

Living on the edge of a shrinking habitat: the ivory gull, *Pagophila eburnea*, an endangered sea-ice specialist

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Supplementary material

Statistical analyses

We used an Information Theoretic approach [1] to choose which variables best predict distance to ice edge, fitting linear mixed-effect models using the “*lmer*” function in the R package *lme4* (R Foundation for Statistical Computing, Vienna, Austria [2]). Models included as fixed effects geophysical variables, *i.e.*, *IC3x3* (the averaged ice concentration found on every gull position and on the eight adjacent pixels), *d2col* (the orthodromic distance from the known breeding colony of the bird) and country of origin of the bird in interaction with month and sex. Prior to analysis, we ensured that there was no significant multi-collinearity among explanatory variables. To do so, we calculated variance inflation factors (VIF) using the package “*car*” implemented in R. The test performed on a full linear model revealed no multi-collinearity problem: the highest VIF was 2.7 and multi-collinearity begins to affect parameter estimates when the VIF values are >10 (for a discussion see [3]). As we had repeated locations for individuals taken in different years, individual identity (nested in country) and year were added as random effects in all the models. We ranked candidate models using the Akaike’s Information Criterion (*AICc*) as implemented in *dredge* function of the R package “*MuMIn*” [4], and calculated $\Delta AICc$ and *AICc* weights. Models with $\Delta AICc \leq 2$ were considered equivalent [1]. We used a standard model averaging method to calculate parameter estimates of equivalent models [1]. We ensured that all residuals were normally distributed and applied log-transformation to variables when necessary. We used least square mean, package “*lsmeans*” [5], to conduct post-hoc comparisons. Results are presented as means \pm standard error (s.e.). Pseudo- R^2 -values were calculated for the eight best models with the *r.squared-GLMM* function of “*MuMIn*” [4]. Marginal R^2 (R^2_m) corresponds to the variance explained by fixed factors, while conditional R^2 (R^2_c) represents the variance explained by both fixed and random factors.

