

Supplementary Material

Effects of geolocators on hatching success, return rates, breeding movements, and change in body mass in 16 species of Arctic-breeding shorebirds

Weiser et al.
Movement Ecology

Supplementary Methods

The main text provides a general overview of field methods for the authors' studies, with further details or differences described here as needed. Studies are listed in alphabetical order. Sites and species included from each study are listed; see Table 1 for details on species and Table S1 for details on sites.

Published return rates that were included in our analysis were from Lindström et al. [1] and Klaassen et al. [2] (site B22, GRSN), Niles et al. [3] and Burger et al. [4] (sites N07-N08, REKNruf), and Smith et al. [5] (site B21, RNPH).

Species codes used here are defined in Table 1 of the main text; sites are listed in Table S1 and mapped on main Figure 1.

Arctic Shorebird Demographics Network

Sites: B03, B04, B06-B08, B10-B16

Species: SESA, WESA, DUNLpac, DUNLarc, DUNLhud, RUTUmor, AMGP, WHIM

Field methods are detailed by Brown et al. [6].

Battley & Conklin

Site: N06

Species: REKNrog, BTGO

Field methods for this study have been previously published [7–9].

Coleman et al.

Site: N05

Species: GTTA

Birds were caught using mist and cannon nets between March and May, 2011 and between December 2012 and March 2013 for banding and geolocator attachment. Birds developing breeding plumage in those catches were selected for geolocator attachment. Twenty-one geolocators were attached in 2011 and a further 20 in 2012. Geolocators in the first batch were MK10 Bastrak units, supplied by the British Antarctic Survey, with the later batch of Intigeo W65A9RJ devices supplied by Migrate Technology Ltd. Units weighed 1.1 grams and were attached to yellow leg flags using monofilament line and also glued to the flag using a solvent cement. The geolocators were then activated and left in an elevated open space for one week to allow accurate placement and identify any need for recalibration of location data on later

download. The exact date and time of activation for each device was also recorded as a baseline time stamp for the data collected.

All birds caught received a metal bird band issued by the Australian Bird and Bat Banding Society which was placed on the left tarsus along with a green engraved leg flag placed on the right tibia. Those birds selected for geolocator attachment also received a yellow leg flag with the geolocator attached which was placed on the left tibia. Returning birds were caught using cannon nets and the flag with geolocator removed in the field. The metal band and green engraved flag was left on the bird to allow further observations of the individual.

GeoSpoi

Site: B19

Species: WHIMisl

Detailed field methods have been published for the control birds [10, 11]. Geolocators were Intigeo-W65, Migrate Technology Ltd and were attached with a cable tie and leg flag for a total mass of ~ 1 g.

Gilg, Lang, & Bollache

Sites: B17, B20

Species: SANDalb

Field methods followed those described in the main text. Details about field site B17 are available in the literature [12, 13].

Lanctot & Yezerinac

Sites: B02, B05

Species: DUNLpac

Field methods followed those of the Arctic Shorebird Demographics Network [6], except no defined study plots were used and nests were not monitored.

Minton et al.

Sites: N01-N04

Species: SANDrub, GSAP, RUTUint, GRKN, FECU

All control and geolocator birds were caught with cannon nets at high tide roosts on sandy shores at a range of locations. Details have been published for most species [14–16].

Pakanen et al.

Site: B23

Species: DUNLsch

Field methods are detailed in Pakanen et al. [17].

Reneerkens et al.

Site: B18

Species: SANDalb

The field site is approximately 60 km² large and was annually visited for 4-8 weeks in June and July by 1-2 teams of 1-3 persons. Researchers, on foot, were solely focusing on sanderlings and used spotting telescopes to read color-banded sanderlings [18, 19]. Adult and juvenile sanderlings were annually color-banded in the whole area. Each year the whole area was searched for nests and color-banded individuals, but especially early in the season snow cover limited the time that can be spend in areas further away from the field station. It is for this reason that we tried as much as possible to deploy geolocators to birds nesting in two sub-areas within the total study area, that were close to the field station and/or bred in areas that are usually snow-free early in the season. Birds were mostly captured on the nest using a small clapnet, but adults guiding chicks were also captured with mistnets. Small spacer bands were applied below the flag with the geolocator to enable free movement of the flag and distribute the weight equally on the leg joint.

Taylor et al.

Site: B01

Species: BLTU

We trimmed feathers from a geolocator-sized area about 2 cm above the uropygial gland and glued the geolocator to this site using Loctite 454 cyanoacrylate instant adhesive. We used 1.0 mm thick Stretch Magic beading cord to secure the geolocator in place with the leg-loop harness described by Warnock & Warnock [10]. The light sensor of the geolocator (Lotek MK 5780, 1.5 g) was on a 20mm stalk attached at 30 degree angle. We searched for all birds that were banded in 2013 when we returned in 2014; this entailed spending ~200 hours searching the plots. We spent about 4 hours off-plot looking specifically for geolocator birds.

