Supplemental Material

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A. Patch-Assessment Methods and Results

METHODS

Patch Attributes

Location and dimension.—We recorded the following patch-location covariates during patch layer development (Wiest et al. 2016): state (e.g., Massachusetts, Rhode Island), subregion (e.g., Cape Cod – Casco Bay, Southern New England), and centroid coordinates (longitude and latitude). We calculated 2 patch-dimension covariates: area and perimeter length.

Land use/land cover.—We calculated the proportion of high marsh in a patch using a raster file developed by M. D. Correll, University of Maine (unpublished data). The raster quantified high marsh areas in the Northeast, USA using Landsat Thematic Mapper imagery and local tidal covariates; high marsh was characterized by saltmeadow cordgrass (*Spartina patens*), smooth cordgrass-short form (*S. alterniflora*), black grass (*Juncus gerardii*), and saltgrass (*Distichlis spicata*).

We calculated the proportion of land in 5 land use/land cover categories (i.e., natural lands, agriculture, developed, open water, and marsh) within 150-m and 1000-m buffers of each patch using The Nature Conservancy's spatial data (Ferree and Anderson 2013). We considered any land cover type not classified as agriculture, developed lands, or open water, to be natural lands. We used a subset of the natural land cover types to calculate the proportion of marsh as an

index of habitat connectivity (Winfree et al. 2005). We considered the following 5 categories to be marsh: (1) Acadian estuary marsh; (2) Acadian coastal salt marsh, Acadian estuary marsh; (3) North Atlantic coastal plain tidal salt marsh: salt/brackish/oligohaline; (4) North Atlantic coastal plain brackish/fresh & oligohaline tidal marsh; and (5) Atlantic coastal plain embayed region tidal freshwater/brackish marsh (Comer et al. 2003, Ferree and Anderson 2013).

Geomorphic setting.—We reviewed aerial photographs in ArcGIS ver. 10.2.2 (Environmental Systems Research Institute, Inc., Redlands, CA, USA) to characterize patch geomorphic setting. The physical setting of Northeast tidal marshes varies along the coast and settings are characterized by differences in hydrodynamics, sediment sources, and plant community characteristics (Cahoon et al. 2009). We evaluated patches using 6 broad geomorphic settings: open coast, back-barrier lagoon marsh, estuarine embayment, estuarine brackish marsh, tidal fresh marsh, and nontidal brackish marsh. When a patch was situated in multiple broad settings, we recorded the primary setting (i.e., the dominant setting, >50%), followed by secondary and tertiary settings, if applicable. Settings were based on a classification scheme modified from Reed et al. 2008 (based on Woodroffe 2002 and Cahoon 2006). We did not assess the effect of patch sub-setting.

Sea-level trend.—We used data from the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service, Center for Operational Oceanographic Products and Services (CO-OPS) to calculate sea-level trend for each patch. CO-OPS calculates sea-level trends, i.e., changes in mean sea-level (rise or fall, mm per year), for long-term water level stations using a minimum of 30 years of consecutive station observations (NOAA, National Ocean Service, CO-OPS 2013, 2014). In most cases, we recorded the trend for each patch as that from the nearest water level station that was located in an area most similar to the patch; this

was usually the nearest station and applied to the majority of patches. In cases where there was no single nearby station, we used the mean sea-level trend from multiple stations that were in the broader vicinity. For example, we recorded the mean sea-level trend of the Kings Point, Port Jefferson, and Montauk stations as the sea-level trend for patches on Long Island's southern shore (Far Rockaway to Southampton, New York) where a long-term water level station is not present.

Human disturbance.—We calculated road density as an index of human disturbance using U.S. Census Bureau TIGER/Line road spatial data (U.S. Census Bureau 2013). We estimated road density by creating a 500-m buffer around each patch, calculating the total road length in the patch and buffer, and dividing by the area of the patch and buffer. Although road presence within tidal marshes is usually minimal, we included patch road length in the calculation so that roads present in patches were accounted for.

RESULTS

Patch Attributes

Location and dimension.—For results for the patch-location covariates (i.e., state, subregion, and longitude/latitude coordinates) and the patch-dimension covariate area, see Wiest et al. (2016) and Table A1, respectively. Patch perimeter length ranged from 40 to 2,544,677 m and mean perimeter was greatest in Delaware Bay (33,502 ± 11,956 m; mean ± standard error; Table A1).

Land use/land cover.—In patches with high marsh spatial data, 45% of patches contained no high marsh and 7% of patches contained all high marsh. The mean proportion of high marsh was greatest in Cape Cod – Casco Bay (0.49 ± 0.02; Table A1). The remote sensing data necessary to classify marsh vegetation into high marsh and non-high marsh areas did not exist

for a proportion of the patches in each subregion (29% of total patches = 2,416): Coastal Maine to Delaware Bay – 7% of patches or less, Coastal Delmarva – 16% of patches, and Eastern Chesapeake Bay – 64% of patches.

Across subregions, the mean proportion of natural lands and open water typically ranged from 0.25 to 0.50 and the mean proportion of agriculture and developed lands ranged from 0.0 to 0.35 (Table A1). Within subregion, the mean proportion of natural lands was similar for the 150-m and 1000-m buffers. The same pattern was true for agriculture, developed lands, and open water. For both buffers, Coastal Maine contained the greatest mean proportion of natural lands; Eastern Chesapeake Bay, agriculture; Coastal New Jersey, developed lands; and Coastal Delmarva, open water. Mean proportion of marsh was greatest in Long Island for the 150-m buffer (0.19 ± 0.01) and in Delaware Bay for the 1000-m buffer (0.17 ± 0.01), and was lowest in Coastal Maine for both buffers (0.04 ± 0.00 and 0.03 ± 0.00 for 150-m and 1000-m, respectively).

Geomorphic setting.—The primary, broad geomorphic setting was estuarine embayment for 63% of patches (n = 5,254), back-barrier lagoon marsh for 27% of patches (n = 2,296), and estuarine brackish marsh for 8% of patches (n = 679; Table A2). Few patches were classified as tidal fresh marsh (n = 153) or open coast (n = 23). No patches were classified as nontidal brackish marsh.

Sea-level trend.—There were 33 NOAA long-term water level stations in our study area, including all Chesapeake Bay stations. On average, 3.7 stations occurred in each subregion, and 6 subregions contained 2 or 3 stations. Southern New England contained the greatest number of stations (n = 6), although there were 9 stations on the western shore of the Chesapeake Bay; some of the western shore stations informed sea-level trend in patches on the Chesapeake Bay's

eastern shore. The sea-level trend for all stations exhibited a rise, from 1.76 mm per year (Seavey Island, Maine) to 6.05 mm per year (Chesapeake Bay Bridge Tunnel, Virginia). The northernmost (Eastport, Maine) and southernmost (Portsmouth, Virginia) stations had sea-level trends of 2.00 and 3.76 mm per year, respectively. Mean sea-level trend by subregion ranged from 1.95 ± 0.0 mm per year in Coastal Maine to 4.39 ± 0.05 mm per year in Coastal Delmarva (Table A1).

Human disturbance.—Patch road density ranged from 0.0 to 221.7 m/ha. Road density was 0 m/ha for 9% of patches (n = 722), between 0.0 and 50.0 m/ha for 66% of patches (n = 5,569), and >50.0 m/ha for 25% of patches (n = 2,114). Overall, mean road density was greater in northern subregions than in southern subregions, but was greatest in Coastal New Jersey (54.4 ± 1.8 m/ha; Table A1).

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Supplementary Material Table A1. Tidal-marsh patches (*n*) and patch covariates in the Northeast United States, by subregion (north to south). Patch covariates are grouped by category and means (SE) are reported. Land use/land cover covariates are proportions; NA, not applicable. Number of patches and mean area are reproduced from Wiest et al. 2016.

	Subregion							
Category Covariate	Coastal Maine	Cape Cod - Casco Bay	Southern New England	Long Island	Coastal New Jersey	Delaware Bay	Coastal Delmarva	Eastern Chesapeake Bay
Patches (*n*)	1,441	536	1,201	716	533	166	471	3,341
Dimension								
Area (ha)	4 (0)	38 (8)	8 (1)	14 (1)	95 (26)	360 (145)	96 (29)	23 (9)
Perimeter (m)	1,580 (98)	7,269 (1,143)	2,663 (155)	3,883 (310)	10,662 (2,410)	33,502 (11,956)	11,388 (2,613)	2,971 (811)
Land use/land cover [a]								
High marsh	0.14 (0.01)	0.49 (0.02)	0.31 (0.01)	0.34 (0.01)	0.14 (0.01)	0.02 (0.0)	0.22 (0.01)	0.22 (0.01)
Natural 150	0.52 (0.01)	0.39 (0.01)	0.40 (0.01)	0.39 (0.01)	0.25 (0.01)	0.33 (0.02)	0.22 (0.01)	0.25 (0.0)
Agriculture 150	0.03 (0.0)	0.04 (0.0)	0.01 (0.0)	0.03 (0.0)	0.03 (0.0)	0.19 (0.01)	0.09 (0.01)	0.35 (0.0)

	Subregion							
Category Covariate	Coastal Maine	Cape Cod - Casco Bay	Southern New England	Long Island	Coastal New Jersey	Delaware Bay	Coastal Delmarva	Eastern Chesapeake Bay
Developed 150	0.11 (0.0)	0.26 (0.01)	0.30 (0.01)	0.27 (0.01)	0.33 (0.01)	0.12 (0.01)	0.08 (0.01)	0.05 (0.0)
Open water 150	0.34 (0.01)	0.32 (0.01)	0.28 (0.01)	0.32 (0.01)	0.39 (0.01)	0.36 (0.02)	0.61 (0.02)	0.35 (0.0)
Marsh 150	0.04 (0.0)	0.10 (0.0)	0.11 (0.0)	0.19 (0.01)	0.10 (0.0)	0.07 (0.01)	0.08 (0.0)	0.08 (0.0)
Natural 1000	0.50 (0.01)	0.36 (0.01)	0.32 (0.0)	0.29 (0.01)	0.26 (0.01)	0.37 (0.01)	0.26 (0.01)	0.25 (0.0)
Agriculture 1000	0.03 (0.0)	0.03 (0.0)	0.02 (0.0)	0.04 (0.0)	0.02 (0.0)	0.24 (0.02)	0.12 (0.01)	0.37 (0.0)
Developed 1000	0.09 (0.0)	0.27 (0.01)	0.31 (0.01)	0.28 (0.01)	0.37 (0.01)	0.14 (0.01)	0.07 (0.0)	0.04 (0.0)
Open water 1000	0.38 (0.01)	0.33 (0.01)	0.35 (0.01)	0.39 (0.01)	0.35 (0.01)	0.24 (0.02)	0.55 (0.01)	0.33 (0.0)
Marsh 1000	0.03 (0.0)	0.09 (0.0)	0.07 (0.0)	0.12 (0.0)	0.13 (0.01)	0.17 (0.01)	0.14 (0.0)	0.07 (0.0)
Sea-level trend								
Sea-level trend (mm/yr)	1.95 (0.0)	2.24 (0.02)	2.46 (0.01)	2.61 (0.01)	3.67 (0.02)	3.50 (0.01)	4.39 (0.05)	3.50 (0.0)
Human disturbance								

	Subregion							
Category Covariate	Coastal Maine	Cape Cod - Casco Bay	Southern New England	Long Island	Coastal New Jersey	Delaware Bay	Coastal Delmarva	Eastern Chesapeake Bay
Road density (m/ha)	27.58 (0.56)	53.39 (1.56)	52.73 (0.95)	43.4 (1.24)	54.38 (1.76)	28.98 (2.18)	28.23 (1.64)	27.91 (0.37)

[a] Land use/land cover data were unavailable for 11 patches for the 150-m buffer calculation and for 6 patches for the 1000-m buffer calculation.