Table S1. Individual details for the 104 ivory gulls monitored in this study

Argos ID	Age	Sex ¹	Deployment year	Manufact.	PTT weight (g)	Power	Duty cycle	Attachement	Country	Region	Colony	Latitude	Longitude	Deployment date	Last position	Monitoring duration	Total Nb locations	Used locations (see methods)
37729	Adult	M ^m	2007	NorthStar	20	Battery	Yes	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	03/07/2007	18/12/2007	168	630	255
37720	Adult	M ^m	2007	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	04/07/2007	06/08/2009	764	3229	709
37721	Adult	M ^m	2007	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	04/07/2007	13/12/2007	162	1679	163
37725	Adult	M ^m	2007	NorthStar	20	Battery	Yes	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	04/07/2007	10/06/2008	342	682	229
37728	Adult	M ^m	2007	NorthStar	20	Battery	Yes	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	05/07/2007	27/01/2008	206	605	243
75855	Adult	M ^m	2007	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	05/07/2007	07/10/2007	94	2062	723
75856	Adult	M ^m	2007	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	05/07/2007	18/01/2008	197	1605	244
37722	Adult	M ^m	2007	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Henrik Kroyer Holme	80.6433	-13.75	12/07/2007	21/08/2009	771	7157	1973
75857	Adult	F ^m	2007	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Henrik Kroyer Holme	80.6433	-13.75	12/07/2007	08/06/2010	1062	10130	2999
37724	Adult	F ^m	2007	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Henrik Kroyer Holme	80.6433	-13.75	13/07/2007	04/12/2007	144	843	410
37726	Adult	M ^m	2007	NorthStar	20	Battery	Yes	Harness	Greenland	North Greenland	Henrik Kroyer Holme	80.6433	-13.75	13/07/2007	17/12/2007	157	583	314
37727	Adult	M ^m	2007	NorthStar	20	Battery	Yes	Harness	Greenland	North Greenland	Henrik Kroyer Holme	80.6433	-13.75	13/07/2007	17/01/2008	188	527	217
37723	Adult	F ^m	2007	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Henrik Kroyer Holme	80.6433	-13.75	14/07/2007	05/10/2008	449	6733	2732
74888	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Russia	Franz Josef Land	Hayes Island	80.5667	57.33	31/07/2007	02/01/2008	155	697	69
74883	Adult	F ^m	2007	Microwave	20	Battery	Yes	Harness	Russia	Franz Josef Land	Hayes Island	80.5667	57.33	03/08/2007	20/02/2008	201	765	377
74884	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Russia	Franz Josef Land	Hayes Island	80.5667	57.33	03/08/2007	17/12/2007	136	684	200
74886	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Russia	Franz Josef Land	Hayes Island	80.5667	57.33	03/08/2007	04/06/2008	306	600	44
74889	Adult	F ^m	2007	Microwave	20	Battery	Yes	Harness	Russia	Franz Josef Land	Hayes Island	80.5667	57.33	03/08/2007	03/12/2007	122	570	99
74878	Adult	M ^m	2007	Microwave	20	Battery	Yes	Harness	Russia	Franz Josef Land	Hayes Island	80.5667	57.33	04/08/2007	09/11/2007	97	2164	358
74887	Adult	M ^m	2007	Microwave	20	Battery	Yes	Harness	Russia	Franz Josef Land	Hayes Island	80.5667	57.33	04/08/2007	27/12/2007	145	619	29
74890	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Russia	Franz Josef Land	Hayes Island	80.5667	57.33	04/08/2007	30/03/2008	239	732	122
74879	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	06/07/2007	19/12/2007	166	2650	695
74891	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	07/07/2007	02/08/2007	26	93	4
74881	Adult	F ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	08/07/2007	25/07/2007	17	110	29
74894	Adult	F ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	08/07/2007	21/11/2007	136	533	109
74895	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	08/07/2007	02/11/2007	117	546	99
74893	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	09/07/2007	01/07/2008	358	775	264
74897	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	09/07/2007	03/08/2007	25	129	83
74892	Adult	M ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	10/07/2007	26/09/2007	78	515	193
74896	Adult	F ^d	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	10/07/2007	16/10/2007	98	523	104
74880	Adult	M ^m	2007	Microwave	20	Battery	Yes	Harness	Svalbard	Kong Karls Land	Svenskoya	78.7167	26.6667	11/07/2007	26/06/2008	351	1097	354
83870	Adult	F ^d	2008	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	28/06/2008	16/08/2008	49	3011	665
83872	Adult	F ^d	2008	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	28/06/2008	11/01/2009	197	3538	785
83867	Adult	M ^d	2008	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	29/06/2008	12/10/2008	105	2581	445
83875	Adult	F ^d	2008	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	29/06/2008	18/01/2009	203	2996	307
83876	Adult	M ^d	2008	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	29/06/2008	29/12/2008	183	2429	629
83871	Adult	M ^d	2009	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	08/07/2009	21/01/2010	197	3632	633
96288	Adult	F ^d	2009	NorthStar	11	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	08/07/2009	07/01/2010	183	2722	686
83869	Adult	M ^d	2009	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	10/07/2009	19/03/2011	617	13465	5247
83873	Adult	F ^d	2009	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	11/07/2009	16/01/2010	189	3162	1536
83868	1st summer	?	2009	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	04/08/2009	02/11/2009	90	1511	261
83874	1st summer	M ^d	2009	NorthStar	12	Solar	No	Harness	Greenland	North Greenland	Station Nord	81.625	-16.675	04/08/2009	03/11/2009	91	1283	183

Table S1 (continued). Individual details for the 104 ivory gulls monitored in this study

