Table S1. Metadata associated with observations of *Vazella pourtalesii* recorded from Deep Discoverer remotely operated vehicle video footage collected during NOAA's Okeanos Explorer Mid- and Southeast US oceanographic missions in 2018 (EX1806) and 2019 (EX1903). The range (min = minimum and max = maximum) in depth (m), temperature (Temp; °C), salinity and oxygen (mg l^{-1}) associated with the observations is shown, as well as the total number of individual *V. pourtalesii* recorded on each dive.

Mission	Dive	Geographic Location	Site	Depth (m)		Temp. (°C)		Salinity		Oxygen (mg l^{-1})		Counts
				Min	Max	Min	Max	Min	Max	Min	Max	
EX1806	07	Blake Plateau	Richardson Ridge	778	839	5.6	8.6	35.0	35.1	3.1	4.9	252
EX1806	10	Blake Plateau	Cape Fear	373	406	8.6	8.6	35.1	35.1	2.9	3.1	663
EX1903	01	Southeast US	Canaveral Deep	715	757	7.1	7.1	34.9	34.9	2.9	3.0	12
EX1903	04	Blake Plateau	Blake Plateau Knolls	759	772	10.1	11.2	35.3	35.4	4.2	4.3	17
EX1903	05	Blake Plateau	Central Plateau Mounds	794	813	9.8	10.4	35.3	35.3	3.0	3.1	16
EX1903	06	Blake Plateau	Stetson Mesa Seep	749	787	7.4	7.5	35.0	35.0	3.4	3.5	58
EX1903	08	Blake Plateau	Central Plateau Scarp	919	935	5.7	5.7	35.0	35.0	5.0	5.0	5
EX1903	10	Blake Plateau	Richardson "Jellyfish"	615	615	8.9	8.9	35.1	35.1	3.0	3.0	1
EX1903	18	Mid-US Shelf	Baltimore Canyon	495	511	5.9	7.1	35.0	35.1	4.0	4.8	27

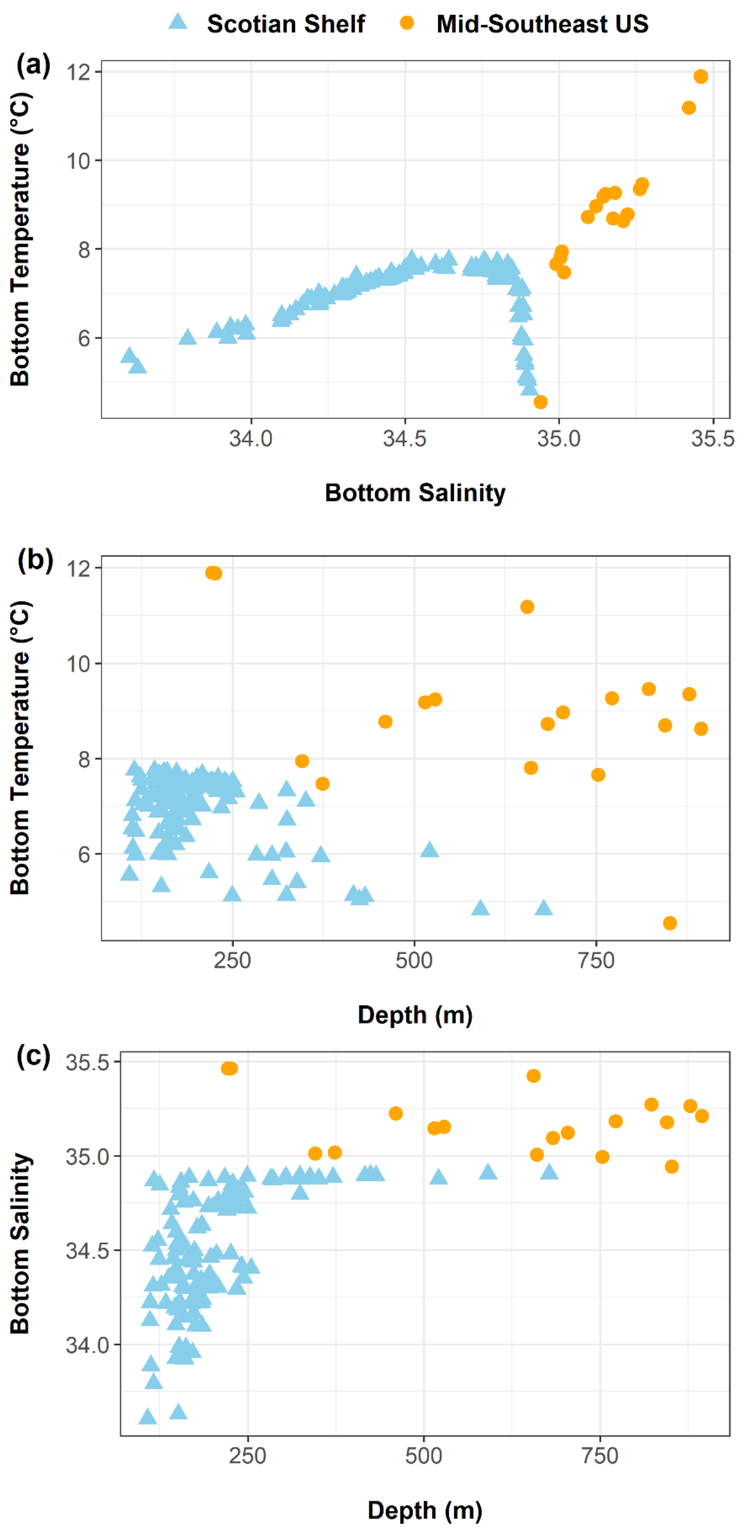

Fig. S1. a) Temperature-salinity (T-S) plot, and bivariate plots of b) depth and mean bottom temperature (b) and c) depth and mean bottom salinity at *Vazella pourtalesii* presence locations on the Scotian Shelf and off the mid-southeast USA.

