Ecography

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Supplementary material

Appendix 1. Determination of the minimum stopover duration

Migration consists of a series of migratory flights interspersed with stopover periods. Evidence indicates that waterbirds make prolonged stopovers to rest and accumulate energy (by feeding). For example, the relationship between flying and stopover times is typically 1:7 for small passerines and between 1:14 and 1:30 for larger species that travel by flapping flight, such as waterbirds (the ratio for swans can reach 1:43) (Hedenström and Alerstam 1997; Newton 2008). Therefore it may be expected that waterbirds spend at least 93% (1/14) of the total time of migration in stopovers.

Stopover duration cannot be directly estimated from ringing data, because the date of departure (from the ringing site) and the date of arrival at the recovery site are not known. For instance, in a period of 10 days (between capture and recapture) a given bird might not move, make one displacement or make more than one displacement. However, if the minimum stopover duration (for a given population or species) is 10 days, then the bird has not moved, moved only at local scale, or made only one migratory displacement (long distance displacement of more than 100 Km) at some time in the 10-day period. Satellite telemetry is the only method capable of accurately measure stopover duration, as it allows to tracking single individuals at short time scales. Miller et al. (2005) reported minimum stopover durations (given by the lower 90% confidence interval) ranging from 5.3 to 7.2 days (average = 6.25 days) for individual pintails (*Anas acuta*) travelling indirectly to Canada, i.e. those individuals that stopped while *en route*. For direct migrants, minimum stopover durations ranged from 58 to 71 days. The ducks were tracked during spring migration, when birds tend to increase migration speed by minimising stopover duration, in order to reach breeding grounds as early as possible (e.g. Bauchinger and Klaassen 2005; Kokko 1999).

Therefore stopovers during fall migration might be longer than those reported for spring migration. A radar study (O'Neal et al. 2009) also measured stopover duration of migratory dabbling ducks, and, although measurements are not taken at the individual level, the radar is capable of identifying arriving and departing flocks accurately. They observed that the minimum stopover duration was 6 days, which is in agreement with the former study. In order to test whether migratory distance (i.e. distance of >100 Km movements) was correlated with time (days), we performed Spearman's correlation tests for a time interval between ringing and recovery of six days (the minimum stopover duration referred above). We expect that if marked individuals are doing several migratory movements within the six-day intervals, then cumulative migratory distance should be correlated with time (the number of days elapsed between ringing and recovery). Otherwise, if the movements recorded within the six-day intervals are single migratory movements, cumulative migratory distance should be unrelated to time. Because migratory distance was not correlated with time (Table A1), we concluded that waterbirds made a single movement bout within the six days.

The maximum distances recorded in such time interval could be covered by waterbirds within a single displacement. For example, the largest distance recorded (2302 Km, for *Anas crecca carolinensis*) could be covered in 31 hours of flight at an average speed of 74 Km/h (flight speed reported in Alerstam et al. 2007) – a flight time well within the physiological limit of this species (49-63 hours maximum flight time; Clausen et al. 2002). Furthermore, recent satellite data on migratory movement showed that dabbling ducks make single movements of up to 2000 Km in a time interval of four days and occasionally up to 3000 Km (Gaidet et al. 2010).

In summary, the probability of including only a single migratory displacement using the chosen stopover threshold (6 days) is very high. Therefore all analyses were based on ringing records that spanned up to six days until recovery.

Table A1. Spearman's correlation tests between cumulative migratory distance and time, for a maximum period of 6 days (corresponding to the minimum stopover duration chosen for all subsequent analysis).

