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Body condition and fuel deposition patterns of calidrid sandpipers during migratory stopover

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We compared seasonal variations in body condition and fuel deposition patterns of five calidrid sandpipers at Chongming Dongtan (eastern China), a stopover site in the East Asian–Australasian Flyway. We tested the hypothesis that long-distance migrants show different body condition and fuel deposition patterns relative to those undertaking short-distance flights. Results indicated that the body condition and fuel deposition patterns of the sandpipers varied between the northward and southward migration seasons and between age-classes. Great Knots *Calidris tenuirostris* and Red Knots *Calidris canutus* migrate southwards on a long-distance nonstop flight from Chongming Dongtan to northwest Australia, while covering on the return flight a relatively short-distance between Chongming Dongtan and the north Yellow Sea region. Both species attained a significantly higher body condition at Chongming Dongtan during the southward than northward migration. Moreover, they showed a significant increase in body condition at Chongming Dongtan during northward migration stopover, which we see as a recovery from the long flight from Australia. In contrast, Red-necked Stints *Calidris ruficollis* and Long-toed Stints *Calidris subminuta*, employing series of relatively short-distance flights during migration, indicated no significant difference in departure body condition at Chongming Dongtan between seasons, nor significant increase in body condition during either migration stopover. Dunlins *Calidris alpina* on the other hand, showed a significantly higher body condition during northward than southward migration stopover, most likely in anticipation of the longer travelling distance after leaving Chongming Dongtan during northward migration. This study confirms that the body condition and fuel deposition patterns among shorebird species that undertake long-distance nonstop flights are different from those that undertake series of short-distance flights, suggesting that the comparison of body condition and fuel deposition patterns of calidrid sandpipers can be an important tool to understand their migration strategies.

Key words: migration strategy, fuel deposition, body condition, calidrid sandpipers, East Asian–Australasian Flyway

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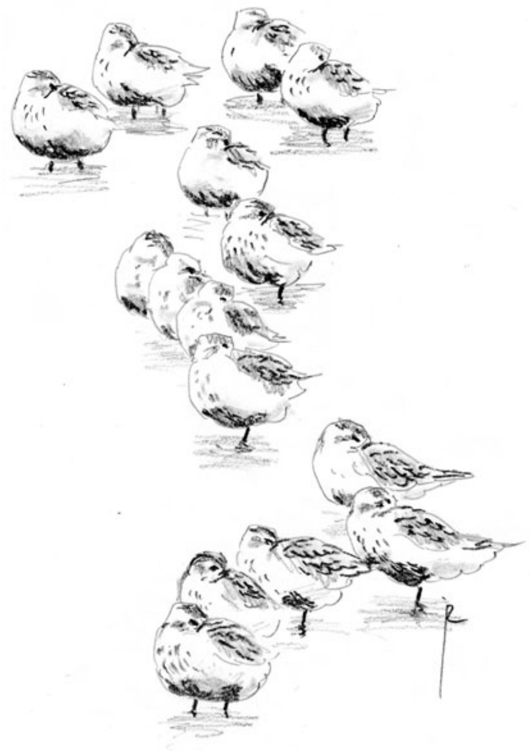

INTRODUCTION

The fuel deposition rate of migrants at stopover sites may reflect their migration strategies (Harrington *et al.* 1991, Scheiffarth *et al.* 2002, Lindström 2003). Piersma (1987) categorised the migration strategies of Afro-European shorebirds into three major travel schemes: ‘hop’, ‘skip’ and ‘jump’. These in turn were then renamed as short, intermediate and long distance bouts to describe the migration strategies used by North American shorebirds (O’Reilly & Wingfield 1995). The fuel deposition rate at stopover sites was one of the crucial factors determining the overall speed of migration and its success (Schaub & Jenni 2000b). Its variation determines the stopover duration and the length of each flight bout between stopover sites (Schaub & Jenni 2001a,b).