Argos ID	Age	Sex ¹	Deployment year	Manufact.	PTT weight (g)	Power	Duty cycle	Attachement	Country	Region	Colony	Latitude	Longitude	Deployment date	Last position	Monitoring duration	Total Nb locations	Used locations (see methods)
44509	Adult	?	2010	NorthStar	20	Battery	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	23/01/2011	206	634	126
44516	Adult	?	2010	NorthStar	20	Battery	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	18/11/2010	140	536	86
44517	Adult	?	2010	NorthStar	20	Battery	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	18/02/2011	232	868	245
44519	Adult	M ^m	2010	NorthStar	20	Battery	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	03/03/2011	245	766	298
44522	Adult	?	2010	NorthStar	20	Battery	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	26/11/2010	148	542	128
44523	Adult	F ^m	2010	Microwave	15	Solar	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	21/07/2013 ²	1116	11119	4328
44524	Adult	F ^m	2010	Microwave	15	Solar	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	26/09/2012	818	8701	2876
44525	Adult	M ^m	2010	Microwave	15	Solar	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	20/08/2012	781	8694	2423
44526	Adult	M ^m	2010	Microwave	15	Solar	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	21/07/2013	1116	15216	1652
44529	Adult	M ^m	2010	Microwave	15	Solar	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	22/11/2010	144	2003	93
44530	Adult	F ^m	2010	Microwave	15	Solar	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	11/07/2011	375	4054	849
44531	Adult	F ^m	2010	Microwave	15	Solar	Yes	Leg-loop	Canada	Nunavut	Seymour Island	78.8	-101.27	01/07/2010	20/05/2011	323	3479	866
61132	Adult	M ^d	2010	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	19/07/2010	8	310	100
61133	Adult	M ^d	2010	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	16/01/2011	189	4293	299
61134	Adult	M ^d	2010	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	10/08/2010	30	1577	404
61135	Adult	F ^d	2010	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	19/07/2011	373	6470	2283
61138	Adult	M ^d	2010	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	14/09/2011	430	6720	2403
61139	Adult	F ^d	2010	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	19/02/2011	223	2098	750
61140	Adult	F ^d	2010	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	06/01/2012	544	7008	2324
61141	Adult	F ^d	2010	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	25/07/2010	14	421	58
61143	Adult	F ^d	2010	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	09/02/2011	213	2265	699
61144	Adult	M ^d	2010	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	18/07/2010	7	112	0
74885	Adult	M ^d	2010	Microwave	20	Battery	Yes	Harness	Svalbard	Barentsøya	Auga	78.51389	21.75433	11/07/2010	19/10/2010	100	578	162
52178	Adult	M ^m	2011	NorthStar	20	Battery	Yes	Harness	Russia	Severnaya Zemlya	Domashny Island	79.5	91.0000	18/05/2011	14/02/2012	272	728	194
52179	Adult	M ^m	2011	NorthStar	20	Battery	Yes	Harness	Russia	Severnaya Zemlya	Domashny Island	79.5	91.0000	18/05/2011	02/07/2011	45	136	52
52182	Adult	M ^m	2011	NorthStar	20	Battery	Yes	Harness	Russia	Severnaya Zemlya	Domashny Island	79.5	91.0000	18/05/2011	26/06/2011	39	130	63
52188	Adult	M ^m	2011	NorthStar	20	Battery	Yes	Harness	Russia	Severnaya Zemlya	Domashny Island	79.5	91.0000	18/05/2011	15/04/2012	333	817	272
52183	Adult	M ^m	2011	NorthStar	20	Battery	Yes	Harness	Russia	Severnaya Zemlya	Domashny Island	79.5	91.0000	19/05/2011	01/09/2011	105	390	218
52089	1st winter	M ^m	2011	NorthStar	9,5	Solar	No	Harness	Svalbard	Framstredet	At sea	80.9	20.06667	15/04/2011	21/04/2011	6	185	108
52090	1st winter	M ^m	2011	NorthStar	9,5	Solar	No	Harness	Svalbard	Framstredet	At sea	80.9	20.06667	15/04/2011	22/04/2011	7	805	594
52092	1st winter	M ^d	2011	NorthStar	9,5	Solar	No	Harness	Svalbard	Framstredet	At sea	80.9	20.06667	15/04/2011	21/05/2011	36	3461	616
52055	Adult	M ^m	2011	NorthStar	9,5	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	04/07/2011	15/08/2012	408	2044	348
52056	Adult	F ^d	2011	NorthStar	9,5	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	04/07/2011	04/10/2013	823	5818	1213
52058	Adult	M ^d	2011	NorthStar	9,5	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	04/07/2011	10/04/2013	646	4003	858
52470	Adult	M ^d	2011	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	04/07/2011	02/09/2011	60	3534	341
52473	Adult	M ^d	2011	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	04/07/2011	24/01/2012	204	5504	2762
108702	Adult	M ^d	2011	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	04/07/2011	20/07/2011	16	1946	2
108703	Adult	M ^d	2011	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	04/07/2011	20/09/2011	78	4249	856
108704	Adult	M ^d	2011	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	04/07/2011	08/09/2011	66	4257	640
52059	Adult	M ^d	2011	NorthStar	9,5	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	11/07/2011	10/04/2013	639	2871	663

