

Supplementary material

Table S1. Seabird breeding colonies where GLS loggers have been deployed as part of the SEATRACK project 2014–2020. BRGU = Brünnich’s guillemot, COGU = common guillemot, ATPU = Atlantic puffin, BLKI = black-legged kittiwake, GLGU = glaucous gull, COEI = common eider, NOFU = northern fulmar, EUSH = European shag, LIAU = little auk, HEGU = herring gull, LBBG = Lesser black-backed gull.

Country	Region	Colony name	Longitude	Latitude	Species	Responsible scientist(s)
Canada	Newfoundland and Labrador	Funk Island	-53.18	49.76	COGU	William Montevecchi
Canada	Newfoundland and Labrador	Witless Bay	-52.78	47.24	ATPU, BLKI, COGU	April Hedd
Canada	Nunavut	Coats Island	-82.02	62.48	BRGU, GLGU	Grant Gilchrist, Kyle Elliott
Canada	Nunavut	Prince Leopold Island ¹	-90.07	74.03	BLKI, BRGU	Mark Mallory
Faroe Islands	Faroe Islands		-6.80	61.95	ATPU, BLKI, COEI, COGU, NOFU, LBBG	Bergur Olsen, Johannes Danielsen
Great Britain	Fife	Isle of May	-2.56	56.19	ATPU, BLKI, COGU, EUSH	Francis Daunt
Great Britain	Hebrides	Isle of Canna	-6.53	57.07	BLKI, COGU ² , NOFU	Robert Swann
Great Britain	Hebrides	Treshnish Isles	-6.40	56.50	ATPU, COGU ²	Robin Ward
Great Britain	Orkney	Eynhallow	-3.11	59.14	NOFU	Paul Thompson
Great Britain	Shetland	Fair Isle	-1.65	59.51	ATPU, COGU ²	Mark Bolton
Greenland	North Greenland	Qaanaaq ¹	-69.23	77.47	BLKI, BRGU, LIAU ²	Anders Mosbech
Greenland	North-east Greenland	Kap Höegh	-21.55	70.72	LIAU	David Gremillet, Jerome Fort
Greenland	North-west Greenland	Kippaku	-56.66	73.72	BLKI, BRGU	Flemming Ravn Merkel, Morten Frederiksen
Greenland	South-west Greenland	Sermilinnuaq	-52.90	65.42	BLKI, BRGU	Aili Lage Labansen, Flemming Ravn Merkel
Iceland	Eastern Region	Papey	-14.17	64.59	ATPU	Erpur Snær Hansen
Iceland	Northeastern Region	Langanes and Skjalfandi	-15.99	66.18	BLKI, BRGU, COGU, NOFU	Thorkell Lindberg Thorarinsson
Iceland	Northeastern Region	Grimsey	-17.99	66.53	ATPU, BRGU	Erpur Snær Hansen, Thorkell Lindberg Thorarinsson
Iceland	Northeastern Region	Eyjafjörður	-18.13	65.71	HEGU, LBGU	Gunnar Thor Hallgrímsson, Sunna Björk Ragnarsdóttir
Iceland	Southern Peninsula	Reykjanes	-22.22	63.97	HEGU, LBGU	Gunnar Thor Hallgrímsson, Sunna Björk Ragnarsdóttir
Iceland	Southern Region	Vestmannaeyjar	-20.28	63.44	ATPU	Erpur Snær Hansen