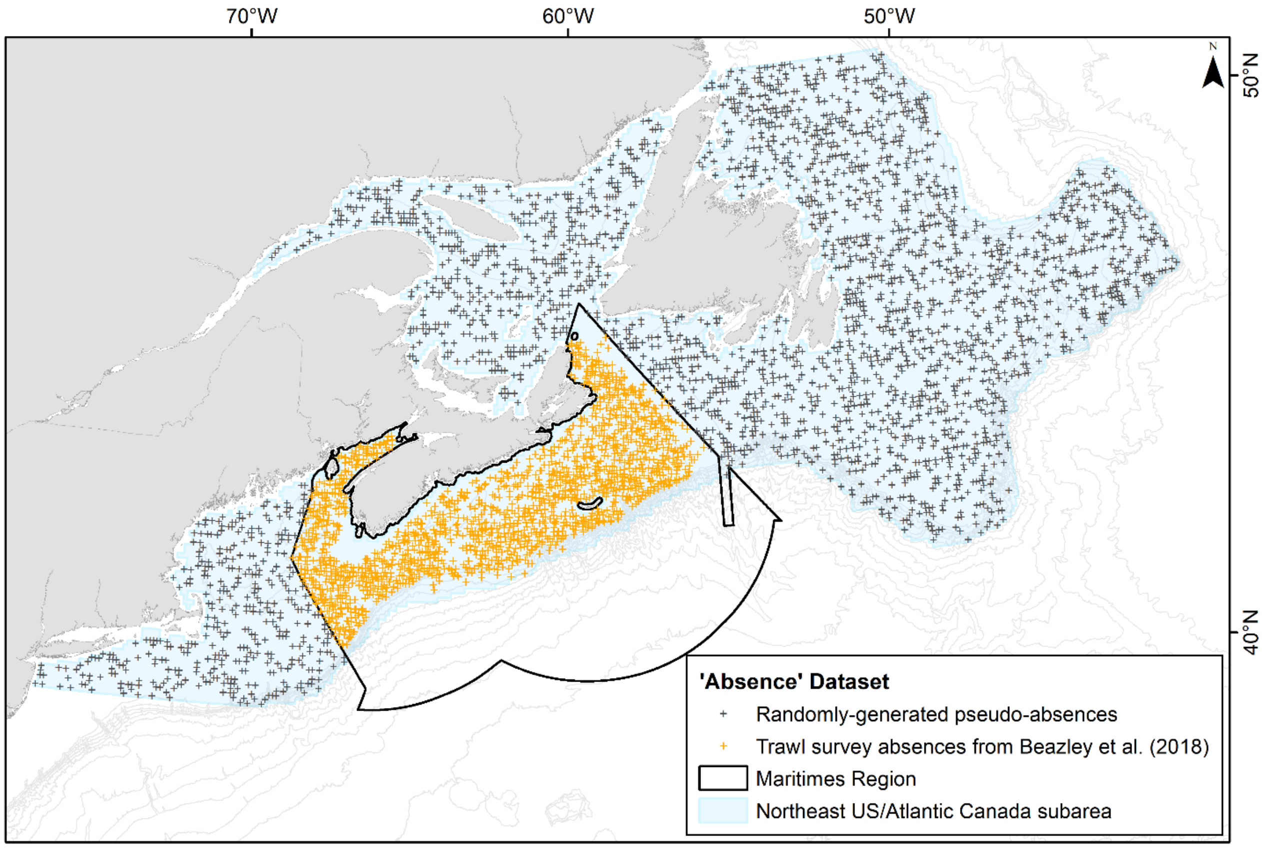

Fig. S2. Pseudo-absences (2757) randomly-generated using R package 'mopa' and absences generated from null catches (1611) from Fisheries and Oceans Canada's multispecies trawl survey conducted in Fisheries and Oceans Canada's Maritimes Region. Data were extracted for comparative purposes only and were not used as the final presence/pseudo-absence dataset.

Table S2. Accuracy measures from 5-fold spatial block cross-validation of Random Forest and GAM models built on *Vazella pourtalesii* presences, absences from DFO's multispecies trawl survey for the Scotian Shelf, and randomly-generated pseudo-absences. Models were run for comparative purposes only and were not selected as the final models in this study.

Model	Mean AUC ± SD	Sensitivity	Specificity	TSS	MSS Threshold
Random Forest	0.92 ± 0.01	0.93	0.81	0.74	0.02
GAM	0.92 ± 0.02	0.96	0.83	0.79	0.01