Table S1 (continued). Individual details for the 104 ivory gulls monitored in this study

Argos ID	Age	Sex ¹	Deployment year	Manufact.	PTT weight (g)	Power	Duty cycle	Attachement	Country	Region	Colony	Latitude	Longitude	Deployment date	Last position	Monitoring duration	Total Nb locations	Used locations (see methods)
113916	Adult	M ^d	2012	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Hübnerbreen	78.40583	21.68306	15/07/2012	22/07/2012	7	186	0
113917	Adult	M ^d	2012	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	16/07/2012	21/07/2012	5	24	1
113918	Adult	M ⁿ	2012	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	16/07/2012	29/07/2012	13	1607	349
113928	Adult	M ^d	2012	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	16/07/2012	20/07/2012	4	1178	1
113929	Adult	M ^d	2012	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	16/07/2012	08/08/2012	23	1891	1580
113919	Adult	M ^d	2012	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	17/07/2012	02/09/2013	412	7077	2235
113920	Adult	M ^d	2012	NorthStar	12	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	17/07/2012	16/09/2013	426	2244	625
113926	Adult	M ⁿ	2012	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	17/07/2012	25/02/2013	223	6319	3974
113927	Adult	M ^d	2012	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	17/07/2012	30/01/2013	197	3184	148
113930	Adult	M ^d	2012	Microwave	18	Solar	No	Harness	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	17/07/2012	11/04/2013	268	7342	2794
129645	Adult	M ^d	2013	NorthStar	10/11	Solar	No	Leg-loop	Svalbard	Barentsøya	Hübnerbreen	78.40583	21.68306	14/07/2013	09/11/2013	118	294	75
129652	Adult	M ^d	2013	Microwave	18	Solar	No	Leg-loop	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	14/07/2013	17/11/2013	126	3452	1970
129656	Adult	F ^d	2013	Microwave	18	Solar	No	Leg-loop	Svalbard	Barentsøya	Hübnerbreen	78.40583	21.68306	14/07/2013	25/10/2013	103	2683	1185
129642	Adult	M ^d	2013	NorthStar	10/11	Solar	No	Leg-loop	Svalbard	Barentsøya	Auga	78.51389	21.75433	16/07/2013	18/11/2013	125	1380	158
129653	Adult	M ^d	2013	Microwave	18	Solar	No	Leg-loop	Svalbard	Barentsøya	Hübnerbreen	78.40583	21.68306	16/07/2013	02/08/2013	17	1249	17
129643	Adult	M ^d	2013	NorthStar	10/11	Solar	No	Leg-loop	Svalbard	Barentsøya	Hübnerbreen	78.40583	21.68306	17/07/2013	18/09/2013	63	258	63
129644	Adult	M ^d	2013	NorthStar	10/11	Solar	No	Leg-loop	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	17/07/2013	08/11/2013	114	459	105
129654	Adult	M ^d	2013	Microwave	18	Solar	No	Leg-loop	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	17/07/2013	02/11/2013	108	4707	2682
129646	Adult	M ^d	2013	NorthStar	10/11	Solar	No	Leg-loop	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	18/07/2013	09/10/2013	83	863	206
129655	Adult	M ^d	2013	Microwave	18	Solar	No	Leg-loop	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	18/07/2013	10/08/2013	23	1298	671
52101	Adult	M ^d	2013	Microwave	18	Solar	No	Leg-loop	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	21/07/2013	25/10/2013	96	1012	335
52099	Adult	F ^d	2013	Microwave	18	Solar	No	Leg-loop	Svalbard	Barentsøya	Freemanbreen	78.58236	12.58194	26/07/2013	01/09/2013	37	126	8
Total:																23730	268772	78254

¹sexing from morphometrics (m) or DNA (d) ; see Yannic et al (2016)

²last position used in this study but later positions collected for this individual

Table S2. Geographical limits (in degrees) of the nine regions used to produce Figure 1d.

Regions	Lat. 1 (SW corner)	Long. 1 (SW corner)	Lat. 2 (NE corner)	Long. 2 (NE corner)
Region 1	55	45	67	-25
Region 2	67	-45	86	0
Region 3	67	0	86	70
Region 4	67	70	86	150
Region 5	67	150	86	-130
Region 6	55	170	67	-150
Region 7	67	-130	86	-80
Region 8	67	-80	86	-45
Region 9	45	-80	67	-45

Table S3. Results of linear mixed-effect model performed to compare monthly means of *d2edge*, *d2ice* and *d2water* presented on Figure 2a; obtained using the “*lmer*” function in R with individual identity and year as random effects.