Country	Region	Colony name	Longitude	Latitude	Species	Responsible scientist(s)
Iceland	Western Region	Breidafjordur	-22.74	65.08	COEI	Jón Einar Jónsson
Iceland	Western Region	Melrakkaey	-23.37	65.00	EUSH, GLGU	Gunnar Thor Hallgrímsson, Sunna Björk Ragnarsdóttir
Iceland	Westfjords	Latrabjarg	-24.47	65.48	BRGU, COGU	Thorkell Lindberg Thorarínsson
Ireland	East Ireland	Little Saltee	-6.62	52.13	ATPU, NOFU	Mark Jessopp
Ireland	East Ireland	Rockabill	-6.00	53.60	BLKI	Stephen Newton
Ireland	South Ireland	Skellig Michael	-10.54	51.77	ATPU	Mark Jessopp
Ireland	West Ireland	Donegal Bay	-8.50	54.53	BLKI	Kendrew Colhoun
Ireland	West Ireland	Inishmurray	-8.66	54.533	NOFU	Kendrew Colhoun
Ireland	West Ireland	Inishkea Islands	-10.20	54.13	NOFU	Mark Jessopp
Norway	Agder	Mandal and Lindesnes	7.37	58.01	COEI, HEGU, LBGU	Morten Helberg, Runar Jåbekk
Norway	Jan Mayen		-8.72	70.92	BRGU, COGU, NOFU	Hallvard Strøm
Norway	Møre og Romsdal	Runde and Aalesund	5.87	62.44	ATPU, BLKI	Ingar Støyle Bringsvør, Signe Christensen-Dalsgaard
Norway	Nordland	Anda	15.17	69.07	ATPU, BLKI, HEGU	Signe Christensen-Dalsgaard, Magdalene Langset
Norway	Nordland	Selvaer	12.23	66.59	COEI	Thomas Holm Carlsen
Norway	Nordland	Horsvaer	11.63	65.32	LBGU	Jan Ove Bustnes
Norway	Nordland	Rost	11.91	67.45	ATPU, BLKI, EUSH	Tycho Anker-Nilssen
Norway	Rogaland	Jarsteinen	5.17	59.15	EUSH, NOFU	Arne Follestad, Oskar Bjørnstad
Norway	Svalbard	Alkefjellet	18.46	79.59	BLKI, BRGU, NOFU	Sebastien Descamps
Norway	Svalbard	Isfjorden	15.51	78.25	ATPU, BLKI, BRGU, LIAU	Sebastien Descamps
Norway	Svalbard	Kongsfjorden	12.22	78.90	BRGU, COEI, GLGU, LIAU, BLKI	Børge Moe, Olivier Chastel, Sebastien Descamps, Kjetil Sagerup, Geir Wing Gabrielsen
Norway	Svalbard	Hornsund	15.55	77.00	LIAU	Katarzyna Wojczulanis-Jakubas
Norway	Svalbard	Bjørnøya	18.96	74.50	ATPU, BLKI, BRGU, COGU, GLGU, LIAU, NOFU	Hallvard Strøm
Norway	Troms og Finnmark	Hornøya	31.15	70.38	ATPU, BLKI, COGU, EUSH, HEGU	Kjell Einar Erikstad, Tone Reiertsen
Norway	Troms og Finnmark	Grindøya	18.85	69.64	COEI	Sveinn Are Hanssen
Norway	Troms og Finnmark	Lemmingsvaer	16.91	69.03	LBGU	Jan Ove Bustnes
Norway	Troms og Finnmark	Hjelmsøya	24.73	71.11	ATPU, BLKI, COEI, COGU, EUSH, HEGU	Geir Helge Systad
Norway	Troms og Finnmark	Loppa	21.40	70.36	LBGU	Morten Helberg
Norway	Trøndelag	Sklinna	11.00	65.20	ATPU, BLKI, COEI, COGU, EUSH, HEGU	Nina Dehnhard, Svein-Håkon Lorentsen
Norway	Vestland	Lyngøy	4.75	60.67	HEGU	Morten Helberg, Arild Breistøl
Russia	Franz Josef Land	Cape Flora/Hooker Isl.	51.47	80.14	BKLI, BRGU, GLGU, LIAU	Maria Gavrilov