Factors as sex, age or moult, as well as variation in season, weather, or geography may have an impact on the migration strategies employed. This can lead to different migration strategies among populations of the same species, e.g. Ruddy Turnstone *Arenaria interpres* (Nettleship 2000) and Bar-tailed Godwit *Limosa lapponica* (Scheiffarth *et al.* 2002), or among seasons within the same population, e.g. Semipalmated Sandpiper *Calidris pusilla* (Gratto-Trevor 1992) and Red Knot *Calidris canutus* (Helseth *et al.* 2005). Similarly, age-classes may differ in migration strategy as in Honey Buzzard *Pernis apivorus* (Hake *et al.* 2003), Dunlin *Calidris alpina* (Gromadzka 1989) and Great Knot *Calidris tenuirostris* (Battley 2002). Moreover, migration strategies may change through the migratory season. For example, arctic juvenile waders started migration with short hops before flying long bouts to the wintering grounds (Lindström *et al.* 2002), and adult White-rumped Sandpipers *Calidris fuscicollis* made a long-distance non-stop flight over the Atlantic Ocean before gradually ‘hopping’ to the wintering ground in South America (Harrington *et al.* 1991). In general, body condition at stopover sites varied with the distance of the next flight (Harrington *et al.* 1991, Scheiffarth *et al.* 2002, Lindström *et al.* 2002). Therefore, we expect that birds about to take a long-distance nonstop flight have more energy reserves than those taking a short-distance flight.

Supporting five million migratory shorebirds, the East Asian–Australasian Flyway is a major component of the Global Flyway (Barter 2002, Piersma 2007). Previous research along the East Asian–Australasian Flyway has yielded important insights into the variation in migration strategies of different shorebirds (Battley *et al.* 2000, 2005, Driscoll & Mutsuyuki 2002, Gill *et al.* 2005). Based on satellite tracking, recovery records and flight range estimates, these studies have shown that shorebirds are capable of a nonstop transoceanic flight between Australia and East China. Moreover, Tulp *et al.* (1994) suggested that large calidrid sandpipers such as Great Knot and Red Knot, fly directly from northwest Australia to the east China coast, while small species such as Red-necked Stint *Calidris ruficollis* are bound to stage and refuel in southeast Asia before continuing their northward migration. Their hypotheses are supported by the observation of Red-necked Stints in large flocks in southeast Asia during migration, while Great Knots and Red Knots occurred only in small numbers (Bamford *et al.* 2008). However, the relationship between energy deposition patterns at stopover sites and migration strategies has not been studied in detail in the East Asian–Australasian Flyway.

Figure 1. Map of Chongming Dongtan in the Yellow Sea region. The inset shows the location of Yellow Sea region within the East Asian–Australasian Flyway.

Chongming Dongtan (hereafter CMDT), China, is located in the middle of the East Asian–Australasian Flyway (Fig. 1) and is an important stopover site for shorebirds (Ma *et al.* 2004). Calidrid sandpipers at CMDT account for more than 70% of all shorebirds counted (Jing *et al.* 2007). Of the calidrid species, Great Knot, Red Knot and Red-necked Stint winter mainly in Australia although some Red-necked Stints winter in the Philippines and Malaysia and small numbers of Great Knots winter in southeast Asia (Bamford *et al.* 2008). Most of the Long-toed Stints *Calidris subminuta* winter in southeast Asia and the Philippines, with a few hundred in Australia, while Dunlins winter mainly in East Asia including CMDT (Hayman *et al.* 1986, Piersma *et al.* 1996). Bamford *et al.* (2008) indicated that in boreal autumn no staging site supports more than 0.25% of the estimated flyway population beyond CMDT along the coast of southeast China including Taiwan. This suggests that sandpipers are likely to fly to southeast Asia or even directly to Australia after leaving CMDT during southward migration. In contrast, in boreal spring several staging sites supporting more than 1% of the estimated population of the flyway have been identified in the nearby Yellow Sea region (Bamford *et al.* 2008), north of CMDT. This indicates that sandpipers can travel for a relatively short distance before making another stopover after leaving CMDT during northward migration (Barter *et al.* 1997). Due to the diverse role of CMDT as stopover site, there is reason to expect differences in body condition and fuel deposition patterns among species and between spring and autumn.

In this study, we compare the body condition and fuel deposition patterns of five calidrid species (Great Knot, Red Knot, Red-necked Stint, Long-toed Stint and Dunlin) at CMDT during northward and southward migration. Moreover, we relate the energetic dynamics to the migration strategies of each of the species by testing the hypothesis that species undertaking long-distance nonstop flights show different body condition and fuel deposition patterns relative to those undertaking a short-distance flight.

