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Contact UKCEH NORA team at
noraceh@ceh.ac.uk

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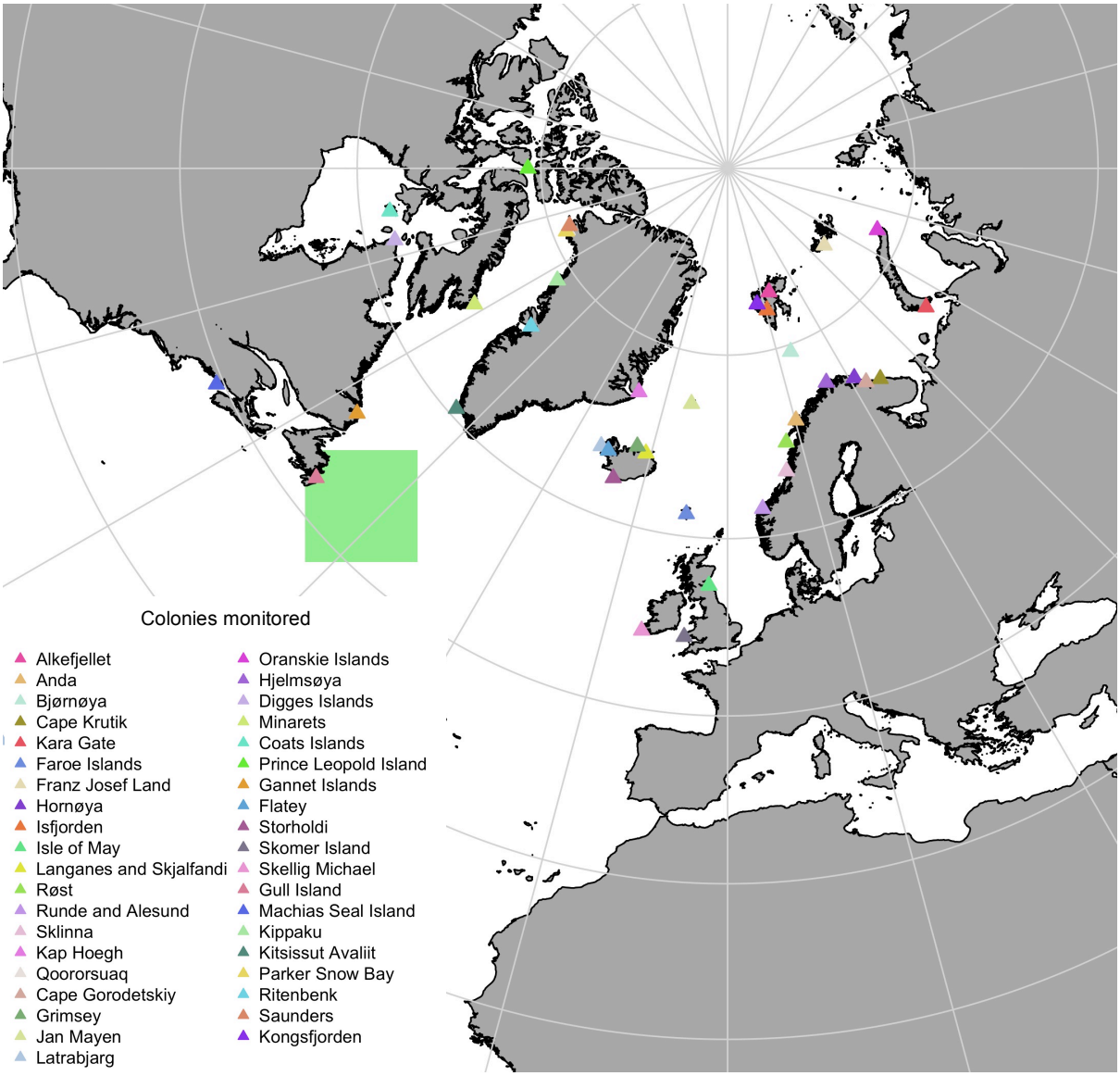

Figure S1. Colonies monitored within the North Atlantic Ocean and adjacent seas related to STAR Methods.

Graticules are set at a 15° intervals and the map is projected North Pole Lambert Azimuthal Equal Area. The 1000km*1000km area off North Newfoundland which was used to investigate the incidence of winter storms on seabird energetics is shown in green.