Supplementary Material Table A2. Tidal-marsh patches (*n*) categorized by broad geomorphic setting, by subregion (north to south). Each patch is accounted for once based on the patch's primary setting. Settings were based on a classification scheme modified from Reed et al. 2008 (based on Woodroffe 2002 and Cahoon 2006).

Broad geomorphic setting[a]	Subregion							
	Coastal Maine	Cape Cod - Casco Bay	Southern New England	Long Island	Coastal New Jersey	Delaware Bay	Coastal Delmarva	Eastern Chesapeake Bay
Open coast[b]	8	6	8	1	0	0	0	0
Back-barrier lagoon marsh[c]	78	180	552	676	341	0	469	0
Estuarine embayment[d]	1,233	346	557	38	122	52	2	2,904
Estuarine brackish marsh[e]	122	4	49	1	44	86	0	373
Tidal fresh marsh[f]	0	0	35	0	26	28	0	64

[a] No patches were categorized as nontidal brackish marsh (transgressive marshes bordering uplands in estuaries with restricted tidal regimes).

[b] Areas sheltered from waves and currents due to coastal topography or bathymetry.

[c] Areas that occupy fill within transgressive back-barrier lagoons.

[d] Shallow coastal embayments with some river discharge, which are frequently drowned river valleys.

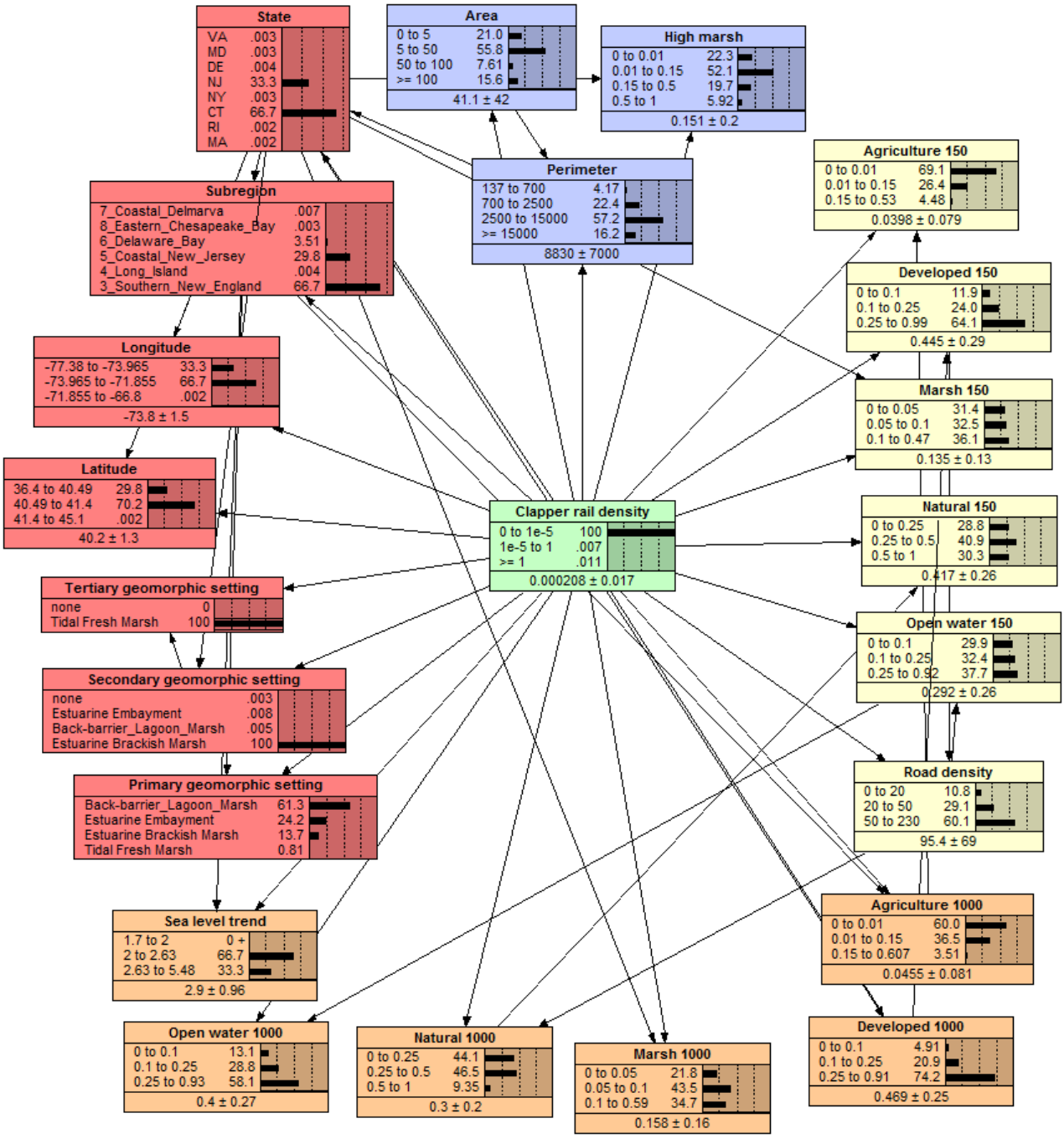
[e] Areas located in the vicinity of the turbidity maxima zone.

[f] Areas located above the turbidity maxima zone, which develop in drowned river valleys as filled with sediment.

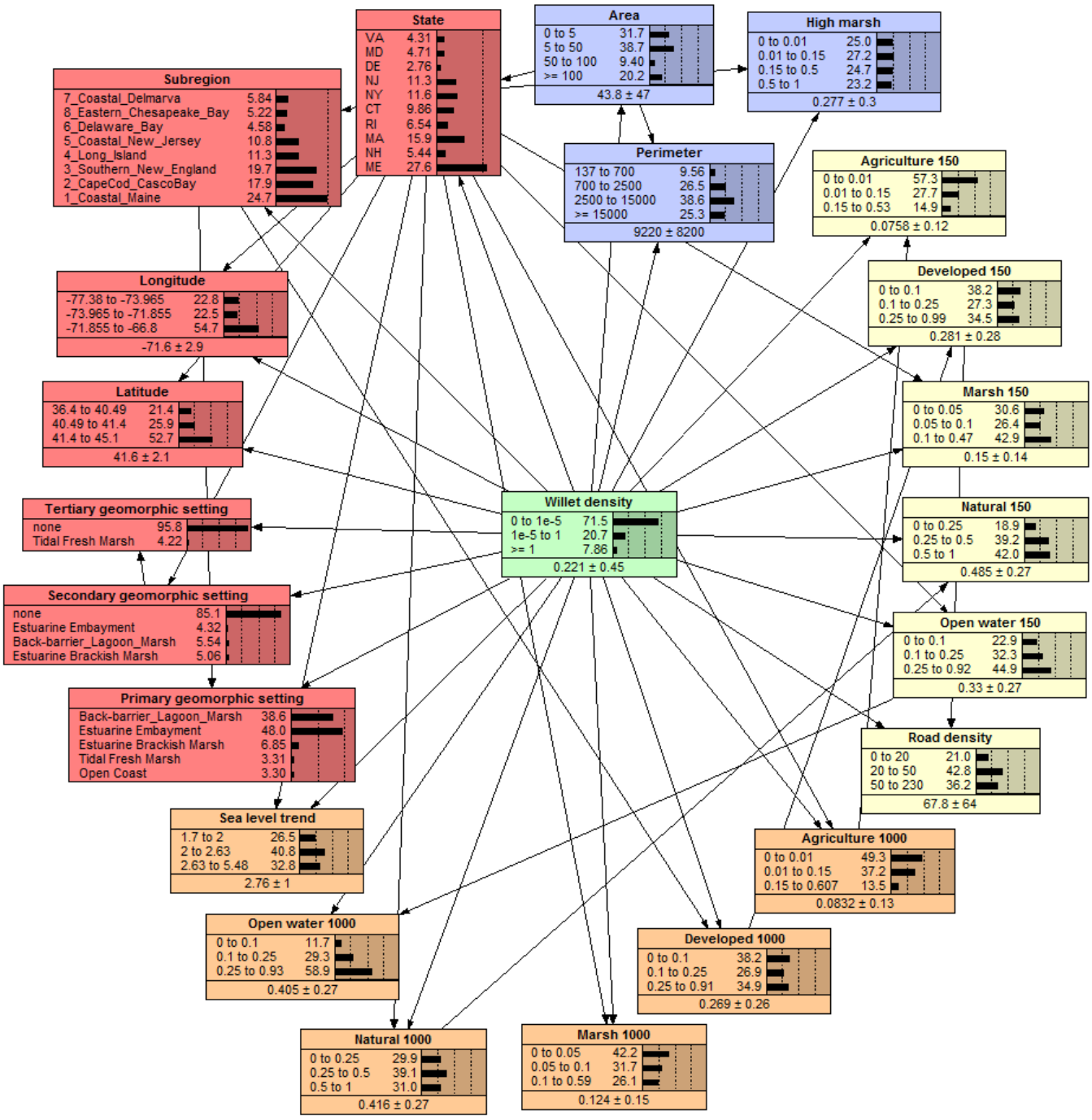
B. Species Bayesian Network Models

The following figures present the final selected Bayesian network models developed for each species, using a tree-augmented naive Bayes algorithm to develop the model structures and the expectation maximization algorithm to parameterize the probability tables (e.g., see Supplementary Material Table B1) from field data. Nodes in the following figures are color-coded according to the 4 geographic levels of the covariates, and the response variable, listed as follows in increasing spatial scales: purple = *patch* geographic level, beige = *local* geographic level, orange = *landscape* geographic level, red = *regional* geographic level; and green = bird species density response variable. Each arrow (link) indicates that probability relationships exist between 2 nodes. In each node, the values on the left are the states (bin categories) of the covariate (or response variable), and the values on the right with the accompanying belief bars show the probability of a certain state expressed as a percentage. The mean value ± standard deviation is shown at the bottom of the node when a node is continuous. Each figure shows the results for a single patch as an example. See Tables 1, 2, and Supplementary Material A for node descriptions, units of measure, and node bin categories.