Region	Species	Stopover duration	Correlation test (rho)	p-value
Europe	*Anas crecca*	6	0.0229	0.8193
	Anas platyrhynchos	6	-0.0157	0.9085
North America	*Anas crecca*	6	-0.0253	0.8942
	Anas platyrhynchos	6	0.0687	0.3174

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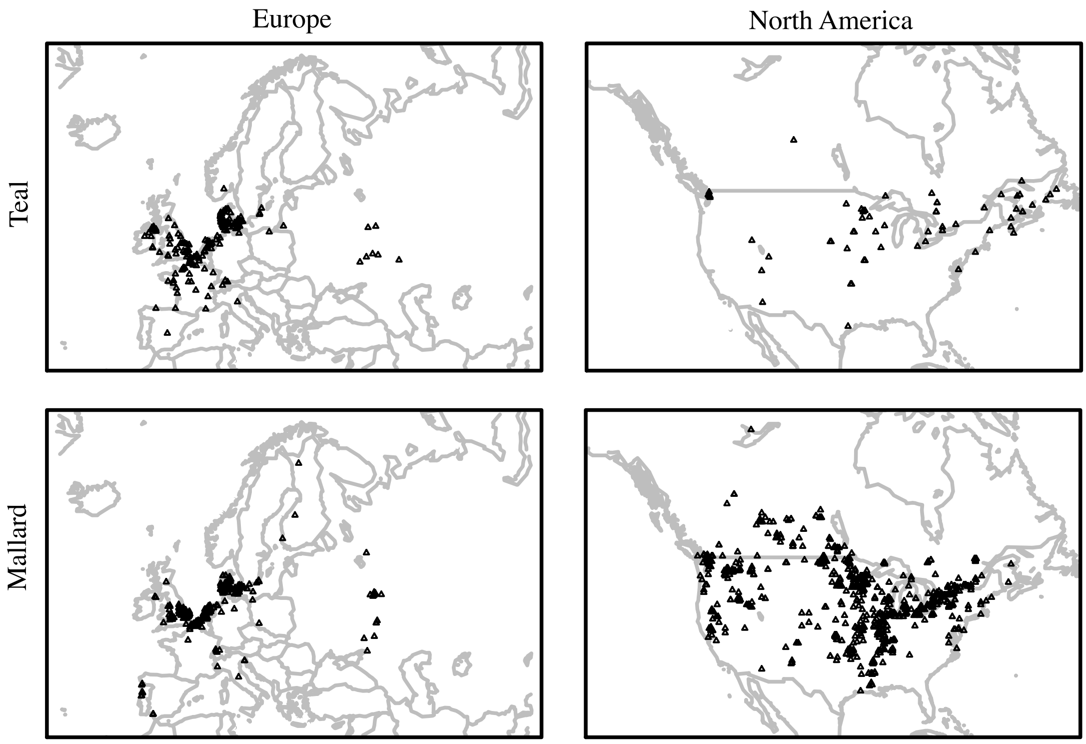
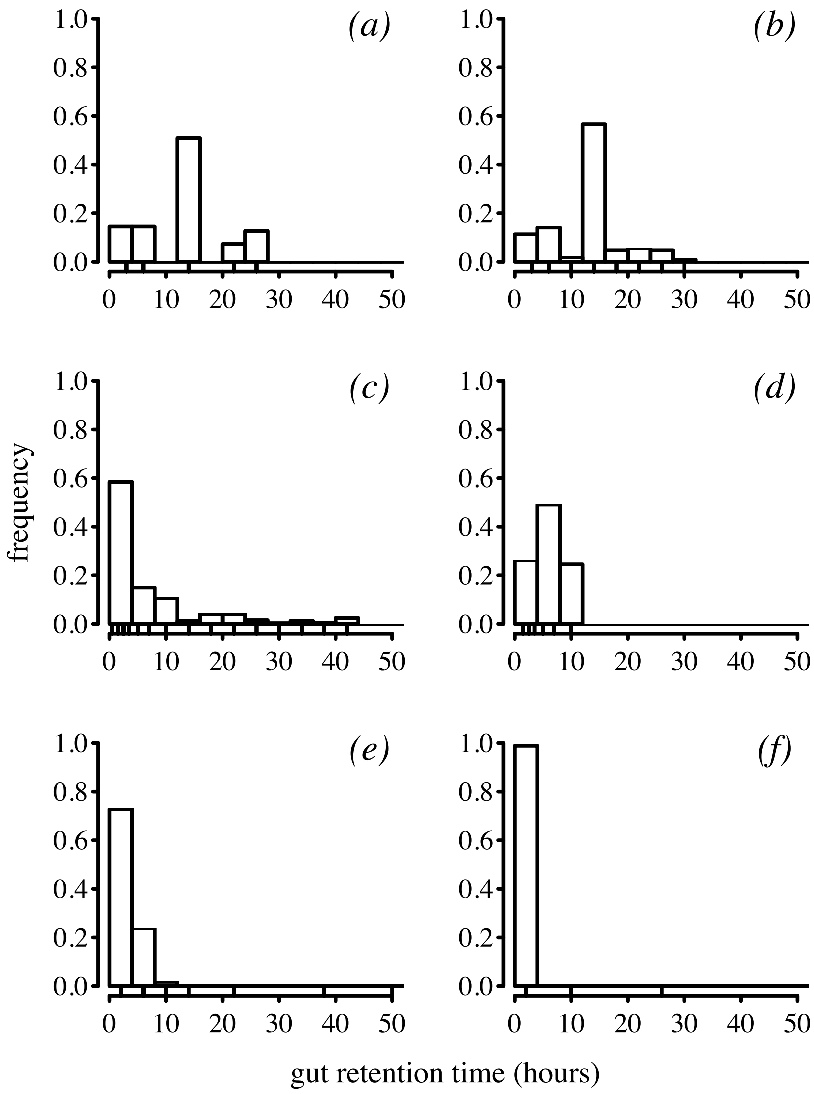
Appendix 2. Geographical distribution of ring recoveries