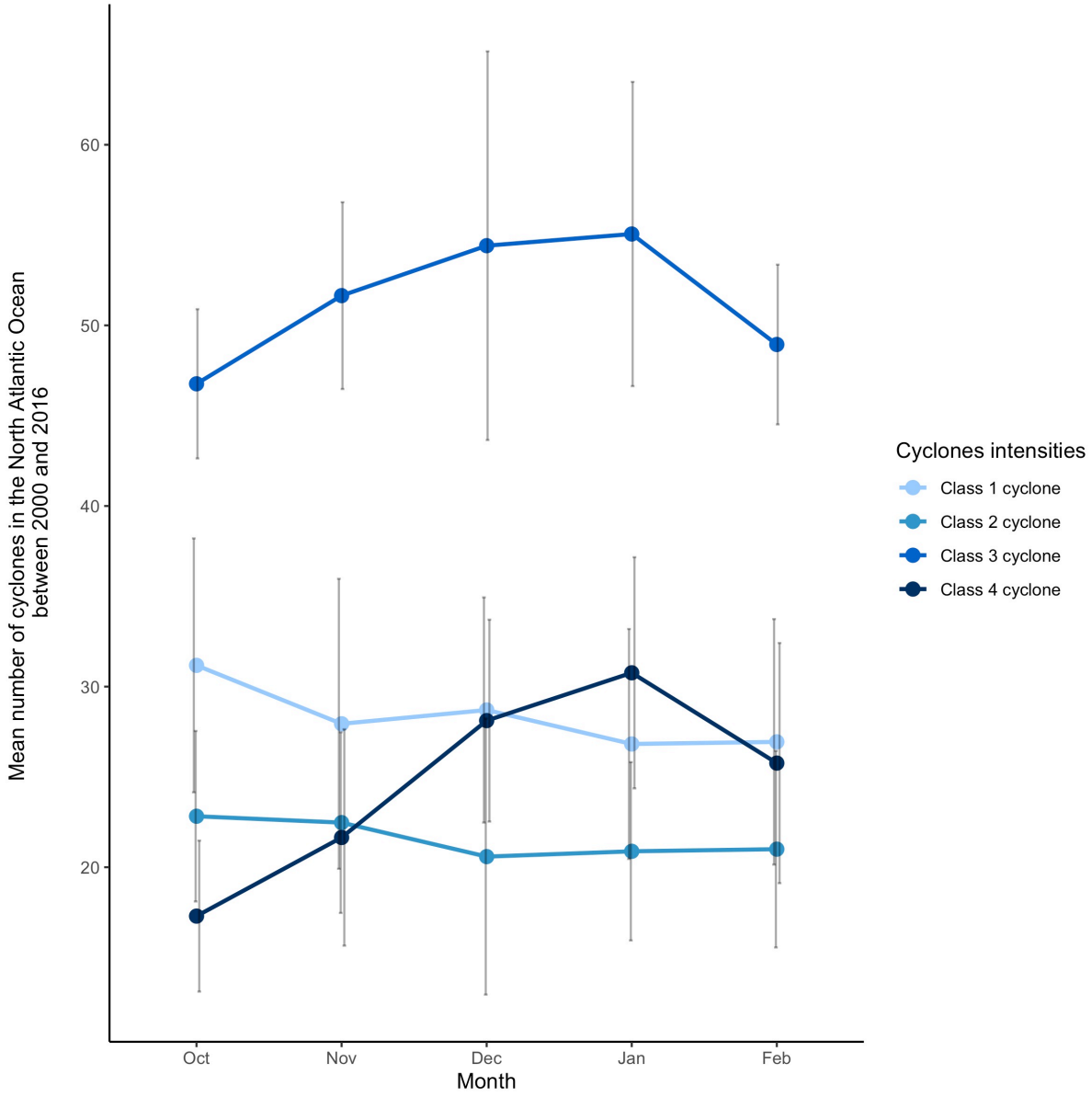

Figure S2. Mean number of cyclones in the North Atlantic Ocean and adjacent seas (100°W-100°E, 30°N-90°N), between 2000 and 2016 for each winter month related to STAR Methods.

Error bars correspond to standard deviations capturing the variation between years.