Ward & Helmericks

Site: B09

Species: RUTUmor

Observations and captures of ruddy turnstones were made at the Helmericks homestead located on the north end of Anachlik Island at the mouth of the Colville River Delta, Alaska, 2011-2014. All captures were made with a bow trap by baiting birds to a trap site with food and marking followed procedures in Brown et al. [6]. Observations of marked birds were made primarily at the trap site and occasionally at other locations on the island. Handling time averaged 21 + 10 (SD) min (n = 22). Blood and feather samples were taken only on 10 geolocator birds in 2013. No nests were monitored at the Helmericks homestead.

Supplementary References

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Table S1. Study sites included in the analysis of geocator effects on shorebirds. Breeding areas are indicated with “B” code while nonbreeding areas are indicated with an “N”; sites in each category are numbered from west to east.

Code	Site name	Study*	Latitude	Longitude	Capture years		Species
					Control	Geocator	
B01	Tutakoke River, Alaska, USA	1	61.25	-165.62	2013	2013	BLTU
B02	Manokinak River, Alaska, USA	2	61.19	-165.10	-	2010	DUNLpac
B03	Nome, Alaska, USA	3	64.44	-164.96	2010-2013	2011-2013	SESA, WESA
B04	Cape Krusenstern, Alaska, USA	3	67.11	-163.50	2010-2013	2010, 2013	SESA, DUNLpac
B05	Izembek Lagoon, Alaska, USA	2	55.25	-162.85	-	2010	DUNLpac
B06	Barrow, Alaska, USA	3	71.30	-156.76	2010-2013	2010, 2012, 2013	SESA, DUNLarc, AMGP
B07	Ikpikpuk River, Alaska, USA	3	70.55	-154.74	2011-2013	2010, 2013	SESA, DUNLarc, AMGP
B08	Colville River, Alaska, USA	3	70.44	-150.68	2011-2012	2013	RUTU _{mor}
B09	Helmericks Homestead, Alaska, USA	4	70.43	-150.40	2011-2013	2012-2013	RUTU _{mor}
B10	Canning River, Alaska, USA	3	70.12	-145.85	2010-2013	2010, 2013	SESA, DUNLarc
B11	Mackenzie Delta, NWT, Canada	3	69.37	-134.89	2010-2013	2013	SESA
B12	Churchill, Manitoba, Canada	3	58.74	-93.82	2010-2013	2010, 2012, 2013	SESA, DUNL _{hud} , AMGP, WHIM _{hud}
B13	Coats Island, Nunavut, Canada	3	62.86	-82.50	-	2013	SESA
B14	East Bay, Nunavut, Canada	3	63.99	-81.70	2010-2013	2010, 2012, 2013	RUTU _{mor}
B15	Igloodik, Nunavut, Canada	3	69.34	-81.54	-	2013	AMGP, SESA
B16	Bylot Island, Nunavut, Canada	3	73.16	-79.97	2010-2013	2011-2013	AMGP
B17	Karupelv Valley, Greenland	5	72.50	-23.99	2011-2013	2013	SAND _{alb}
B18	Zackenbergl, Greenland	6	74.50	-21.00	2007-2013	2011-2013	SAND _{alb}
B19	Keldur, Iceland	7	63.78	-20.12	2009, 2010, 2013	2012-2014	WHIM _{isl}
B20	Hochstetter Forland, Greenland	5	75.15	-19.70	2010-2013	2013	SAND _{alb}
B21	Fetlar RSPB Nature Reserve	8	60.58	-0.78	2012	2012	RNPH
B22	Storulvån, Jämtland, Sweden	9	63.20	12.41	2009, 2011, 2013	2009, 2011, 2013	GRSN
B23	Oulu, Finland	10	64.93	24.87	2002-2013	2013	DUNL _{sch}
N01	Broome, Western Australia	11	-18.00	122.37	2009-2012	2009-2012	GSAP, GRKN
N02	Canunda National Park, South Australia	11	-37.62	140.18	2010	2011	SAND _{rub}
N03	King Island, Tasmania	11	-39.83	143.87	2010-2012	2010-2012	RUTU _{int}
N04	Inverloch, Victoria, Australia	11	-38.62	145.75	2010	2010	FECU
N05	Moreton Bay, Queensland, Australia	12	-27.43	153.17	2011-2012	2012	GTTA
N06	Manawatu River Estuary, Manawatu, NZ	13	-40.47	175.22	2008, 2012	2008, 2012	REKN _{rog} , BTGO
N07	Delaware Bay, New Jersey, USA	14	39.22	-75.02	2009	2009	REKN _{ruf}
N08	Monomoy Refuge, Massachusetts, USA	15	41.58	-69.99	2009	2009	REKN _{ruf}