Canada (CAN):

d2edge/d2ice	estimate	SE	z.ratio	p.value	
January	26.03780488	4.333918	6.007913e+00	<.0001	higher
February	8.41105263	2.847153	2.954197e+00	0.0031	higher
March	7.58810496	2.321300	3.268904e+00	0.0011	higher
April	16.37867884	2.227786	7.351999e+00	<.0001	higher
May	49.98746452	2.090792	2.390839e+01	<.0001	higher
June	200.10050302	3.049089	6.562633e+01	<.0001	higher
July	196.97910714	2.345355	8.398690e+01	<.0001	higher
August	72.40988185	2.227786	3.250307e+01	<.0001	higher
September	11.69245130	2.738785	4.269211e+00	<.0001	higher
October	-16.06642229	3.681045	-4.364637e+00	<.0001	lower
November	-69.96415094	9.337064	-7.493164e+00	<.0001	lower
December	3.84065934	10.077263	3.811213e-01	0.7031	ns
d2edge/d2water	estimate	SE	z.ratio	p.value	
January	-16.98617886	4.333918	-3.919358e+00	0.0001	lower
February	-11.01245614	2.847153	-3.867883e+00	0.0001	lower
March	-10.34839650	2.321300	-4.458018e+00	<.0001	lower
April	-14.32400644	2.227786	-6.429705e+00	<.0001	lower
May	-29.96017029	2.090792	-1.432958e+01	<.0001	lower
June	-63.18782696	3.049089	-2.072351e+01	<.0001	lower
July	-89.35875000	2.345355	-3.810031e+01	<.0001	lower
August	-31.42626208	2.227786	-1.410650e+01	<.0001	lower
September	-10.81866883	2.738785	-3.950171e+00	0.0001	lower
October	-2.22917889	3.681045	-6.055832e-01	0.5448	ns
November	86.47547170	9.337064	9.261527e+00	<.0001	higher
December	-3.07692308	10.077263	-3.053332e-01	0.7601	ns
d2ice/d2water	estimate	SE	z.ratio	p.value	
January	-43.02398374	4.333918	-9.927272e+00	<.0001	lower
February	-19.42350877	2.847153	-6.822081e+00	<.0001	lower
March	-17.93650146	2.321300	-7.726922e+00	<.0001	lower
April	-30.70268528	2.227786	-1.378170e+01	<.0001	lower
May	-79.94763482	2.090792	-3.823797e+01	<.0001	lower
June	-263.28832998	3.049089	-8.634984e+01	<.0001	lower
July	-286.33785714	2.345355	-1.220872e+02	<.0001	lower
August	-103.83614393	2.227786	-4.660957e+01	<.0001	lower
September	-22.51112013	2.738785	-8.219382e+00	<.0001	lower
October	13.83724340	3.681045	3.759053e+00	0.0002	higher
November	156.43962264	9.337064	1.675469e+01	<.0001	higher
December	-6.91758242	10.077263	-6.864545e-01	0.4924	ns

Table S3 (continued).

Greenland (GRL):