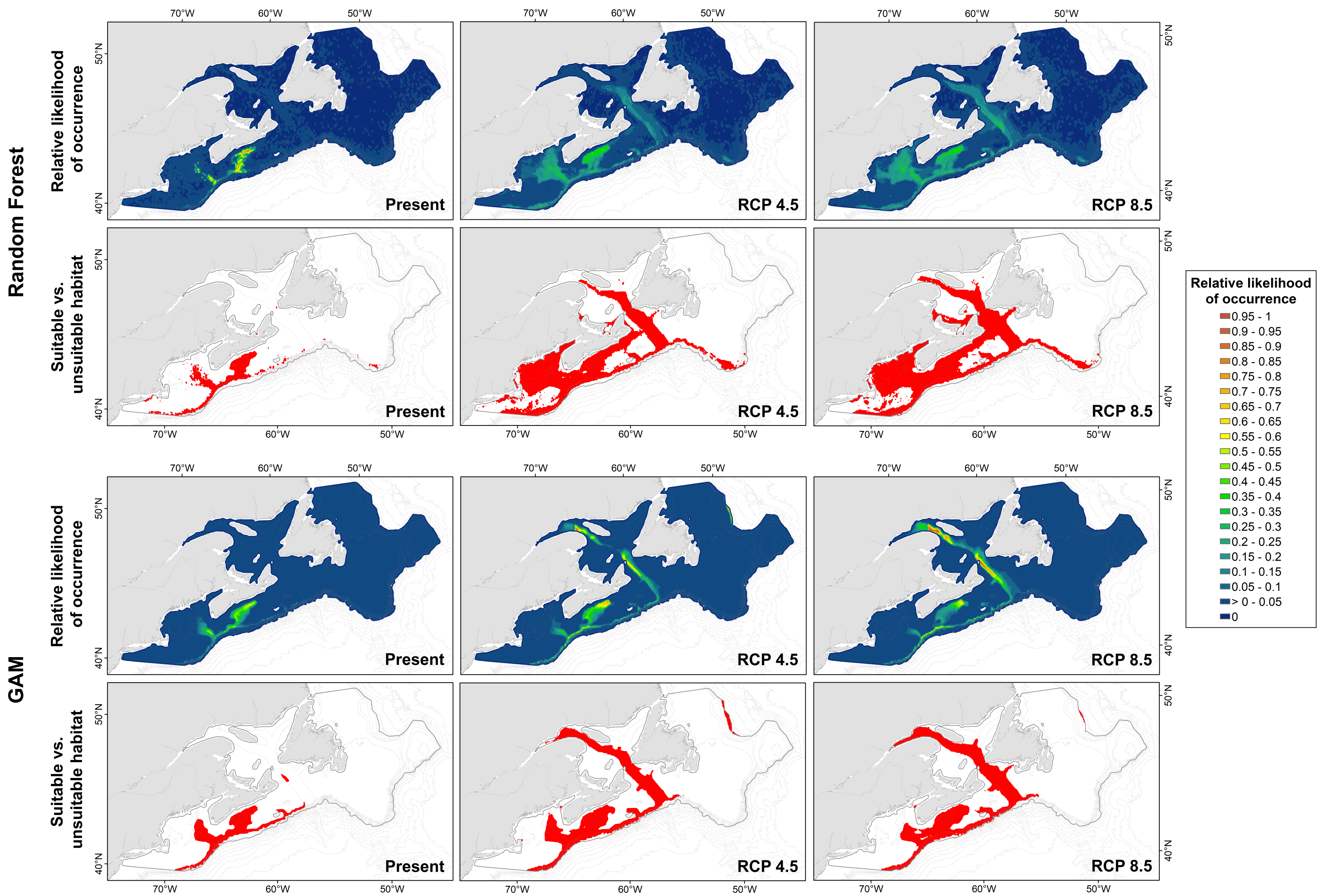

Fig. S3. Relative likelihood of occurrence and suitable habitat (red) of *Vazella pourtalesii* predicted/projected by Random Forest (top) and GAM (bottom) under present day, RCP 4.5 and RCP 8.5 future climatic conditions using *V. pourtalesii* presence data and 'absences' generated from a combination of trawl survey null catches used in Beazley et al. (2018) and randomly-generated pseudo-absences using R package 'mopa'. Relative occurrences were thresholded using the maximum of sensitivity + specificity in Table S2 above to identify suitable (red) versus unsuitable habitat. Models were run for comparative purposes only.

Text S1 – Description of methodology used for pseudo-absence generation

While there is no consensus on the best approach for the generation of pseudo-absences (Iturbide et al. 2018), the most commonly applied method is to randomly sample from the environmental or modelling background (Iturbide et al. 2015). However, this approach has shown to increase the risk of creating false absences, leading to increased omission error and an underestimation of the species' fundamental niche (Anderson & Raza 2010, Iturbide et al. 2015). To help alleviate this problem, some studies have generated pseudo-absences based on a minimum distance away from the presence points, or outside a pre-defined area based on a preliminary model to identify suitable versus unsuitable habitat (i.e., environmental profiling; Barbet-Massin et al. 2012, Senay et al. 2013). We investigated the use of both random sampling (RS) with a buffer exclusion zone around the presences, and random sampling with environmental profiling (RSEP), implemented using the R statistical software version 3.6.1 (R Core Team 2019) package 'mopa' (Iturbide et al., 2018). For the RSEP method, the R function 'OSCVMprofiling' was used to perform a preliminary binary classification of the background using the species-environment relationship at presence locations. However, this identified areas of suitable habitat on the Scotian Shelf (e.g., canyons) where real *V. pourtalesii* absence data were previously collected (see Beazley et al. 2018). To avoid over-prediction of *V. pourtalesii*'s habitat, we therefore chose to generate pseudo-absences using the RS method.

Prior to pseudo-absence generation, occurrence data were filtered to 1 presence per environmental grid cell, resulting in 136 presences with 18 and 118 located in the Mid-Southeast US and Northeast US/Atlantic Canada subareas, respectively. The 'pseudoAbsences' function of package 'mopa' was used to randomly select pseudo-absences 0.088° away from each presence location (buffer based on the size of the environmental grid cell) to ensure no absence data were placed into cells with presences. While many studies recommend using a large number of pseudo-absences (e.g., 10,000; Barbet-Massin et al. 2012) to optimize model performance, given the cell size of our environmental data layers, 10,000 pseudo-absences would populate ~60% and 100% of the Northeast US/Atlantic Canada subarea and Mid-Southeast US subareas, respectively. The 10,000 pseudo-absences found by Barbet-Massin et al. (2012) to optimize the accuracy metrics of regression techniques occupied only 20% of their study extent. Based on this ratio we generated two pseudo-absence datasets and tested the performance of Random Forest and GAM models built on each. First, pseudo-absences were generated for 20% of each subarea (excluding those cells containing presences), resulting in 3373 and 1164 pseudo-absences in the Northeast US/Atlantic Canada and Mid-Southeast US subareas, respectively. Secondly, pseudo-absences were generated based on the prevalence (i.e., proportion of observed presences; 0.07) of *V. pourtalesii* on the Scotian Shelf (Beazley et al. 2018). The number of prevalence-based pseudo-absences generated in the Northeast US/Atlantic Canada and Mid-Southeast US subareas was 1675 and 237, respectively. Random Forest and GAM models were then trained on each dataset and the accuracy metrics (AUC, Sensitivity, Specificity, and TSS) examined. Based on this evaluation, the pseudo-absences occupying 20% of the study area in the Northeast US/Atlantic Canada subarea were chosen for both Random Forest and GAM, while in the Mid-Southeast US subarea, the best GAM model was built on the 20% pseudo-absence dataset, while for Random Forest the pseudo-absence dataset based on prevalence was chosen.

Table S3. Number of presences (P) and pseudo-absences (A) allocated to the training (Train) and testing (Test) datasets of each fold from five-fold spatial block cross-validation. Pseudo-absence datasets were generated based on 20% of the study area in the Scotian Shelf subarea (used by both Random Forest and GAM), and 20% of the study area (GAM) and prevalence (Random Forest), in the Mid-Southeast US study area. The prevalence (proportion of presences) rate of each training dataset is also shown.

Northeast US/Atlantic Canada subarea - pseudo-absences based on 20% study area					
Fold	Train A	Train P	Test A	Test P	Prevalence
1	2674	114	699	4	0.041
2	2645	89	728	29	0.033
3	2804	70	569	48	0.024
4	2716	90	657	29	0.032
5	2653	109	720	9	0.040
Mid-Southeast US subarea – pseudo-absences based on 20% study area					
Fold	Train A	Train P	Test A	Test P	Prevalence
1	929	17	235	1	0.018
2	929	14	235	4	0.015
3	921	15	243	3	0.016
4	930	10	234	8	0.011
5	947	16	217	2	0.017
Mid-Southeast US subarea – pseudo-absences based on prevalence					
Fold	Train A	Train P	Test A	Test P	Prevalence
1	191	12	46	6	0.059
2	188	17	49	1	0.090
3	184	13	53	5	0.071
4	197	16	40	2	0.081
5	188	14	49	4	0.074

Table S4. Mean, minimum (min) and maximum (max) values of each predictor variable under present day and future (RCP 4.5 and 8.5) scenarios in the Northeast US/Atlantic Canada and Mid-Southeast US subareas. * indicates variable not included in Random Forest and GAM models; † indicates variable not included in GAM model.