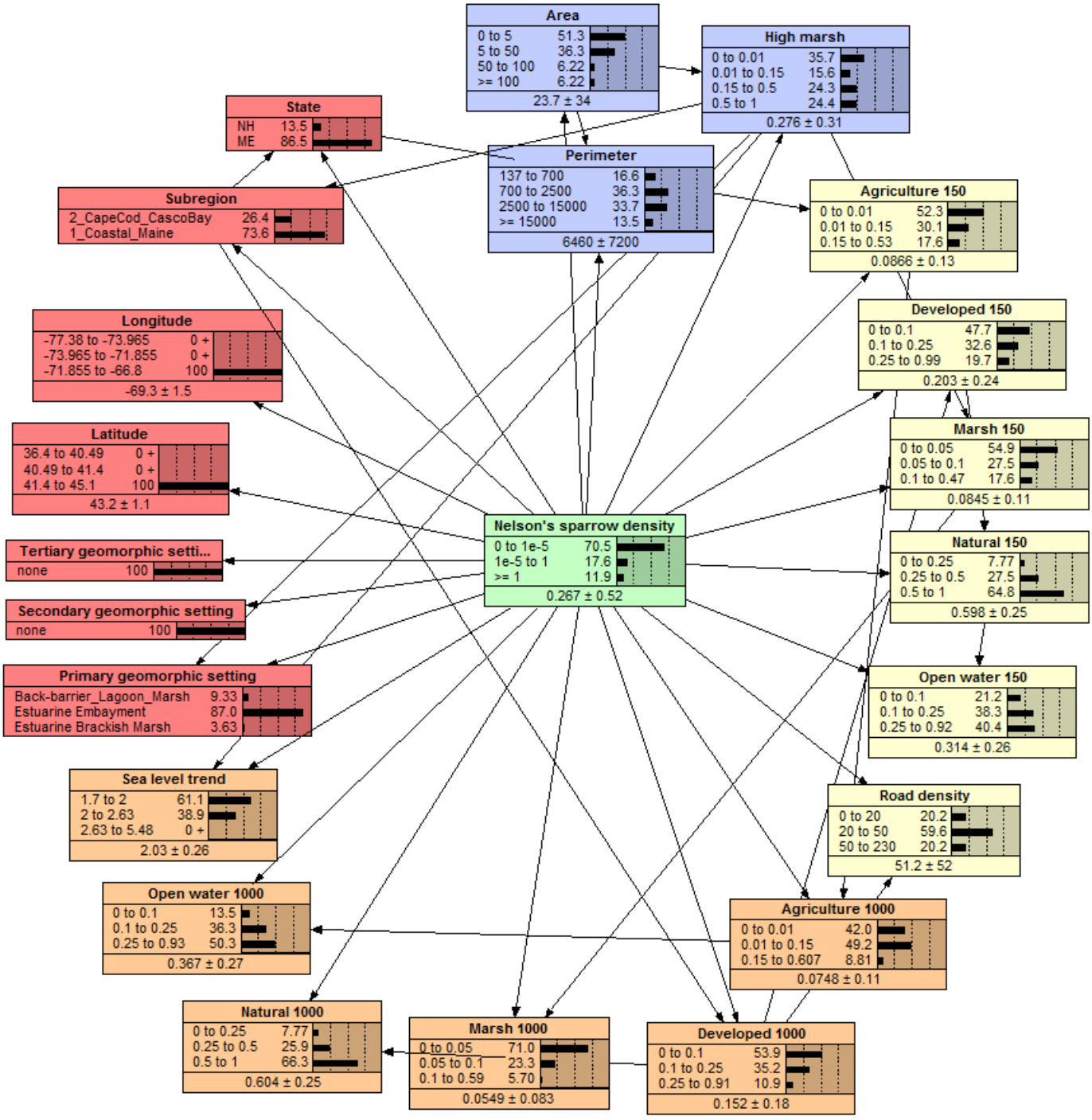
Supplementary Material Figure B1. Clapper rail density – global model.



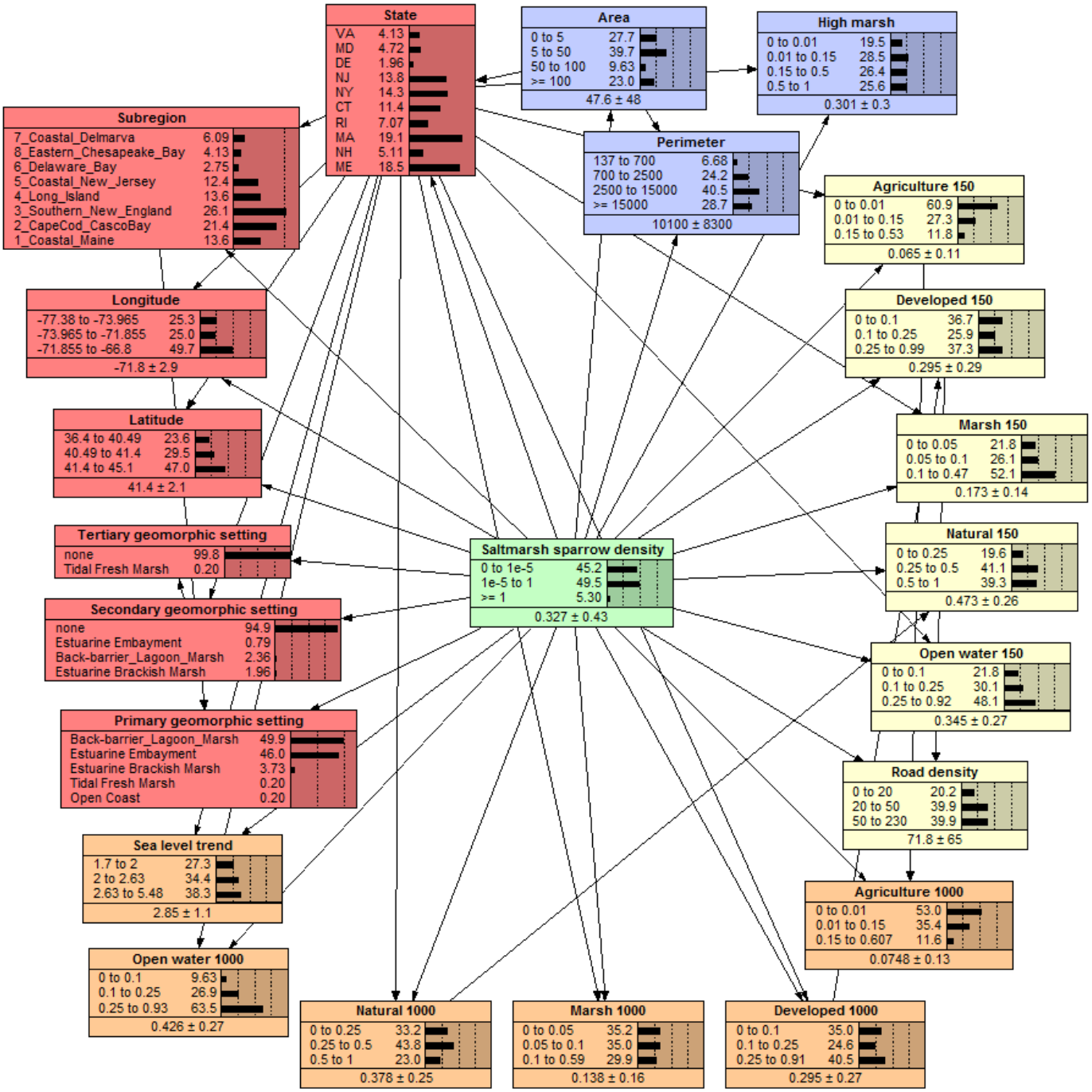
Supplementary Material Figure B2. Willet density – global model.



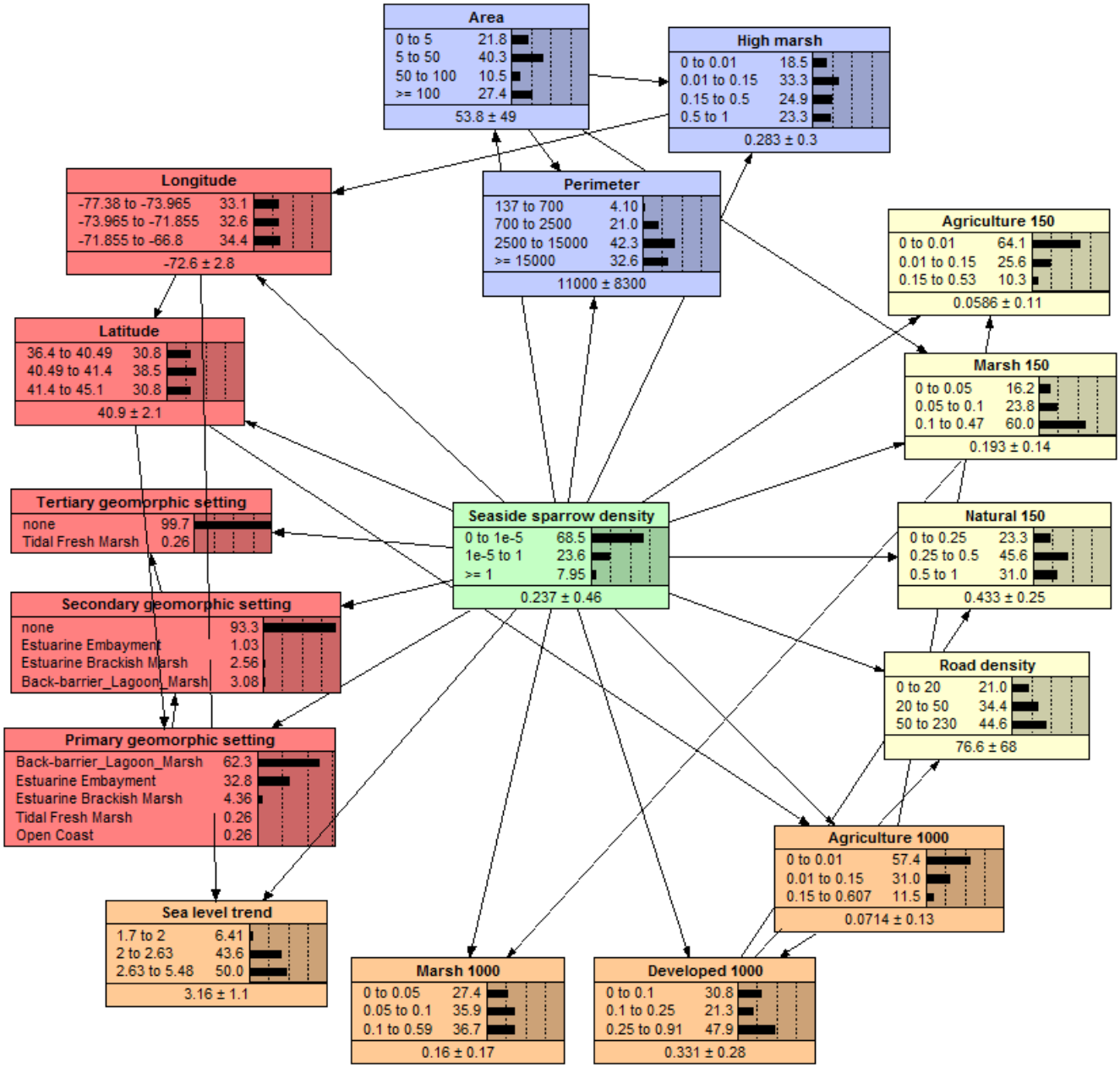
Supplementary Material Figure B3. Nelson's sparrow density – global model.



Supplementary Material Figure B4. Saltmarsh sparrow density – global model.



