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Supplementary material

Appendix 1. Calculation of *overall* migration speed

We defined *overall* migration speed as

$$\frac{total\ migration\ distance}{migration\ duration + pre-migratory\ staging\ duration}.$$

Total migration distance and migration duration were estimated from individual tracks as outlined in the main text. In this appendix, we focused on the estimation of pre-migratory staging duration to calculate *overall* migration speed. Pre-migratory staging duration for Red Knot was obtained from the literature (Battley 1999). For all other species, a species-specific pre-migratory staging duration was estimated using segment regression of body masses of birds captured at their respective non-breeding (i.e. wintering) grounds against time (i.e. date number; Supplementary material Appendix 1, Fig. A1). For Sanderling, Turnstone, Great Knot and Far Eastern Curlew body masses were collected by the Victorian Wader Study Group and Australasian Wader Studies Group, Grey-tailed Tattler by the Queensland Wader Study Group and Bar-tailed Godwit by P. Battley *et al.* (unpublished pers. comm.).

During most of the wintering season, body mass is maintained at a "baseline" level (Cadée et al. 1996, Piersma 2002, Piersma et al. 2008). For this period, regressing body mass against time thus results in a regression slope of, or close to, zero. During the subsequent pre-migratory staging period, shorebirds deposit body stores for migration, resulting in a positive slope of body mass against time. For each species, by plotting body mass data against time these two different regression slopes and the associated turning point marking the start of the pre-migratory staging period, were estimated using segment regression, using the 'segmented' function in the R-package 'segmented' (Supplementary material Appendix 1, Fig. A1). Throughout the analysis, date number was used with the 1st January equating to 0, defining days post 1st January until 1st of July as positive, days starting from

the 1st of July and prior to 1st January as negative. Heavy individuals may depart earlier, resulting into a stable or even in a decline of body mass with date over the migration season. To avoid the potential interference of this period, we excluded data after the first departure date shown by the tracked individuals.

We define the end of pre-migratory staging as the departure date from the birds' wintering grounds. Since the start of the pre-migratory staging was estimated at population rather than the individual level we used the median departure date of tracked individuals to represent the end of the pre-migratory staging period. Accordingly, the duration of the pre-migratory staging was calculated as the number of days elapsed between the start and the end of the pre-migratory staging period.

Body mass data for Grey-tailed Tattler was limited and thus estimation of a turning point for this species problematic. The first body mass data was recorded on date number 43, with an average body mass of 106 g, and thus very close to the species' estimated lean body mass of 108 g (Johnsgard 1981). Given that body mass at date number 43 was close to lean body mass and the fact that body mass showed a gradual increase from that date onwards, we used date number 43 as the species' turning point. For all species the estimated start and end date and duration of pre-migratory fuelling are presented in Table A1.

Table A1. Estimation of start date (date number; date 0 = 1st January, defining days post 1st January until 1st of July as positive, days starting from the 1st of July and prior to 1st January as negative), end date and duration of pre-migratory staging for seven sandpiper species migrating northward along the East Asian-Australasian Flyway towards their breeding grounds. Species are ranked in the increasing order of lean body mass. For Grey-tailed Tattler no start date and therefore no duration of the pre-migratory season could be calculated.

Species	Start date	End date	Duration	n	Data source
Sanderling	89	122.5	33.5	4255	Victorian Wader Study Group
Ruddy Turnstone	62	109	47	4921	Victorian Wader Study Group
Grey-tailed Tattler	43	124	81	100	Queensland Wader Study Group
Red Knot			55		Battley (1999)
Great Knot	-8	90	98	7761	Australasian Wader Studies Group
Bar-tailed Godwit	1	80	79	780	P. Battley *et al.* unpublished
Far Eastern Curlew	-13	69	82	653	Victorian Wader Study Group