Country	Region	Colony name	Longitude	Latitude	Species	Responsible scientist(s)
Russia	Murman Coast	Seven Islands	37.57	68.75	ATPU, EUSH	Ekaterina Tolmacheva
Russia	Murman Coast	Cape Krutik	35.95	69.15	BLKI	Alexey Ezhov
Russia	Murman Coast	Cape Gorodetskiy	32.94	69.58	BRGU, COGU	Alexey Ezhov
Russia	Novaya Zemlya	Kara Gate	55.02	70.59	BLKI, BRGU	Alexey Ezhov
Russia	Novaya Zemlya	Oranskie Islands	67.64	77.07	BRGU	Maria Gavriilo, Ivan Mizin
Russia	Novaya Zemlya	Russkaya Gavan ¹	62.58	76.20	BLKI	Alexey Ezhov
Russia	White Sea	Solovetsky archipelago	35.79	65.05	COEI, HEGU, LBGU	Grigori Tertitski

¹Deployment postponed due to the Covid-19 pandemic

²In collaboration with other projects

Table S2. Importance of the non-breeding season in driving North Atlantic seabird demography. Only studies focusing specifically on seabird non-breeding distribution have been considered (i.e. studies that have linked large-scale climate indices for example with survival without specifically considering their winter distribution were not considered in this review). Within each theme, studies are ordered by species and publication date. “ns” and “s” indicate non-significant and significant effect, respectively. “+” and “-” represent the sign of the effect (when significant). All studies addressing survival rates have used modelling of capture-mark-recapture (CMR) data. In the list of parameters tested, δ = Southern Oscillation and SST = sea surface temperature. The review was performed in November 2020 using Google scholar and key words “seabird”, “migration”, “Atlantic”, “survival”, “reproduction”, “carry-over” and/or “demography”.

Species	Colony/Country	Life-history trait	Parameter tested	Sign of the observed effect	Method to assess non-breeding distribution or activity	Reference
Link between survival and winter environmental conditions						
Atlantic puffin	Hornøya/Norway	Survival	Extratropical cyclones	+	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Isle of May/UK	Survival	Extratropical cyclones	+	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Runde/Norway	Survival	Extratropical cyclones	-	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Røst/Norway	Survival	Extratropical cyclones	-	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Anda/Norway	Survival	Extratropical cyclones	+	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Hornøya/Norway	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Isle of May/UK	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Runde/Norway	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS

Atlantic puffin	Røst/Norway	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Anda/Norway	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Black-legged kittiwake	Hornøya/Norway	Survival	Prey availability	+	GLS and PTT	Reiertsen et al. (2021), this TS
Brünnich's guillemot	Svalbard/Norway	Survival	Subpolar gyre (SGI), winter NAO (wNAO) and SST	+ (wNAO and SGI), ns (SST)	GLS ¹	Fluhr et al. (2017)
Common eider	East Bay/Canada	Survival	Extratropical cyclones	-	PTT	Guéry et al. (2019)
Common eider	Grindøya/Norway	Survival	Extratropical cyclones	-	GLS	Guéry et al. (2019)
Common eider	Svalbard/Norway	Survival	Extratropical cyclones	-	GLS	Guéry et al. (2019)
Common guillemot	Skomer Island/UK	Survival	NAO, SST	- (NAO), ns (SST)	Band recoveries	Votier et al. (2005)
Common guillemot	Skomer Island/UK	Survival	SST	- (weak effect on juvenile survival)	Band recoveries	Votier et al. (2008)
Common guillemot	Skomer Island	Recruitment	SST	- (weak effect)	Band recoveries	Votier et al. (2008)
Common tern	Banter See/Germany	Survival	Primary productivity (PP), spring NAO, winter SOI, winter fish abundance	+ (for the PP; effect on subadults only), ns (for the others)	GLS ¹ and band recoveries	Szostek & Becker (2015)