Northeast US/Atlantic Canada Subarea													
	Bottom Temperature (°C)			**Bottom Salinity†**			**Bottom Current ($m\ s^{-1}$)†**			**Bottom Shear (Pa)***			**Depth (m)***
	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	
Mean	3.61±2.34	4.18±2.60	4.41±2.75	33.68±1.11	33.65±1.21	33.68±1.21	0.02±0.03	0.02±0.03	0.02±0.03	0.01±0.02	0.01±0.02	0.01±0.02	322±423
Min	-0.72	-0.65	-0.60	26.92	26.22	26.02	0	0	0	0	0	0	3
Max	11.15	12.00	12.51	35.02	35.15	35.19	0.30	0.30	0.30	0.35	0.33	0.34	1998
	Surface Temperature (°C)			**Surface Salinity**			**Surface Current ($m\ s^{-1}$)†**			**MLD (m)**			**Slope (°)**
	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	
Mean	6.91 ± 2.41	7.57 ± 2.55	7.81 ± 2.58	31.51 ± 1.59	31.28 ± 1.76	31.26 ± 1.78	0.10±0.10	0.10±0.10	0.10±0.10	17.84±4.09	17.41±6.08	17.25±5.66	0.79±1.56
Min	2.22	2.45	2.63	22.71	22.02	21.74	0	0	0	4.17	4.20	4.18	0
Max	13.07	13.88	14.43	34.07	34.22	34.21	0.61	0.61	0.63	31.77	61.43	52.66	28.64
Mid-Southeast US Subarea													
	Bottom Temperature (°C)			**Bottom Salinity†**			**Bottom Current ($m\ s^{-1}$)†**			**Bottom Shear (Pa)***			**Depth (m)***
	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	
Mean	12.22±6.68	12.56±6.87	12.60±6.88	35.00±0.94	34.99±0.97	34.98±0.97	0.04±0.06	0.04±0.05	0.04±0.05	0.03±0.05	0.03±0.04	0.03±0.05	520±502
Min	3.33	3.32	3.36	30.93	30.70	30.63	0	0	0	0	0	0	0
Max	26.74	27.09	27.27	36.45	36.38	36.44	0.42	0.36	0.38	0.64	0.49	0.54	2031
	Surface Temperature (°C)			**Surface Salinity†**			**Surface Current ($m\ s^{-1}$)**			**MLD (m)**			**Slope (°)**
	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	
Mean	23.26±4.41	23.76±4.19	23.84±4.19	34.94±1.49	34.84±1.52	34.83±1.54	0.30±0.44	0.30±0.44	0.30±0.43	27.46±12.36	27.22±11.78	27.11±11.87	1.00±2.15
Min	12.56	13.26	13.63	29.15	28.88	28.75	0	0	0	4.26	4.27	4.20	0
Max	27.47	27.76	27.86	36.35	36.39	36.44	1.66	1.70	1.65	54.69	53.31	51.32	26.91

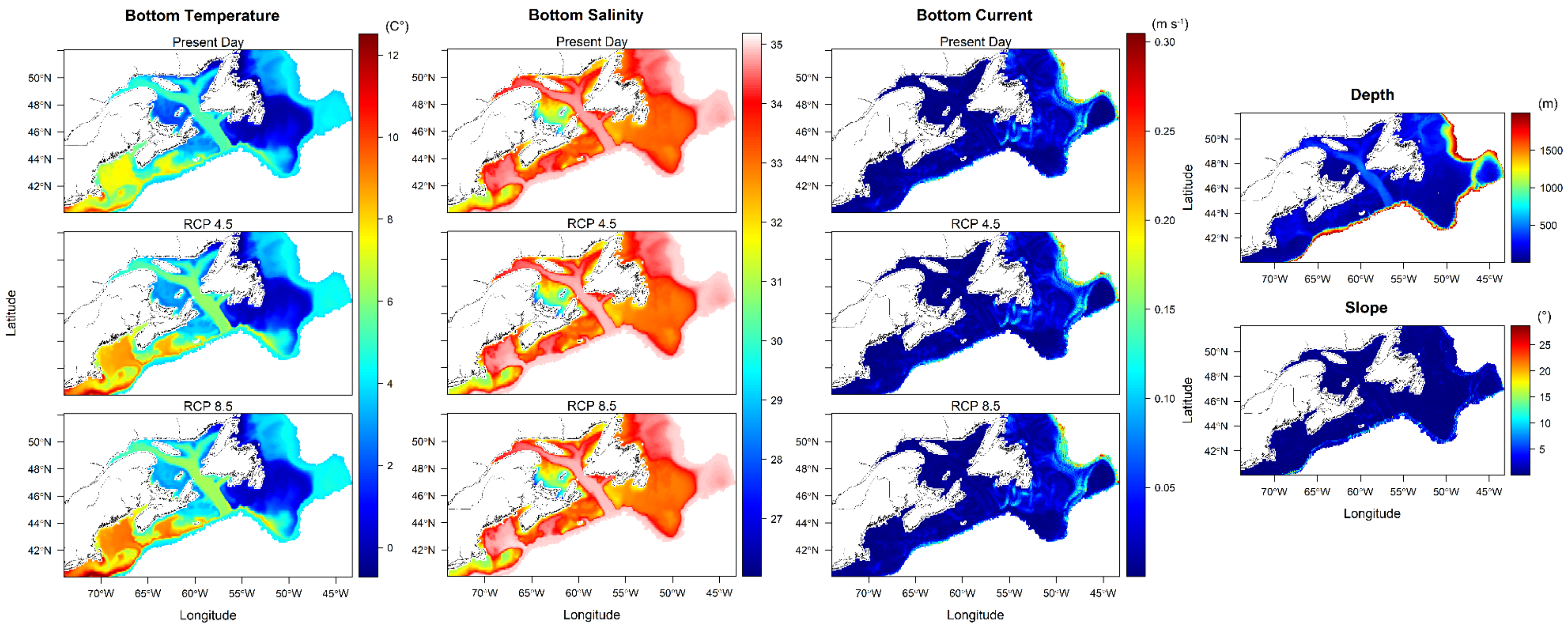

Fig. S4. Environmental predictor layers representing present day and future RCP 4.5, and RCP 8.5 environmental conditions the Northeast US/Atlantic Canada subarea. Shown here is Mean Bottom Temperature, Mean Bottom Salinity, and Mean Bottom Current. Also shown here are static variables Depth and Slope. Note that Depth is shown here for illustrative purposes and was not included in the models. Note the differences in colour ramp for Bottom Salinity, where the highest values are highlighted in white.