* 1) Taylor et al., unpubl.; 2) Lanctot & Yezerinac, unpubl.; 3) Arctic Shorebird Demographics Network, unpubl. [6]; 4) Ward & Helmericks, unpubl.; 5) Gilg, Lang, & Bollache, unpubl.; 6) Reneerkens, unpubl.; 7) GeoSpoi [10, 11]; 8) Smith et al. [5]; 9) Lindström et al. [1, 2]; 10) Pakanen et al. [17, 20]; 11) Minton et al. [14–16]; 12) Coleman, unpubl.; 13) Battley & Conklin [8, 9, 21]; 14) Niles et al. [3]; 15) Burger et al. [4]. See Supplementary Methods for details on unpublished studies and their field methods.

Table S2. Final number of capture events (control; geolocator) used in each analysis for each species-site combination. Species codes are defined in Table 1; site codes are in Table S1.

Species	Site	Nest success	Cause of nest failure	Partial hatching of clutches	Return rate	Breeding movement	Change in body mass	Geolocator orientation*	
								Nest success	Return rate
SESA	B03	86; 43	8; 0	61; 19	197; 60	66; 7	12; 10	71; 43	164; 32; 28
	B04				137; 18	42; 6	15; 7		
	B06	123; 2	60; 11	111; 0	203; 28	96; 2	86; 1		
	B07	73; 20	10; 18	63; 2	158; 29	47; 4	38; 3		
	B10	148; 13	3; 3	86; 1	234; 29	66; 13	9; 13		
	B11	7; 8	24; 23	4; 4	20; 13	3; 1	1; 0		
	B13				0; 35				
	B15				0; 12				
WESA	B03	136; 19	41; 8	90; 11	276; 21	95; 6	51; 6		
RNPH	B21				21; 7				
DUNLsch	B23				57; 30				
SANDrub	N02				55; 44				
DUNLpac	B02				0; 48				
	B04	34; 11	5; 8	26; 10	57; 30	31; 11	14; 11		
	B05				0; 46				
DUNLhud	B12				133; 35	30; 11	4; 16		
DUNLarc	B06	95; 27	8; 1	86; 17	176; 47	124; 6	94; 15		
	B07				52; 35	9; 2	7; 3		
	B10				27; 22	13; 5	1; 4		
SANDalb	B17				47; 7				
	B18	289; 10			284; 15				
	B20				99; 11				
GSAP	N01				289; 59				
GTTA	N05				160; 19				
RUTUint	N03				112; 77				
RUTUmor	B08				9; 5	3; 1			
	B09				44; 22				
	B14				9; 39	0; 1	6; 0		
BLTU	B01				51; 30				
REKNrog	N06				11; 25				
REKNruf	N07				622; 47				
	N08				89; 40				
AMGP	B06	19; 21	0; 7	17; 12	40; 24	6; 3	3; 4		
	B07				0; 5				
	B12	1; 9			2; 14	1; 3			
	B15				0; 15		0; 4		
	B16				13; 71	2; 1	0; 12		13; 47; 24
GRSN	B22				34; 45				
GRKN	N01				126; 64				
BTGO	N06				16; 58				
WHIMhud	B12	25; 21	9; 17	16; 4	31; 24				
WHIMisl	B19	36; 2		18; 1	55; 23				
FECU	N04				7; 23				

* Given as control; PAB geolocator; PAF geolocator (Figure 2).

Table S3. Model-averaged effects of geolocators on nest success for six species of Arctic-breeding shorebirds. Species are sorted by ascending body mass; codes are defined in Table 1. All models included random effects of site and year. Submodel sets are given in Table S4; sample sizes are given in Table 2.

Species	Intercept	Geolocator	
	Mean (SE)	Mean (SE)	RI*
SESA	0.34 (0.28)	-0.87 (0.24)	1.00
WESA	0.13 (0.32)	-0.23 (0.36)	0.30
DUNL	0.83 (0.17)	-0.57 (0.39)	0.45
SAND	0.51 (0.13)	0.37 (0.43)	0.34
AMGP	0.52 (0.82)	0	0
WHIM	-0.34 (0.29)	-1.12 (0.57)	0.56

* RI = relative importance of the covariate in the averaged model; bold text indicates $RI \geq 0.80$.

Table S4. Full model sets for nest success of six species of Arctic-breeding shorebirds. Species codes are defined in Table 1.