Common tern	Banter See/Germany	Recruitment	Primary productivity (PP), spring NAO, winter SOI, winter fish abundance	+ (for the PP), ns (for the others)	GLS ¹ and band recoveries	Szostek & Becker (2015)
Cory's shearwater	Balearic and Chafarinas Archipelago/Spain	Survival	SOI, NAO, hurricanes	- (SOI), ns (NAO, hurricanes)	GLS ¹	Genovart et al. (2013)
Cory's shearwater	Selvagem Grande/Portugal	Survival	SOI and SST	- (for both variables)	GLS	Ramos et al. (2012)
European storm petrel	Benidorm Island/Spain	Survival	Western Mediterranean Oscillation Index (wMOI), Winter HIX (St. Helena index), winter ENSO, winter SOI, winter Multivariate Enso Index, winter NAO	+ (for the wMOI), ns (for the others)	Band recoveries	Matović et al. (2017)
European storm petrel	Molene archipelago/France	Survival	Winter HIX (wHIX, St. Helena index), winter ENSO (wENSO), winter SOI, winter Multivariate Enso Index, winter NAO	- (for wHIX and wENSO), ns (for the others)	Band resightings and recoveries	Matović et al. (2017)
Sabine's gull	Nasaruvaalik Island/Canada	Survival	Tropical-Northern hemisphere	- (for the TNH), ns (for the others)	GLS	Fife et al. (2018)

Sooty tern	Dry Tortugas/USA	Survival ²	pattern (TNH), NAO, SOI Hurricanes and cumulative wind speed	- (for both variables)	GLS and PTT	Huang et al. (2017)
Variation in survival as a function of the migration strategy						
Atlantic puffin	Isle of May/UK	Survival	Winter distribution ³	ns	GLS	Harris et al. (2013)
Atlantic puffin	5 colonies (Norway and UK)	Survival	Synchrony ⁴	s		Reiertsen et al. (2021), this TS
Northern gannet	Bonaventure Island/Canada	Survival	Activity as a function of migration strategy	ns	GLS	Pelletier et al. (2020)
Northern gannet	Bassrock and Grassholm/UK	Survival	Sex effect (on winter distribution and survival)	s	GLS	Deakin et al. (2019)
Little auk	Svalbard/Norway	Survival	Synchrony ⁴	ns	GLS	Descamps et al. (2020), this TS
Variation in breeding parameters as a function of winter strategy						
Black-legged kittiwake	Multi-colony study	Breeding success	Non-breeding distribution	Ns	GLS	Bogdanova et al. (2017)
Great cormorant	Vorsø/Denmark	Timing of arrival	Migration distance	-	Band resightings	Bregnballe et al. (2006)
Great cormorant	Vorsø/Denmark	Fledging production	Migration distance	ns	Band resightings	Bregnballe et al. (2006)

Great cormorant	Vorsø/Denmark	Lifetime reproductive success	Migration distance	- (for males)	Band resightings	Bregnballe et al. (2006)
Little auk	Svalbard/Norway	Breeding phenology	Migration distance	ns	GLS	Dufour et al. (2021), this TS
Little auk	Hornsund	Breeding success	Migration distance	ns	GLS	Dufour et al. (2021), this TS
Atlantic puffin	Skomer Island/UK	Breeding phenology	Winter distribution	ns	GLS	Fayet et al. (2016a)
Atlantic puffin	Skomer Island	Breeding success	Migration strategy / winter area	s	GLS	Fayet et al. (2016a)
Manx shearwater	Skomer Island/UK	Breeding phenology	Winter activity and migration timing	s	GLS	Fayet et al. (2016a)
Manx shearwater	Skomer Island	Breeding success	Winter activity/migration timing	s	GLS	Fayet et al. (2016a)
Manx shearwater	Skomer Island	Egg/chick size	Winter activity/migration timing	s	GLS	Fayet et al. (2016b)
Atlantic puffin	multi-colony/North East Atlantic	Breeding success ⁵	Migration distance, wintering latitude	- (for both variables)	GLS	Fayet et al. (2017a)
Atlantic puffin	Skomer Island/UK	Breeding phenology	Similarity in partner migration route	-	GLS	Fayet et al. (2017b)
Atlantic puffin	Skomer Island	Breeding	Similarity in pair	+	GLS	Fayet et al. (2017b)

		success	migration route			
Atlantic puffin	Skomer Island	Breeding success	Winter foraging effort	-	GLS	Fayet et al. (2017b)
Northern gannet	Bonaventure Island/Canada	Breeding phenology ⁶	Activity (as a function of migration strategy)	Ns	GLS	Pelletier et al. (2020)
Northern gannet	Bonaventure Island	Breeding success	Activity as a function of migration strategy	ns	GLS	Pelletier et al. (2020)
Cory's shearwater	Selvagem Grande	Breeding success	CORT (in winter feathers)	+	GLS	Pérez et al. (2016)