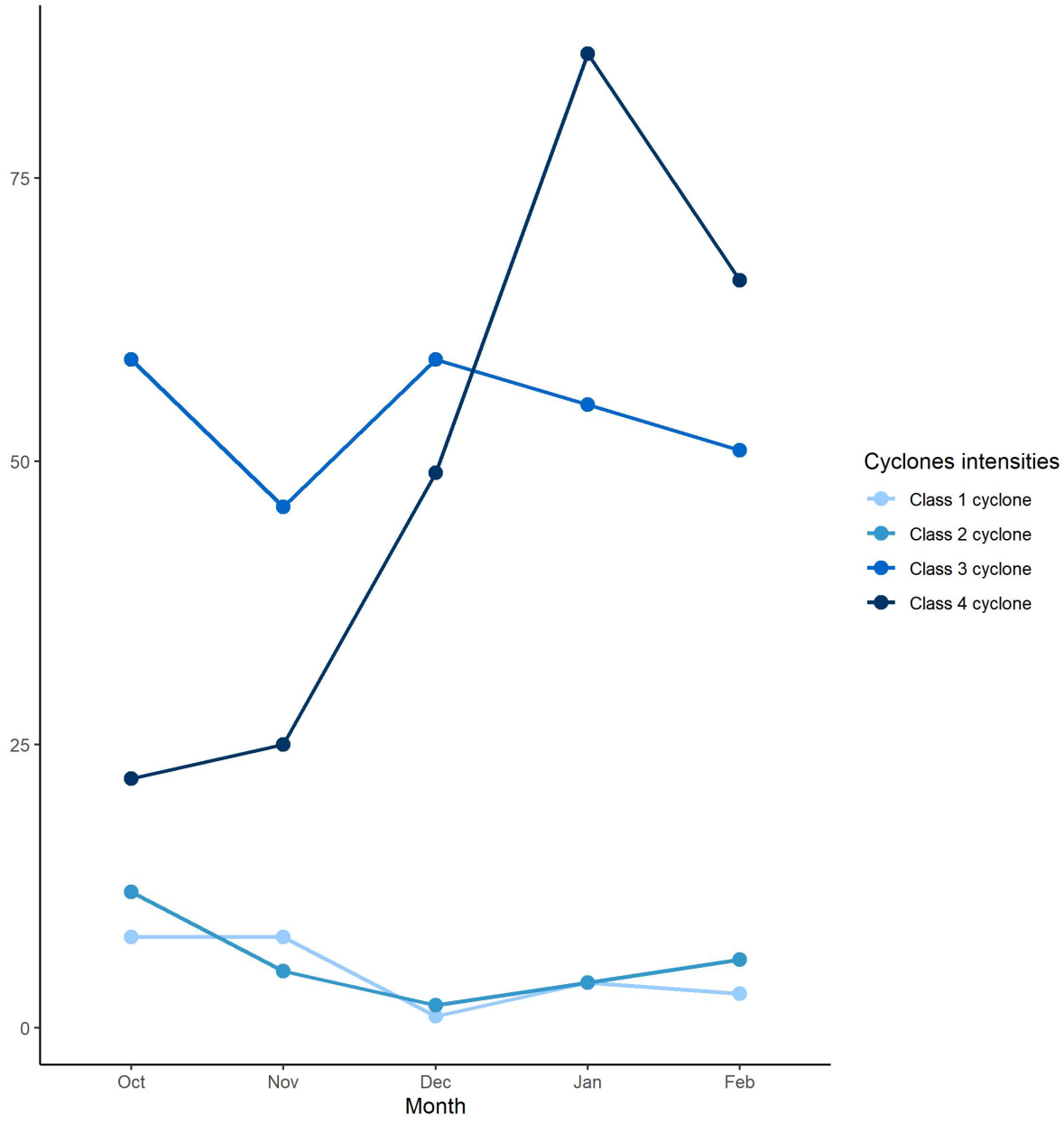

Figure S3. Total number of cyclone in the studied areas off Newfoundland between 2000 and 2016, for each winter month related to STAR Methods.