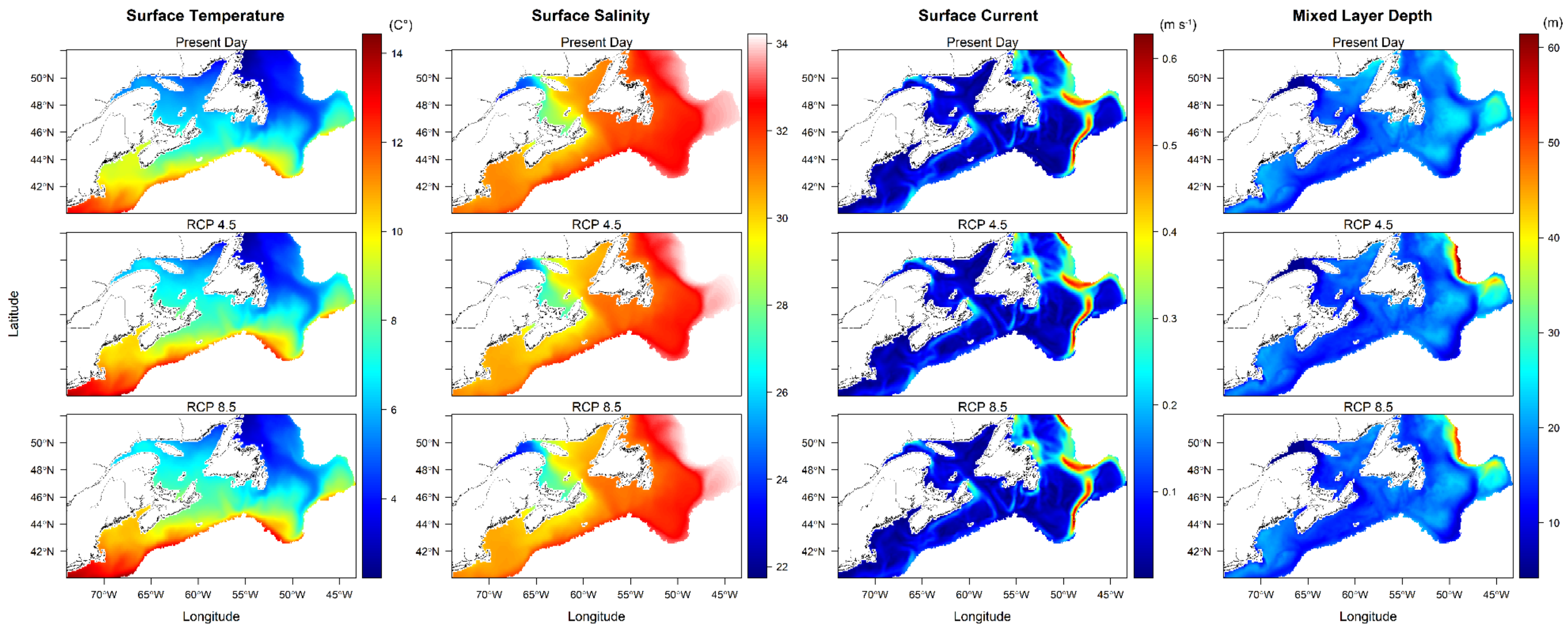

Fig. S4 continued. Environmental predictor layers representing present day and future RCP 4.5, and RCP 8.5 environmental conditions the Northeast US/Atlantic Canada subarea. Shown here is Mean Surface Temperature, Mean Surface Salinity, Mean Surface Current, and Mean Maximum Mixed Layer Depth. Note the differences in colour ramp for Bottom Salinity, where the highest values are highlighted in white.

