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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.





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 puffi	ns			
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			
Skellig Michael (-10.54°E; 51.77°N)	30	2010-2013	ΡΑςτραςν		
Skomer Island (-5.30°E; 51.74°N)	41	2007-2014	DASTRACK		
Storholdi (-20.27°E; 63.43°N)	7	2007-2009			
	Common guiller	nots			
Bjørnøya (18.955°E; 74.502°N)	37	2014 2017	BASTRACK and INTIPROC		
Cape Gorodetskiy (32.936°E; 69.582°N)	7	2014-2017 -	BASTRACK		
Faroe Islands (-6.798°E; 61.95°N)	7	2015-2017	BASTRACK and INTIPROC		
Grimsey (-17.99°E; 66.528°N)	9	2010 2017	BASTRACK		
Hjelmsøya (24.732°E; 71.112°N)	27	2014 2017	BIOTRACK and INTIPROC		
Hornøya (31.15°E; 70.383°N)	37	2014-2017 -			
Jan Mayen (-8.717°E; 70.92°N)	29	2013-2017	BASTRACK and INTIPROC		
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		

Alkefjellet (18.459°E; 79.585°N) 23 2015-2017 Bjørnøya (18.955°E; 74.502°N) 31 2013-2017 BASTRACK and INTIPROC Cape Gorodetskiy (32.936°E; 69.582°N) 14 2014-2017 BASTRACK and INTIPROC Coats Islands (-82.75°E; 62.58°N) 32 2008-2010 BASTRACK Digges Islands (-77.83°E; 62.58°N) 13 2014-2015 and 2016-2017 BASTRACK Gannet Islands (-56.651°E; 53.95°N) 22 2008-2010 BASTRACK Grimsey (-17.99°E; 66.528°N) 14 2015-2017 BASTRACK and INTIPROC Hornøya (-56.67°E; 70.383°N) 48 2012-2017 BASTRACK and INTIPROC Jan Mayen (-58.07°E; 70.528°N) 43 2015-2017 BASTRACK and GEOLIGHT Kara Gate (-58.07°E; 73.7°N) 71 2011-2013 BASTRACK and GEOLIGHT Kisissut Avaliit (-59.6°°E; 66.179°N) 7 2009-2012 BASTRACK and GEOLIGHT Latrabjarg (-61.77°E; 66.93°N) 14 2007-2008 NTIPROC Uatrabjarg (-61.77°E; 66.93°N) 14 2007-2008 BASTRACK Oranskie Islands (07.069°E); 74.03°N) 14 2007-2008 BAS	Brünnich's guillemots				
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Prince Leopoid Island 14 2008-2010 (-90°E; 74.03°N) 14 2008-2010 Parker Snow Bay 3 2010-2011 (-68.67°E; 76.17°N) 3 2011-2012 Ritenbenk 7 2011-2012 BASTRACK and GEOLIGHT Saunders 19 2007-2008 and 2012-2013 GEOLIGHT	(07.042 E, 77.009 N)		2010-2017		
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Ritenbenk 7 2011-2012 BASTRACK and GEOLIGHT Saunders 19 2007-2008 and 2012-2013 GEOLIGHT	$(-68, 67^{\circ}\text{E}, 76, 17^{\circ}\text{N})$	3	2010-2011		
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Saunders 19 2007-2008 and (-70.03°E; 76.56°N) 19 2012-2013	(-51 22°E: 69 78°N)	7	2011-2012	GEOLIGHT	
(-70.03°E; 76.56°N) 19 2012-2013	Saunders 2007-2008 and		2007-2008 and	GLOLIGIT	
	(-70.03°E; 76.56°N)	19	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		
Bjørnøya (18.955°E; 74.502°N)	39	2013-2017	BASTRACK	
Cape Krutik (35.948°E; 69.150°N)	33	2014-2017	DADTRACK	
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		
Kara Gate (55.021°E; 70.593°N)	7	2015-2017	BASTRACK	
Kippaku (-56.67°E; 73.7°N)	20	2008-2010		
Kongsfjorden (12.217°E; 78.90°N)	32 2014-2017		BASTRACK and	
Langanes (-15.98°E; 66.179°N)	27	2014-2017	INTIPROC	
Røst (12.078°E; 67.505°N)	43	2013-2017		
Runde and Ålesund (5.874°E; 62.435°N)	26	2015-2017	DASTRACK	
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	<u>\$9</u>			
Behavioral properties					
Proportion of time spent flying per day during	9	S10			
winter under non-cyclonic conditions (%)					
Proportion of time spent diving per day under	24	S11			
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's classification			
Black-le	gged kittiwak	(es			
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	Considered as the same as gumemots			
Plumage reflectivity (d-v) (%)	29.6-61.4	This study			
Body feather length (d-v) (mm)	48.2-43.3				
Head feather length (d-v) (mm)	16.3-15.7	Considered as the same as guillemots			
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 guillemets			
Oxygen extraction efficiency (%)	35	Considered as the same as gumemots			
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			
	11.0	510			