Species	Model rank	Intercept (control)	Geolocator ^a	df	Deviance	AICc	$\Delta AICc$	w_i^b
SESA	1	0.34	X	4	-274.0	556.2	-	0.997
	2	0.21	-	3	-281.0	568.1	11.97	0.003
WESA	1	0.13	-	2	-95.0	194.0	-	0.696
	2	0.15	X	3	-94.8	195.7	1.660	0.304
DUNL	1	0.77	-	3	-65.6	137.4	-	0.547
	2	0.89	X	4	-64.8	137.7	0.38	0.453
SAND	1	0.53	-	2	-149.7	303.3	-	0.658
	2	0.51	X	3	-149.3	304.7	1.310	0.342
AMGP	1	0.52	-	3	-21.5	49.5	-	0.763
	2	0.43	X	4	-21.5	51.8	2.340	0.237
WHIM	1	-0.23	X	4	-53.8	116.2	-	0.563
	2	-0.48	-	3	-55.2	116.7	0.510	0.437

^a "X" indicates a categorical covariate present in the submodel; "-" indicates a covariate tested in the full model but not present in the submodel.

^b Submodels are ranked and sorted by descending model weight (w_i).

Table S5. Full model set for the effect of geolocators on cause of nest failure in semipalmated sandpipers. Submodels included random effects of year and site. See Table S4 for definitions of abbreviations.

Model rank	Intercept (control)	Geolocator	df	Deviance	AICc	$\Delta AICc$	w_i
1	2.48	-	3	-45.8	97.6	-	0.726
2	2.40	+	4	-45.7	99.6	1.95	0.274

Table S6. Top model sets for return rate for each species and subspecies of Arctic-breeding shorebirds. Submodels with $\Delta AICc < 2.0$ are shown here, and are sorted by descending model weight (w_i) within each species. Covariates were not tested for a given taxon when there was insufficient variation. All submodels included random effects of year, site, and individual if relevant. Species codes are defined in Table 1; see Table S4 for definitions of abbreviations.

Species	Model rank	Inter-cept	Geo-locator	Sex	Nest fate	Previously marked	Body mass	Day of capture	Marker mass	k	Dev-iance	AICc	$\Delta AICc$	w_i
SESA	1	-0.62	X		-	X	-	-	-	7	-747.1	1508.3	-	0.090
	2	-0.75	X		X	X	-	-	-0.37	10	-744.1	1508.3	0.002	0.090
	3	-0.59	X		-	-	-	-	-	6	-748.1	1508.3	0.050	0.088
	4	-0.89	X		X	X	-	-	-	9	-745.1	1508.4	0.066	0.087
	5	-0.55	X		-	X	-	-	-0.32	8	-746.2	1508.4	0.134	0.084
	6	-0.52	X		-	-	-	-	-0.3	7	-747.3	1508.8	0.468	0.071
	7	-0.66	X		X	-	-	-	-0.35	9	-745.4	1509.0	0.707	0.063
	8	-0.76	X		X	-	-	-	-	8	-746.5	1509.1	0.819	0.06
	9	-0.63	X		-	X	-	0.06	-	8	-746.9	1510	1.698	0.039
	10	-0.56	X		-	X	-	0.06	-0.32	9	-746	1510.1	1.810	0.037
	11	-0.6	X		-	-	-	0.05	-	7	-748	1510.2	1.867	0.035
	12	-0.74	X		X	X	-	0.03	-0.37	11	-744	1510.3	1.980	0.034
WESA	1	-0.73	X	-	X	X	-	-	-0.59	7	-195.2	404.8	-	0.120
	2	-0.85	-	-	X	X	-	-	-	5	-197.3	404.9	0.075	0.116
	3	-0.93	-	X	X	X	-	-	-	7	-195.7	405.8	1.006	0.073
	4	-0.86	-	-	X	X	-	-	-0.14	6	-197.0	406.3	1.507	0.057
	5	-0.74	X	-	X	X	-	-0.12	-0.63	8	-195.0	406.5	1.725	0.051
	6	-0.61	X	-	X	-	-	-	-0.67	6	-197.2	406.6	1.854	0.048
	7	-0.83	X	-	X	X	-	-	-	6	-197.2	406.7	1.953	0.045
RNPH	1	-0.47	-							1	-19.3	40.8	-	0.633
	2	-0.30	X							2	-18.7	41.9	1.090	0.367
DUNLsch	1	0.97	-	X		-	-			3	-30.0	66.4	-	0.507
	2	0.90	X	X		-	-			4	-29.9	68.3	1.889	0.197
SANDrub	1	-1.99	X				-			3	-48.5	103.2	-	0.717
	2	-1.46	-				-			2	-50.5	105.1	1.857	0.283
DUNLpac	1	-0.11	X		-	X	-	-		7	-116.6	247.9	-	0.154
	2	0.10	X		-	X	-	-0.41		8	-115.6	248.0	0.047	0.151
	3	-0.23	-		X	X	-	-0.48		9	-114.8	248.6	0.645	0.112
	4	-0.54	-		X	X	-	-		8	-115.9	248.7	0.798	0.103
	5	0.41	X		-	-	-	-0.55		7	-117.2	249.0	1.059	0.091
	6	-0.39	-		-	X	-	-		6	-118.3	249.0	1.088	0.089
	7	-0.08	X		X	X	-	-0.53		10	-114.2	249.7	1.769	0.064
DUNLhud	1	-0.58	-		-	-	-	-		2	-114.7	233.5	-	0.249
	2	-0.58	-		-	-	-	-0.25		3	-114.2	234.5	1.028	0.149
	3	-0.66	X		-	-	-	-		3	-114.3	234.7	1.162	0.139
	4	-0.61	-		-	X	-	-		3	-114.6	235.4	1.838	0.099
DUNLarc	1	-0.76	X	X		-	-			8	-226.7	469.8	-	0.413
	2	-0.78	X	X		X	-			9	-225.9	470.3	0.483	0.324
	3	-0.80	-	X		-	-			7	-228.7	471.7	1.892	0.160
SANDalb	1	-1.32	-			-	-		-	3	-255.9	517.9	-	0.294
	2	-1.33	-			X	-		0.22	4	-255.2	518.6	0.719	0.205
	3	-1.24	-			-	-		-	4	-255.6	519.4	1.520	0.138
GSAP	1	-0.29	X							3	-236.2	478.5	-	0.819
GTTA	1	-0.08	-			-		-		2	-120.2	244.5	-	0.314
	2	-0.08	-			-		0.23		3	-119.5	245.2	0.702	0.221
RUTUint	1	-1.09	X							3	-103.5	213.2	-	0.580
	2	-1.29	-							2	-104.9	213.8	0.646	0.420