As discussed in Zwarts et al. (1990) the use of segmented regression to estimate pre-migratory staging duration has its limitations. In our case the main drawback is that we acquired estimates at the species/population level ignoring variations between individuals and thus compromising statistical power.
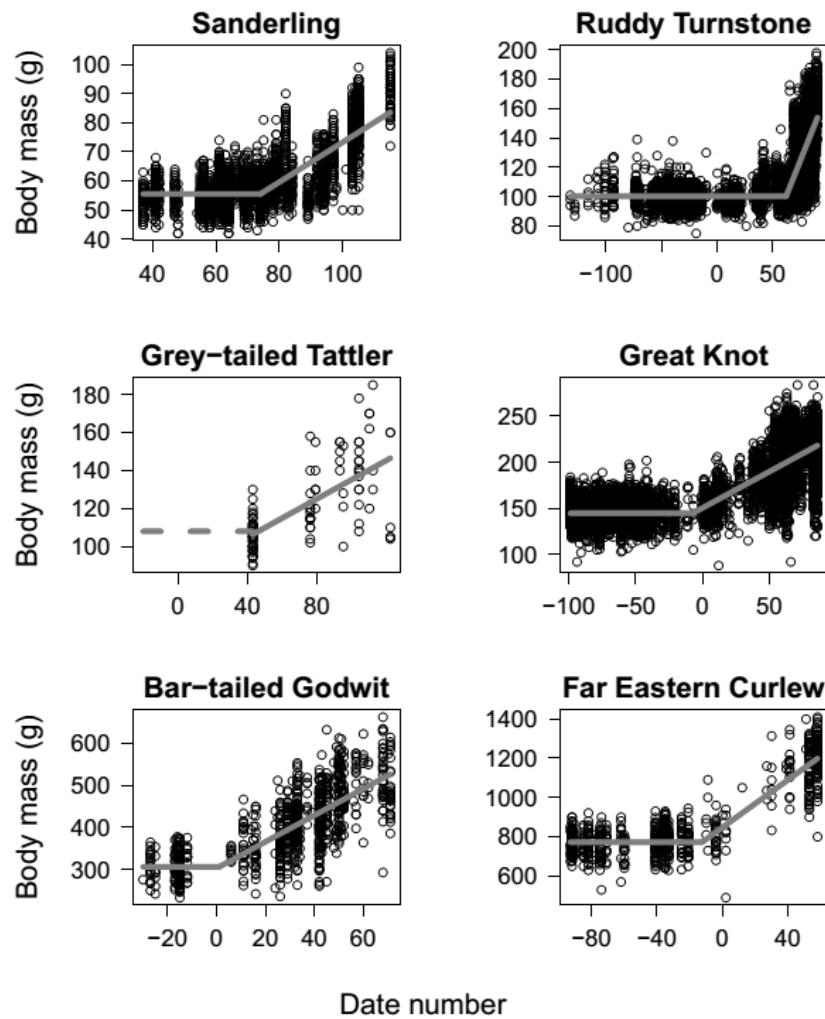
Fig. A1. Body mass as a function of time (i.e. date number; with the 1st January equating to 0, defining days post 1st January until 1st of July as positive, days starting from the 1st of July and prior to 1st January as negative) for five shorebird species. Thick solid lines represent piecewise regressions. No turning point could be determined for Grey-tailed Tattler, dotted line representing lean body mass, which intersects with the slope of body mass with time since date number 43, where the first date number body mass data is available.

Reference

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PIERSMA, T., BRUGGE, M., SPAANS, B. and BATTLEY, P. F. 2008. Endogenous circannual rhythmicity in body mass, molt, and plumage of Great Knots (Calidris tenuirostris). -*Auk,* **125**: 140-148.

ZWARTS, L., ENS, B. J., KERSTEN, M. and PIERSMA, T. 1990. Moult, mass and flight range of waders ready to take off for long-distance migrations. -*Ardea,* **78**: 339-364.

Appendix 2

Table A2. Original data for all seven investigated migration variables for each individual across seven sandpiper species migrating northward

along the East Asian-Australasian Flyway towards their breeding grounds.