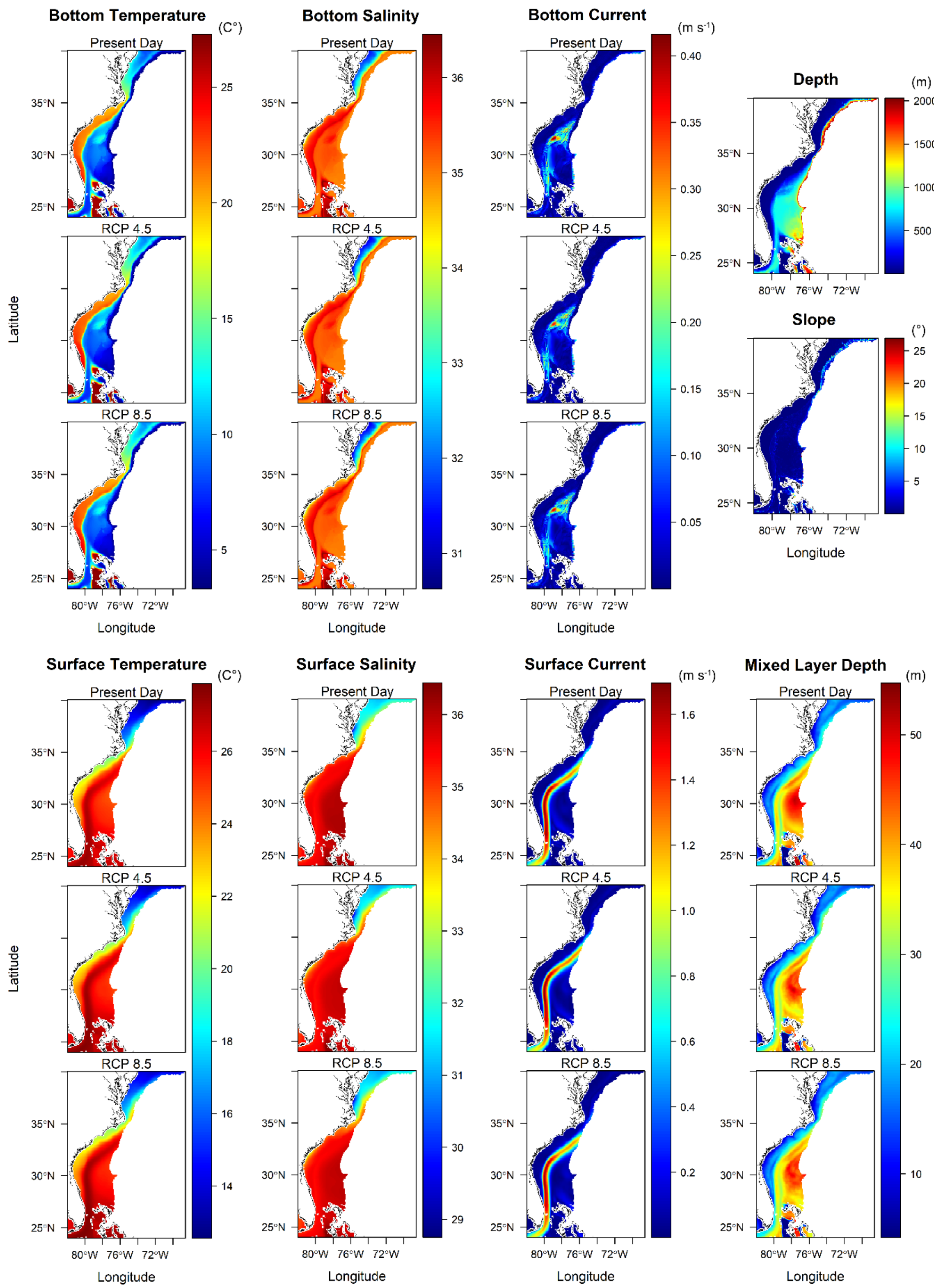

Fig. S5. Environmental predictor layers representing present day and future RCP 4.5, and RCP 8.5 environmental conditions the Mid-Southeast US subarea. Also shown here are static variables Depth and Slope. Note that Depth is shown here for illustrative purposes and was not included in the models.

Table S5. Parametric coefficients and approximate significance of smooth terms in generalized additive models developed to predict the distribution of *Vazella pourtalesii* in the Northeast US/Atlantic Canada and Mid-Southeast US study areas. Within term types (parametric or smooth), environmental variables are listed in order of their lowest p-value, which equates to the order of variable importance in Fig. S6. *indicates significance at the α = 0.05 level.

Northeast US/Atlantic Canada		R^2 (adj.) = 0.63	Deviance explained = 74.12%	
Parametric terms:	Estimate	Std. Error	z value	p-value
(intercept)	-49.70	14.01	-3.55	3.89×10^{-4}*
Bottom Current	29.24	13.63	2.15	0.03*
Slope	0.20	0.10	2.07	0.04*
Smooth terms:	edf	Ref.df	Chi.sq	p-value
s(Surface Salinity)	1.77	2.03	40.28	7.82×10^{-9}*
s(Bottom Salinity)	1.66	1.89	27.17	7.75×10^{-7}*
s(Surface Temperature)	2.75	2.93	23.78	2.08×10^{-5}*
s(MLD)	1.90	2.16	27.18	1.18×10^{-4}*
s(Bottom Temperature)	2.86	2.98	14.65	2.18×10^{-3}*
Mid-Southeast US		R^2 (adj.) = 0.06	Deviance explained = 21.70%	
Parametric terms:	Estimate	Std. Error	z value	p-value
(intercept)	-11.21	4.02	-2.79	5.36×10^{-3}*
Slope	0.29	0.08	3.52	4.36×10^{-4}*
Surface Current	0.81	0.50	1.63	0.10
Surface Temperature	0.15	0.11	1.33	0.18
Smooth terms:	edf	Ref.df	Chi.sq	p-value
s(Bottom Temperature)	1.89	2.07	3.16	0.16