Table S6 continued

Species	Model rank	Intercept	Geo-locator	Sex	Nest fate	Previously marked	Body mass	Day of capture	Marker mass	k	Deviance	AICc	$\Delta AICc$	w_i
RUTU _{mor}	1	-1.01	-	-		-				5	-73.5	157.4	-	0.436
	2	-1.30	X	-		-				6	-73.0	158.7	1.249	0.233
BLTU	1	0.11	-	-			-0.73	-	-	2	-49.0	102.2	-	0.107
	2	-1.12	-	X			-	-1.00	-	4	-47.0	102.6	0.418	0.087
	3	-0.47	-	X			-0.55	-	-	4	-47.1	102.6	0.460	0.085
	4	-0.95	-	X			-0.54	-0.97	-	5	-46.0	102.7	0.540	0.082
	5	-0.60	-	X			-	-	-	3	-48.2	102.8	0.619	0.079
	6	0.23	X	-			-0.75	-	-	3	-48.4	103.2	0.976	0.066
	7	0.11	-	-			-0.73	-	-0.25	3	-48.7	103.6	1.457	0.052
	8	0.11	-	-			-0.74	0.16	-	3	-48.9	104.1	1.875	0.042
REKN _{rog}	1	0.27	-			-	0.79			2	-19.7	43.7	-	0.338
	2	0.25	-			-	-			1	-21.3	44.7	0.909	0.215
REKN _{ruf}	1	-0.99	-							1	-493.7	989.5	-	0.626
	2	-1.02	X							2	-493.2	990.5	1.032	0.374
AMGP	1	-1.23	-	-	-	-	-0.52	-0.98	-0.69	6	-87.3	187.1	-	0.068
	2	-1.24	-	-	-	-	-0.64	-0.91	-	5	-88.7	187.7	0.620	0.050
	3	-2.06	-	-	X	-	-	-1.05	-0.92	7	-86.5	187.7	0.627	0.050
	4	-1.20	-	-	-	-	-	-0.91	-0.85	5	-88.8	188.1	0.970	0.042
	5	-1.18	-	-	-	X	-0.57	-1.00	-0.70	7	-86.8	188.3	1.191	0.038
	6	-1.60	X	-	-	-	-0.68	-0.87	-	6	-87.9	188.4	1.261	0.036
	7	-1.95	-	-	X	-	-0.36	-1.06	-0.79	8	-85.8	188.6	1.505	0.032
	8	-1.50	X	-	-	-	-0.54	-0.94	-0.48	7	-86.9	188.6	1.532	0.032
GRSN	1	-0.61	-							2	-53.7	111.5	-	0.716
	2	-0.73	X							3	-53.5	113.4	1.854	0.284
GRKN	1	0.19	X							3	-91.7	189.5	-	0.726
	2	0.49	-							2	-93.7	191.4	1.952	0.274
BTGO	1	0.81	-	-						1	-25.5	53.0	-	0.477
	2	1.04	X	-						2	-25.2	54.5	1.517	0.223
WHIM _{hud}	1	0.01	-	-	-					2	-36.1	76.3	-	0.280
	2	-0.21	X	X	-					3	-35.3	77.1	0.736	0.194
	3	-0.14	X	-	-					3	-35.6	77.6	1.277	0.148
WHIM _{isl}	1	-1.03	X	X	-	-				3	-46.2	98.8	-	0.278
	2	-1.30	X	X	X	-				4	-45.4	99.3	0.486	0.218
	3	-0.23	-	-	-	-				2	-48.0	100.1	1.323	0.143
	4	-0.45	-	-	X	-				3	-47.2	100.8	1.967	0.104
FECU	1	-1.09	X							2	-16.2	36.9	-	0.847

