Table S1. Parameter values used in GLS location estimates for the three types of loggers used in this study.

	LAT 2800S	MK5	MK7
Light threshold[1]	175	12	12
Solar range (°)		-6 to -1	
Speed – Fly (m/s)			
Mean	15	3	3
SD	5	5	5
Max	25	15	15
Speed – On water (m/s)			
Mean	1	3	3
SD	1.3	5	5
Max	5	15	15
SST SD (°C)	0.1	0.1	--
Max SST difference (°C)	2	2	--
Spring equinox (days)		-21 to 14	
Fall equinox (days)		-14 to 21	
Ice concentration cut-off (%)		90	
Boundary box (°)		-110W, -10W, 30N, 75N	

[1] Unitless values specific to tag model.

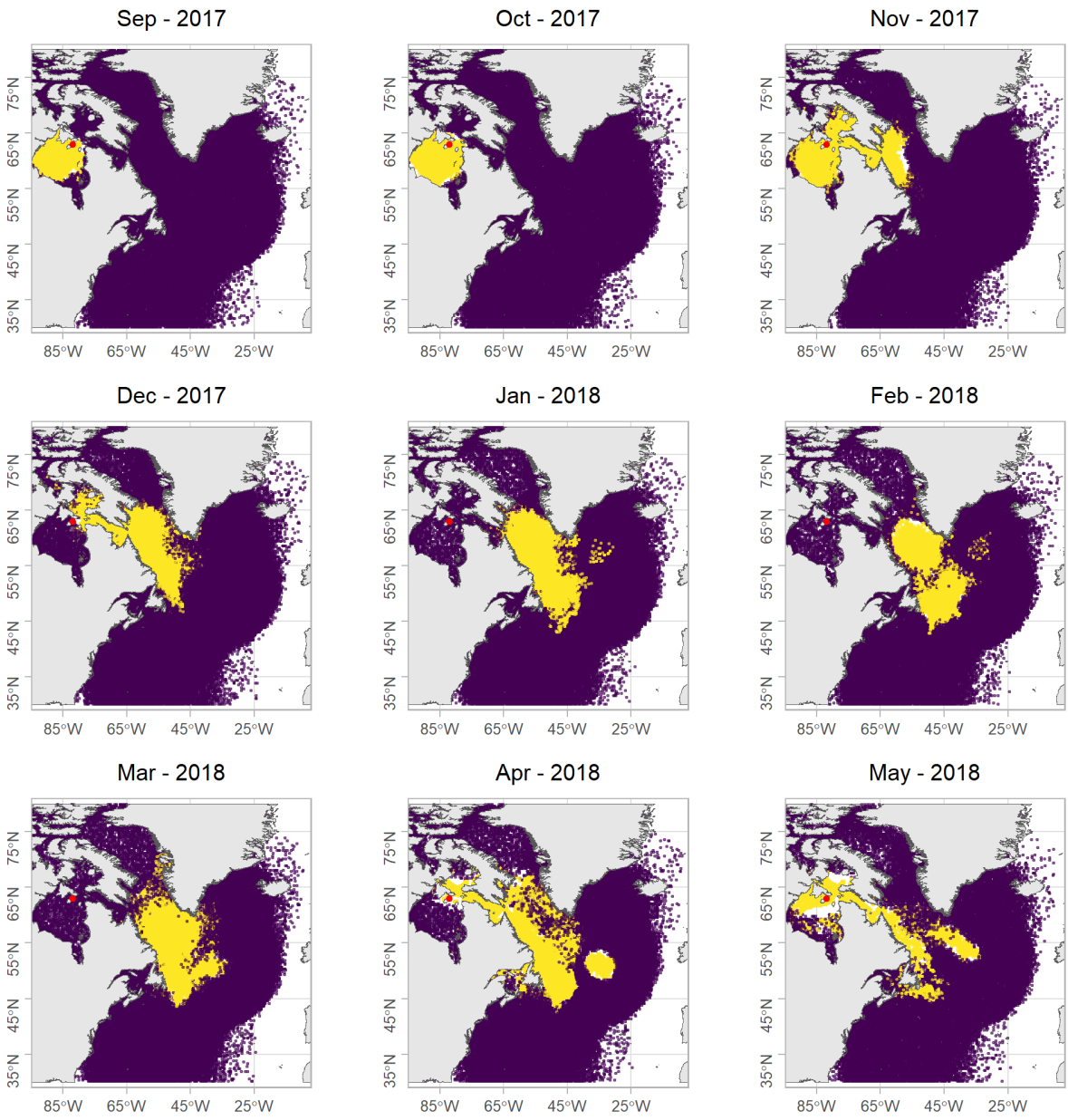

Figure S1. Maps showing the distribution of used locations (yellow) and pseudo absences (purple) for the 2017/18 tracking year. Pseudo absences were selected from all areas within 1,000 km of any observed location within each tracking year, excluding areas within 200 km of used locations collected within the same month.