Supplementary Material Figure B5. Seaside sparrow density – regional subset model.



Supplementary Material Table B1. Clapper rail Bayesian network probability tables.

The full parameter structure of the clapper rail global model (see Supplementary Material Fig. B1) is presented here as an example of all the species models (Supplementary Material Figs. B1-B5). All Bayesian network models in Netica© (Norsys Inc.) format.

Each table below is the conditional probability table for the denoted node (covariate) in the model (except for the last table which is the unconditional probability table for the response variable), as parameterized using the expectation maximization machine-learning algorithm with the empirical case file data (see text for explanation). In each table, the discrete states of the node are shown in columns with single underlines, and discrete states of each linked parent (input) node are shown in columns with double underlines and italic node names. Probability values sum to 1 in each row.

PATCH GEOGRAPHIC LEVEL VARIABLES (purple nodes in Supplementary Material Fig. B1)

Area:

0 to 5	5 to 50	50 to 100	>= 100	*CLRA_dens*
0.22561	0.530488	0.0731708	0.170732	0 to 1e-5
0.0140846	0.0985916	0.169014	0.71831	1e-5 to 1
4.99999e-7	0.15	0.25	0.599999	>= 1

High marsh:

0 to 0.01	0.01 to 0.15	0.15 to 0.5	0.5 to 1	*CLRA_dens*	*State*
0.999994	1.99998e-6	1.99998e-6	1.99998e-6	0 to 1e-5	VA
0.125001	0.624998	0.25	1.24999e-6	0 to 1e-5	MD
4.9999e-6	0.499995	0.499995	4.9999e-6	0 to 1e-5	DE
0.210526	0.605263	0.131579	0.0526318	0 to 1e-5	NJ
0.344828	0.293103	0.12069	0.241379	0 to 1e-5	NY
0.229167	0.479167	0.229167	0.0625002	0 to 1e-5	CT
0.749995	0.25	2.49997e-6	2.49997e-6	0 to 1e-5	RI
9.9996e-6	9.9996e-6	0.99997	9.9996e-6	0 to 1e-5	MA
2.49997e-6	2.49997e-6	2.49997e-6	0.999992	1e-5 to 1	VA
6.24998e-7	0.375	0.562499	0.0625004	1e-5 to 1	MD
1.42856e-6	0.571427	0.42857	1.42856e-6	1e-5 to 1	DE
0.0370374	0.333333	0.481481	0.148148	1e-5 to 1	NJ
0.538461	0.153846	0.230769	0.0769236	1e-5 to 1	NY
0.25	0.499997	0.25	2.49997e-6	1e-5 to 1	CT
0.25	0.25	0.25	0.25	1e-5 to 1	RI
0.25	0.25	0.25	0.25	1e-5 to 1	MA
8.3333e-7	8.3333e-7	0.666665	0.333333	>= 1	VA
0.25	0.25	0.25	0.25	>= 1	MD
9.9996e-6	9.9996e-6	0.99997	9.9996e-6	>= 1	DE
1.99998e-6	0.399999	0.2	0.399999	>= 1	NJ
0.499995	0.499995	4.9999e-6	4.9999e-6	>= 1	NY
0.25	0.25	0.25	0.25	>= 1	CT
0.25	0.25	0.25	0.25	>= 1	RI
0.25	0.25	0.25	0.25	>= 1	MA

Perimeter:

137 to 700	700 to 2500	2500 to 15000	>= 15000	*CLRA_dens*	*Area*
0.162162	0.783783	0.0540543	2.7027e-7	0 to 1e-5	0 to 5
1.14943e-7	0.149425	0.816092	0.0344829	0 to 1e-5	5 to 50
8.3333e-7	8.3333e-7	0.749998	0.25	0 to 1e-5	50 to 100
3.57142e-7	3.57142e-7	0.142857	0.857142	0 to 1e-5	>= 100
9.9996e-6	0.99997	9.9996e-6	9.9996e-6	1e-5 to 1	0 to 5
1.42856e-6	1.42856e-6	0.999996	1.42856e-6	1e-5 to 1	5 to 50
8.3333e-7	8.3333e-7	0.499999	0.499999	1e-5 to 1	50 to 100
1.96078e-7	1.96078e-7	0.0392159	0.960784	1e-5 to 1	>= 100
0.25	0.25	0.25	0.25	>= 1	0 to 5
3.33329e-6	3.33329e-6	0.99999	3.33329e-6	>= 1	5 to 50
1.99998e-6	1.99998e-6	0.999994	1.99998e-6	>= 1	50 to 100

8.3333e-7	8.3333e-7	0.0833339	0.916664	>= 1 >= 100

LOCAL GEOGRAPHIC LEVEL VARIABLES (beige nodes in Supplementary Material Fig. B1)

Agriculture 150:

0 to 0.01	0.01 to 0.15	0.15 to 0.53	*CLRA_dens*	*Agriculture 1000*
0.929293	0.0707071	1.0101e-7	0 to 1e-5	0 to 0.01
0.361702	0.595744	0.0425534	0 to 1e-5	0.01 to 0.15
0.055556	0.111111	0.833332	0 to 1e-5	0.15 to 0.607
0.833333	0.166667	4.16666e-7	1e-5 to 1	0 to 0.01
0.148148	0.851851	3.7037e-7	1e-5 to 1	0.01 to 0.15
4.99999e-7	0.2	0.799999	1e-5 to 1	0.15 to 0.607
0.999998	9.09088e-7	9.09088e-7	>= 1	0 to 0.01
0.285715	0.571428	0.142858	>= 1	0.01 to 0.15
4.99992e-6	4.99992e-6	0.99999	>= 1	0.15 to 0.607

Developed 150:

0 to 0.1	0.1 to 0.25	0.25 to 0.99	*CLRA_dens*	*Developed 1000*
0.861111	0.138889	2.77778e-7	0 to 1e-5	0 to 0.1
0.25	0.5	0.25	0 to 1e-5	0.1 to 0.25
0.0326088	0.173913	0.793478	0 to 1e-5	0.25 to 0.91
0.97619	0.0238097	2.38095e-7	1e-5 to 1	0 to 0.1
0.333333	0.599999	0.0666672	1e-5 to 1	0.1 to 0.25
7.14284e-7	0.285714	0.714285	1e-5 to 1	0.25 to 0.91
0.833332	0.166667	5.55555e-7	>= 1	0 to 0.1
0.99998	9.9997e-6	9.9997e-6	>= 1	0.1 to 0.25
9.9997e-6	0.99998	9.9997e-6	>= 1	0.25 to 0.91

Marsh_150:

0 to 0.05	0.05 to 0.1	0.1 to 0.47	*CLRA_dens*	*State*
0.599998	1.99999e-6	0.4	0 to 1e-5	VA
0.125001	0.749999	0.125001	0 to 1e-5	MD
4.99992e-6	0.499997	0.499997	0 to 1e-5	DE
0.026316	0.473684	0.5	0 to 1e-5	NJ
1.72414e-7	0.172414	0.827586	0 to 1e-5	NY
0.458333	0.25	0.291667	0 to 1e-5	CT
2.49998e-6	2.49998e-6	0.999995	0 to 1e-5	RI
0.99998	9.9997e-6	9.9997e-6	0 to 1e-5	MA
2.49998e-6	2.49998e-6	0.999995	1e-5 to 1	VA
6.24999e-7	0.25	0.749999	1e-5 to 1	MD
1.42857e-6	0.714284	0.285715	1e-5 to 1	DE
0.0370374	0.111111	0.851851	1e-5 to 1	NJ
7.69229e-7	7.69229e-7	0.999999	1e-5 to 1	NY
0.250001	0.499999	0.250001	1e-5 to 1	CT
0.333333	0.333333	0.333333	1e-5 to 1	RI
0.333333	0.333333	0.333333	1e-5 to 1	MA
8.33331e-7	0.083334	0.916665	>= 1	VA
0.333333	0.333333	0.333333	>= 1	MD
9.9997e-6	0.99998	9.9997e-6	>= 1	DE
1.99999e-6	0.200001	0.799997	>= 1	NJ
4.99992e-6	4.99992e-6	0.99999	>= 1	NY
0.333333	0.333333	0.333333	>= 1	CT
0.333333	0.333333	0.333333	>= 1	RI
0.333333	0.333333	0.333333	>= 1	MA

Natural_150:

0 to 0.25	0.25 to 0.5	0.5 to 1	*CLRA_dens*	*Natural_1000*
0.507463	0.402985	0.0895524	0 to 1e-5	0 to 0.25
0.1375	0.4375	0.425	0 to 1e-5	0.25 to 0.5
5.88234e-7	0.294118	0.705882	0 to 1e-5	0.5 to 1
0.3	0.55	0.15	1e-5 to 1	0 to 0.25
0.0909093	0.636363	0.272727	1e-5 to 1	0.25 to 0.5
0.142858	1.42857e-6	0.857141	1e-5 to 1	0.5 to 1
0.444444	0.444444	0.111112	>= 1	0 to 0.25
0.4	0.4	0.2	>= 1	0.25 to 0.5
9.9997e-6	9.9997e-6	0.99998	>= 1	0.5 to 1

Open Water 150:

0 to 0.1	0.1 to 0.25	0.25 to 0.92	*CLRA_dens*	*Road density*
0.0333336	0.1	0.866666	0 to 1e-5	0 to 20
0.127273	0.290909	0.581818	0 to 1e-5	20 to 50
0.43038	0.379747	0.189874	0 to 1e-5	50 to 230
3.7037e-7	3.7037e-7	0.999999	1e-5 to 1	0 to 20
0.16129	0.16129	0.677419	1e-5 to 1	20 to 50
0.23077	0.538461	0.23077	1e-5 to 1	50 to 230
9.09088e-7	9.09088e-7	0.999998	>= 1	0 to 20
1.24999e-6	0.125001	0.874998	>= 1	20 to 50
9.9997e-6	9.9997e-6	0.99998	>= 1	50 to 230

Road density:

0 to 20	20 to 50	50 to 230	*CLRA_dens*	*Development 150*
0.534884	0.44186	0.023256	0 to 1e-5	0 to 0.1
0.153846	0.666666	0.179487	0 to 1e-5	0.1 to 0.25
0.0121952	0.121951	0.865853	0 to 1e-5	0.25 to 0.99
0.586956	0.413043	2.17391e-7	1e-5 to 1	0 to 0.1
7.14284e-7	0.714285	0.285714	1e-5 to 1	0.1 to 0.25
9.09088e-7	0.181819	0.818181	1e-5 to 1	0.25 to 0.99
0.687499	0.25	0.0625005	>= 1	0 to 0.1
2.49998e-6	0.999995	2.49998e-6	>= 1	0.1 to 0.25
0.333333	0.333333	0.333333	>= 1	0.25 to 0.99

LANDSCAPE GEOGRAPHIC LEVEL VARIABLES (orange nodes in Supplementary Material Fig. B1)

Agriculture 1000:

0 to 0.01	0.01 to 0.15	0.15 to 0.607	*CLRA_dens*	*Subregion*
0.499999	1.66666e-6	0.499999	0 to 1e-5	7_Coastal_Delmarva
1.11111e-6	1.11111e-6	0.999998	0 to 1e-5	8_Eastern_Chesapeake_Bay
2.49998e-6	2.49998e-6	0.999995	0 to 1e-5	6_Delaware_Bay
0.324324	0.675675	2.7027e-7	0 to 1e-5	5_Coastal_New_Jersey
0.8	0.163636	0.0363637	0 to 1e-5	4_Long_Island
0.754717	0.245283	1.88679e-7	0 to 1e-5	3_Southern_New_England
0.285714	0.142858	0.571428	1e-5 to 1	7_Coastal_Delmarva
9.99997e-7	0.499999	0.499999	1e-5 to 1	8_Eastern_Chesapeake_Bay
1.11111e-6	0.222223	0.777776	1e-5 to 1	6_Delaware_Bay
0.272727	0.727272	4.54545e-7	1e-5 to 1	5_Coastal_New_Jersey
0.916665	0.083334	8.33331e-7	1e-5 to 1	4_Long_Island
0.749997	0.250001	2.49998e-6	1e-5 to 1	3_Southern_New_England
0.454545	0.363636	0.181819	>= 1	7_Coastal_Delmarva
0.499997	0.499997	4.99992e-6	>= 1	8_Eastern_Chesapeake_Bay
9.9997e-6	0.99998	9.9997e-6	>= 1	6_Delaware_Bay
0.749997	0.250001	2.49998e-6	>= 1	5_Coastal_New_Jersey
0.99999	4.99992e-6	4.99992e-6	>= 1	4_Long_Island
0.333333	0.333333	0.333333	>= 1	3_Southern_New_England

Developed 1000:

0 to 0.1	0.1 to 0.25	0.25 to 0.91	*CLRA_dens*	*State*
0.999996	1.99999e-6	1.99999e-6	0 to 1e-5	VA
0.999997	1.24999e-6	1.24999e-6	0 to 1e-5	MD
0.499997	0.499997	4.99992e-6	0 to 1e-5	DE
0.105263	0.210526	0.68421	0 to 1e-5	NJ
0.258621	0.258621	0.482759	0 to 1e-5	NY
0.0208335	0.208333	0.770833	0 to 1e-5	CT
0.250001	0.499999	0.250001	0 to 1e-5	RI
0.99998	9.9997e-6	9.9997e-6	0 to 1e-5	MA
0.999995	2.49998e-6	2.49998e-6	1e-5 to 1	VA
0.999999	6.24999e-7	6.24999e-7	1e-5 to 1	MD
0.428571	0.428571	0.142858	1e-5 to 1	DE
0.444444	0.296296	0.259259	1e-5 to 1	NJ
0.538461	0.153847	0.307692	1e-5 to 1	NY
2.49998e-6	0.499999	0.499999	1e-5 to 1	CT
0.333333	0.333333	0.333333	1e-5 to 1	RI
0.333333	0.333333	0.333333	1e-5 to 1	MA
0.999998	8.33331e-7	8.33331e-7	>= 1	VA
0.333333	0.333333	0.333333	>= 1	MD
0.99998	9.9997e-6	9.9997e-6	>= 1	DE
0.599998	0.200001	0.200001	>= 1	NJ
0.99999	4.99992e-6	4.99992e-6	>= 1	NY
0.333333	0.333333	0.333333	>= 1	CT
0.333333	0.333333	0.333333	>= 1	RI
0.333333	0.333333	0.333333	>= 1	MA

Marsh 1000:

0 to 0.05	0.05 to 0.1	0.1 to 0.59	*CLRA_dens*	*State*
0.599998	0.4	1.99999e-6	0 to 1e-5	VA
0.25	0.375	0.375	0 to 1e-5	MD
0.499997	0.499997	4.99992e-6	0 to 1e-5	DE
0.236842	0.263158	0.5	0 to 1e-5	NJ
0.327586	0.275862	0.396552	0 to 1e-5	NY
0.208333	0.520833	0.270833	0 to 1e-5	CT
2.49998e-6	0.250001	0.749997	0 to 1e-5	RI
0.99998	9.9997e-6	9.9997e-6	0 to 1e-5	MA
2.49998e-6	0.499999	0.499999	1e-5 to 1	VA
0.25	0.375	0.375	1e-5 to 1	MD
0.428571	0.428571	0.142858	1e-5 to 1	DE
0.148148	0.259259	0.592592	1e-5 to 1	NJ
7.69229e-7	0.153847	0.846153	1e-5 to 1	NY
0.250001	0.499999	0.250001	1e-5 to 1	CT
0.333333	0.333333	0.333333	1e-5 to 1	RI
0.333333	0.333333	0.333333	1e-5 to 1	MA
8.33331e-7	0.416666	0.583333	>= 1	VA
0.333333	0.333333	0.333333	>= 1	MD
9.9997e-6	9.9997e-6	0.99998	>= 1	DE
1.99999e-6	1.99999e-6	0.999996	>= 1	NJ
4.99992e-6	4.99992e-6	0.99999	>= 1	NY
0.333333	0.333333	0.333333	>= 1	CT
0.333333	0.333333	0.333333	>= 1	RI
0.333333	0.333333	0.333333	>= 1	MA

Natural 1000:

0 to 0.25	0.25 to 0.5	0.5 to 1	*CLRA_dens*	*Road_density*
0.3	0.633333	0.0666669	0 to 1e-5	0 to 20
0.254546	0.527273	0.218182	0 to 1e-5	20 to 50
0.556962	0.405063	0.0379748	0 to 1e-5	50 to 230
0.333333	0.629629	0.0370374	1e-5 to 1	0 to 20
0.0967744	0.741935	0.16129	1e-5 to 1	20 to 50
0.615384	0.307692	0.0769237	1e-5 to 1	50 to 230
0.727272	0.272727	9.09088e-7	>= 1	0 to 20
0.125001	0.749999	0.125001	>= 1	20 to 50
9.9997e-6	0.99998	9.9997e-6	>= 1	50 to 230

Open water 1000:

0 to 0.1	0.1 to 0.25	0.25 to 0.93	*CLRA_dens*	*Open water 150*
0.333333	0.309524	0.357143	0 to 1e-5	0 to 0.1
0.0816328	0.346939	0.571428	0 to 1e-5	0.1 to 0.25
0.0136988	0.219178	0.767123	0 to 1e-5	0.25 to 0.92
1.24999e-6	0.874998	0.125001	1e-5 to 1	0 to 0.1
0.083334	0.583333	0.333333	1e-5 to 1	0.1 to 0.25
1.96078e-7	0.0588237	0.941176	1e-5 to 1	0.25 to 0.92
0.333333	0.333333	0.333333	>= 1	0 to 0.1
0.99998	9.9997e-6	9.9997e-6	>= 1	0.1 to 0.25
5.26315e-7	5.26315e-7	0.999999	>= 1	0.25 to 0.92

Sea level trend:

1.7 to 2	2 to 2.63	2.63 to 5.48	*CLRA_dens*	*Subregion*
1.66666e-6	1.66666e-6	0.999997	0 to 1e-5	7_Coastal_Delmarva
1.11111e-6	1.11111e-6	0.999998	0 to 1e-5	8_Eastern_Chesapeake_Bay
2.49998e-6	2.49998e-6	0.999995	0 to 1e-5	6_Delaware_Bay
2.7027e-7	2.7027e-7	1	0 to 1e-5	5_Coastal_New_Jersey
1.81818e-7	0.872727	0.127273	0 to 1e-5	4_Long_Island
1.88679e-7	1	1.88679e-7	0 to 1e-5	3_Southern_New_England
7.14284e-7	7.14284e-7	0.999999	1e-5 to 1	7_Coastal_Delmarva
9.99997e-7	9.99997e-7	0.999998	1e-5 to 1	8_Eastern_Chesapeake_Bay
1.11111e-6	1.11111e-6	0.999998	1e-5 to 1	6_Delaware_Bay
4.54545e-7	4.54545e-7	0.999999	1e-5 to 1	5_Coastal_New_Jersey
8.33331e-7	0.916665	0.083334	1e-5 to 1	4_Long_Island
2.49998e-6	0.999995	2.49998e-6	1e-5 to 1	3_Southern_New_England
9.09088e-7	9.09088e-7	0.999998	>= 1	7_Coastal_Delmarva
4.99992e-6	4.99992e-6	0.99999	>= 1	8_Eastern_Chesapeake_Bay
9.9997e-6	9.9997e-6	0.99998	>= 1	6_Delaware_Bay
2.49998e-6	2.49998e-6	0.999995	>= 1	5_Coastal_New_Jersey
4.99992e-6	0.499997	0.499997	>= 1	4_Long_Island
0.333333	0.333333	0.333333	>= 1	3_Southern_New_England

REGIONAL GEOGRAPHIC LEVEL VARIABLES (red nodes in Supplementary Material Fig. B1)

Primary geomorphic setting:

Back-barrier lagoon marsh	Estuarine embayment	Estuarine brackish marsh	Tidal fresh marsh	*CLRA_dens*	*Subregion*
0.999995	1.66666e-6	1.66666e-6	1.66666e-6	0 to 1e-5	7_Coastal_Delmarva
1.11111e-6	0.888886	0.111112	1.11111e-6	0 to 1e-5	8_Eastern_Chesapeake_Bay
2.49997e-6	0.749995	0.25	2.49997e-6	0 to 1e-5	6_Delaware_Bay
0.621621	0.216216	0.135135	0.0270273	0 to 1e-5	5_Coastal_New_Jersey
0.963636	0.0363638	1.81818e-7	1.81818e-7	0 to 1e-5	4_Long_Island
0.641509	0.226415	0.132076	1.88679e-7	0 to 1e-5	3_Southern_New_England
0.928569	0.0714291	7.14284e-7	7.14284e-7	1e-5 to 1	7_Coastal_Delmarva
9.99996e-7	0.999997	9.99996e-7	9.99996e-7	1e-5 to 1	8_Eastern_Chesapeake_Bay
1.11111e-6	0.999997	1.11111e-6	1.11111e-6	1e-5 to 1	6_Delaware_Bay
0.772726	0.227273	4.54545e-7	4.54545e-7	1e-5 to 1	5_Coastal_New_Jersey
0.999997	8.3333e-7	8.3333e-7	8.3333e-7	1e-5 to 1	4_Long_Island
0.499997	0.499997	2.49997e-6	2.49997e-6	1e-5 to 1	3_Southern_New_England
0.999997	9.09088e-7	9.09088e-7	9.09088e-7	>= 1	7_Coastal_Delmarva
4.9999e-6	0.999985	4.9999e-6	4.9999e-6	>= 1	8_Eastern_Chesapeake_Bay
9.9996e-6	0.99997	9.9996e-6	9.9996e-6	>= 1	6_Delaware_Bay
0.999992	2.49997e-6	2.49997e-6	2.49997e-6	>= 1	5_Coastal_New_Jersey
0.999985	4.9999e-6	4.9999e-6	4.9999e-6	>= 1	4_Long_Island
0.25	0.25	0.25	0.25	>= 1	3_Southern_New_England