METHODS

Study site

CMDT (31°30'N, 122°05'E) is located on the eastern side of Chongming Island in the Yangtze River estuary. It is an estuarine wetland, consisting of salt marshes and bare tidal flats with an estimated area of 102 km^2 available for shorebirds (Jing *et al.* 2007). The dominant plant species of the salt marshes includes the native Common Reed *Phragmites australis*, Sea Bulrush *Scirpus mariqueter*, and introduced Smooth Cordgrass *Spartina alterniflora*. CMDT supports as many as 250 000 shorebirds annually (Barter 2002). It has been recognised as a Ramsar site and listed as one of BirdLife's 'Important Bird Areas'. Calidrid sandpipers forage mainly at the *Scirpus* zone and on the bare tidal flats, where the highest density of prey for shorebirds occur (Jing 2005). The prey for shorebirds include infaunal macrobenthos, consisting mainly of bivalves, dominating the bare flats, and epifaunal macrobenthos, consisting mainly of crustaceans and gastropods, dominating the salt marshes (Jing *et al.* 2007). Of the five species of calidrid sandpipers in this study, Dunlin winters at CMDT, while the other four species only stage at CMDT during migration.

Bird capture and measurement

Shorebirds were captured and ringed at CMDT during migratory stopovers each year from 2003 to 2007. Catching periods were between 8 March and 22 May and between 23 July and 19 October. The capture efforts varied between years with a minimum of 14 (in 2003) and a maximum of 59 days (in 2007) during northward migration, and a minimum of 17 (in 2004) and a maximum of 78 days (in 2007) during southward migration. Local hunters, using clap nets (2.5 x 12 m), decoys and mimicked bird calls, were hired for the catch, which took place in the mudflats. All birds captured were provided with numbered metal rings issued by the National Bird Banding Centre of China and coloured leg flags on tibia or tarsus. Wing length was measured as flattened and stretched wing chord with a stopped ruler to the nearest 1 mm (maximum chord), bill length (exposed culmen) and tarsus were measured with callipers to the nearest 0.1 mm. Body mass was measured to the nearest 0.1 g using electronic digital balances. Most captured birds were processed and released within 3–4 hours.

In late boreal summer and autumn, birds were aged as either adults, second-year or first-year (calendar year) birds, based mainly on the wear of primaries, since adults have more worn primaries than first-year birds, and second-year birds have a distinct moult pattern in most calidrid species (Prater *et al.* 1977). The same ageing method was used in boreal spring except that adults have fresh primaries while second-year birds have either worn primaries or partially moulted primaries (Prater *et al.* 1977). The Dunlin is an exception as most adults moult their flight-feathers completely before the southward migration, resulting in fresh wing and tail feathers as first-year birds have. Adult Dunlin were therefore distinguished by a combination of criteria, including the remnants of breeding plumage on belly, the pattern of white bars on primary coverts (Persson 2007) and the colour of inner median coverts (Gromadzka 1986).

Data analysis

Data of each calidrid species were classified into three groups: adults on northward migration, adults on southward migration and first-year birds on southward migration. In northward migration, only adults were analyzed since second-year calidrid sandpipers generally do not attempt breeding in their first summer and rarely were recorded at CMDT. The Dunlin was an exception, but since first-year Dunlins also attempt breeding (Holmes 1966; Pienkowski *et al.* 1979, Warnock & Gill 1996), we have pooled all Dunlins and treated them as adults. In southward migration, second-year birds were excluded from further analysis because their numbers were negligible (<3% of total numbers for each species).

Groups with fewer than 20 records in any season were excluded from analysis, included here are adult Great Knots and Red Knots on southward migration. Individuals were excluded if they were injured or dead, were weighed more than five hours after capture, had wet feathers, or could not be aged with certainty, as well if they had been caught earlier in the same season. This resulted in a dataset of 6412 Great Knot, 642 Red Knot, 895 Red-necked Stint, 1631 Long-toed Stint and 1606 Dunlin for analysis. Sample sizes may differ among analyses due to incomplete ringing records.

The condition index (hereafter CI), provides a non-destructive method to estimate individual energy stores by correcting body mass for body size (Schulte-Hostedde *et al.* 2005). CI was calculated as (body mass / body size variable) x 100 (Winker *et al.* 1992, Winker 1995). Although the wing length is commonly used as correcting factor for structural size in shorebirds (Castro & Myers 1990), it varies with age, sex and season in the five study species (Appendix 1), thus giving a biased result. For example, the primaries of Great Knots are more worn (shorter) during southward than northward migration because they moult their primaries on the wintering grounds (Prater *et al.* 1977). Therefore, bill length or tarsus length were preferred as body size variables in several studies (Mascher & Marcstrom 1976, Shepherd *et al.* 2001, Dinsmore & Collazo 2003). Regression of wing length on bill and tarsus length indicated that there was always a stronger correlation between bill length and wing length than between tarsus length and wing length (Appendix 2). Therefore, we used bill length as body size variable to calculate CI.