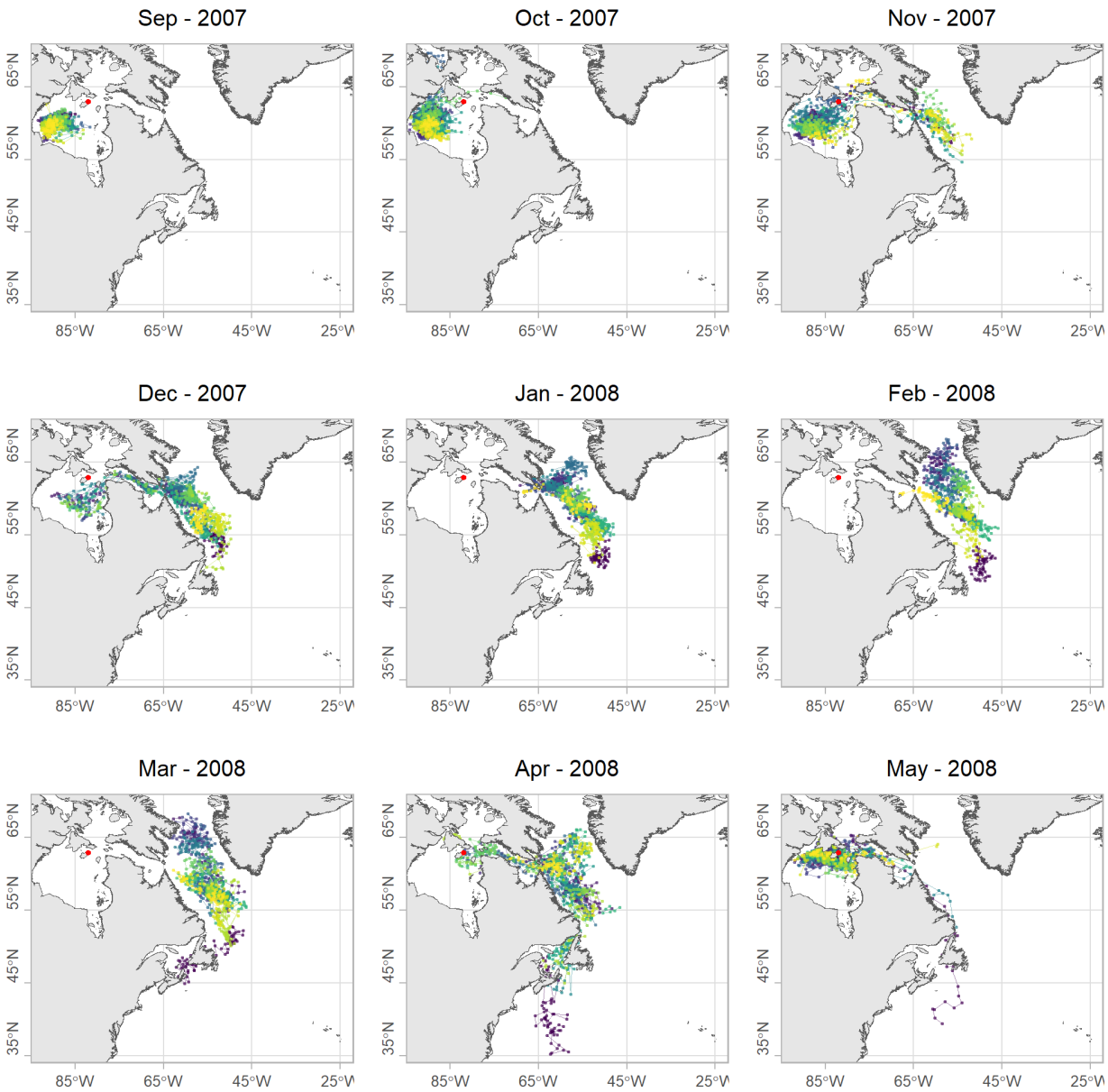

Figure S2. Monthly movements of thick-billed murres tracked from Coats Island (red point), Nunavut, Canada, during the 2007/08 non-breeding period.