Table S7. Top model sets for GLMMs testing sublethal effects of geolocators for five species of Arctic-breeding shorebirds pooled. Submodels with $\Delta\text{AICc} < 2.0$ are shown here, and are ranked and sorted by descending model weight (w_i). All submodels included random effects of species, site, and year. See Table S4 for definitions of abbreviations.

Response	Model rank	Intercept (control)	Geocator	Nest fate	Sex	Previously marked	Date difference	Nest age difference	k	Deviance	AICc	ΔAICc	w_i
Interannual breeding movements	1	4.08	-	X	X	-			9	-1205.3	2428.9	-	0.397
	2	4.06	-	X	X	-0.15			10	-1204.5	2429.2	0.32	0.339
Proportional change in body mass	1	0.001	-				-	-	5	476.9	-943.6	-	0.288
	2	0.004	X				-	-	6	477.5	-942.9	0.71	0.202
	3	0.001	-				-0.005	-	6	477.1	-942.0	1.63	0.127
	4	0.001	-				-	0.003	6	476.9	-941.7	1.89	0.112

Table S8. Model-averaged effects of geocator orientation on nest success and return rate for semipalmated sandpipers at site B03 and return rate for American golden-plovers at site B16. Effect size estimates are given as mean (SE), and effects of two geocator leg attachments were tested: PAB = parallel-band; PEF = perpendicular-flag. Top model sets are provided in Table S9; sample sizes are in Table S2. See Table S4 for definitions of abbreviations.

Species	Response	Intercept (control)	Geocator		Nest fate	Previously marked		Day of capture	
		Mean (SE)	PAB	PEF		Hatched	Unknown	Mean (SE)	RI
SESA	Nest success	0.16 (0.29)	0.01 (0.38)	-2.98 (1.04)	1.00				
	Return rate	-0.89 (0.29)	-1.31 (0.43)	-0.64 (0.48)	1.00	0.79 (0.30)	0.48 (0.35)	1.00	0.34 (0.34) 0.35
AMGP	Return rate	-1.63 (0.82)	1.49 (0.81)	1.30 (0.76)	0.39				-0.98 (0.50) 0.82

Table S9. Top model sets for covariates of nest fate and return rate for semipalmated sandpipers at site B03 and American golden-plovers at site B16 with either parallel-band or perpendicular-flag geocator attachments. All submodels included random effects of year. See Table S4 for definitions of abbreviations.

Species	Response	Model rank	Intercept (control)	Geocator type	Nest fate	Previously marked	Day of capture	k	Deviance	AICc	ΔAICc	w_i
SESA	Nest fate	1	0.16	X				4	59.2	126.8	-	0.996
		2	-0.20	-				2	-67.0	138.0	11.28	0.004
	Return rate	1	-0.87	X	X	-		6	-140.0	292.3	-	0.535
		2	-0.92	X	X	X		7	-139.5	293.5	1.22	0.291
AMGP	Return rate	1	-1.04	-			-0.71	3	-50.0	106.3	-	0.423
		2	-2.30	X			-1.29	5	-47.9	106.5	0.24	0.374
		3	-	-			-	2	-52.0	108.1	1.79	0.172