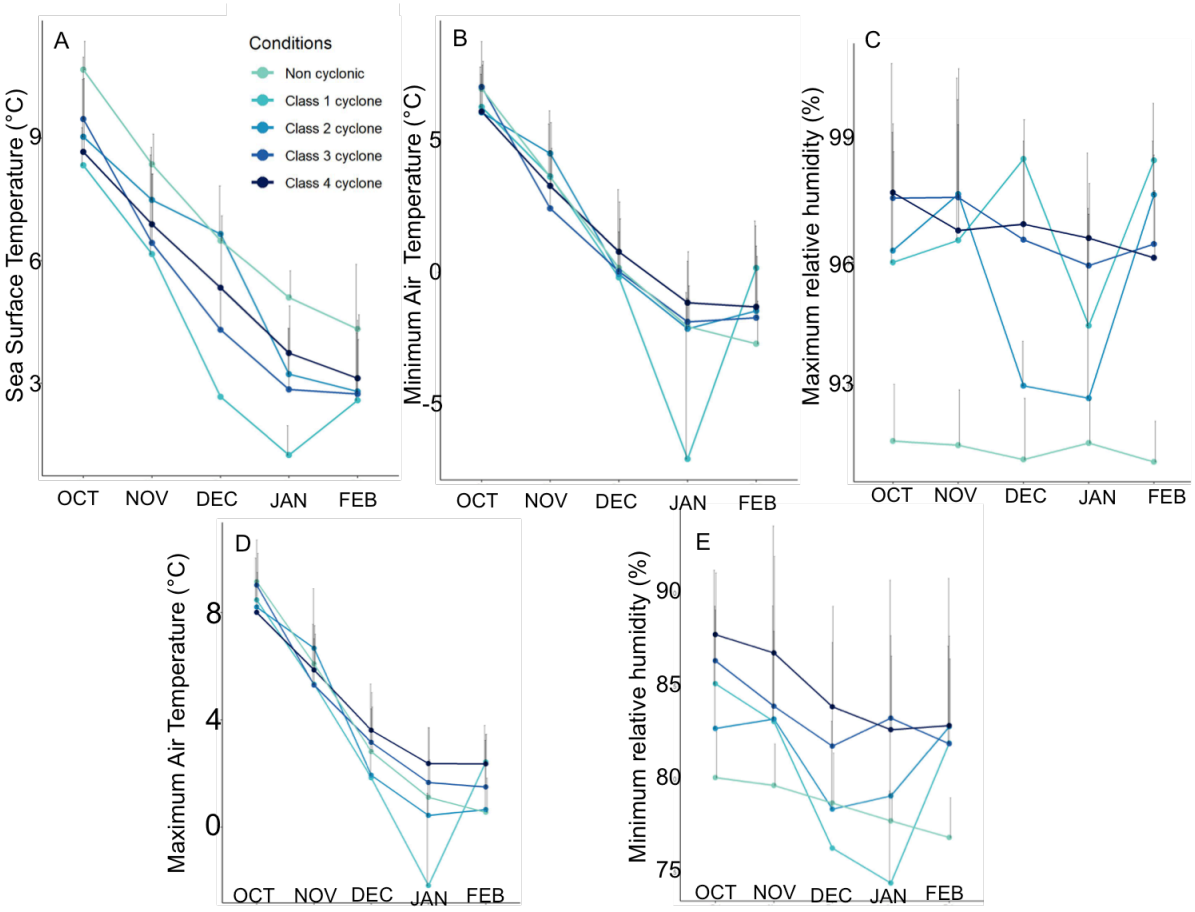

Figure S4. Mean environmental conditions under cyclonic and non-cyclonic conditions related to STAR Methods.

Average sea surface temperature (A), minimum air temperature (B), maximum relative humidity (C), maximum air temperature (D) and minimum relative humidity (E) between 200 and 2016 for each wintering month under cyclonic and non-cyclonic conditions in the studied area off Newfoundland. Error bars were halved for clarity reasons and correspond to standard deviations capturing the variation between years.

Little auks			
Colony	**Number of individuals equipped and retrieved**	**Years monitored**	**Software used**
Kap Hoegh (-21.63°E; 70.72°N)	135	2010-2018	BASTRACK and GEOLIGHT
Qoororsuaq (-68.95°E; 76.27°N)	39	2010-2013	BASTRACK
Atlantic puffins			
Flatey (-22.92°E ; 65.38°N)	6	2007-2017	BASTRACK
Gull Island (-53.04°E; 47.95°N)	18	2013-2014	GEOLIGHT
Machias Seal Island (-67.10°E; 44.50°N)	19	2014-2016	BASTRACK
Skellig Michael (-10.54°E; 51.77°N)	30	2010-2013	
Skomer Island (-5.30°E; 51.74°N)	41	2007-2014	
Storholdi (-20.27°E; 63.43°N)	7	2007-2009	
Common guillemots			
Bjørnøya (18.955°E; 74.502°N)	37	2014-2017	BASTRACK and INTIPROC
Cape Gorodetskiy (32.936°E; 69.582°N)	7		BASTRACK
Faroe Islands (-6.798°E; 61.95°N)	7	2015-2017	BASTRACK and INTIPROC
Grimsey (-17.99°E; 66.528°N)	9		BASTRACK
Hjelmsøya (24.732°E; 71.112°N)	27	2014-2017	BIOTRACK and INTIPROC
Hornøya (31.15°E; 70.383°N)	37		BASTRACK and INTIPROC
Jan Mayen (-8.717°E; 70.92°N)	29	2013-2017	
Langanes (-15.98°E; 66.179°N)	27	2014-2017	
Latrabjarg (-24.467°E; 65.48°N)	4	2013-2017	BASTRACK
Sklinna (10.995°E; 65.202°N)	41	2013-2017	BIOTRACK and INTIPROC