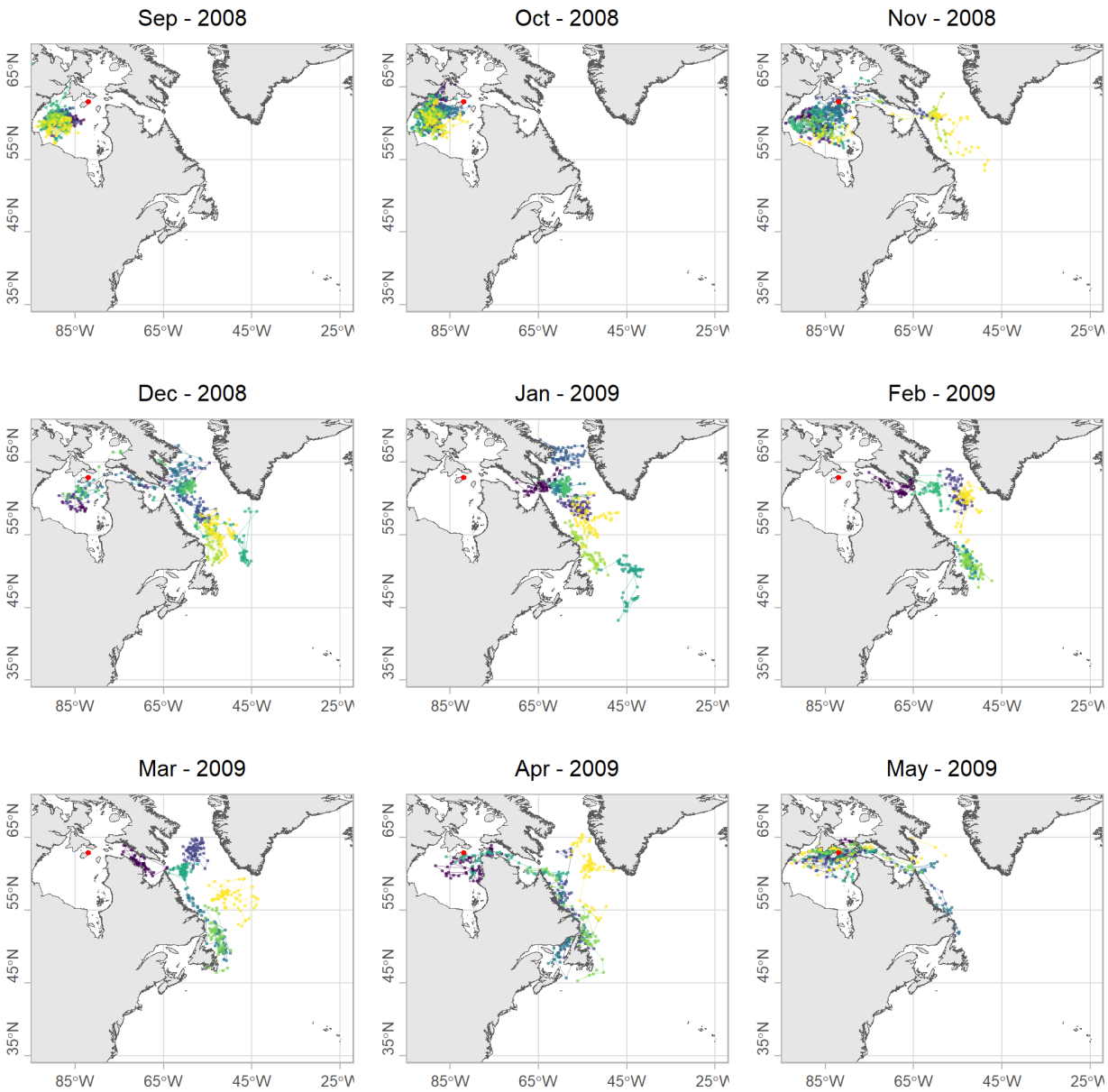

Figure S3. Monthly movements of thick-billed murres tracked from Coats Island (red point), Nunavut, Canada, during the 2008/09 non-breeding period.