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		
wind speed (m.s.)		Dvorak's classification		
Atla	ntic puffins			
Morphological properties	Value	References		
Body mass (g)	540	S17		
Body plumage depth (dorsal-ventral) (mm)	8.1-13.4			
Head plumage depth (d-v) (mm)	6.2-11.4			
Plumage reflectivity (d-v) (%)	13.5-58.1	This study		
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	Considered as the same as gumemots		
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	5 71	During broading \$21		
winter under non-cyclonic conditions (%)	5.71	During breeding, 521		
Proportion of time spent diving per day under	16.9	822		
non-cyclonic conditions (%)	10.9	522		
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		
wind speed (m.s.)		Dvorak's classification		
Comm	on guillemots			
Morphological properties	Value	References		
Body mass (g)	1100	S23		
Body plumage depth (dorsal-ventral) (mm)	7.8-10.3			
Head plumage depth (d-v) (mm)	6.2-6.8			
Plumage reflectivity (d-v) (%)	13.7-52	This study		
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		
	Jan/Feb/N			
Proportion of time spent diving per day under	ov 16.3	822 824-826		
non-cyclonic conditions (%)	Oct14.3	522, 524-520		
	Dec16.9			
Environmental data		NOAAH IN IN IA COT		
Sea surface temperature (°C)		NOAA High Resolution SS1		
Air temperature (°C)	0.100	NCEP/NCAR Reanalysis dataset		
Cloud cover (%)	0-100			
Relative humidity (%)		NCEP/NCAR Reanalysis dataset		
Wind speed $(m.s^{-1})$		NCEP/NCAR Reanalysis dataset or		
Dutter:		Dvorak s classification		
Mounhological reconcerties	Volue	Bafaranaaa		
Rody mass (g)	value	Kelelences		
Body nlumage denth (dersal ventral) (mm)				
Hoad plumage depth (d y) (mm)				
Plumage reflectivity (d, y) (%)				
Production for the curve $(d - v) (70)$				
Head fasther length (d v) (mm)				
Faathar diamatar (d, y) (um)				
Peatiel diameter (d-v) (µm)				
Pady are temperature (°C)				
Elogh thermal conductivity $(W m^{-1} \circ C^{-1})$				
$\frac{1}{2} \sum_{i=1}^{n} \frac{1}{2} \sum_{i=1}^{n} \frac{1}$				
Bird density $(\log m^{-3})$				
Dird density (Kg.iii) Reacting matchelia rate (W)				
Flight metabolism (W)				
Diving metabolism (W)	2 /*DMD	50		
Behavioral properties	2.4° DIVIR	57		
Proportion of time spent flying per day during				
winter under non-cyclonic conditions (%)				
Proportion of time spent diving per day under				
non-evelopic conditions (%)				
Environmental data				
Sea surface temperature (°C)		NOAA High Resolution SST		
Air temperature (°C)		NCEP/NCAR Reanalysis dataset		
Cloud cover (%)	0-100			
Relative humidity (%)	- 100	NCEP/NCAR Reanalysis dataset		
		NCEP/NCAR Reanalysis dataset or		
Wind speed (m.s ⁻⁺)		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 NicheMapperTM 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
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Table S3. Observations of seabird behavior under cyclonic conditions related to STARMethods.

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