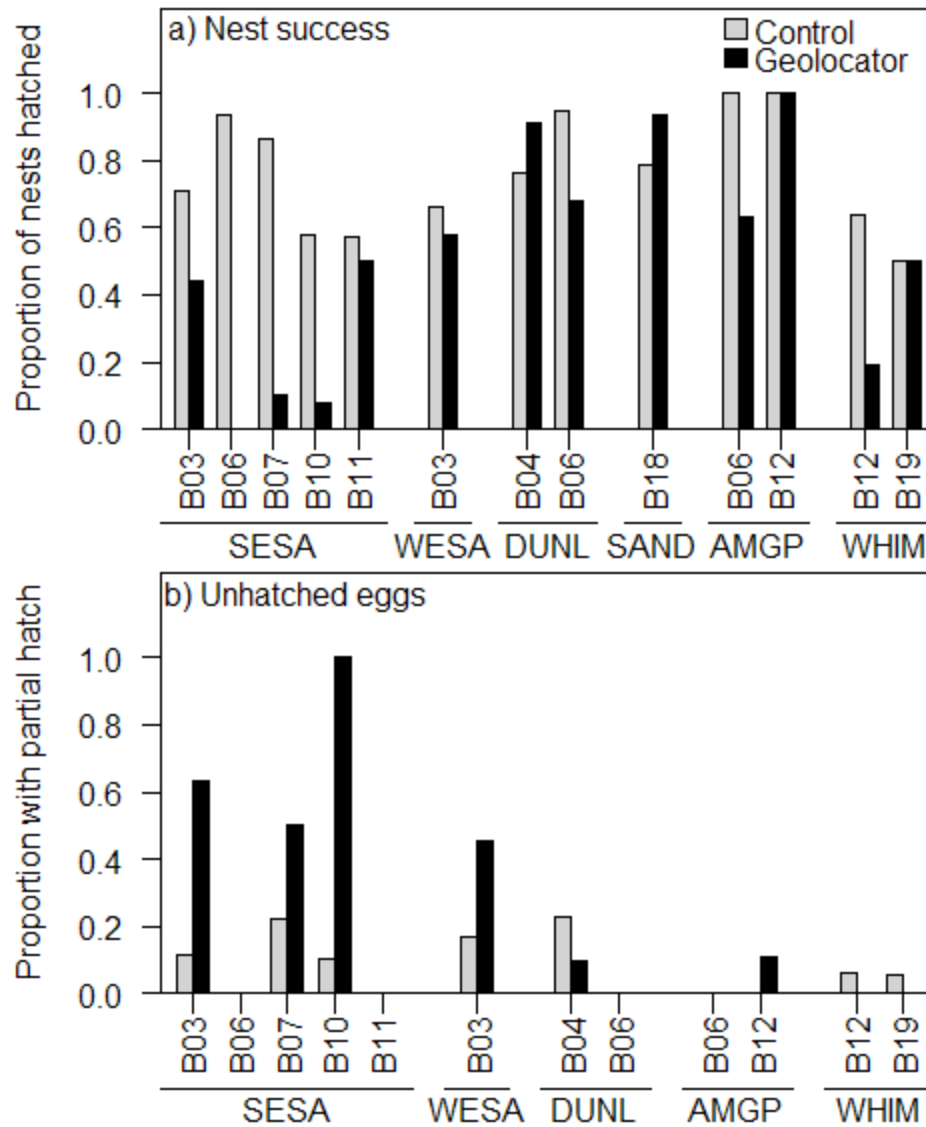


Figure S1. Nest success and partial hatching of clutches of control and geolocator nests for Arctic-breeding shorebirds. a) Proportion of nests hatched of those with known fate for control and geolocator groups of six species of Arctic-breeding shorebirds at a subset of sites. b) Proportion of hatched nests with unhatched eggs remaining for control and geolocator birds for five species. A dash instead of a bar indicates no data available for a given group to distinguish from groups for which no successful nests or no unhatched eggs were recorded. Species are ordered from smallest to largest; species codes are defined in Table 1 and site codes are in Table S1; sample sizes are given in Table S2.

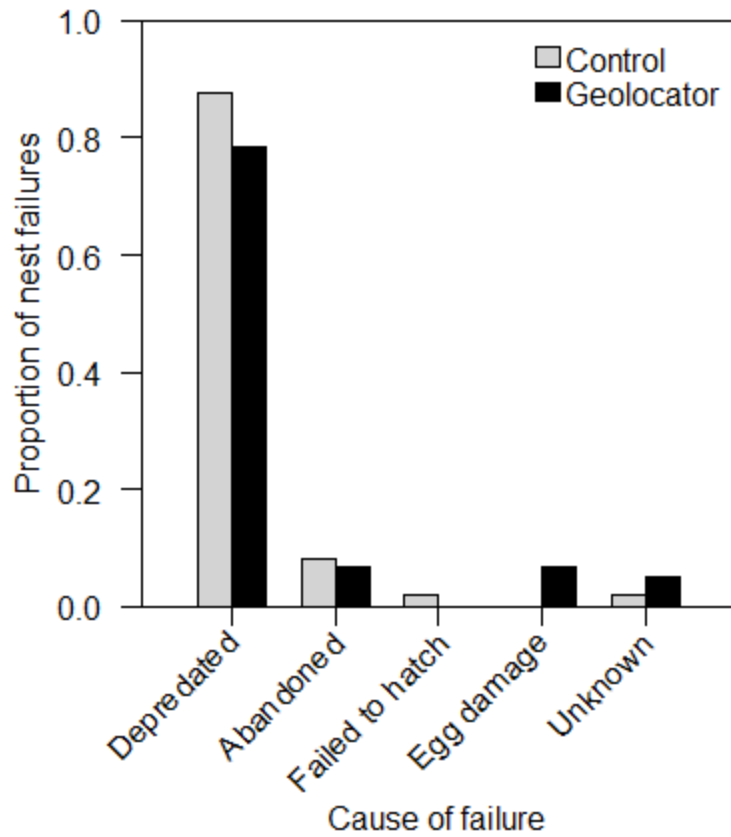


Figure S2. Cause of failure for control and geolocator semipalmated sandpiper nests that did not hatch, which together comprised 26% of nests with known fate.