Data from all years were pooled for further analysis for two reasons. First, because we focused on seasonal variation in body condition, and secondly because annual differences in CI among species were inconsistent. One-way ANOVAs were used to compare the CI by season and age-class for each species separately. Some of the data did not qualify for the assumptions regarding the homogeneity of variances nor were they normally distributed, but these deficiencies can be neglected due to the large sample sizes (Zar 1999).

In each season we designated the earliest captured 20 and the latest captured 20 individuals of each species as those just arrived and those just about to depart, respectively. Most of these records come from the years 2005–2007, when coverage was most complete. The two groups were compared by one-way ANOVA to test if CI differed among arriving and departing individuals. To avoid biases, groups containing less than 60 individuals were excluded in this analysis. In addition, linear regression of CI on capture date (Julian date) was performed to assess changes of CI with time. Due to small sample sizes, recapture data were not used to calculate fuel deposition patterns.

All analyses were performed using SPSS 12.0 for Windows (SPSS Inc. 2003). Significance level (α) 0.05 was used for all statistical tests if not otherwise mentioned, and statistics are stated as mean ± SD.

RESULTS

Body condition

CI of first-year Great Knots and Red Knots on southward migration were significantly higher than the CI of adults on northward migration (Table 1). Similarly, adult Red-necked Stints and Long-toed Stints showed significantly higher CI on southward than on northward migration. Dunlins showed a reverse pattern, with CI on northward

Table 1. Comparison of the Condition Index CI among season/age-classes in five sandpiper species (data from 2003–2007). Adult Great Knots and Red Knots during northward migration were not included because of small sample sizes. Different superscript letters indicate significant differences among classes (Tukey HSD multiple comparison tests, $P < 0.05$). Given are means ± SD, and sample sizes in parentheses.

Species	Southward migration		Northward migration	*F*	*P*
	First-year birds	Adults			
Great Knot	368 ± 50.6^a (240)	-	301 ± 31.3^b (4856)	965.3	<0.001
Red Knot	333 ± 48.9^a (54)	-	302 ± 36.2^b (579)	33.8	<0.001
Red-necked Stint	145 ± 23.3^a (222)	161 ± 25.4^b (119)	150 ± 15.3^c (544)	27.9	<0.001
Long-toed Stint	131 ± 15.7^a (1308)	153 ± 23.5^b (280)	140 ± 14.5^a (22)	179.3	<0.001
Dunlin	130 ± 11.9^a (456)	138 ± 14.7^b (73)	153 ± 17.5^c (917)	344.2	<0.001