Species	Migration speed (km/d)			Total staging duration (d)	Total migration duration (d)	Migration distance (km)	Average step length (km)	Departure date (1st January = 0)	Arrival date (1st January = 0)
	Traditional	*Partial*	*Overall*						
Sanderling	295	213	174	68	82	14170	2834	118	166
Sanderling	349	258	192	60	74	14290	3573	120	161
Sanderling	405	236	207	56	68	14174	3543	123	158
Sanderling	328	195	178	63	74	13108	3277	122	162
Sanderling	364	213	196	60	72	14205	3551	123	162
Sanderling	312	226	179	61	78	14021	2804	126	171
Sanderling	327	207	176	58	72	12768	4256	130	169
Sanderling	370	273	199	58	72	14432	3608	127	166
Sanderling	293	148	165	64	76	12592	4197	116	159
Sanderling	317	178	180	60	78	13960	3490	122	166
Sanderling	359	210	193	59	72	14008	3502	120	159
Sanderling	374	252	199	57	72	14193	3548	123	161
Ruddy Turnstone	330	172	152	70	87	13214	4405	116	156
Ruddy Turnstone	331	136	141	75	82	11598	3866	122	157
Ruddy Turnstone	307	185	143	78	88	12581	3145	109	150
Ruddy Turnstone	259	245	141	82	103	14517	2903	118	174
Ruddy Turnstone	285	154	139	78	92	12834	4278	109	154
Ruddy Turnstone	284	203	142	83	94	13328	2221	113	160
Ruddy Turnstone	290	213	143	80	93	13345	3336	113	159
Ruddy Turnstone	372	215	159	66	82	13035	4345	118	153
Ruddy Turnstone	242	112	131	90	102	13316	4439	98	153
Ruddy Turnstone	283	144	141	86	94	13281	4427	99	146
Ruddy Turnstone	273	139	141	85	97	13646	4549	102	152
Ruddy Turnstone	331	165	150	71	86	12894	6447	113	152
Ruddy Turnstone	331	171	154	72	88	13567	6783	116	157
Ruddy Turnstone	361	217	159	68	84	13355	4452	113	150
Ruddy Turnstone	372	211	166	70	85	14143	4714	114	152
Ruddy Turnstone	266	130	137	82	97	13302	4434	105	155
Ruddy Turnstone	289	101	131	81	86	11262	3754	106	145

Ruddy Turnstone	365	143	158	74	83	13135	6568	114	150
Ruddy Turnstone	322	169	150	78	88	13191	6596	107	148
Ruddy Turnstone	405	229	167	68	80	13370	3342	116	149
Ruddy Turnstone	375	240	160	72	82	13131	3283	112	147
Ruddy Turnstone	355	184	157	74	84	13151	6576	115	152
Ruddy Turnstone	312	174	145	76	88	12781	4260	106	147
Ruddy Turnstone	398	287	170	66	82	13920	3480	117	152
Ruddy Turnstone	299	147	144	81	91	13138	4379	104	148
Ruddy Turnstone	381	214	165	72	83	13721	4574	116	152
Ruddy Turnstone	364	242	155	68	82	12745	3186	115	150
Ruddy Turnstone	396	213	163	70	80	13056	4352	112	145
Ruddy Turnstone	330	174	150	76	86	12873	4291	107	146
Ruddy Turnstone	418	238	166	70	78	12956	4319	116	147
Ruddy Turnstone	313	149	148	79	89	13141	4380	102	144
Ruddy Turnstone	258	156	139	82	102	14209	4736	102	157
Ruddy Turnstone	264	121	135	84	96	12938	6469	103	152
Ruddy Turnstone	257	130	135	88	99	13387	4462	101	153
Ruddy Turnstone	260	128	134	88	97	13017	4339	96	146
Ruddy Turnstone	283	142	143	86	95	13580	4527	97	145
Ruddy Turnstone	375	198	163	70	83	13488	4496	110	146
Ruddy Turnstone	269	106	127	83	89	11285	3762	107	149
Ruddy Turnstone	263	154	135	83	97	13141	4380	99	149
Ruddy Turnstone	277	144	141	86	96	13564	4521	100	149
Ruddy Turnstone	253	124	134	90	100	13392	3348	99	152
Ruddy Turnstone	224	114	125	92	106	13239	4413	90	149
Ruddy Turnstone	256	256	136	86	100	13580	3395	100	153
Ruddy Turnstone	353	236	158	72	85	13427	4476	122	160
Ruddy Turnstone	275	165	140	85	96	13483	3371	100	149
Ruddy Turnstone	238	146	128	90	102	13087	2617	94	149
Ruddy Turnstone	304	163	147	82	91	13378	4459	109	153
Ruddy Turnstone	243	122	132	93	103	13584	2717	100	156
Ruddy Turnstone	329	199	151	70	87	13141	3285	111	151
Ruddy Turnstone	321	196	155	77	91	14120	4707	115	159
Ruddy Turnstone	287	151	142	83	93	13194	3299	102	148
Ruddy Turnstone	329	182	157	76	90	14160	4720	112	155
Ruddy Turnstone	281	145	142	80	95	13494	4498	106	154
Ruddy Turnstone	301	156	146	77	91	13266	4422	110	154
Ruddy Turnstone	378	210	161	70	82	13227	4409	114	149
Ruddy Turnstone	316	161	149	76	89	13269	4423	113	155
Ruddy Turnstone	259	121	136	88	99	13477	3369	105	157
Ruddy Turnstone	339	169	154	72	86	13228	4409	119	158