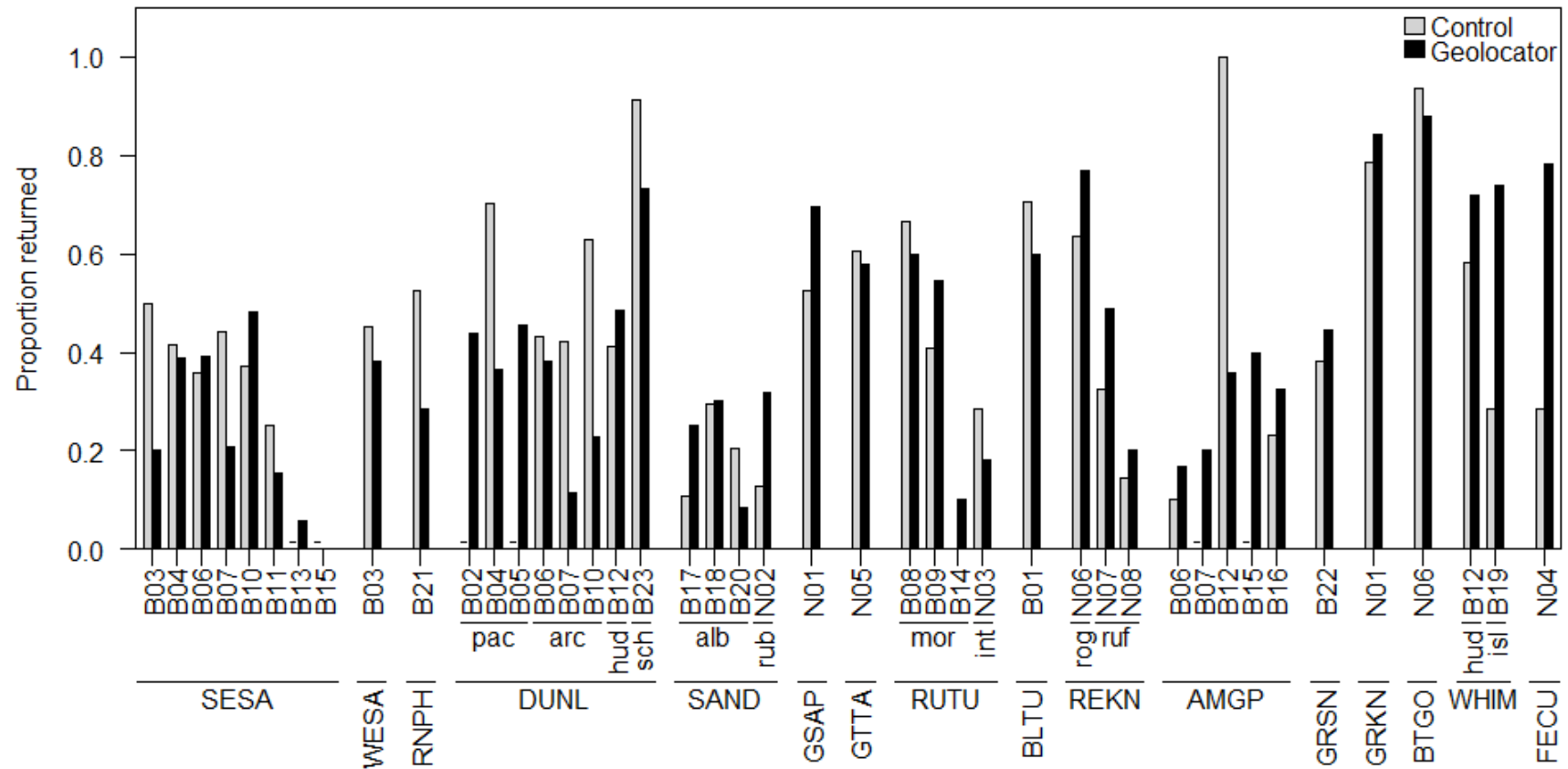


Figure S3. Proportion of shorebirds with and without geolocators that returned to each site one year after capture. A dash instead of a bar indicates no data for a given group to distinguish from cases where birds were marked but none returned. Species are ordered from smallest to largest; species codes are defined in Table 1, site codes are given in Table S1, and sample sizes are given in Table S2.