Brünnich's guillemots			
Alkefjellet (18.459°E; 79.585°N)	23	2015-2017	BASTRACK and INTIPROC
Bjørnøya (18.955°E; 74.502°N)	31	2013-2017	
Cape Gorodetskiy (32.936°E; 69.582°N)	14	2014-2017	
Coats Islands (-82.75°E; 62.58°N)	32	2008-2010	BASTRACK
Digges Islands (-77.83°E; 62.58°N)	13		
Franz Josef Land (51.568°E; 80.143°N)	4	2014-2015 and 2016-2017	
Gannet Islands (-56.51°E; 53.95°N)	22	2008-2011	
Grimsey (-17.99°E; 66.528°N)	14	2015-2017	BASTRACK and INTIPROC
Hornøya (31.15°E; 70.383°N)	48	2012-2017	
Isfjorden (15.507°E; 78.252°N)	17	2013-2017	
Jan Mayen (-8.717°E; 70.92°N)	44		
Kara Gate (55.021°E; 70.593°N)	43	2015-2017	
Kippaku (-56.67°E; 73.7°N)	71	2011-2013	BASTRACK and GEOLIGHT
Kitsissut Avaliit (-48.47°E; 60.77°N)	7	2009-2012	BASTRACK and GEOLIGHT
Langanes (-15.98°E; 66.179°N)	19	2014-2017	BASTRACK and INTIPROC
Latrabjarg (-24.467°E; 65.48°N)	6	2015-2016	BASTRACK
Minarets (-61.77°E; 66.93°N)	14	2007-2008	
Oranskie Islands (67.642°E; 77.069°N)	10	2013-2014 and 2016-2017	
Prince Leopold Island (-90°E; 74.03°N)	14	2008-2010	
Parker Snow Bay (-68.67°E; 76.17°N)	3	2010-2011	BASTRACK and GEOLIGHT
Ritenbenk (-51.22°E; 69.78°N)	7	2011-2012	
Saunders (-70.03°E; 76.56°N)	19	2007-2008 and 2012-2013	

Black-legged kittiwakes			
Alkefjellet (18.459°E; 79.585°N)	20	2016-2017	BASTRACK and INTIPROC
Anda (15.17°E; 69.065°N)	56	2013-2017	BASTRACK
Bjørnøya (18.955°E; 74.502°N)	39	2013-2017	
Cape Krutik (35.948°E; 69.150°N)	33	2014-2017	
Faroe Islands (-6.798°E; 61.95°N)	27	2014-2017	
Franz Josef Land (51.568°E; 80.143°N)	54	2013-2017	BASTRACK and INTIPROC
Hornøya (31.15°E; 70.383°N)	53	2012-2017	BASTRACK
Isfjorden (15.507°E; 78.252°N)	27	2012-2013 and 2014-2017	BASTRACK and INTIPROC
Isle of May (-2.557°E; 56.185°N)	36	2014-2017	BASTRACK
Kara Gate (55.021°E; 70.593°N)	7	2015-2017	
Kippaku (-56.67°E; 73.7°N)	20	2008-2010	
Kongsfjorden (12.217°E; 78.90°N)	32	2014-2017	BASTRACK and INTIPROC
Langanes (-15.98°E; 66.179°N)	27	2014-2017	
Røst (12.078°E; 67.505°N)	43	2013-2017	BASTRACK
Runde and Ålesund (5.874°E; 62.435°N)	26	2015-2017	
Sklinna (10.995°E; 65.202°N)	37	2014-2017	BASTRACK and BIOTRACK

Table S1. Details of the GLS experiment related to STAR methods.

Little auks		
Morphological properties	Value	References
Body mass (g)	152	S1
Body plumage depth (dorsal-ventral) (mm)	7.4-12.8	S2
Head plumage depth (d-v) (mm)	5.2-9.4	S3
Plumage reflectivity (d-v) (%)	40.4-65.0	S2
Body feather length (d-v) (mm)	20.0-19.2	S2
Head feather length (d-v) (mm)	11.6-10.7	S3
Feather diameter (d-v) (µm)	33.0-33.0	S2
Physiological properties		
Body core temperature (°C)	40	S4
Flesh thermal conductivity ($W.m^{-1}.°C^{-1}$)	0.4-2.8	S5
Oxygen extraction efficiency (%)	35	S6
Bird density ($kg.m^{-3}$)	932.9	S7
Resting metabolic rate (W)	2.02	S4
Flight metabolism (W)	12.9	S8
Diving metabolism (W)	2.5*RMR	S9
Behavioral properties		
Proportion of time spent flying per day during winter under non-cyclonic conditions (%)	9	S10
Proportion of time spent diving per day under non-cyclonic conditions (%)	24	S11
Environmental data		
Sea surface temperature (°C)		NOAA High Resolution SST
Air temperature (°C)		NCEP/NCAR Reanalysis dataset
Cloud cover (%)	0-100	
Relative humidity (%)		NCEP/NCAR Reanalysis dataset
Wind speed ($m.s^{-1}$)		NCEP/NCAR Reanalysis dataset or Dvorak's classification
Black-legged kittiwakes		
Morphological properties	Value	References
Body mass (g)	480	S12
Body plumage depth (dorsal-ventral) (mm)	7.8-10.3	Considered as the same as guillemots
Head plumage depth (d-v) (mm)	6.2-6.8	
Plumage reflectivity (d-v) (%)	29.6-61.4	This study
Body feather length (d-v) (mm)	48.2-43.3	Considered as the same as guillemots
Head feather length (d-v) (mm)	16.3-15.7	
Feather diameter (d-v) (µm)	33.0-33.0	
Physiological properties		
Body core temperature (°C)	40.2	S4
Flesh thermal conductivity ($W.m^{-1}.°C^{-1}$)	0.5	Considered as the same as guillemots
Oxygen extraction efficiency (%)	35	
Bird density ($kg.m^{-3}$)	932.9	S7
Resting metabolic rate (W)	2.27	S13
Flight metabolism (W)	15.03	Flight software (version 1.25, S14)
Diving metabolism (W)	1.8*BMR	S15
Behavioral properties		
Proportion of time spent flying per day during winter under non-cyclonic conditions (%)	11.8	S16