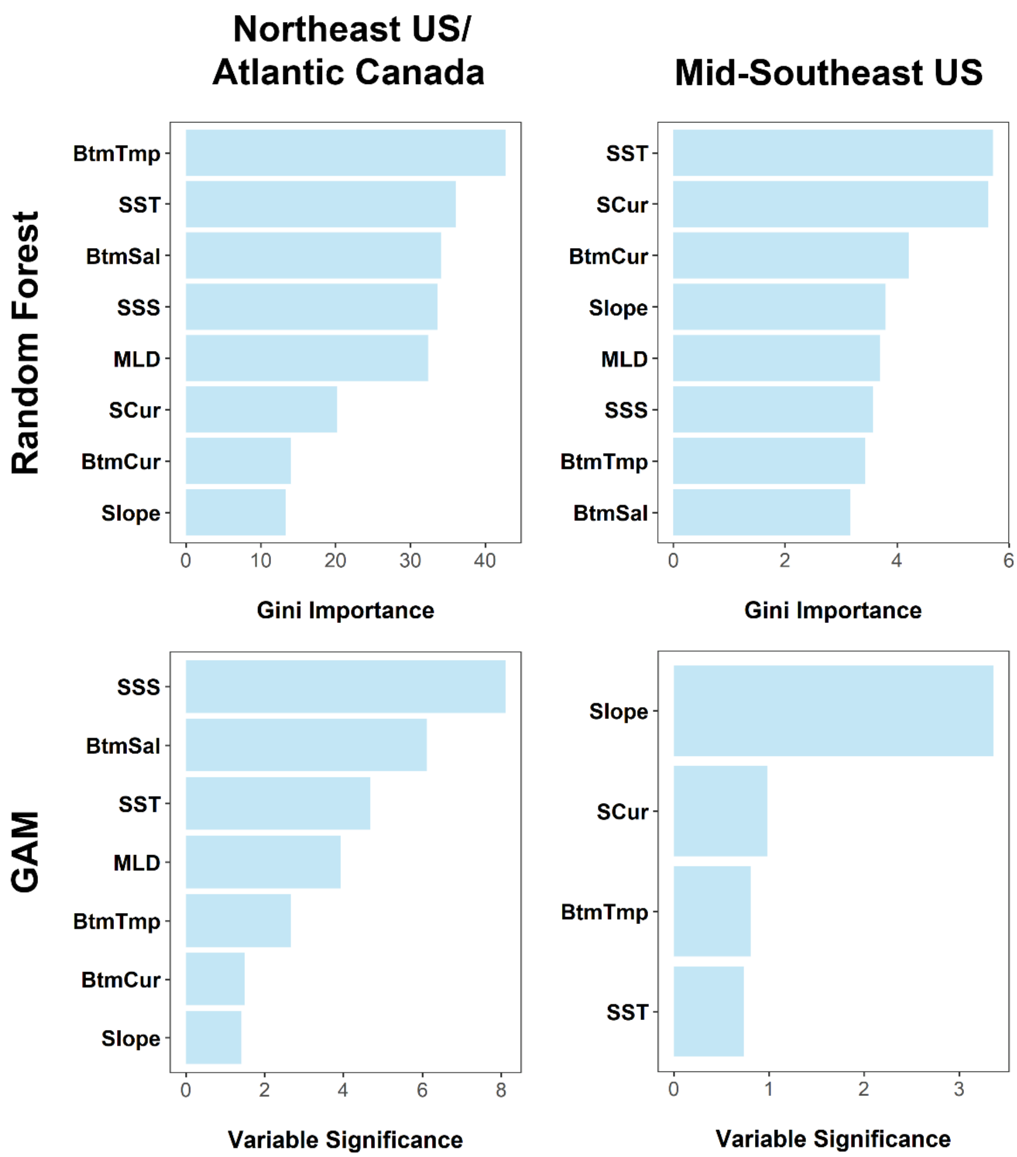

Fig. S6. Importance of environmental predictor variables in Random Forest (top row) and GAM (bottom row) models built to predict the present-day distribution of *V. pourtalesii* in the Northeast US/Atlantic Canada (left panel) and Mid-Southeast US (right panel) subareas. Abbreviated variables are as follows: BtmTmp = Mean Bottom Temperature, BtmSal = Mean Bottom Salinity, BtmCur = Mean Bottom Current, SST = Mean Surface Temperature, SSS = Mean Surface Salinity, SCur = Mean Surface Current, MLD = Mean Maximum Mixed Layer Depth.

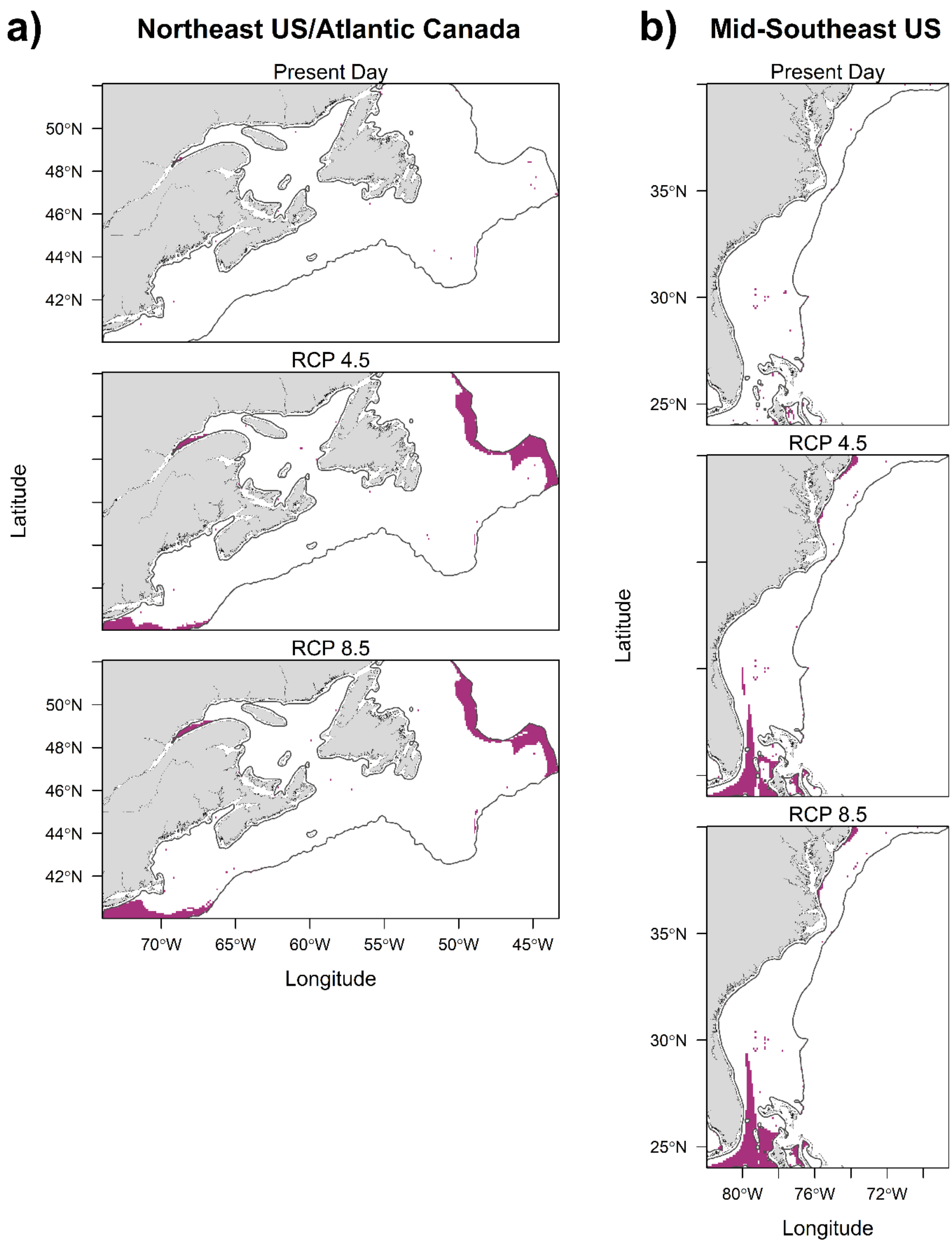

Fig. S7. Areas of model extrapolation (purple) in the a) Northeast US/Atlantic Canada and b) Mid-southeast US subareas for present-day and RCP 4.5 and 8.5 scenarios. Extrapolated areas are those where the values of at least one of the 8 environmental variables considered for modelling were either higher or lower than those present-day variables used to train the models.

Table S6. Mean, minimum (min) and maximum (max) values of each predictor variable in the Northeast US/Atlantic Canada subarea associated with the area predicted by the Random Forest and GAM models as suitable habitat in the present day (Present Day), and the gain in suitable habitat predicted to occur under the RCP 4.5 and 8.5 scenarios. * indicates variable not included in Random Forest and GAM models; † indicates variable was not included in GAM model.