¹: based on geolocator data from another study

²: survival estimated by CMR and using wreck data

³: comparison among years (changes in winter distribution associated with changes in mean survival)

⁴: test of the prediction that similar winter distribution should lead to synchronous survival inter-annual fluctuations

⁵: average productivity at the colony level

⁶: timing of arrival at the colony (not breeding phenology per se)

Species	Colony/Country	Life-history trait	Parameter tested	Sign of the observed effect	Method to assess non-breeding distribution or activity	Reference
Link between survival and winter environmental conditions						
Atlantic puffin	Hornøya/Norway	Survival	Extratropical cyclones	+	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Isle of May/UK	Survival	Extratropical cyclones	+	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Runde/Norway	Survival	Extratropical cyclones	-	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Røst/Norway	Survival	Extratropical cyclones	-	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Anda/Norway	Survival	Extratropical cyclones	+	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Hornøya/Norway	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Isle of May/UK	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Runde/Norway	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Røst/Norway	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Atlantic puffin	Anda/Norway	Survival	NAO	ns	GLS	Reiertsen et al. (2021), this TS
Black-legged kittiwake	Hornøya/Norway	Survival	Prey availability	+	GLS and PTT	Reiertsen et al. (2014)
Brünnich's	Svalbard/Norway	Survival	Subpolar gyre (SGI), winter NAO	+(wNAO and SGI),	GLS ¹	Fluhr et al. (2017)

guillemot			(wNAO) and SST	ns (SST)		
Common eider	East Bay/Canada	Survival	Extratropical cyclones	-	PTT	Guéry et al. (2019)
Common eider	Grindøya/Norway	Survival	Extratropical cyclones	-	GLS	Guéry et al. (2019)
Common eider	Svalbard/Norway	Survival	Extratropical cyclones	-	GLS	Guéry et al. (2019)
Common guillemot	Skomer Island/UK	Survival	NAO, SST	-(NAO), ns (SST)	Band recoveries	Votier et al. (2005)
Common guillemot	Skomer Island/UK	Survival	SST	-(weak effect on juvenile survival)	Band recoveries	Votier et al. (2008)
Common guillemot	Skomer Island	Recruitment	SST	-(weak effect)	Band recoveries	Votier et al. (2008)
Common tern	Banter See/Germany	Survival	Primary productivity (PP), spring NAO, winter SOI, winter fish abundance	+(for the PP; effect on subadults only), ns (for the others)	GLS ¹ and band recoveries	Szostek & Becker (2015)
Common tern	Banter See/Germany	Recruitment	Primary productivity (PP), spring NAO, winter SOI, winter fish abundance	+(for the PP), ns (for the others)	GLS ¹ and band recoveries	Szostek & Becker (2015)
Cory's shearwater	Balearic and Chafarinas	Survival	SOI, NAO, hurricanes	-(SOI), ns (NAO, hurricanes)	GLS ¹	Genovart et al. (2013)

	Archipelago/Spain					
Cory's shearwater	Selvagem Grande/Portugal	Survival	SOI and SST	- (for both variables)	GLS	Ramos et al. (2012)
European storm petrel	Benidorm Island/Spain	Survival	Western Mediterranean Oscillation Index (wMOI), Winter HIX (St. Helena index), w̄winter ENSO, winter SOI, winter Multivariate Enso Index, winter NAO	+ (for the wMOI), ns (for the others)	Band recoveries	Matović et al. (2017)
European storm petrel	Molene archipelago/France	Survival	Winter HIX (wHIX, St. Helena index), w̄winter ENSO (wENSO), winter SOI, winter Multivariate Enso Index, winter NAO	- (for wHIX and wENSO), ns (for the others)	Band resightings and recoveries	Matović et al. (2017)
Sabine's gull	Nasaruvaalik Island/Canada	Survival	Tropical-Northern hemisphere pattern (TNH), NAO, SOI	- (for the TNH), ns (for the others)	GLS	Fife et al. (2018)
Sooty tern	Dry Tortugas/USA	Survival ²	Hurricanes and cumulative wind speed	- (for both variables)	GLS and PTT	Huang et al. (2017)