Secondary geomorphic setting:

none	Estuarine embayment	Back-barrier lagoon marsh	Estuarine brackish marsh	*CLRA_dens*	*State*
0.999994	1.99998e-6	1.99998e-6	1.99998e-6	0 to 1e-5	VA
0.874997	0.125001	1.24999e-6	1.24999e-6	0 to 1e-5	MD
0.999985	4.9999e-6	4.9999e-6	4.9999e-6	0 to 1e-5	DE
0.973683	2.63158e-7	2.63158e-7	0.026316	0 to 1e-5	NJ
1	1.72414e-7	1.72414e-7	1.72414e-7	0 to 1e-5	NY
0.8125	2.08333e-7	0.145833	0.0416668	0 to 1e-5	CT
0.999992	2.49997e-6	2.49997e-6	2.49997e-6	0 to 1e-5	RI
0.99997	9.9996e-6	9.9996e-6	9.9996e-6	0 to 1e-5	MA
0.999992	2.49997e-6	2.49997e-6	2.49997e-6	1e-5 to 1	VA
0.999998	6.24998e-7	6.24998e-7	6.24998e-7	1e-5 to 1	MD
0.42857	1.42856e-6	0.142858	0.42857	1e-5 to 1	DE
0.851851	3.7037e-7	3.7037e-7	0.148148	1e-5 to 1	NJ
0.999998	7.69228e-7	7.69228e-7	7.69228e-7	1e-5 to 1	NY
0.999992	2.49997e-6	2.49997e-6	2.49997e-6	1e-5 to 1	CT
0.25	0.25	0.25	0.25	1e-5 to 1	RI
0.25	0.25	0.25	0.25	1e-5 to 1	MA
0.999997	8.3333e-7	8.3333e-7	8.3333e-7	>= 1	VA
0.25	0.25	0.25	0.25	>= 1	MD
0.99997	9.9996e-6	9.9996e-6	9.9996e-6	>= 1	DE
0.999994	1.99998e-6	1.99998e-6	1.99998e-6	>= 1	NJ
0.999985	4.9999e-6	4.9999e-6	4.9999e-6	>= 1	NY
0.25	0.25	0.25	0.25	>= 1	CT
0.25	0.25	0.25	0.25	>= 1	RI
0.25	0.25	0.25	0.25	>= 1	MA

Tertiary geomorphic setting:

none	Tidal fresh marsh	*CLRA_dens*	*Secondary geomorphic setting*
1	6.53595e-8	0 to 1e-5	none
0.99999	9.9998e-6	0 to 1e-5	Estuarine embayment
0.999999	1.42857e-6	0 to 1e-5	Back-barrier lagoon marsh
0.666666	0.333334	0 to 1e-5	Estuarine brackish marsh
1	1.5873e-7	1e-5 to 1	none
0.5	0.5	1e-5 to 1	Estuarine embayment
0.99999	9.9998e-6	1e-5 to 1	Back-barrier lagoon marsh
0.999999	1.42857e-6	1e-5 to 1	Estuarine brackish marsh
1	4.99999e-7	>= 1	none
0.5	0.5	>= 1	Estuarine embayment
0.5	0.5	>= 1	Back-barrier lagoon marsh
0.5	0.5	>= 1	Estuarine brackish marsh

Latitude:

36.4 to 40.49	40.49 to 41.4	41.4 to 45.1	*CLRA_dens*	*State*
0.999996	1.99999e-6	1.99999e-6	0 to 1e-5	VA
0.999997	1.24999e-6	1.24999e-6	0 to 1e-5	MD
0.99999	4.99992e-6	4.99992e-6	0 to 1e-5	DE
0.894736	0.105263	2.63158e-7	0 to 1e-5	NJ
1.72414e-7	1	1.72414e-7	0 to 1e-5	NY
2.08333e-7	1	2.08333e-7	0 to 1e-5	CT
2.49998e-6	0.999995	2.49998e-6	0 to 1e-5	RI
9.9997e-6	0.99998	9.9997e-6	0 to 1e-5	MA
0.999995	2.49998e-6	2.49998e-6	1e-5 to 1	VA
0.999999	6.24999e-7	6.24999e-7	1e-5 to 1	MD
0.999997	1.42857e-6	1.42857e-6	1e-5 to 1	DE
0.962962	0.0370374	3.7037e-7	1e-5 to 1	NJ
7.69229e-7	0.999999	7.69229e-7	1e-5 to 1	NY
2.49998e-6	0.999995	2.49998e-6	1e-5 to 1	CT
0.333333	0.333333	0.333333	1e-5 to 1	RI
0.333333	0.333333	0.333333	1e-5 to 1	MA
0.999998	8.33331e-7	8.33331e-7	>= 1	VA
0.333333	0.333333	0.333333	>= 1	MD
0.99998	9.9997e-6	9.9997e-6	>= 1	DE
0.999996	1.99999e-6	1.99999e-6	>= 1	NJ
4.99992e-6	0.99999	4.99992e-6	>= 1	NY
0.333333	0.333333	0.333333	>= 1	CT
0.333333	0.333333	0.333333	>= 1	RI

0.333333 0.333333 0.333333 >= 1 MA

Longitude:

-77.38 to -73.96	-73.965 to -71.8	-71.855 to -66.8	*CLRA_dens*	*State*
0.999996	1.99999e-6	1.99999e-6	0 to 1e-5	VA
0.999997	1.24999e-6	1.24999e-6	0 to 1e-5	MD
0.99999	4.99992e-6	4.99992e-6	0 to 1e-5	DE
1	2.63158e-7	2.63158e-7	0 to 1e-5	NJ
0.0517243	0.948276	1.72414e-7	0 to 1e-5	NY
2.08333e-7	1	2.08333e-7	0 to 1e-5	CT
2.49998e-6	2.49998e-6	0.999995	0 to 1e-5	RI
9.9997e-6	9.9997e-6	0.99998	0 to 1e-5	MA
0.999995	2.49998e-6	2.49998e-6	1e-5 to 1	VA
0.999999	6.24999e-7	6.24999e-7	1e-5 to 1	MD
0.999997	1.42857e-6	1.42857e-6	1e-5 to 1	DE
0.999999	3.7037e-7	3.7037e-7	1e-5 to 1	NJ
0.0769237	0.923076	7.69229e-7	1e-5 to 1	NY
2.49998e-6	0.999995	2.49998e-6	1e-5 to 1	CT
0.333333	0.333333	0.333333	1e-5 to 1	RI
0.333333	0.333333	0.333333	1e-5 to 1	MA
0.999998	8.33331e-7	8.33331e-7	>= 1	VA
0.333333	0.333333	0.333333	>= 1	MD
0.99998	9.9997e-6	9.9997e-6	>= 1	DE
0.999996	1.99999e-6	1.99999e-6	>= 1	NJ
4.99992e-6	0.99999	4.99992e-6	>= 1	NY
0.333333	0.333333	0.333333	>= 1	CT
0.333333	0.333333	0.333333	>= 1	RI
0.333333	0.333333	0.333333	>= 1	MA

Subregion:

7 Coastal Delmarva	8 Eastern Chesapeake Bay	6 Deleware Bay	5 Coastal New Jersey	4 Long Island	3 Southern New England	*CLRA_dens*	*State*
1.99998e-6	0.99999	1.99998e-6	1.99998e-6	1.99998e-6	1.99998e-6	0 to 1e-5	VA
0.499997	0.499997	1.24999e-6	1.24999e-6	1.24999e-6	1.24999e-6	0 to 1e-5	MD
0.999975	4.99985e-6	4.99985e-6	4.99985e-6	4.99985e-6	4.99985e-6	0 to 1e-5	DE
2.63157e-7	2.63157e-7	0.105263	0.894736	2.63157e-7	2.63157e-7	0 to 1e-5	NJ
1.72414e-7	1.72414e-7	1.72414e-7	0.0517243	0.948275	1.72414e-7	0 to 1e-5	NY
2.08333e-7	2.08333e-7	2.08333e-7	2.08333e-7	2.08333e-7	0.999999	0 to 1e-5	CT
2.49996e-6	2.49996e-6	2.49996e-6	2.49996e-6	2.49996e-6	0.999987	0 to 1e-5	RI
9.9994e-6	9.9994e-6	9.9994e-6	9.9994e-6	9.9994e-6	0.99995	0 to 1e-5	MA
0.499995	0.499995	2.49996e-6	2.49996e-6	2.49996e-6	2.49996e-6	1e-5 to 1	VA
0.499999	0.499999	6.24998e-7	6.24998e-7	6.24998e-7	6.24998e-7	1e-5 to 1	MD
0.571425	1.42856e-6	0.428569	1.42856e-6	1.42856e-6	1.42856e-6	1e-5 to 1	DE
3.70369e-7	3.70369e-7	0.222222	0.777776	3.70369e-7	3.70369e-7	1e-5 to 1	NJ
7.69227e-7	7.69227e-7	7.69227e-7	0.0769235	0.923073	7.69227e-7	1e-5 to 1	NY
2.49996e-6	2.49996e-6	2.49996e-6	2.49996e-6	2.49996e-6	0.999987	1e-5 to 1	CT
0.166667	0.166667	0.166667	0.166667	0.166667	0.166667	1e-5 to 1	RI
0.166667	0.166667	0.166667	0.166667	0.166667	0.166667	1e-5 to 1	MA
0.83333	0.166667	8.33329e-7	8.33329e-7	8.33329e-7	8.33329e-7	>= 1	VA
0.166667	0.166667	0.166667	0.166667	0.166667	0.166667	>= 1	MD
0.99995	9.9994e-6	9.9994e-6	9.9994e-6	9.9994e-6	9.9994e-6	>= 1	DE
1.99998e-6	1.99998e-6	0.2	0.799992	1.99998e-6	1.99998e-6	>= 1	NJ
4.99985e-6	4.99985e-6	4.99985e-6	4.99985e-6	0.999975	4.99985e-6	>= 1	NY
0.166667	0.166667	0.166667	0.166667	0.166667	0.166667	>= 1	CT
0.166667	0.166667	0.166667	0.166667	0.166667	0.166667	>= 1	RI
0.166667	0.166667	0.166667	0.166667	0.166667	0.166667	>= 1	MA

State:

VA	MD	DE	NJ	NY	CT	RI	MA	*CLRA_dens*	*Perimeter*
0.333331	1.66664e-6	1.66664e-6	1.66664e-6	0.166666	0.499995	1.66664e-6	1.66664e-6	0 to 1e-5	137 to 700
0.0476192	0.0714287	0.0238097	0.119048	0.357142	0.309523	0.0476192	0.0238097	0 to 1e-5	700 to 2500
0.011628	0.011628	1.16279e-7	0.27907	0.372093	0.302325	0.0232559	1.16279e-7	0 to 1e-5	2500 to 15000
3.33333e-7	0.133333	0.0333336	0.299999	0.333333	0.2	3.33333e-7	3.33333e-7	0 to 1e-5	>= 15000
0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	1e-5 to 1	137 to 700
9.9992e-6	9.9992e-6	9.9992e-6	0.99993	9.9992e-6	9.9992e-6	9.9992e-6	9.9992e-6	1e-5 to 1	700 to 2500
6.66663e-7	6.66663e-7	0.133333	0.333332	0.333332	0.2	6.66663e-7	6.66663e-7	1e-5 to 1	2500 to 15000
0.0727274	0.290909	0.0909092	0.381818	0.145454	0.018182	1.81818e-7	1.81818e-7	1e-5 to 1	>= 15000
0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	>= 1	137 to 700
0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	>= 1	700 to 2500

0.333331	1.1111e-6	0.111111	0.333331	0.222221	1.1111e-6	1.1111e-6	1.1111e-6	>= 1	2500 to 15000
0.818177	9.09084e-7	9.09084e-7	0.181818	9.09084e-7	9.09084e-7	9.09084e-7	9.09084e-7	>= 1	>= 15000

BIRD SPECIES DENSITY RESPONSE VARIABLE (green node in Supplementary Material Fig. B1)

CLRA_dens (Clapper rail density):

0 to 1e-5	1e-5 to 1	>= 1
0.643137	0.278431	0.0784314

C. Geospatial Data for Tidal Marsh Patches

SHARP Data: Habitat Patches for Tidal Marsh Bird Conservation in the Northeast United States

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CITATION

Wiest, W. A., M. D. Correll, B. G. Marcot, B. J. Olsen, C. S. Elphick, T. P. Hodgman, G. R. Guntenspergen, and W. G. Shriver. 2017. SHARP Data: Habitat Patches for Tidal Marsh Bird Conservation in the Northeast United States (Version 1.0, July 2017) Available from: http://www.tidalmarshbirds.org.