Ruddy Turnstone	284	136	142	82	94	13330	4443	108	155
Ruddy Turnstone	283	137	141	77	94	13280	4427	113	160
Ruddy Turnstone	329	250	153	78	88	13477	3369	114	155
Ruddy Turnstone	265	127	137	83	97	13256	6628	103	153
Ruddy Turnstone	318	229	154	74	91	13974	4658	118	162
Grey-tailed Tattler	333	214	101	103	116	11665	3888	123	158
Grey-tailed Tattler	329	140	95	97	114	10868	5434	124	157
Grey-tailed Tattler	373	170	98	100	110	10816	5408	127	156
Red Knot	254	91	130	102	113	14742	4914	87	145
Red Knot	183	179	96	108	115	10988	3663	82	142
Great Knot	341	247	80	116	128	10234	3411	110	140
Great Knot	191	147	64	144	148	9541	3180	88	138
Great Knot	184	144	65	142	151	9755	2439	90	143
Great Knot	171	128	63	146	155	9729	3243	86	143
Great Knot	213	155	69	133	145	10009	3336	94	141
Great Knot	339	196	73	117	125	9162	3054	149	176
Great Knot	177	138	63	150	153	9712	3237	86	141
Great Knot	180	136	63	140	151	9557	2389	90	143
Bar-tailed Godwit	321	131	134	109	128	15723	7861	82	131
Bar-tailed Godwit	257	102	121	123	140	15673	7837	72	133
Bar-tailed Godwit	301	118	130	117	131	15666	7833	80	132
Bar-tailed Godwit	295	112	129	117	132	15648	7824	89	142
Bar-tailed Godwit	283	110	126	119	134	15551	7775	86	141
Bar-tailed Godwit	285	127	128	125	135	15961	7980	89	145
Bar-tailed Godwit	241	93	118	119	145	15886	7943	86	152
Bar-tailed Godwit	230	83	115	120	148	15848	7924	85	154
Bar-tailed Godwit	289	157	128	110	134	15877	7938	72	127
Bar-tailed Godwit	309	128	132	112	130	15761	7880	80	131
Bar-tailed Godwit	284	115	126	115	134	15645	7822	77	132
Bar-tailed Godwit	297	117	129	116	138	15751	7875	77	130
Bar-tailed Godwit	262	122	122	113	138	15740	7870	71	131
Bar-tailed Godwit	261	124	122	115	139	15687	7843	72	132
Bar-tailed Godwit	280	102	126	118	135	15685	7842	77	133
Bar-tailed Godwit	326	107	134	120	127	15624	7812	85	133
Far Eastern Curlew	278	44	83	109	117	9744	4872	69	104
Far Eastern Curlew	304	38	83	105	113	9425	4713	71	102
Far Eastern Curlew	308	57	86	106	114	9852	4926	69	101
Far Eastern Curlew	273	32	83	111	118	9820	4910	63	99
Far Eastern Curlew	267	29	80	109	117	9334	4667	69	104
Far Eastern Curlew	340	65	89	103	111	9852	4926	63	92
Far Eastern Curlew	266	46	83	112	119	9852	4926	73	110

| Far Eastern Curlew | 244 | 47 | 79 | 114 | 121 | 9508 | 4754 | 63 | 102 |