Variation in survival as a function of the migration strategy

Atlantic puffin	Isle of May/UK	Survival	Winter distribution ³	ns	GLS	Harris et al. (2013)
Atlantic puffin	5 colonies (Norway and UK)	Survival	Synchrony ⁴	s		Reiertsen et al. (2021), this TS
Northern gannet	Bonaventure Island/Canada	Survival	Activity as a function of migration strategy	ns	GLS	Pelletier et al. (2020)
Northern gannet	Bassrock and Grassholm/UK	Survival	Sex effect (on winter distribution and survival)	s	GLS	Deakin et al. (2019)
Little auk	Svalbard/Norway	Survival	Synchrony ⁴	ns	GLS	Descamps et al. (2020), this TS

Variation in breeding parameters as a function of winter strategy

Black-legged kittiwake	Multi-colony study	Breeding success	Non-breeding distribution	Ns	GLS	Bogdanova et al. (2017)
Great cormorant	Vorsø/Denmark	Timing of arrival	Migration distance	-	Band resightings	Bregnballe et al. (2006)
Great cormorant	Vorsø/Denmark	Fledging production	Migration distance	ns	Band resightings	Bregnballe et al. (2006)
Great cormorant	Vorsø/Denmark	Lifetime reproductive success	Migration distance	-(for males)	Band resightings	Bregnballe et al. (2006)
Little auk	Svalbard/Norway	Breeding phenology	Migration distance	ns	GLS	Dufour et al. (2021), this TS
Little auk	Hornsund	Breeding	Migration distance	ns	GLS	Dufour et al. (2021),

		success				this TS
Atlantic puffin	Skomer Island/UK	Breeding phenology	Winter distribution	ns	GLS	Fayet et al. (2016a)
Atlantic puffin	Skomer Island	Breeding success	Migration strategy / winter area	s	GLS	Fayet et al. (2016a)
Manx shearwater	Skomer Island/UK	Breeding phenology	Winter activity and migration timing	s	GLS	Fayet et al. (2016b)
Manx shearwater	Skomer Island	Breeding success	Winter activity/migration timing	s	GLS	Fayet et al. (2016b)
Manx shearwater	Skomer Island	Egg/chick size	Winter activity/migration timing	s	GLS	Fayet et al. (2016b)
Atlantic puffin	multi-colony/North East Atlantic	Breeding success ⁵	Migration distance, wintering latitude	- (for both variables)	GLS	Fayet et al. (2017a)
Atlantic puffin	Skomer Island/UK	Breeding phenology	Similarity in partner migration route	-	GLS	Fayet et al. (2017b)
Atlantic puffin	Skomer Island	Breeding success	Similarity in pair migration route	+	GLS	Fayet et al. (2017b)
Atlantic puffin	Skomer Island	Breeding success	Winter foraging effort	-	GLS	Fayet et al. (2017b)
Northern gannet	Bonaventure Island/Canada	Breeding phenology ⁶	Activity (as a function of migration strategy)	Ns	GLS	Pelletier et al. (2020)

Northern gannet	Bonaventure Island	Breeding success	Activity as a function of migration strategy	ns	GLS	Pelletier et al. (2020)
Cory's shearwater	Selvagem Grande	Breeding success	CORT (in winter feathers)	+	GLS	Pérez et al. (2016)

¹: based on geolocator data from another study

²: survival estimated by CMR and using wreck data

³: comparison among years (changes in winter distribution associated with changes in mean survival)

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