LAYER INFORMATION

This shapefile contains tidal marsh patches located in the Northeast United States (Maine to Virginia) and is intended to be used as a conservation tool for the protection and management of specialist birds of high conservation concern in the region: clapper rail (*Rallus crepitans*), willet (*Tringa semipalmata*), Nelson's sparrow (*Ammospiza nelsoni*), saltmarsh sparrow (*A. caudacuta*), and seaside sparrow (*A. maritima*). Patches were derived from polygons of estuarine emergent marsh from the National Wetlands Inventory (Wilen and Bates 1995, U.S. Fish and Wildlife Service National Wetlands Inventory 2010). The shapefile's attribute table includes patch covariate values developed to predict species density in each patch using Bayesian network models. Final estimates of species density and abundance are included. The shapefile can be downloaded from www.tidalmarshbirds.org.

Users of this dataset should review the context, methods, and data considerations surrounding this layer prior to use. This information is available from:

Wiest, W. A., M. D. Correll, B. J. Olsen, C. S. Elphick, T. P. Hodgman, D. R. Curson, and W. G. Shriver. 2016. Population estimates for tidal marsh birds of high conservation concern in the northeastern USA from a design-based survey. The Condor: Ornithological Applications 118:274–288.

Wiest, W. A., M. D. Correll, B. G. Marcot, B. J. Olsen, C. S. Elphick, T. P. Hodgman, G. R. Guntenspergen, and W. G. Shriver. 2018. Estimates of tidal-marsh bird densities using Bayesian networks. Journal of Wildlife Management. *This manuscript*.

Users should recognize that the species density and abundance estimates contained in this layer were derived from models that incorporated missing and imperfect data and are therefore subject to model limitations and statistical uncertainty. While every effort was made to use data

from presumably reliable sources, no dataset is perfect and contains quantitative and qualitative errors. For these reasons, there will be patches with inaccurate results, not necessarily because the methods employed are wrong, but because of inherent uncertainty with the input data and the limitations that exist with any model. Users should use caution and consider the limits of the data and models upon which the layer is based when interpreting and using this spatial dataset.

GIS METADATA

Data Type: Shapefile Feature Class

Shapefile: SHARP_patches_bird_density.shp

Geometry Type: Polygon

Coordinates have Z values: No

Coordinates have measures: No

Projected Coordinate System: NAD_1983_Albers

Projection: Albers

False_Easting: 0.00000000

False_Northing: 0.00000000

Central_Meridian: -96.00000000

Standard_Parallel_1: 29.50000000

Standard_Parallel_2: 45.50000000

Latitude_Of_Origin: 23.00000000

Linear Unit: Meter

Geographic Coordinate System: GCS_North_American_1983

Datum: D_North_American_1983

Prime Meridian: Greenwich

Angular Unit: Degree

Attributes

PatchID = unique numeric code for marsh patches. Patches were created by adding a 50 m buffer to all National Wetlands Inventory (NWI) estuarine emergent marsh (NWI code: E2EM)

polygons in the Northeast USA (Wilen and Bates 1995, U.S. Fish and Wildlife Service National Wetlands Inventory 2010, Wiest et al. 2016). Patch buffers that intersected were considered the same patch.

State = U.S. Postal Service state abbreviation.

Subregion = Subregions defined for marshbird monitoring in the Northeast USA (Wiest et al. 2016), generally based on Conway and Droege (2006).

Subregion number_name (boundaries):

1_Coastal Maine (Lubec, ME to north of Casco Bay, ME)

2_Cape Cod to Casco Bay (Casco Bay, ME to Cape Cod, MA [including north side of U.S. Route 6 – Mid-Cape Highway])

3_Southern New England (South of Cape Cod, MA [including south side of U.S. Route 6 – Mid-Cape Highway, Nantucket, and Martha's Vineyard] to Hudson River, NY)

4_Long Island (Long Island)

5_Coastal New Jersey (NJ Meadowlands to Cape May, NJ [oceanside])

6_Delaware Bay (Cape May, NJ [bayside] to Lewes, DE [bayside])

7_Coastal Delmarva (Delmarva Peninsula oceanside, from Lewes, DE to Fishermans Island NWR, VA)

8_Eastern Chesapeake Bay (Chesapeake Bay coastline east of Susquehanna River mouth)

X = longitude coordinate of the patch polygon centroid in decimal degrees.

Y = latitude coordinate of the patch polygon centroid in decimal degrees.

area_ha = size of the patch area (hectares).

perim_m = length of the patch perimeter (meters).

hm_info = values informing the hm_prop column:

- data = proportion of high marsh (as shown in hm_prop) calculated using the Test 7 raster file from M. D. Correll, University of Maine (unpublished data).
- no data = high marsh data unavailable.

hm_prop = proportion of patch that is high marsh. An area considered high marsh is dominated by *Spartina patens*, *Spartina alterniflora* short form, *Juncus gerardii*, and/or *Distichlis spicata*. The proportion of high marsh in a patch was calculated using the highest performing regional raster file (Test 7) from M. D. Correll (unpublished data). "9999" was recorded when a patch was inadequately covered by the raster file and proportion calculations could not be computed; the corresponding hm_info value is "no data".

nhm_info = values informing the nhm_prop column:

- data = proportion of non-high marsh (as shown in nhm_prop) calculated using the Test 7 raster file from M. D. Correll (unpublished data).
- no data = non-high marsh data unavailable.

nhm_prop = proportion of patch that is non-high marsh. An area considered non-high marsh consists of any of the following habitat communities: low marsh (dominated by *Spartina alterniflora* tall form), pools/pannes/creeks, open water, upland (any non-marsh area), salt marsh terrestrial border, brackish terrestrial border, invasives (dominated by *Phragmites australis*), and wrack. The proportion of non-high marsh in a patch was calculated using the highest performing regional raster file (Test 7) from M. D. Correll (unpublished data). "9999" was recorded when a patch was inadequately covered by the raster file and proportion calculations could not be computed; the corresponding nhm_info value is "no data".

Nat_150 = proportion of the area that is natural lands in a 150 m buffer around the patch. All NatureServe land use land cover categories not considered agriculture, developed lands, or open

water are considered natural lands (Comer et al. 2003, Ferree and Anderson 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

Ag_150 = proportion of the area that is agriculture in a 150 m buffer around the patch. One NatureServe land use land cover category is considered agriculture (ES_Name, Value): NLCD agricultural classes 81-82, 80 (Comer et al. 2003, Ferree and Anderson 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

Dev_150 = proportion of the area that is developed lands in a 150 m buffer around the patch. One NatureServe land use land cover category is considered developed lands (ES_Name, Value): NLCD developed classes 21-24 & 31, 20 (Comer et al. 2003, Ferree and Anderson 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

OpenW_150 = proportion of the area that is open water in a 150 m buffer around the patch. One NatureServe land use land cover category is considered open water (ES_Name, Value): NLCD-NHD open water, 11 (Comer et al. 2003, Ferree and Anderson 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

Marsh_150 = proportion of the area that is marsh in a 150 m buffer around the patch. Five NatureServe land use land cover categories are considered marsh (ES_Name, Value): North Atlantic Coastal Plain Tidal Salt Marsh: salt/brackish/oligohaline, 519; Acadian Coastal Salt Marsh, Acadian Estuary Marsh, 578; Acadian Estuary Marsh, 579; North Atlantic Coastal Plain Brackish/Fresh & Oligohaline Tidal Marsh, 894516; Atlantic Coastal Plain Embayed Region Tidal Freshwater/Brackish Marsh, 259260 (Comer et al. 2003, Ferree and Anderson 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

Nat_1000 = proportion of the area that is natural lands in a 1,000 m buffer around the patch. All NatureServe land use land cover categories not considered agriculture, developed lands, or open

water are considered natural lands (Comer et al. 2003, Ferree and Anderson 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

Ag_1000 = proportion of the area that is agriculture in a 1,000 m buffer around the patch. One NatureServe land use land cover category is considered agriculture (ES_Name, Value): NLCD agricultural classes 81-82, 80 (Comer et al. 2003, Ferree and Anderson 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

Dev_1000 = proportion of the area that is developed lands in a 1,000 m buffer around the patch. One NatureServe land use land cover category is considered developed lands (ES_Name, Value): NLCD developed classes 21-24 & 31, 20 (Comer et al., 2003; Ferree and Anderson, 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

OpenW_1000 = proportion of the area that is open water in a 1,000 m buffer around the patch. One NatureServe land use land cover category is considered open water (ES_Name, Value): NLCD-NHD open water, 11 (Comer et al., 2003; Ferree and Anderson, 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

Marsh_1000 = proportion of the area that is marsh in a 1,000 m buffer around the patch. Five NatureServe land use land cover categories are considered marsh (ES_Name, Value): North Atlantic Coastal Plain Tidal Salt Marsh: salt/brackish/oligohaline, 519; Acadian Coastal Salt Marsh, Acadian Estuary Marsh, 578; Acadian Estuary Marsh, 579; North Atlantic Coastal Plain Brackish/Fresh & Oligohaline Tidal Marsh, 894516; Atlantic Coastal Plain Embayed Region Tidal Freshwater/Brackish Marsh, 259260 (Comer et al. 2003, Ferree and Anderson 2013). "9999" was recorded when a patch had no land use land cover data to calculate a proportion.

geo1 = primary broad geomorphic setting of the patch. When a patch lies in two or more broad geomorphic settings, the broad setting listed under geo1 is the primary (dominant) broad setting.