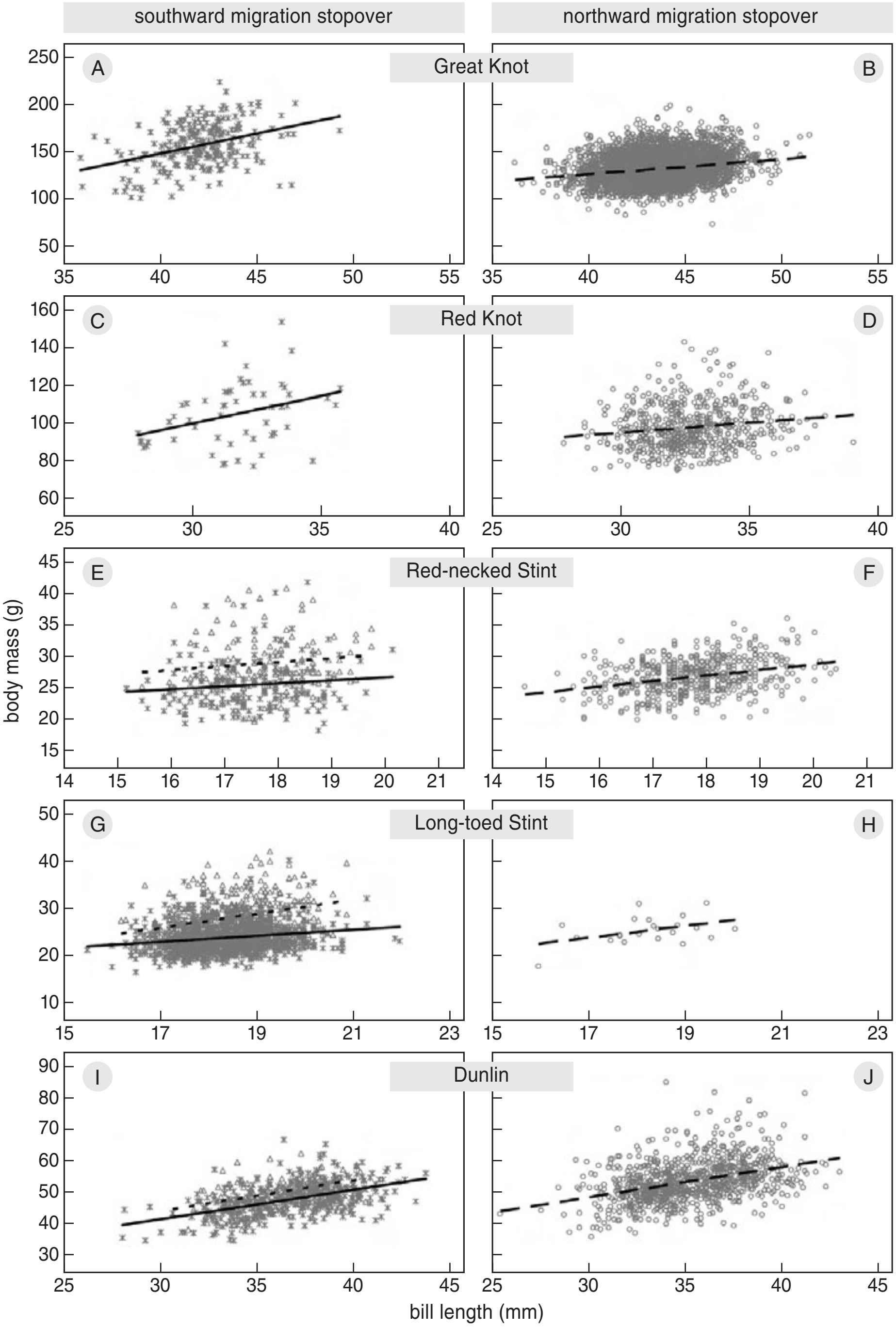

Figure 2. Body mass plotted against bill length during southward (left) and northward (right) migration stopover. The stars denote first-year birds during southward migration stopover; triangles denote adults during southward migration stopover; circles denote all individuals during northward migration stopover; solid lines denote the trend for first-year birds during southward migration stopover; dotted lines denote the trend for adults during southward migration stopover; long dashed lines denote the trend for all individuals during northward migration stopover.

migration significantly higher than on southward migration. Moreover, in species where both adults and first-year birds were present during southward migration (Red-necked Stints, Long-toed Stints and Dunlins), the CI of adults was always significantly higher than that of first-year birds (Table 1, Fig. 2).

When comparing the CI of the earliest and latest 20 captured Great Knots on southward and northward migration, significantly higher values occurred during southward migration (Table 2). Other species showed similar patterns. However, the CI of the latest 20 captured Red-necked Stints did not differ significantly among seasons and age-classes. In addition, the CI of the latest 20 captured adult and first-year Long-toed Stints did not differ significantly during southward migration. There were no significant differences in CI between first-year and adult Dunlins on southward migration. In both the earliest and latest 20 individuals adults on northward migration had a higher CI than birds on southward migration (Table 2).

Fuel deposition rates

Linear regression of CI on capture date of adults during southward migration showed that there was no significant change in CI in Great Knots, Red Knots and Red-necked Stints, a decrease in Long-toed Stints, and an increase in Dunlins (Table 3). First-year birds of all species showed a significant increase in CI during southward

Table 2. Comparison of the Condition Index CI of the earliest 20 and latest 20 captured sandpipers between seasons and age-classes (data from 2003–2007). Categories with a total sample size of fewer than 60 were excluded. Different superscript letters indicate significant differences among classes (Tukey HSD multiple comparison tests, $P < 0.05$). Given are means ± SD. S: southward migration, N: northward migration.

Species	Season/age-classes	Earliest 20 individuals			Latest 20 individuals		
		CI	*F*	*P*	CI	*F*	*P*
Great Knot	First-year birds (S)	339 ± 33.0	11.4	0.002	377 ± 59.5	9.69	0.004
	Adults (N)	307 ± 27.7			324 ± 46.3		
Red-necked Stint	First-year birds (S)	143 ± 20.7^{a}	5.29	0.008	160 ± 29.2	0.032	0.968
	Adults (S)	164 ± 26.9^{b}			158 ± 31.7		
	Adults (N)	153 ± 9.2^{a,b}			158 ± 12.8		
Long-toed Stint	First-year birds (S)	129 ± 11.8^{a}	69.5	<0.001	134 ± 24.1	3.22	0.081
	Adults (S)	177 ± 22.9^{b}			148 ± 24.0		
Dunlin	First-year birds (S)	126 ± 11.8^{a}	18.7	<0.001	133 ± 10.1^{a}	65.8	<0.001
	Adults (S)	130 ± 12.3^{a}			141 ± 10.7^{a}		
	Adults (N)	148 ± 12.9^{b}			189 ± 25.3^{b}		

Table 3. Summary of linear regressions of Condition Index (Y) with date (X, 1 = 1 January). Equations are $Y = m \times X + c$. S: southward migration, N: northward migration.