Figure A1. Maps showing the distribution of ring recoveries (triangles) of teal and mallard in Europe and North America.



Appendix 3. Distribution of gut retention times

Figure A2. Frequency distribution of gut retention times for the various propagule species, *Scirpus litoralis* (a), *Scirpus maritimus* (*b*, *d*), *Scirpus lacustris* (*c*), *Potamogeton pectinatus* (*e*) and *Artemia franciscana* (*f*), ingested by teals (*a*, *b*) and mallards (*c*-*f*).



Appendix 4. Quantification of different components of the dispersal curves

Table A2. Summary of different components of the dispersal curves (dispersal distances): frequency of realized dispersal (FRD), median (Km), mean (Km), average maximum (Km), absolute maximum (Km) and frequency of LDD (relative to successful dispersal events).

Continent	**Vector**	**Propagule**	**N**	**FRD**	**Median**	**Mean**	**Max. (avg)**	**Max. (abs.)**	**LDD**
Europe	Teal	*Scirpus litoralis*	3	0.95	33	107	946	1086	0.26
		Scirpus maritimus	3	0.94	31	103	947	1086	0.25
	Mallard	*Scirpus lacustris*	6	0.95	21	39	867	1582	0.08
		Scirpus maritimus	4	0.97	22	40	484	664	0.09
		Potamogeton pectinatus	12	0.95	22	36	501	1582	0.08
		Artemia franciscana	8	0.94	21	32	226	658	0.06
North America	Teal	*Scirpus litoralis*	3	0.86	64	177	1028	1313	0.36
		Scirpus maritimus	3	0.86	48	171	1209	1313	0.36
	Mallard	*Scirpus lacustris*	6	0.89	30	64	1026	1273	0.14
		Scirpus maritimus	4	0.90	28	57	492	719	0.13
		Potamogeton pectinatus	12	0.86	27	47	567	1214	0.09
		Artemia franciscana	8	0.84	25	40	230	640	0.07

Appendix 5. Results of the multiple comparisons for different components of the dispersal curves

Table A3. Multiple comparisons of maximum (upper diagonal) and mean (lower diagonal) dispersal distances of propagules dispersed by mallards.