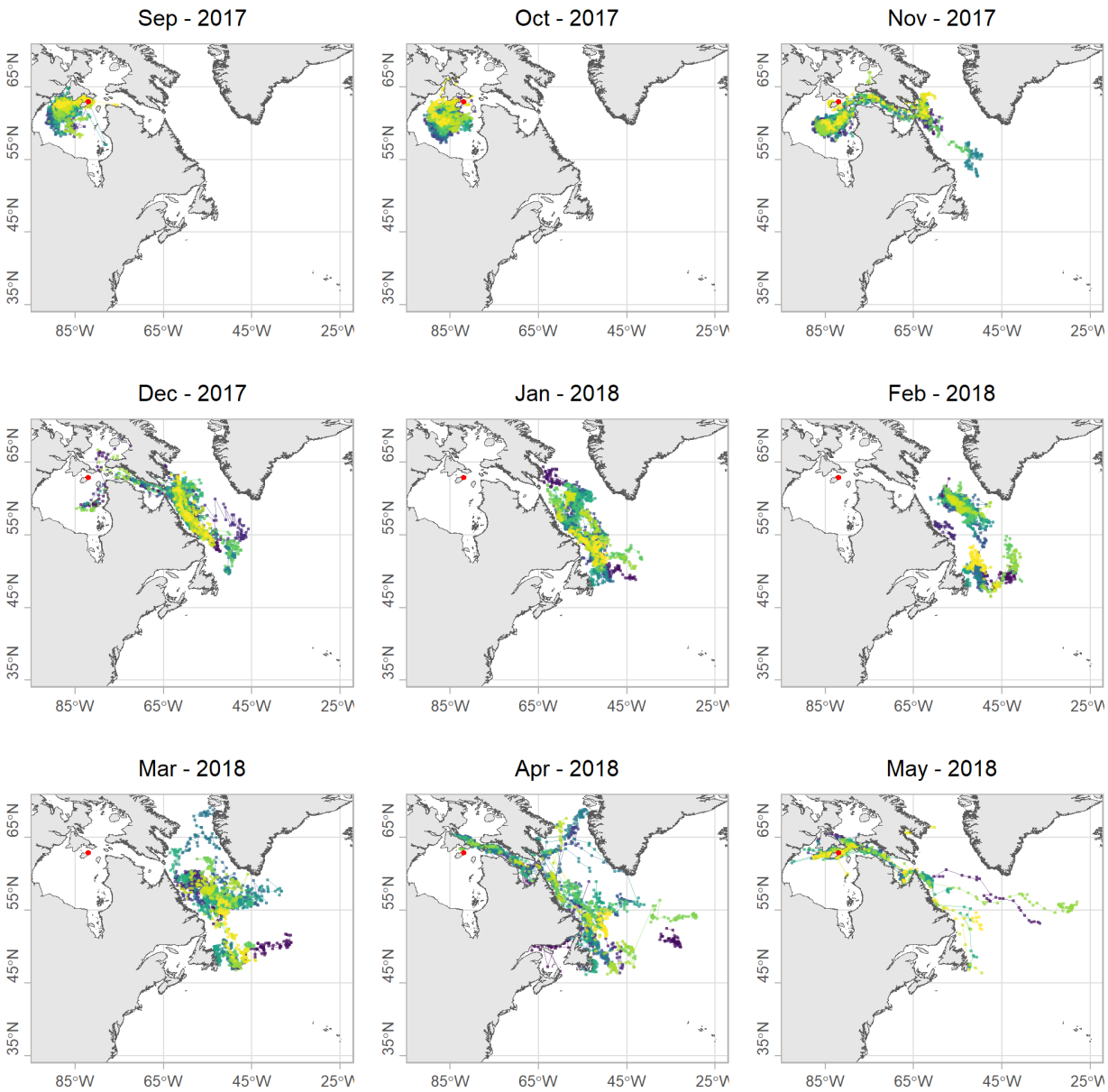

Figure S4. Monthly movements of thick-billed murres tracked from Coats Island (red point), Nunavut, Canada, during the 2017/18 non-breeding period.

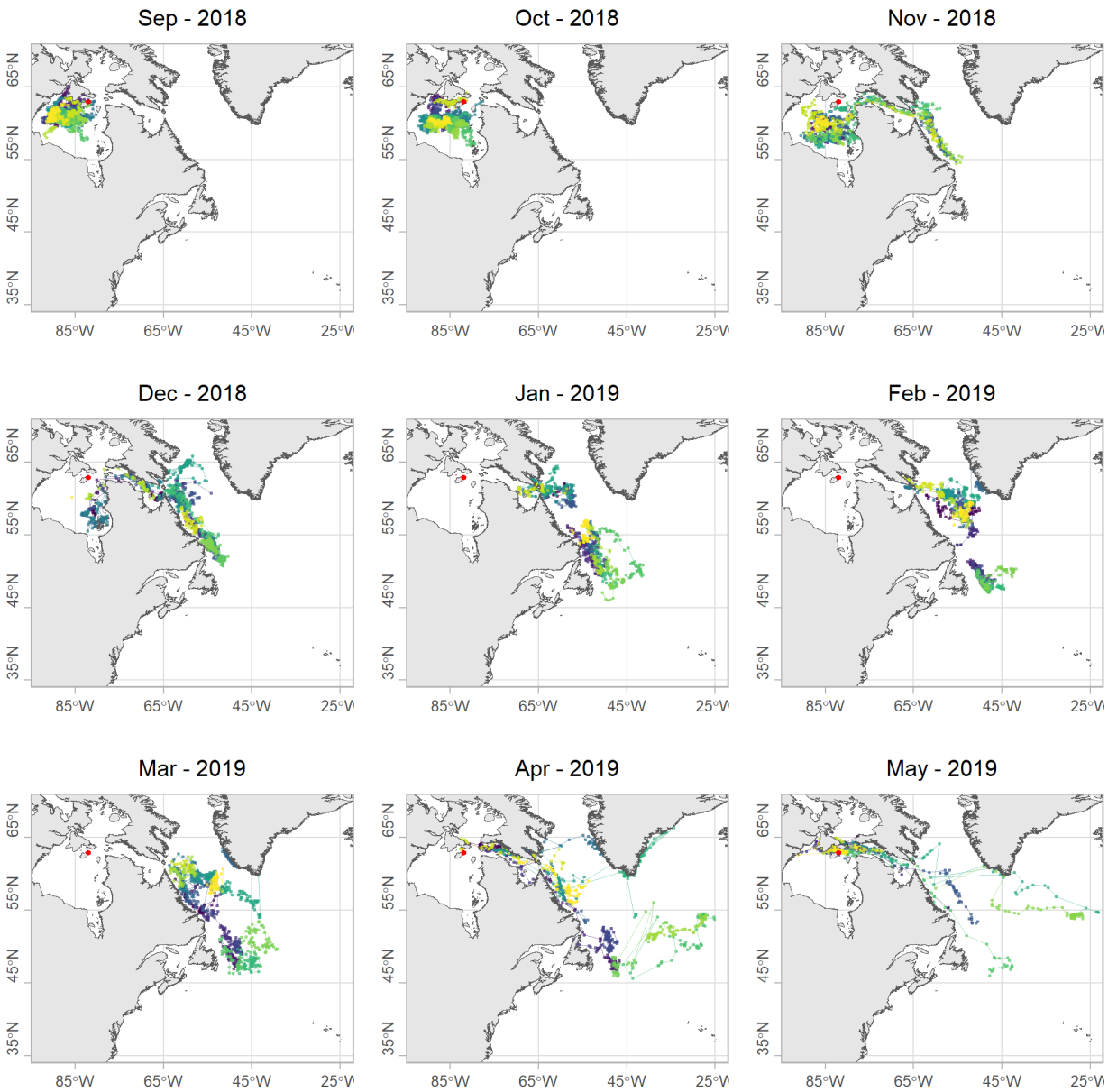

Figure S5. Monthly movements of thick-billed murres tracked from Coats Island (red point), Nunavut, Canada, during the 2018/19 non-breeding period.