Species	Season/age	*n*	*m*	*c*	R^2	*F*	*P*
Great Knot	First-year birds (S)	240	1.36	12.2	0.13	36.3	<0.001
	Adults (N)	4856	0.324	270	0.01	31.8	<0.001
Red Knot	First-year birds (S)	53	1.67	–91.2	0.09	5.54	0.027
	Adults (N)	579	0.428	254	0.03	17.7	<0.001
Red-necked Stint	First-year birds (S)	222	0.517	13.9	0.07	16.6	<0.001
	Adults (S)	119	–0.134	190	0.01	0.32	0.577
	Adults (N)	544	–0.014	151	0.01	0.06	0.815
Long-toed Stint	First-year birds (S)	1308	0.111	106.7	0.01	7.09	0.008
	Adults (S)	279	–0.533	270	0.03	8.25	0.004
	Adults (N)	22	0.694	52.7	0.06	1.26	0.275
Dunlin	First-year birds (S)	456	0.332	41.5	0.10	52.1	<0.001
	Adults (S)	73	0.276	64.8	0.12	9.58	0.003
	Adults (N)	917	0.214	134	0.04	35.2	<0.001

migration. During northward migration, adult Great Knots, Red Knots and Dunlins showed a significant increase in CI, while changes were non-significant in Red-necked Stints and Long-toed Stints (Table 3).

DISCUSSION

Our study provided evidence that body condition and fuel deposition patterns vary between the migration seasons and between age-classes. Moreover, we showed that Great Knot and Red Knot, which undertake a nonstop trans-oceanic flight, attained significantly higher body condition at CMDT during their southward than northward migration. These species also increased most in body condition after a long-distance flight from Australia during northward migration. In contrast, Red-necked Stints and Long-toed Stints, which undertake a series of relatively short-distance flights, showed neither a difference in departure body condition between seasons, nor – at least in adults – a significant increase in body condition during stopover at CMDT. Moreover, first-year birds of species of which both age-classes were present at CMDT in autumn, showed a significant increase in body condition, but not the adults, with Dunlin as an exception. This study confirms that the body condition and fuel deposition patterns of shorebird species undertaking long-distance nonstop flights are different from those undertaking a series of short-distance flights.

Body condition

Previous studies concluded that most Great Knots and Red Knots make a long-distance direct flight between Australian wintering grounds and mainland China stopover areas, but may make short distance hops when moving along the stopover sites between southern and northern Yellow Sea region (Tulp *et al.* 1994, Barter *et al.* 1997, Battley *et al.* 2000, Battley 2002, Battley *et al.* 2005). Wilson & Barter (1998) have speculated that the northern Yellow Sea region may be a final staging area for Great Knots before reaching their breeding grounds. Such speculation is further supported by the records of CMDT-flagged Great Knots and Red Knots in Bohai Bay (Fig. 1) within a month after being ringed at CMDT (X. Hui, pers. comm.). In this study, the low body condition of Great Knots and Red Knots at arrival at CMDT on northward migration is the likely result of depleted energy stores after a long flight. When going south, the preparation for the same long-distance flight is a plausible explanation for their high body condition at CMDT. The lower fuel loads for northward migration may be explained by relatively short travel bouts ahead.

Although the overall body conditions of adult Red-necked Stints and Long-toed Stints were significantly higher in southward than northward migration stopover, neither species showed significant differences in body condition prior to departure between different seasons and age-classes, suggesting that they might fly for similar distances in both seasons after leaving CMDT. These observations are consistent with recoveries of ringed Red-necked Stint (Tulp *et al.* 1994) and records of Long-toed Stints in large flocks in northern and southern Yellow Sea regions and also in southeast Asia (Bamford *et al.* 2008), which suggest that they take a relatively short distance flight after leaving CMDT on southward and northward migration. Moreover, we found that part of the adult Long-toed Stints were in active primary moult (C. Choi, unpubl. data), which is an energy-consuming process, possibly resulting in the observed decrease in body condition over time.