d2edge/d2ice	estimate	SE	z.ratio	p.value	
January	19.4826087	5.808143	3.354361e+00	0.0008	higher
February	19.4172619	4.298101	4.517638e+00	<.0001	higher
March	3.3935197	2.808399	1.208347e+00	0.2269	ns
April	10.9580049	1.955029	5.605034e+00	<.0001	higher
May	68.0773712	1.522443	4.471589e+01	<.0001	higher
June	66.1662579	1.678949	3.940933e+01	<.0001	higher
July	118.3694572	1.027705	1.151785e+02	<.0001	higher
August	95.2255885	1.089941	8.736764e+01	<.0001	higher
September	49.2030224	1.420308	3.464251e+01	<.0001	higher
October	-17.4513966	4.163942	-4.191076e+00	<.0001	lower
November	-19.1762821	6.307887	-3.040048e+00	0.0024	lower
December	-10.7130952	8.596201	-1.246259e+00	0.2127	ns
d2edge/d2water					
d2edge/d2water	estimate	SE	z.ratio	p.value	
January	-8.4565217	5.808143	-1.455977e+00	0.1454	ns
February	-8.6883929	4.298101	-2.021449e+00	0.0432	lower
March	-7.3237611	2.808399	-2.607806e+00	0.0091	lower
April	-5.6105296	1.955029	-2.869794e+00	0.0041	lower
May	-29.5134802	1.522443	-1.938561e+01	<.0001	lower
June	-27.9199818	1.678949	-1.662944e+01	<.0001	lower
July	-27.4328739	1.027705	-2.669334e+01	<.0001	lower
August	-17.0816651	1.089941	-1.567210e+01	<.0001	lower
September	-15.5090348	1.420308	-1.091949e+01	<.0001	lower
October	16.4248603	4.163942	3.944546e+00	0.0001	higher
November	71.1025641	6.307887	1.127201e+01	<.0001	higher
December	29.0119048	8.596201	3.374968e+00	0.0007	higher
d2ice/d2water					
d2ice/d2water	estimate	SE	z.ratio	p.value	
January	-27.9391304	5.808143	-4.810338e+00	<.0001	lower
February	-28.1056548	4.298101	-6.539087e+00	<.0001	lower
March	-10.7172808	2.808399	-3.816153e+00	0.0001	lower
April	-16.5685345	1.955029	-8.474828e+00	<.0001	lower
May	-97.5908514	1.522443	-6.410150e+01	<.0001	lower
June	-94.0862398	1.678949	-5.603876e+01	<.0001	lower
July	-145.8023311	1.027705	-1.418718e+02	<.0001	lower
August	-112.3072536	1.089941	-1.030397e+02	<.0001	lower
September	-64.7120572	1.420308	-4.556200e+01	<.0001	lower
October	33.8762570	4.163942	8.135621e+00	<.0001	higher
November	90.2788462	6.307887	1.431206e+01	<.0001	higher
December	39.7250000	8.596201	4.621227e+00	<.0001	higher

Table S3 (continued).

Svalbard (SVA):

d2edge/d2ice	estimate	SE	z.ratio	p.value	
January	12.50141643	4.1739327	2.995117e+00	0.0027	higher
February	5.11377551	2.2868050	2.236210e+00	0.0253	higher
March	5.09828571	1.7873822	2.852376e+00	0.0043	higher
April	53.51959799	1.4857380	3.602223e+01	<.0001	higher
May	52.44257675	1.7592755	2.980919e+01	<.0001	higher
June	58.57926899	1.8740869	3.125750e+01	<.0001	higher
July	17.15939017	0.9658823	1.776551e+01	<.0001	higher
August	61.09120898	0.5904003	1.034742e+02	<.0001	higher
September	38.70891550	1.1678651	3.314502e+01	<.0001	higher
October	23.86289683	3.4931523	6.831336e+00	<.0001	higher
November	-1.62727273	4.9302908	-3.300561e-01	0.7414	ns
December	3.84065934	10.077263	3.811213e-01	0.7031	ns
d2edge/d2water	estimate	SE	z.ratio	p.value	
January	-16.86997167	4.1739327	-4.041745e+00	0.0001	lower
February	-4.62363946	2.2868050	-2.021877e+00	0.0432	lower
March	-0.18431169	1.7873822	-1.031182e-01	0.9179	ns
April	-14.80272793	1.4857380	-9.963215e+00	<.0001	lower
May	-29.79396074	1.7592755	-1.693536e+01	<.0001	lower
June	-23.43398058	1.8740869	-1.250421e+01	<.0001	lower
July	4.78853155	0.9658823	4.957676e+00	<.0001	higher
August	-23.95684407	0.5904003	-4.057729e+01	<.0001	lower
September	-33.35289421	1.1678651	-2.855886e+01	<.0001	lower
October	-19.41686508	3.4931523	-5.558551e+00	<.0001	ns
November	0.13280632	4.9302908	2.693681e-02	0.9785	ns
December	0.14166667	7.1588320	1.978908e-02	0.9842	ns
d2ice/d2water	estimate	SE	z.ratio	p.value	
January	-29.37138810	4.1739327	-7.036862e+00	<.0001	lower
February	-9.73741497	2.2868050	-4.258087e+00	<.0001	lower
March	-5.28259740	1.7873822	-2.955494e+00	0.0031	lower
April	-68.32232592	1.4857380	-4.598545e+01	<.0001	lower
May	-82.23653749	1.7592755	-4.674455e+01	<.0001	lower
June	-82.01324957	1.8740869	-4.376171e+01	<.0001	lower
July	-12.37085862	0.9658823	-1.280783e+01	<.0001	lower
August	-85.04805305	0.5904003	-1.440515e+02	<.0001	lower
September	-72.06180971	1.1678651	-6.170388e+01	<.0001	lower
October	-43.27976190	3.4931523	-1.238989e+01	<.0001	lower
November	1.76007905	4.9302908	3.569930e-01	0.7211	ns
December	12.91083333	7.1588320	1.803483e+00	0.0713	ns