		Depth (m)*			Bottom Temperature (°C)			Bottom Salinity			Bottom Current (m s^{-1})			Bottom Shear (Pa)*		
		Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5
RF	Mean	203±125	289±180	285±178	6.97±0.78	7.24±1.53	7.39±1.63	34.49±0.34	34.45±0.71	34.52±0.81	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01
	Min	45	13	12	4.32	2.80	2.57	33.18	26.22	26.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Max	972	1544	1544	9.20	12.00	12.48	34.93	35.15	35.19	0.06	0.05	0.06	0.03	0.02	0.03
GAM	Mean	219±177	341±167	335±164	6.77±0.92	5.91±0.82	6.04±0.72	34.42±0.42	34.49±0.49	34.48±0.50	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01	0.01±0.01
	Min	40	72	39.43	4.15	4.49	4.39	33.29	33.11	33.14	0.00	<0.01	0.00	<0.01	<0.01	<0.01
	Max	1516	1500	1511.49	9.20	8.81	9.33	34.94	34.96	34.97	0.07	0.06	0.08	0.03	0.03	0.04
		Slope (°)			Surface Temperature (°C)			Surface Salinity			Surface Current (m s^{-1})†			MLD (m)		
		Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5
RF	Mean	0.96±1.91	0.74±1.75	0.73±1.64	9.26±0.89	9.27±1.86	9.35±1.85	30.83±0.46	30.67±0.65	30.64±0.71	0.09±0.05	0.06±0.04	0.06±0.71	14.05±1.65	16.09±2.45	16.04±2.53
	Min	0.01	0.00	0.00	7.45	6.11	6.31	30.09	25.81	25.59	<0.01	<0.01	<0.01	10.98	4.28	4.18
	Max	15.25	21.34	21.34	12.45	13.51	14.03	31.84	33.06	33.00	0.24	0.21	0.28	19.03	21.25	21.71
GAM	Mean	1.22±2.60	0.74±1.63	0.70±1.41	9.29±0.82	7.73±1.26	7.79±1.14	30.91±0.48	29.46±2.54	29.42±2.55	0.08±0.05	0.07±0.05	0.07±0.05	14.46±1.89	13.35±4.15	13.42±4.20
	Min	0.01	0.02	0.01	7.36	6.04	6.22	30.06	23.07	22.70	<0.01	<0.01	0.01	10.98	4.73	4.53
	Max	28.64	18.97	18.97	12.51	13.19	12.38	32.13	32.01	31.96	0.24	0.26	0.31	18.87	18.72	18.68

Table S7. Mean Bottom Temperature (°C) associated with the areas predicted to gain suitable habitat in the Gulf of Maine and Laurentian Channel (see yellow areas in the Northeast US/Atlantic Canada subarea in Fig. 6), as predicted by Random Forest and GAM for environmental conditions under RCP 4.5 and RCP 8.5 emission scenarios. Present-day mean bottom temperature associated with the same areas was extracted as a comparison.

	Mean Bottom Temperature (°C)			
Random Forest	Present day	Suitable habitat gained under RCP 4.5	Present day	Suitable habitat gained under RCP 8.5
Gulf of Maine	7.35 ± 0.35	8.59 ± 0.33	7.20 ± 0.58	8.97 ± 0.55
Laurentian Channel	5.31 ± 0.14	6.10 ± 0.16	5.24 ± 0.30	6.25 ± 0.33
GAM	Present day	Suitable habitat gained under RCP 4.5	Present day	Suitable habitat gained under RCP 8.5
Gulf of Maine	7.48 ± 0.13	8.73 ± 0.09	7.49 ± 0.07	9.28 ± 0.02
Laurentian Channel	5.11 ± 0.33	5.77 ± 0.47	5.06 ± 0.40	5.98 ± 0.53

Table S8. Mean, minimum (min) and maximum (max) values of each predictor variable in the Mid-Southeast US subarea associated with the area predicted by Random Forest and GAM as suitable habitat in the present day (Present Day), and the gain in suitable habitat predicted to occur under the RCP 4.5 and 8.5 scenarios. * indicates variable not included in both Random Forest and GAM models; † indicates variable not included in GAM model.

		Depth (m)*			Bottom Temperature (°C)			Bottom Salinity†			Bottom Current ($m\ s^{-1}$)†			Bottom Shear (Pa)*		
		Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5
RF	Mean	637±316	809±404	757±453	9.60±3.14	9.01±4.71	10.47±6.63	35.26±0.28	35.22±0.35	35.26±0.47	0.09±0.08	0.04±0.05	0.04±0.05	0.07±0.09	0.03±0.04	0.03±0.04
	Min	15	0	0	3.33	3.41	3.43	32.32	31.79	31.33	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Max	1972	1991	1991	26.51	27.05	27.27	36.44	36.36	36.41	0.42	0.34	0.34	0.64	0.43	0.43
GAM	Mean	699±270	723±371	775±339	9.01±1.79	7.66±3.00	7.89±3.09	35.21±0.16	35.15±0.22	35.17±0.23	0.08±0.07	0.03±0.04	0.04±0.05	0.06±0.08	0.02±0.03	0.03±0.04
	Min	49	68	68	3.33	4.11	4.03	34.91	34.95	34.96	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Max	1987	1827	1723	13.72	12.84	12.91	35.70	35.58	35.59	0.42	0.17	0.27	0.64	0.13	0.28

		Slope (°)			Surface Temperature (°C)			Surface Salinity†			Surface Current ($m\ s^{-1}$)			MLD (m)†		
		Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5	Present Day	RCP 4.5	RCP 8.5
RF	Mean	1.29±2.76	1.17±2.31	1.37± 2.57	25.94± 1.70	25.74±2.51	25.67±3.01	35.63±0.49	35.53±0.81	35.48±1.01	0.64±0.55	0.31±0.42	0.25±0.36	35.54±7.97	37.84±8.46	35.50±10.68
	Min	<0.01	<0.00	<0.00	12.56	13.53	13.82	31.56	31.31	31.18	<0.01	<0.01	<0.01	13.01	4.93	4.92
	Max	26.91	24.41	23.41	27.47	27.76	27.86	36.14	36.36	36.42	1.66	1.69	1.64	51.39	53.31	51.32
GAM	Mean	1.32±2.86	3.42±4.03	3.56± 4.08	25.94±1.70	23.19±4.25	23.21±4.36	35.63±0.49	34.71±1.38	34.67±1.49	0.64±0.55	0.33±0.41	0.26±0.33	35.55±7.97	31.83±9.79	32.08±9.86
	Min	0.00	0.04	0.04	12.56	13.53	13.82	31.56	31.31	31.31	<0.01	0.03	0.03	13.01	12.93	13.48
	Max	26.91	12.65	12.65	27.47	27.51	27.62	36.14	35.92	35.95	1.66	1.24	1.11	51.39	46.44	46.62

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