Proportion of time spent diving per day under non-cyclonic conditions (%)	18.8	
Environmental data		
Sea surface temperature (°C)		NOAA High Resolution SST
Air temperature (°C)		NCEP/NCAR Reanalysis dataset
Cloud cover (%)	0-100	
Relative humidity (%)		NCEP/NCAR Reanalysis dataset
Wind speed ($m.s^{-1}$)		NCEP/NCAR Reanalysis dataset or Dvorak's classification
Atlantic puffins		
Morphological properties	Value	References
Body mass (g)	540	S17
Body plumage depth (dorsal-ventral) (mm)	8.1-13.4	This study
Head plumage depth (d-v) (mm)	6.2-11.4	
Plumage reflectivity (d-v) (%)	13.5-58.1	
Body feather length (d-v) (mm)	44.3-38	
Head feather length (d-v) (mm)	16.3-15.7	
Feather diameter (d-v) (µm)	33.0-33.0	Considered as the same as guillemots
Physiological properties		
Body core temperature (°C)	40.1	S18
Flesh thermal conductivity ($W.m^{-1}.°C^{-1}$)	0.5	Considered as the same as guillemots
Oxygen extraction efficiency (%)	35	
Bird density ($kg.m^{-3}$)	932.9	S7
Resting metabolic rate (W)	2.57	S19
Flight metabolism (W)	27.7	Flight software (version 1.25, S14)
Diving metabolism (W)	2.6*BMR	S20
Behavioral properties		
Proportion of time spent flying per day during winter under non-cyclonic conditions (%)	5.71	During breeding, S21
Proportion of time spent diving per day under non-cyclonic conditions (%)	16.9	S22
Environmental data		
Sea surface temperature (°C)		NOAA High Resolution SST
Air temperature (°C)		NCEP/NCAR Reanalysis dataset
Cloud cover (%)	0-100	
Relative humidity (%)		NCEP/NCAR Reanalysis dataset
Wind speed ($m.s^{-1}$)		NCEP/NCAR Reanalysis dataset or Dvorak's classification
Common guillemots		
Morphological properties	Value	References
Body mass (g)	1100	S23
Body plumage depth (dorsal-ventral) (mm)	7.8-10.3	This study
Head plumage depth (d-v) (mm)	6.2-6.8	
Plumage reflectivity (d-v) (%)	13.7-52	
Body feather length (d-v) (mm)	48.2-43	
Head feather length (d-v) (mm)	14-12.5	
Feather diameter (d-v) (µm)	33.0-33.0	S2
Physiological properties		
Body core temperature (°C)	40	S2
Flesh thermal conductivity ($W.m^{-1}.°C^{-1}$)	0.5	S5
Oxygen extraction efficiency (%)	35	S6

Bird density (kg.m^{-3})	932.9	S7
Resting metabolic rate (W)	5.07	S13
Flight metabolism (W)	88	S2
Diving metabolism (W)	1.8*BMR	S9
Behavioral properties		
Proportion of time spent flying per day during winter under non-cyclonic conditions (%)	4.5	S24, S25
Proportion of time spent diving per day under non-cyclonic conditions (%)	Jan/Feb/Nov 16.3 Oct14.3 Dec16.9	S22, S24-S26
Environmental data		
Sea surface temperature (°C)		NOAA High Resolution SST
Air temperature (°C)		NCEP/NCAR Reanalysis dataset
Cloud cover (%)	0-100	
Relative humidity (%)		NCEP/NCAR Reanalysis dataset
Wind speed (m.s^{-1})		NCEP/NCAR Reanalysis dataset or Dvorak's classification
Brünnich's guillemots		
Morphological properties	Value	References
Body mass (g)		
Body plumage depth (dorsal-ventral) (mm)		
Head plumage depth (d-v) (mm)		
Plumage reflectivity (d-v) (%)		
Body feather length (d-v) (mm)		
Head feather length (d-v) (mm)		
Feather diameter (d-v) (µm)		
Physiological properties		
Body core temperature (°C)		
Flesh thermal conductivity (W.m^{-1}.°C^{-1})		
Oxygen extraction efficiency (%)		
Bird density (kg.m^{-3})		
Resting metabolic rate (W)		
Flight metabolism (W)		
Diving metabolism (W)	2.4*BMR	S9
Behavioral properties		
Proportion of time spent flying per day during winter under non-cyclonic conditions (%)		
Proportion of time spent diving per day under non-cyclonic conditions (%)		
Environmental data		
Sea surface temperature (°C)		NOAA High Resolution SST
Air temperature (°C)		NCEP/NCAR Reanalysis dataset
Cloud cover (%)	0-100	
Relative humidity (%)		NCEP/NCAR Reanalysis dataset
Wind speed (m.s^{-1})		NCEP/NCAR Reanalysis dataset or Dvorak classification

When not provided, values are considered as the same as for common guillemots (see Fort et al., 2009.)