Table S4. Results of linear mixed-effect models performed to compare monthly means of *IC3x3* and *IC50* presented on Figure 2b ; obtained using the “*lmer*” function in R with individual identity and year as random effects.

CAN	estimate	SE	z.ratio	p.value	
January	0.09878049	1.5262799	0.06471977	0.9484	ns
February	-0.05315789	1.0026845	-0.05301557	0.9577	ns
March	0.30064140	0.8174942	0.36775968	0.7131	ns
April	-0.94301826	0.7845613	-1.20196883	0.2294	ns
May	5.31395459	0.7363160	7.21694832	<.0001	higher
June	2.56378270	1.0738004	2.38757856	0.0170	higher
July	1.27619048	0.8259659	1.54508866	0.1223	ns
August	2.49156821	0.7845613	3.17574691	0.0015	higher
September	-0.19448052	0.9645203	-0.20163445	0.8402	ns
October	-2.43636364	1.2963568	-1.87939281	0.0602	ns
November	1.99150943	3.2882422	0.60564560	0.5448	ns
December	2.57032967	3.5489186	0.72425715	0.4689	ns
GRL	estimate	SE	z.ratio	p.value	
January	2.27010870	2.2206441	1.02227490	0.3067	ns
February	0.73898810	1.6433052	0.44969620	0.6529	ns
March	-6.18437103	1.0737434	-5.75963602	<.0001	lower
April	-2.79532020	0.7474719	-3.73969954	0.0002	lower
May	3.31082898	0.5820799	5.68792904	<.0001	higher
June	2.51171662	0.6419175	3.91283408	0.0001	higher
July	1.63882933	0.3929253	4.17084173	<.0001	higher
August	2.49324402	0.4167204	5.98301469	<.0001	higher
September	4.89489763	0.5430304	9.01404034	<.0001	higher
October	-0.83212291	1.5920121	-0.52268631	0.6012	ns
November	1.31089744	2.4117127	0.54355457	0.5867	ns
December	-1.04642857	3.2866104	-0.31839143	0.7502	ns
SVA	estimate	SE	z.ratio	p.value	
January	4.7957507	1.8454595	2.59867569	0.0094	higher
February	-1.0297619	1.0110863	-1.01847087	0.3085	ns
March	-3.3548052	0.7902718	-4.24512815	<.0001	lower
April	2.3755922	0.6569031	3.61635108	0.0003	higher
May	4.5945143	0.7778448	5.90672397	<.0001	higher
June	3.7537407	0.8286074	4.53018018	<.0001	higher
July	3.7153519	0.4270545	8.69994865	<.0001	higher
August	2.9737233	0.2610392	11.39186690	<.0001	higher
September	4.3380129	0.5163590	8.40115667	<.0001	higher
October	0.8255952	1.5444598	0.53455276	0.5930	ns
November	-2.0881423	2.1798751	-0.95791832	0.3381	ns
December	-0.8225000	3.1652006	-0.25985714	0.7950	ns

Table S5. Distribution of the 123.787 Ivory gull positions (location classes: A123) used in this study according to the month of the year and origin of the birds.

Month	CAN	GRL	NO	RU	Total
1	618	224	487	72	1401
2	1239	342	1230	44	2855
3	1733	798	2168	27	4726
4	1865	1673	3088	21	6647
5	2329	2730	3275	137	8471
6	2933	3434	3672	207	10246
7	4934	11760	18565	505	35764
8	4176	9617	22672	1202	37667
9	2912	3145	4713	988	11758
10	1136	471	542	541	2690
11	149	180	366	265	960
12	110	118	181	193	602
Total	24134	34492	60959	4202	123787

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