Our results indicated that the body condition of Dunlins during northward migration was significantly higher than during southward migration, irrespective of the overall, arrival or departure body condition. Recent study indicated that large numbers of Dunlins overwinter in southeast China including CMDT (Barter *et al.* 2006). Thus the Dunlins captured at CMDT during southward migration were either winterers at CMDT or close to their wintering grounds in southeast China. Individuals at wintering grounds generally carry low levels of fat (Winker 1995), which may give them better manoeuvrability when escaping from predators (Zwarts *et al.* 1990, Swanson *et al.* 1999). Dunlins at CMDT were in higher body condition during northward than southward migration. On northward migration, energy is needed for migratory flight and is acting as extra reserves enabling the birds to face poor weather conditions in the north (O'Reilly & Wingfield 1995).

On southward migration, most of the captured Great Knots and Red Knots were first-year birds. This indicates a differential use of stopover sites and different migration strategies used by different age-classes. The few records of adult Great Knots support Battley's speculation (2002) that adults may fly directly from the Sea of Okhotsk to Australia, without stopping in east and southeast Asia. This indicates that migration strategies can vary between age-classes.

Fuel deposition patterns

Our results indicated that fuel deposition patterns varied among species and age-classes during migration stopovers. During southward migration, first-year Red-necked Stints and Long-toed Stints had low body condition on their initial arrival at CMDT, and exhibited a significant increase of body condition during stopover. Contrarily, the initial arriving adults had high body condition, and showed no significant increase in body condition during stopover. We suspect that the adults had deposited large amounts of energy in the north Yellow Sea region before arriving at CMDT and they may also be effective fliers spending relatively less amount of energy during migration flight than first-year birds, which are inexperienced on migratory flights and more energetically constrained than adults (Rimmer & McFarland 2000). A similar difference in deposition of body stores among age classes was reported in Red Knots at Ottenby in Sweden (Helseth *et al.* 2005). First-year Great Knots and Red Knots showed a significant increase in body condition at CMDT during southward migration stopover as well. This suggests that CMDT is an important stopover site for first-year birds. The significant increase in body condition in both adult and first-year Dunlins on southward migration may act as an insurance against food shortages after arriving at the wintering grounds (Johnson 1985).

On northward migration stopover, Great Knots and Red Knots showed a significant increase in body condition at CMDT, which can be a response to heavy fuel loss during the trans-oceanic flight from Australia. No significant change in body condition was found in Red-necked Stints and Long-toed Stints at CMDT. These birds are likely to take a short-distance flight before arriving and after departing CMDT, which does not necessitate as much replenishment as in migrants using long-distance nonstop flights (Piersma 1987). The increase in body condition of Dunlins at CMDT on northward migration is likely to be a preparation for migratory flight because they overwinter at CMDT and in the surrounding regions.

Conservation implications

Identification of important staging sites for shorebirds according to their numerical distribution (Bamford *et al.* 2008) is the first step for making pertinent management decisions. Once these areas are known, it is important to assess their importance based on their function as topping-up or moulting site. At CMDT, first-year birds of the five calidrid species showed significant increases in body condition during southward migration. This suggests that CMDT is especially important for the energy deposition of first-year birds during southward migration, although the number of shorebirds is much lower during southward than northward migration stopover (Ma *et al.* 2002).

Our results provide insight into the importance of stopover sites further north of CMDT. The relatively low departure body condition of Great Knots and Red Knots during their stopover on northward migration do not seem to be adequate for another long-distance flight. Thus, they must continue to refuel outside CMDT before arriving at the breeding grounds. Adult Red-necked Stints and Long-toed Stints, which stopover at CMDT during southward migration, exhibited no significant changes in body stores which suggests that they may have gained enough energy at stopover sites further to the north before arriving at CMDT. Additional studies are needed in the Yellow Sea region to understand how different stopover sites are used by the various sandpiper species. Management efforts for shorebird conservation thus need to have a regional perspective along the East Asian–Australasian Flyway.

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SAMENVATTING

In China pleisteren grote aantallen steltlopers die tussen het broedgebied in Noordoost-Azië en Alaska en het overwinteringsgebied in Oost-Azië en Australië trekken. Over de precieze betekenis van de Chinese pleisterplaatsen binnen de jaarcyclus van steltlopers is nog betrekkelijk weinig bekend. Het onderhavige onderzoek, uitgevoerd in Chongming Dongtan, een belangrijk wetland aan de oostkust van China, spitste zich toe op een vergelijking van lichaamsconditie en snelheid van aanleg van lichaamsreserves tussen een vijftal steltlopersoorten. Twee soorten, de Grote Kanoet *Calidris tenuirostris* en Kanoet *C. canutus*, zijn langeafstandstrekkers die tussen Chongming Dongtan en Australië een afstand overbruggen van ruim 5000 km. De andere drie soorten leggen minder grote afstanden af en overwinteren in de regio, te weten de Roodkeelstrandloper *C. ruficollis*, Taigastrandloper *C. subminuta* en de Bonte Strandloper *C. alpina*. De waargenomen verschillen tussen de soorten in lichaamsconditie en snelheid waarmee reserves werden aangelegd in Chongming Dongtan, kwamen overeen met de verwachting: langeafstandstrekkers leggen meer reserves aan dan vogels die slechts een korte afstand afleggen. Omdat de Bonte Strandloper in het voorjaar meer reserves aanlegt dan in het najaar, wordt verondersteld dat de voorjaarstrek begint met een forse sprong over de Gele Zee richting het broedgebied. (JS)