Table S2. Summary of parameters used in NicheMapper™ related to STAR Methods.

Species	Location	Wind speed	Observed behavior	Observer/ Reference	Date
Little auk	Kap Høegh-East Greenland	Above 60 $km.h^{-1}$	Stopped flying	David Grémillet and Manon Clairbaux	Summer 2019
European shag	Orkney Islands	Above 103 $km.h^{-1}$	Stopped flying and foraging	David Grémillet	1990
Brünnich's guillemot	Prince Leopold Island-Nunavut	Above 80 $km.h^{-1}$	Difficulty flying	Mark Mallory	2015
Black-legged kittiwake	Labrador Coast	Above 80 $km.h^{-1}$	No birds landing on water (few in air, tossed about)	Mark Mallory	2018
Brünnich's guillemot	Labrador Sea	Above 80 $km.h^{-1}$	Few birds swimming, none flying, did not appear to be diving	Mark Mallory	2018
Northern fulmar	Flemish Caps	Above 103 $km.h^{-1}$	Birds flying in small groups, difficulty landing or no landing	Ashley Bennison	2016
Auk spp	Flemish Caps	Above 103 $km.h^{-1}$	Stopped flying	Ashley Bennison	2016
Little auk	Kap Høegh-East Greenland	Above 50 $km.h^{-1}$	Stopped flying	Jérôme Fort	Summer 2020
Guillemot spp	Hudson Bay		Any evidence about stop diving even under strong winds. Flying seems to be interrupted when winds become too high.	Kyle Elliott	
European shag	Faroes Islands	Above 80 $km.h^{-1}$	Stopped flying and foraging. Remained on land	Bergur Olsen	2021
Auk spp	Faroes Islands	Above 75 $km.h^{-1}$	Stopped flying	Bergur Olsen	2021
Northern fulmar	Faroes Islands	Above 50 $km.h^{-1}$	Hungry and aggressive	Bergur Olsen	2021
European shag	Isle of May	Above 180 $km.h^{-1}$	Stopped flying and foraging. Remained on land	Francis Daunt	April 1998
Atlantic puffin		Above 150 $km.h^{-1}$	Stopped flying and sat on water	S27	
Common guillemot	Isle of May	Above 33 $km.h^{-1}$	Adults still bringing prey to their chicks	S28	Summer 1997
Brünnich's guillemot	Kippaku-North West Greenland	Two cyclones wit h wind speed above 50 $km.h^{-1}$and above 29 $km.h^{-1}$ respectively	Strongly reduced traffic of birds returning to the colony, especially during the first and strongest one	S29	Summer 2010

Atlantic puffin	Røst, North Norway	Above 50 $km.h^{-1}$	Strongly reduced traffic of breeding birds returning to the colony with food for their chicks	S30	Summer 2002

Table S3. Observations of seabird behavior under cyclonic conditions related to STAR Methods.

Supplemental References

S1. Amélineau F. Sensibilité d'un oiseau marin arctique aux changements environnementaux. 2016.

S2. Fort J, Porter WP, Grémillet D. Thermodynamic modelling predicts energetic bottleneck for seabirds wintering in the northwest Atlantic. J Exp Biol [Internet]. 2009;212:2483–90. Available from: http://jeb.biologists.org/cgi/doi/10.1242/jeb.032300

S3. Amélineau F, Fort J, Mathewson PD, Speirs DC, Courbin N, Perret S, et al. Energyscapes and prey fields shape a North Atlantic seabird wintering hotspot under climate change. R Soc Open Sci [Internet]. 2018;5:171883. Available from: http://rsos.royalsocietypublishing.org/lookup/doi/10.1098/rsos.171883

S4. Gabrielsen GW. Energy expenditure in arctic seabirds. 1994.

S5. Cheng HM, Plewes DB. Tissue thermal conductivity by magnetic resonance thermometry and focused ultrasound heating. J Magn Reson imaging. 2002;609:598–609.

S6. Arens JR, Cooper SJ. Seasonal and diurnal variation in metabolism and ventilation in house sparrows. Condor. 2005;107(2):433–44.

S7. Porter WP, Mitchell JW. Method and system for calculating the spatial-temporal effects of climate and other environmental conditions on animals. In: http://www.patentstorm.us/patents/7155377-fulltext.html (ed. U.P Office).Wisconsin Alumni Research Foundation, USA. 2006.