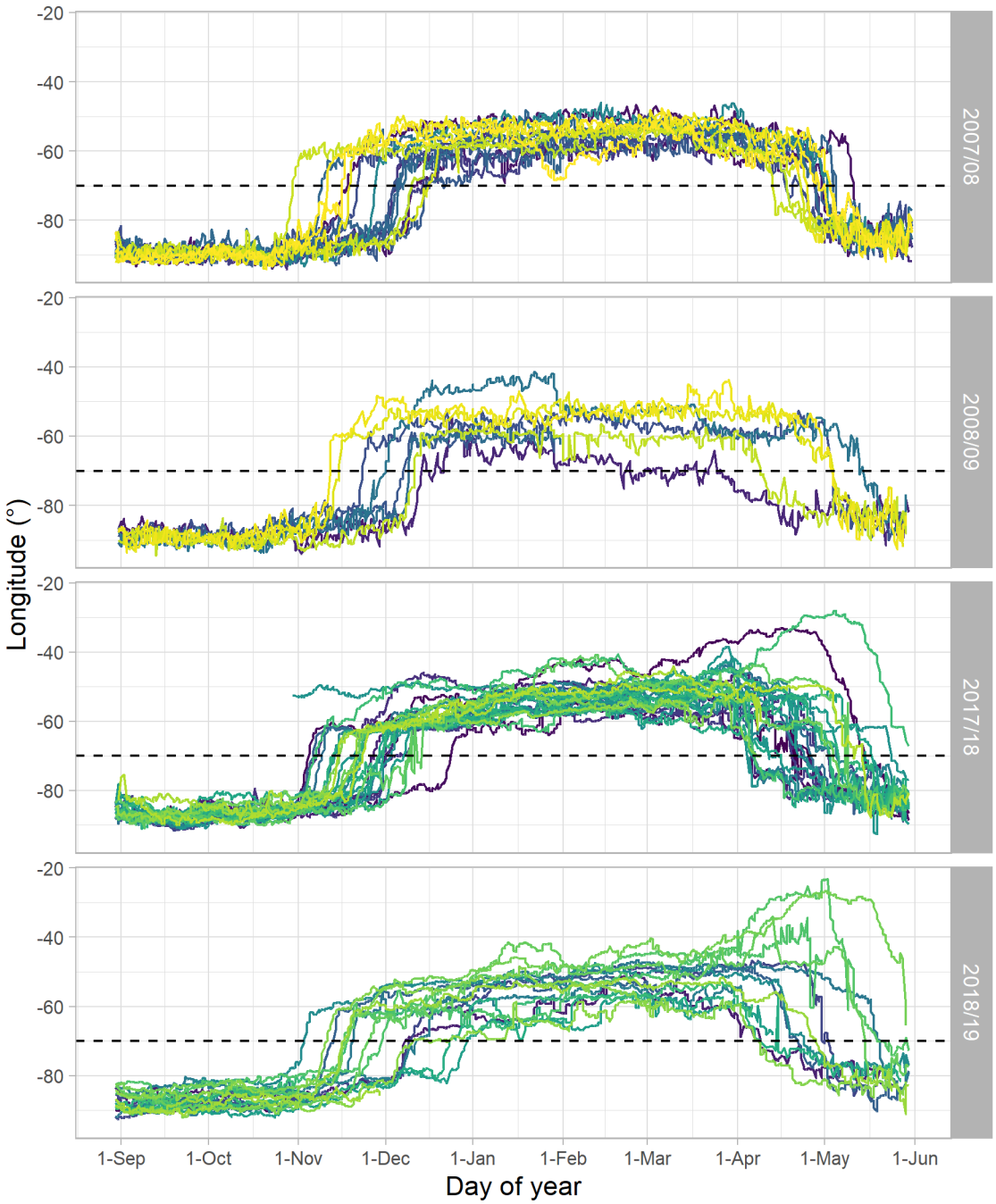

Figure S6. Longitude by date for each individual thick-billed murre track. Colours represent tracks of different individuals. The dashed horizontal line indicates 70°W, which was used to measure eastward migration in fall and westward migration in spring.

Text S1. ***Effect of experimental treatment on model accuracy and variable importance***

In 2017 and 2018, tracked murres were included in a separate study examining the affects of increased reproductive investment on non-breeding behaviour. Within this experiment, 33% of nests had their egg removed during early incubation, to force females to relay; 33% of nests had both adults handicapped by clipping the five outer primaries to the length of the 6th primary; and 33% of nests were in the control group. Initial exploration of the spatial distribution of locations for birds from each treatment showed significant overlap in the non-breeding distributions of control, delay, and handicap murres.