		Europe				North America			
	Species	*S. lac.*	*S. mar.*	*P. pec.*	*A. franc.*	*S. lac.*	*S. mar.*	*P. pec.*	*A. franc.*
Europe	*S. lac.*	-	0.2860	0.1935	**0.0030**	1.0000			
	S. mar.	0.6600	-	0.9490	0.1325		1.0000		
	P. pec.	0.4050	0.4050	-	0.1600			1.0000	
	A. franc.	**0.0060**	**0.0200**	0.0780	-				1.0000
North America	*S. lac.*	**0.0080**				-	0.0675	0.0675	**0.0000**
	S. mar.		0.2595			0.2780	-	0.7400	0.0675
	P. pec.			**0.0000**		**0.0000**	0.1250	-	0.0675
	A. franc.				**0.0025**	**0.0050**	**0.0050**	0.0510	-

Note. Comparisons are made among propagules within a given continent and between continents for the same propagule. Values correspond to p-values of the permutation tests with a progressive Bonferroni correction. Black cells mean that comparisons were not made.

Table A4. Multiple comparisons of median dispersal distance (upper diagonal) and frequency of LDD (lower diagonal) of propagules dispersed by mallards.

		Europe				North America			
	Species	*S. lac.*	*S. mar.*	*P. pec.*	*A. franc.*	*S. lac.*	*S. mar.*	*P. pec.*	*A. franc.*
Europe	*S. lac.*	-	1.0000	1.0000	1.0000	0.0100			
	S. mar.	0.9400	-	1.0000	0.4620		0.0645		
	P. pec.	0.9400	0.7800	-	0.7600			**0.0000**	
	A. franc.	0.0570	0.1050	0.1380	-				**0.0025**
North America	*S. lac.*	**0.0090**				-	0.6860	0.1575	**0.0030**
	S. mar.		0.5200			0.6880	-	0.6860	0.1575
	P. pec.			0.5200		**0.0180**	0.1125	-	0.2445
	A. franc.				0.7260	**0.0000**	0.0075	0.1125	-

Note. Comparisons are made among propagules within a given continent and between continents for the same propagule. Values correspond to p-values of the permutation tests with a progressive Bonferroni correction. Black cells mean that comparisons were not made.

Table A5. Multiple comparisons of maximum (upper diagonal) and mean (lower diagonal) dispersal distances of propagules dispersed by teals.

		Europe		North America	
	Species	*S. litoralis*	*S. maritimus*	*S. litoralis*	*S. maritimus*
Europe	*S. litoralis*	-	1.0000	1.0000	(not compared)
	S. maritimus	0.8120	-	(not compared)	1.0000
North America	*S. litoralis*	0.3940	(not compared)	-	0.7800
	S. maritimus	(not compared)	0.3940	0.8960	-

Note. Comparisons are made among propagules within a given continent and between continents for the same propagule. Values correspond to p-values of the permutation tests with a progressive Bonferroni correction. Black cells mean that comparisons were not made.

Table A6. Multiple comparisons of median dispersal distance (upper diagonal) and frequency of LDD (lower diagonal) of propagules dispersed by teals.

		Europe		North America	
	Species	*S. litoralis*	*S. maritimus*	*S.litoralis*	*S.maritimus*
Europe	*S. litoralis*	-	0.4000	0.3950	(not compared)
	S. maritimus	0.5820	-	(not compared)	0.3880
North America	*S.litoralis*	0.5760	(not compared)	-	0.5920
	S.maritimus	(not compared)	0.5200	0.904	-

Note. Comparisons are made among propagules within a given continent and between continents for the same propagule. Values correspond to p-values of the permutation tests with a progressive Bonferroni correction. Black cells mean that comparisons were not made.

Table A7. Comparison between the dispersal potential of teal and mallard.

	Europe	North America
Maximum	**0.035**	**0.028**
Mean	**0.0245**	**0.034**
Median	**0.0285**	**0.034**
LDD	**0.0185**	**0.028**

Note. Comparisons made with the dispersal curves of *S. maritimus* (the only species dispersed by both vectors. Values correspond to p-values of the permutation tests with a progressive Bonferroni correction.

Appendix 6. Estimated dispersal curves

Figure A3. Dispersal curves of propagules of different species produced by two vector waterbird species (teal and mallard) in Europe and North America. Probability density follows a logarithmic scale to enhance visualization. Insets show cumulative frequency curves corresponding to realized (same data shown in the main plots; solid lines) and maximum (based on average flight speeds of vector waterbirds; dashed lines) dispersal.