S8. Raveling D, Lefebvre E. Energy metabolism and theoretical flight range of birds. Bird-Banding. 1967;38(2):97–113.

S9. Croll DA, Mclaren E. Diving metabolism and thermoregulation in common and thick-billed murres. J Comp Physiol B. 1993;163:160–6.

S10. Fort J. Réponses des oiseaux marins de l'Arctique aux contraintes environnementales hivernales dans le contexte des changements climatiques. Université Montpellier II; 2009.

S11. Fort J, Cherel Y, Harding AMA, Egevang C, Steen H, Kuntz G, et al. The feeding ecology of little auks raises questions about winter zooplankton stocks in North Atlantic surface waters. Biol Lett [Internet]. 2010 Oct 23;6(5):682–4. Available from: https://doi.org/10.1098/rsbl.2010.0082

S12. Erikstad KE. Winter diets of four seabird species in the barents sea after a crash in the capelin stock. Polar Biol. 1990;10:619–27.

S13. Gabrielsen GW, Mehlum F, Karlsen HE. Thermoregulation in four species of arctic seabirds. J Comp Physiol B. 1988;703–8.

S14. Pennycuick CJ. Bird flight performance: a practical calculation manual. Oxford: Oxford University Press; 1989.

S15. Elliott KH, Vaillant M Le, Kato A, Speakman JR, Ropert-coudert Y. Accelerometry predicts daily energy expenditure in a bird with high activity levels. Biol Lett. 2013;9(20120919):1–4.

S16. McKnight A, Irons DB, Allyn AJ, Sullivan KM, Suryan RM. Winter dispersal and activity patterns of postbreeding black-legged kittiwakes *Rissa tridactyla* from Prince William Sound, Alaska. Mar Ecol Prog Ser. 2011;442:241–53.

S17. Anker-nilssen T, Jensen J, Harris MP. Fit is fat : winter body mass of Atlantic Puffins *Fratercula arctica*. Bird Study. 2018;65(4):451–7.

S18. Barrett RT. Adult body temperatures and the development of endothermy in the puffin *Fratercula arctica*, razorbill *Alca torda* and Guillemot *Uria alge*. Fauna norvSer C, Cinclus. 1984;7:119–23.

S19. Bryant D., Furness R. Basal metabolic rates of North Atlantic seabirds. Ibis (Lond 1859). 1995;137:219–26.

S20. Elliott KH, Ricklefs RE, Gaston AJ, Hatch SA, Speakman JR, Davoren GK. High flight costs, but low dive costs, in auks support the biomechanical hypothesis for flightlessness in penguins. PNAS. 2013;110(23):9380–4.

S21. Shoji A, Elliott K, Fayet A, Boyle D, Perrins C, Guilford T. Foraging behaviour of sympatric razorbills and puffins. Mar Ecol Prog Ser. 2015;520:257–67.

S22. Dunn RE, Wanless S, Green JA, Harris MP, Daunt F. Effects of body size, sex, parental care and moult strategies on auk diving behaviour outside the breeding season. J Avian Biol. 2019;

S23. Gaston AJ, Jones IL. The Auks. Oxford, New York, London: Oxford University Press; 1998. 1–349 p.

S24. Burke CM, Montevecchi WA. Taking the bite out of winter : Common Murres (*Uria aalge*) push their dive limits to surmount energy constraints. Front Mar Sci. 2018;5:1–13.

S25. Fort J, Steen H, Strøm H, Tremblay Y, Grønningsæter E, Pettex E, et al. Energetic consequences of contrasting winter migratory strategies in a sympatric Arctic seabird duet. J Avian Biol [Internet]. 2013;44(3):255–62. Available from: http://dx.doi.org/10.1111/j.1600-048X.2012.00128.x

S26. Dunn RE, Wanless S, Daunt F, Harris MP, Green JA. A year in the life of a North Atlantic seabird: behavioural and energetic adjustments during the annual cycle. Sci Rep [Internet]. 2020;10(1):1–11. Available from: http://dx.doi.org/10.1038/s41598-020-62842-x

S27. Lockley R. Puffins. New York: Devin-Adair CO.; 1953.

S28. Finney SK, Wanless S, Harris MP. The effect of weather conditions on the feeding behaviour of a diving bird , the Common Guillemot *Uria aalge*. J Avian Biol [Internet]. 1999;30(1):23–30. Available from: https://www.jstor.org/stable/3677239

S29. Huffeldt NP, Merkel FR. Remote time-lapse photography as a monitoring tool for colonial breeding seabirds: A case study using thick-billed murres (*Uria lomvia*). Waterbirds. 2013;36(3):330–41.

S30. Anker-Nilssen, Aarvak. NINA Oppdragsmelding 736. 2002.