To test if experimental treatments applied to murres in the 2017 and 2018 had any effect of SDM, we ran a separate models on data for tracks from only these two years. One models included the eight predictor variables described in the main manuscript, and the other model included an additional variable for experimental treatment. We compared accuracy for a model including treatment as a predictor and a model without treatment. We compared accuracy for each of these models, using AUC, F1 score, and the Continuous Boyce Index, to determine if treatment influenced model predictions. We also calculated variable importance for all predictors in the model including treatment as an effect, to determine if treatment was useful in predicting murre distributions within any season.

Including treatment in the SDM did not improve model accuracy using any metric (Table S2). Variable importance of treatment was less than 2.2 in all seasons (Figure S7),supporting the conclusion that experimental treatment did not affect model predictions.

Table S2. Species distribution model accuracy including and excluding experimental treatment as a predictor variable. Accuracy measures are area-under-curve (AUC), F1 statistic (F1), and the Continuous Boyce Index (CBI).

Model	AUC	F1	CBI
Including treatment	98.1	93.1	91.1
Excluding treatment	98.9	93.7	92.8

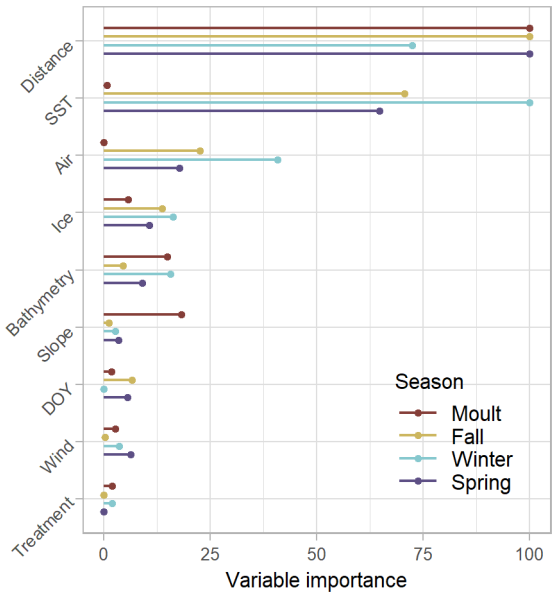

Figure S7. Relative importance of environmental predictors for the species distribution model including treatment as a predictor. Variable importance is scaled between 0–100 for each stage.

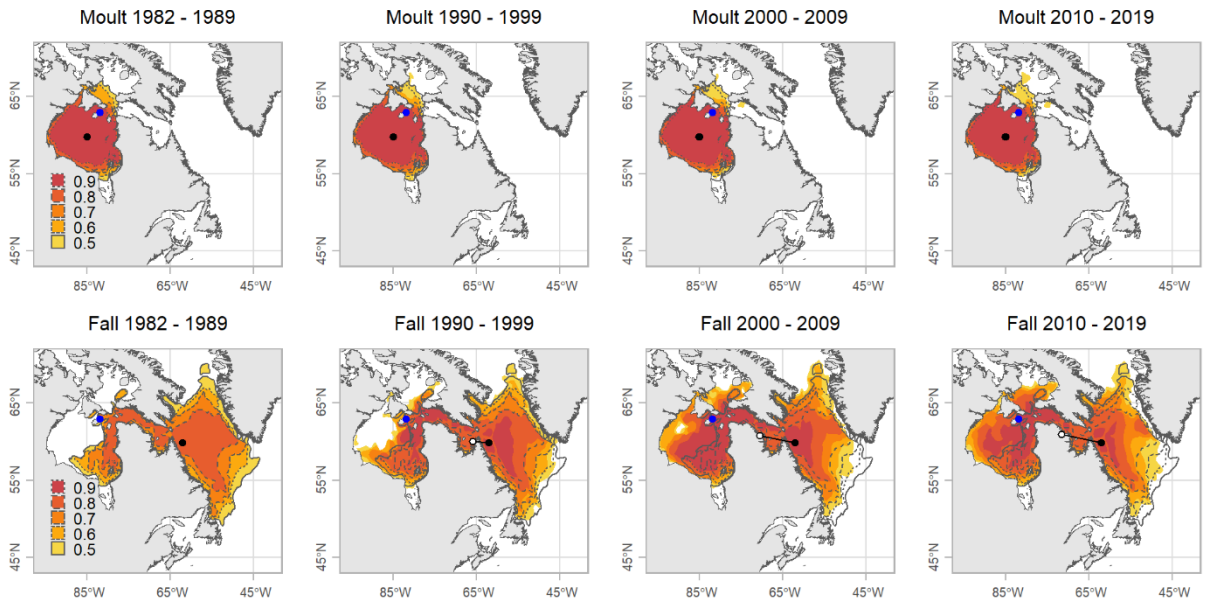

Figure S8. Predicted seasonal distributions of thick-billed murres from Coats Island from 1989 – 2019, by decade. Shading shows the median distribution across each season and time period for probabilities greater than 0.5. Lines indicate the 1982-1989 distribution relative to the each decade. Black points show the median distribution in 1982-1989 and white points show the median distribution in each decade.

