroso, L. Brotons, L. Carrera, O. Clarabuch, A. Elliot, M.A. Franch, D. Frøehlich, S. Galán, P. Garcías, G. Gargallo, M. Garrido, R. Mariné, R. Martí, A. Martínez, R. Mateo, A. Motis, D. Oro, P.M. Pares, X. Riera, A. Salmerón, J. Solans, F. Vicents, R. Vidal for their help and friendship. The comments of J. A. Amat and an anonymous referee improved an earlier manuscript and M. Lockwood improved the English of this paper. J. Piera prepared the figures of this paper.

Key words: body reserves, fat, flight distances, migration, sexual dimorphism, winter distribution, south-west Europe.

RESUMEN

Distancias teóricas de vuelo de limícolas

A partir de los pesos obtenidos con el anillamiento de limícolas en el Delta del Ebro, se calcularon las distancias teóricas de vuelo de cuatro especies durante la migración postnupcial. Las reservas acumuladas por el Chorlitojeo patinegro (Charadrius alexandrinus) no le permitirían alcanzar las zonas más sureñas de su zona de hibernada. En cambio, el Correlimos común (Calidris alpina), el Correlimos menudo (Calidris minuta) y el Correlimos zarapitín (Calidris ferruginea) acumularían reservas suficientes para realizar un vuelo ininterrumpido hasta el límite sur de su zona de hibernada más probable. Las diferencias sexuales encontradas en las distancias de vuelo del Correlimos zarapitín fueron demasiado pequeñas como para ser consideradas significativas. Sin embargo es necesario comprobar el efecto del dimorfismo sexual mediante un método más riguroso antes de descartar su efecto en las distancias de vuelo en esta última especie.

Palabras clave: Distancia de vuelo, grasa, migración, reservas, dimorfismo sexual, Delta del Ebro.

REFERENCES

- BERNIS, F. (1966). *Migración en aves. Tratado teórico práctico*. Publicaciones de la Sociedad Española de Ornitología, Madrid.
- CASTRO, G. and J.P. MYERS (1989). Flight range estimates for shorebirds. *Auk* 106:474-476.
- DAVIDSON, N. C. (1981). *Seasonal changes in nutritional condition of shorebirds during the non-breeding seasons*. Ph. D. thesis, University of Durham.
- DAVIDSON, N. C. (1984). How valid are flight range estimates for waders?. *Ringing & Migration* 5: 49-64.
- FIGUEROLA, J. , J. M. COPETE and L. GUSTAMANTE (1993). *Biología dels limícols al Delta de l'Ebre: Migració i muda postgeneratives*. Mimeogr. rep., Diputació de Tarragona, Tarragona.
- FUCHS, E. (1973). Durchzug und Überwinterung des Alpenstrandläufers *Calidris alpina* in der Camargue. *Der Ornithologische Beobachter* 70: 113-134.
- GUDMUNDSSON, G. A., A. LINDSTROM and T. ALERSTAM (1991). Optimal fat loads and long-distance flights by migrating Knots *Calidris canutus*, Sanderlings *C. alba* and Turnstones *Arenaria interpres*. *Ibis* 133:140-152.
- MCNEIL, R. and F. CADIEUX (1972). Fat content and flight-range capabilities of some adult spring and fall migrant North American shorebirds in relation to migration routes on the Atlantic coast. *Naturalist can.* 99: 589-605.
- PIENKOWSKI, M. W. and W. J. A. DICK (1975). The migration and wintering of Dunlin *Calidris alpina* in north-west Africa. *Ornis Scand.* 6:151-167.
- PIERSMA, T. (1987). Hink, stap of sprong? Reisbeperkingen van arctische steltlopers door roedselzoeven, vetopbouw en vliegsnelheid. *Limosa*, 60: 185-194.
- SKAGEN, S. K. and F. L. KNOPF (1994). Residency patterns of migrating sandpipers at a midcontinental stopover. *Condor* 96:949-958.
- SUMMERS, R. W. (1988). The use of linear measurements when comparing masses. *Bird Study* 36: 77-79
- VELASCO, T. and L. J. ALBERTO (1993). Numbers, main localities and distribution maps of waders wintering in Spain. *Wader Study Group Bulletin* 70: 33-41.
- WELHAM, V.J. (1994). Flight speed of migrating birds: a test of maximum range speed predictions from three aerodynamic equations. *Behavioral Ecology* 5:1-8.
- WILSON, J. R. , M. A. CZAJKOWSKI and M.W. PIENKOWSKI (1980). The migration through Europe and wintering in West Africa of Curlew Sandpipers. *Wildfowl* 31: 107-122.
- ZWARTS, L., B. J. ENS, M. KERSTEN and T. PIERSMA (1990). Moults, mass and flight range of waders ready to take off for long-distance migrations. *Ardea* 78: 339-364.