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Appendix 1. Comparison of calidrid sandpipers' morphology between seasons (data from 2003–2007). Superscript letters show results from *F*-tests or Tukey HSD multiple comparison tests ($P < 0.05$). Different letters indicate significant differences between season/age-classes ($P < 0.05$). Given are means ± SD, and sample sizes in parentheses. S: southward migration, N: northward migration.

Species	Season/age	Body mass (g)	Wing length (mm)	Bill length (mm)	Tarsus (mm)
Great Knot	First-year birds (S)	155 ± 22.8^{a} (241)	183 ± 4.9^{a} (241)	42.1 ± 2.0^{a} (240)	36.3 ± 1.3^{a} (241)
	Adults (N)	132 ± 13.7^{b} (5946)	190 ± 5.3^{b} (4926)	43.6 ± 1.9^{b} (4881)	37.7 ± 2.3^{b} (3369)
Red Knot	First-year birds (S)	105 ± 16.8^{a} (55)	161 ± 3.9^{a} (54)	31.7 ± 2.0^{a} (54)	31.7 ± 1.4^{a} (55)
	Adults (N)	98.8 ± 11.4^{b} (581)	168 ± 5.0^{b} (579)	32.7 ± 1.8^{b} (580)	32.6 ± 1.9^{b} (509)
Red-necked Stint	First-year birds (S)	25.3 ± 3.9^{a} (224)	102 ± 3.0^{a} (222)	17.5 ± 0.9^{a} (223)	20.2 ± 0.9 (224)
	Adults (S)	28.6 ± 4.4^{b} (119)	103 ± 2.6^{b} (115)	17.8 ± 0.9^{b} (119)	20.0 ± 0.8 (118)
	Adults (N)	26.5 ± 2.8^{c} (546)	104 ± 2.9^{c} (544)	17.7 ± 1.0^{b} (548)	20.1 ± 0.8 (512)
Long-toed Stint	First-year birds (S)	24.1 ± 2.9^{a} (1312)	94.5 ± 2.4^{a} (1314)	18.4 ± 0.9^{a} (1312)	22.7 ± 1.0 (1312)
	Adults (S)	28.3 ± 4.6^{b} (280)	93.9 ± 2.6^{b} (258)	18.5 ± 0.9^{b} (282)	22.7 ± 0.8 (282)
	Adults (N)	25.6 ± 2.9^{a} (22)	95.2 ± 3.6^{a} (23)	18.4 ± 1.1^{a,b} (23)	22.8 ± 0.9 (23)
Dunlin	First-year birds (S)	47.6 ± 4.9^{a} (457)	123 ± 3.2^{b} (460)	36.7 ± 2.7^{b} (452)	27.3 ± 1.1^{b} (458)
	Adults (S)	49.1 ± 5.7^{a} (73)	122 ± 3.2^{a} (73)	35.5 ± 2.6^{a} (74)	26.8 ± 0.9^{a} (73)
	Adults (N)	53.8 ± 6.4^{b} (983)	122 ± 3.8^{a} (924)	35.2 ± 2.6^{a} (932)	26.9 ± 1.3^{a} (776)

Appendix 2. Results of linear regressions for five calidrid species of bill and tarsus length with wing length during northward migration (southward migration for Dunlins).

Species	Bill length				Tarsus length			
	n	*R*	*F*	*P*	*n*	*R*	*F*	*P*
Great Knot	4854	0.244	308	<0.001	3351	0.102	35.2	<0.001
Red Knot	579	0.352	81.6	<0.001	508	0.245	32.4	<0.001
Red-necked Stint	542	0.305	55. 6	<0.001	506	0.228	27.5	<0.001
Long-toed Stint	23	0.584	10.9	0.003	23	0.297	2.03	0.169
Dunlin	73	0.403	13.8	<0.001	72	0.345	9.45	0.003

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