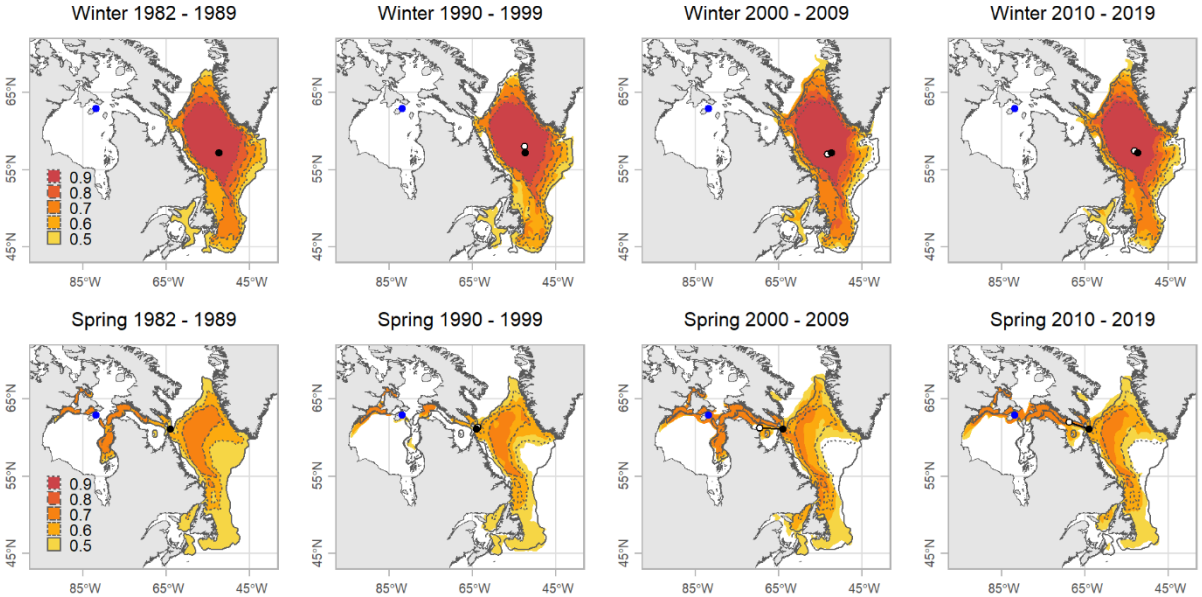

Figure S9. Predicted seasonal distributions of thick-billed murres from Coats Island from 1989-2019, by decade. Shading shows the median distribution across each season and time period for probabilities greater than 0.5. Lines indicate the 1982-1989 distribution relative to the each decade. Black points show the median distribution in 1982-1989 and white points show the median distribution in each decade.

Table S3. Summary of comparisons for changes in predicted distributions of thick-billed murres from Coats Island over time, by season. Intercepts (mean ± SE) represent parameter estimates for 1982; slopes (mean ± SE) are estimated change per year. Area is the total area with a median probability of use of at least 70%. Overlap is the percent overlap of each year's distribution with the average distribution from 1982 – 1989. Easting and northing are the center (median) of each range. Edges are the 5th and 95th percentiles of eastings and northings within each distribution. All spatial analysis was performed using an Albers Equal Area projection with central meridian at 60°W and standard parallels at 45°N and 65°W.

Parameter	Intercept	Slope	F	p-value	r^2
Moult (Sep-Oct)					
Area (1,000 km²)	774.97 (12.85)	0.35 (0.60)	0.34	1.000	-0.02
Overlap (%)	99.1 (0.8)	-0.055 (0.039)	1.98	1.000	0.03
Easting (km)*	-1351.42 (6.33)	0.05(0.29)	0.03	1.000	-0.03
West edge (km)*	-1769.53 (2.51)	0.018 (0.12)	0.02	1.000	-0.03
East edge (km)	-1008.29 (14.37)	1.26 (0.67)	3.55	0.541	0.07
Northing (km)	795.52 (7.11)	0.29 (0.33)	0.75	1.000	-0.01
South edge (km)	312.69 (6.92)	0.91 (0.32)	8.06	0.059	0.16
North edge (km)	1205.50 (28.17)	1.91 (1.31)	2.13	1.000	0.03
Fall (Nov-Dec)					
Area (1,000 km²)	1315.78 (70.85)	8.57 (3.29)	6.76	0.107	0.13
Overlap (%)	***84.3 (0.03)***	***-0.75 (0.14)***	***28.10***	***<0.001***	***0.42***
Easting (km)	***37.49 (88.619)***	***-21.07 (4.13)***	***26.10***	***<0.001***	***0.40***
West edge (km)	***-1242.45 (72.59)***	***-11.56 (3.38)***	***11.70***	***0.012***	***0.22***
East edge (km)	***563.03 (39.26)***	***-7.77 (1.83)***	***18.10***	***0.001***	***0.32***
Northing (km)	***578.60 (20.50)***	***4.96 (0.95)***	***27.00***	***<0.001***	***0.41***
South edge (km)	***-119.44 (33.72)***	***6.74 (1.57)***	***18.50***	***0.001***	***0.32***
North edge (km)	***1070.63 (27.26)***	***6.13 (1.27)***	***23.40***	***<0.001***	***0.38***
Winter (Jan-Mar)					
Area (1,000 km²)	1072.40 (42.52)	4.56 (1.98)	5.36	0.212	0.11
Overlap (%)	***92.7 (1.8)***	***-0.27 (0.08)***	***10.20***	***0.024***	***0.20***
Easting (km)	***486.41 (15.45)***	***-2.86 (0.72)***	***15.80***	***0.003***	***0.29***
West edge (km)	***44.32 (14.9)***	***-2.79 (0.69)***	***16.20***	***0.002***	***0.29***
East edge (km)	***856.88 (13.57)***	***-2.25(0.63)***	***12.80***	***0.008***	***0.24***
Northing (km)	332.67 (16.71)	0.52 (0.78)	0.44	1.000	-0.02
South edge (km)	-708.03 (71.09)	0.66 (3.31)	0.04	1.000	-0.03
North edge (km)	964.94 (33.60)	4.12 (1.56)	6.96	0.098	0.14
Spring (Apr-May)					
Area (1,000 km²)	471.76 (49.02)	-0.56 (2.28)	0.06	1.000	-0.03
Overlap (%)	62.5 (4.1)	-0.31 (0.19)	2.54	0.958	0.04
Easting (km)	-423.45 (126.14)	-6.58 (5.87)	1.26	1.000	0.01
West edge (km)	-1359.58 (42.67)	-2.34 (1.98)	1.39	1.000	0.01
East edge (km)	358.41 (36.07)	-2.39 (1.68)	2.03	1.000	0.03
Northing (km)	770.74 (28.80)	3.79 (1.34)	8.02	0.060	0.16
South edge (km)*	59.00 (64.36)	-1.13 (2.99)	0.14	1.000	-0.02
North edge (km)	1284.45 (19.57)	0.78 (0.91)	0.74	1.000	-0.01

* Residual plots indicated a violation of the normality assumption, the non-significant relationship with year was confirmed using a Spearman's correlation test.

Table S4. Changes in environmental variables between the 1980s (1982-1989) and 2010s (2010-2019) for regions where habitat distribution was stable, declining, or increasing within each season. Table shows the mean (SE) change in each environmental variable between the 1980s and 2010s for each season. Superscript letters indicate which regions had a significant difference in change in each climate variable for each season.

Climate variable	Season	Declining	Stable	Increasing	F	p-value	r^2
Ice cover (%)	***Moult***	***-1.16 (0.2)^a***	***-0.23 (0.09)^b***	***-1.88 (0.67)^a***	***11.88***	***<0.001***	***0.14***
	Fall	***-0.48 (0.28)^a***	***-13.74 (1.32)^b***	***-21.46 (0.51)^c***	***674.35***	***<0.001***	***0.82***
	Winter	***-0.98 (0.19)^a***	***-9.48 (1.15)^b***	***-16.65 (0.8)^c***	***202.38***	***<0.001***	***0.62***
	Spring	***-6.78 (1.01^a***	***-12.22 (0.75)^b***	***-9.49 (0.5)^c***	***9.91***	***<0.001***	***0.12***
SST (°C)	Moult	0.72 (0.02)^a	0.68 (0.06)^a	0.79 (0.04)^a	1.99	0.14	0.03
	Fall	***1.11 (0.03)^a***	***0.79 (0.05)^b***	***0.49 (0.03)^c***	***99.41***	***<0.001***	***0.52***
	Winter	***0.83 (0.01)^a***	***0.79 (0.05)^a***	***0.27 (0.02)^b***	***249.2***	***<0.001***	***0.59***
	Spring	***0.89 (0.08)^a***	***0.49 (0.08)^b***	***0.05 (0.01)^c***	***66.94***	***<0.001***	***0.42***
Air temperature (°C)	***Moult***	***1.43 (0.02)^a***	***1.28 (0.04)^b***	***1.77 (0.07)^c***	***17.34***	***<0.001***	***0.18***
	Fall	***1.68 (0.06)^a***	***3.97 (0.26)^b***	***4.83 (0.15)^c***	***200.08***	***<0.001***	***0.72***
	Winter	***0.98 (0.02)^a***	***3.27 (0.29)^b***	***2.89 (0.21)^b***	***69.32***	***<0.001***	***0.45***
	Spring	***0.75 (0.12)^a***	***1.2 (0.04)^b***	***0.97 (0.05)^a***	***9.72***	***<0.001***	***0.12***
Wind speed (km/hr)	***Moult***	***0.12 (0.01)^a***	***0.03 (0.02)^b***	***0.09 (0.02)^{ab}***	***5.4***	***0.01***	***0.07***
	Fall	***0.1 (0.07)^a***	***0.33 (0.04)^b***	***0.28 (0.05)^{ab}***	***4.06***	***0.02***	***0.05***
	Winter	***-0.76 (0.09)^a***	***-0.22 (0.1)^b***	***0.13 (0.07)^c***	***32.63***	***<0.001***	***0.28***
	Spring	***-0.12 (0.02)^a***	***0.12 (0.03)^b***	***0.23 (0.02)^c***	***69.89***	***<0.001***	***0.45***