Geomorphic settings follow a broad/sub-setting classification scheme (Cahoon et al. 2009). Settings were based on a classification scheme modified from Reed et al. 2008 (based on Woodroffe 2002 and Cahoon 2006):

- Open Coast: Areas sheltered from waves and currents due to coastal topography or bathymetry.
- Back-barrier Lagoon Marsh: Occupies fill within transgressive back-barrier lagoons.
    a. Back-barrier: Lagoonal side of a marine barrier.
    b. Lagoonal fill: Occupies fill in a back-barrier lagoon.
    c. Transgressive marsh: Transgressive marshes bordering uplands in a back-barrier lagoon.
- Estuarine Embayment: Shallow coastal embayments with some river discharge, frequently drowned river valleys.
    a. Saline fringe marsh: Transgressive marshes bordering uplands at the lower end of estuaries.
    b. Stream channel wetlands: Occupy estuarine/ alluvial channels rather than open coast.
- Estuarine Brackish Marshes: Located in vicinity of turbidity maxima zone.
    a. Meander: Expansive marsh with meandering channels.
    b. Fringing: Transgressive marshes bordering uplands.
    c. Island: Island within estuarine channel.
- Tidal Fresh Marsh: Located above turbidity maxima zone; develop in drowned river valleys as filled with sediment.

- Nontidal Brackish Marsh: Transgressive marshes bordering uplands in estuaries with restricted tidal signal.

Additional values:

- not recorded = geomorphic attribute not assessed.
- none = geomorphic attribute does not apply.

sub1a = primary geomorphic sub-setting within the broad setting listed in geo1. See geo1 for classification scheme and additional attribute values.

sub1b = secondary geomorphic sub-setting within the broad setting listed in geo1. See geo1 for classification scheme and additional attribute values.

sub1c = tertiary geomorphic sub-setting within the broad setting listed in geo1. See geo1 for classification scheme and additional attribute values.

geo2 = secondary broad geomorphic setting of the patch. See geo1 for classification scheme and additional attribute values.

sub2a = primary geomorphic sub-setting within the broad setting listed in geo2. See geo1 for classification scheme and additional attribute values.

sub2b = secondary geomorphic sub-setting within the broad setting listed in geo2. See geo1 for classification scheme and additional attribute values.

sub2c = tertiary geomorphic sub-setting within the broad setting listed in geo2. See geo1 for classification scheme and additional attribute values.

geo3 = tertiary broad geomorphic setting of the patch. See geo1 for classification scheme and additional attribute values.

noaa_slt = sea level trend (mm/year). Trends (changes) in mean sea level (rise or fall) were calculated by NOAA's National Ocean Service, Center for Operational Oceanographic Products

and Services (CO-OPS) using a minimum of 30 years of consecutive observations at long-term water level stations (see noaa_gauge; NOAA, National Ocean Service, CO-OPS 2013, 2014). Measurements were averaged by month to remove effects of higher frequency phenomena (e.g., storm surge). The sea level trend of the tide gauge located in the area most similar to a marsh patch is attributed to the patch; in most cases this is the trend of the nearest tide gauge. When the trends of multiple gauges best represent the sea level trend condition of a patch, the average trend is attributed to the patch (e.g., the average trend of the Boston and Nantucket Island gauges is attributed to Cape Cod Bay marshes, and the average trend of Kings Point, Port Jefferson, and Montauk gauges is attributed to marshes on the south side of Long Island from Far Rockaway, NY to Southampton, NY). See http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml for more specific details on sea level trend calculations; gauge locations and trend data downloaded May 2014.

noaa_gauge = name of NOAA tide gauge. Long-term data from gauges are used by NOAA's National Ocean Service, CO-OPs to calculate sea level trends (see noaa_slt; NOAA, National Ocean Service, CO-OPS 2013, 2014). See http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml for more specific details on NOAA tide gauges; gauge locations and trend data downloaded May 2014.

road_dens = density of roads within the patch and a 500 m buffer around the patch. The total length of roads in the patch and the buffer were summed then divided by the area of the buffer to calculate an index of human disturbance (U.S. Census Bureau 2013).

birdsurvey = Yes/No for whether a SHARP bird survey was performed in the patch in 2011 and/or 2012.

CLRA_info = method used to estimate Clapper Rail density (CLRA_dens) for the patch:

- data = density estimated from bird survey data using the unmarked package in Program R (Fiske and Chandler 2011, R Core Team 2014, Wiest et al. 2016).
- predict = expected density predicted using a Bayesian network model in Netica 5.16 (Norsys Software Corp. 2014). The expected density is the average value that will occur weighted by its probability of occurrence.
- NA = not applicable. No density estimate was calculated because the patch lies outside the geographic breeding range of the species.

CLRAdens = Clapper Rail density (birds/ha). Density was calculated for all patches south of 41.3390 degrees latitude (see CLRA_info); "9999" was recorded when the field did not apply.

CLRAdens_s = standard deviation of Clapper Rail expected density (birds/ha) for the patch. This field only applies to patches where density was calculated using a Bayesian network model (see CLRA_info); "9999" was recorded when the field did not apply.

CLRAstate = most probable Clapper Rail density state for the patch: 0–<10^{-5} birds/ha, 10^{-5}–<1 birds/ha, or ≥1 bird/ha. This field only applies to patches where density was calculated using a Bayesian network model (see CLRA_info); "NA" was recorded when the field did not apply.

CLRAdens_0 = probability of the patch being in the 0–<10^{-5} birds/ha density state for Clapper Rail. This field only applies to patches where density was calculated using a Bayesian network model (see CLRA_info); "9999" was recorded when the field did not apply.

CLRAdens_h = probability of the patch being in the 10^{-5}–<1 birds/ha density state for Clapper Rail. This field only applies to patches where density was calculated using a Bayesian network model (see CLRA_info); "9999" was recorded when the field did not apply.

CLRAdens_1 = probability of the patch being in the ≥1 bird/ha density state for Clapper Rail. This field only applies to patches where density was calculated using a Bayesian network model (see CLRA_info); "9999" was recorded when the field did not apply.

CLRAabun = Clapper Rail abundance for the patch (CLRAdens multiplied by area_ha); "9999" was recorded when the field did not apply.

WILL_info = method used to estimate Willet density (WILL_dens) for the patch:

- data = density estimated from bird survey data using the unmarked package in Program R (Fiske and Chandler 2011, R Core Team 2014, Wiest et al. 2016).
- predict = expected density predicted using a Bayesian network model in Netica 5.16 (Norsys Software Corp. 2014). The expected density is the average value that will occur weighted by its probability of occurrence.

WILLdens = Willet density (birds/ha). Density was calculated for all patches (see WILL_info).

WILLdens_s = standard deviation of Willet expected density (birds/ha) for the patch. This field only applies to patches where density was calculated using a Bayesian network model (see WILL_info); "9999" was recorded when the field did not apply.

WILLstate = most probable Willet density state for the patch: 0–<10^{-5} birds/ha, 10^{-5}–<1 birds/ha, or ≥1 bird/ha. This field only applies to patches where density was calculated using a Bayesian network model (see WILL_info); "NA" was recorded when the field did not apply.

WILLdens_0 = probability of the patch being in the 0–<10^{-5} birds/ha density state for Willet. This field only applies to patches where density was calculated using a Bayesian network model (see WILL_info); "9999" was recorded when the field did not apply.

WILLdens_h = probability of the patch being in the 10^{-5}–<1 birds/ha density state for Willet. This field only applies to patches where density was calculated using a Bayesian network model (see WILL_info); "9999" was recorded when the field did not apply.

WILLdens_1 = probability of the patch being in the ≥1 bird/ha density state for Willet. This field only applies to patches where density was calculated using a Bayesian network model (see WILL_info); "9999" was recorded when the field did not apply.

WILLabun = Willet abundance for the patch (WILLdens multiplied by area_ha).

NESP_info = method used to estimate Nelson's Sparrow density (NESP_dens) for the patch:

- data = density estimated from bird survey data using the unmarked package in Program R (Fiske and Chandler 2011, R Core Team 2014, Wiest et al. 2016).
- predict = expected density predicted using a Bayesian network model in Netica 5.16 (Norsys Software Corp. 2014). The expected density is the average value that will occur weighted by its probability of occurrence.
- NA = not applicable. No density estimate was calculated because the patch lies outside the geographic breeding range of the species.

NESPdens = Nelson's Sparrow density (birds/ha). Density was calculated for all patches north of 42.8520 degrees latitude (see NESP_info); "9999" was recorded when the field did not apply

NESPdens_s = standard deviation of Nelson's Sparrow expected density (birds/ha) for the patch. This field only applies to patches where density was calculated using a Bayesian network model (see NESP_info); "9999" was recorded when the field did not apply.

NESPstate = most probable Nelson's Sparrow density state for the patch: 0–<10^{-5} birds/ha, 10^{-5}–<1 birds/ha, or ≥1 bird/ha. This field only applies to patches where density was calculated using a Bayesian network model (see NESP_info); "NA" was recorded when the field did not apply.

NESPdens_0 = probability of the patch being in the 0–<10^{-5} birds/ha density state for Nelson's Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see NESP_info); "9999" was recorded when the field did not apply.

NESPdens_h = probability of the patch being in the 10^{-5}–<1 birds/ha density state for Nelson's Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see NESP_info); "9999" was recorded when the field did not apply.

NESPdens_1 = probability of the patch being in the ≥1 bird/ha density state for Nelson's Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see NESP_info); "9999" was recorded when the field did not apply.

NESPabun = Nelson's Sparrow abundance for the patch (NESPdens multiplied by area_ha); "9999" was recorded when the field did not apply.

SALS_info = method used to estimate Saltmarsh Sparrow density (SALS_dens) for the patch:

- data = density estimated from bird survey data using the unmarked package in Program R (Fiske and Chandler 2011, R Core Team 2014, Wiest et al. 2016).
- predict = expected density predicted using a Bayesian network model in Netica 5.16 (Norsys Software Corp. 2014). The expected density is the average value that will occur weighted by its probability of occurrence.
- NA = not applicable. No density estimate was calculated because the patch lies outside the geographic breeding range of the species.

SALSdens = Saltmarsh Sparrow density (birds/ha). Density was calculated for all patches south of 44.0753 degrees latitude (see SALS_info); "9999" was recorded when the field did not apply.

SALSdens_s = standard deviation of Saltmarsh Sparrow expected density (birds/ha) for the patch. This field only applies to patches where density was calculated using a Bayesian network model (see SALS_info); "9999" was recorded when the field did not apply.

SALSstate = most probable Saltmarsh Sparrow density state for the patch: 0–<10^{-5} birds/ha, 10^{-5}–<1 birds/ha, or ≥1 bird/ha. This field only applies to patches where density was calculated using a Bayesian network model (see SALS_info); "NA" was recorded when the field did not apply.

SALSdens_0 = probability of the patch being in the 0–<10^{-5} birds/ha density state for Saltmarsh Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see SALS_info); "9999" was recorded when the field did not apply.

SALSdens_h = probability of the patch being in the 10^{-5}–<1 birds/ha density state for Saltmarsh Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see SALS_info); "9999" was recorded when the field did not apply.

SALSdens_1 = probability of the patch being in the ≥1 bird/ha density state for Saltmarsh Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see SALS_info); "9999" was recorded when the field did not apply.

SALSabun = Saltmarsh Sparrow abundance for the patch (SALSdens multiplied by area_ha); "9999" was recorded when the field did not apply.

SESP_info = method used to estimate Seaside Sparrow density (SESP_dens) for the patch:

- data = density estimated from bird survey data using the unmarked package in Program R (Fiske and Chandler 2011, R Core Team 2014, Wiest et al. 2016).

- predict = expected density predicted using a Bayesian network model in Netica 5.16 (Norsys Software Corp. 2014). The expected density is the average value that will occur weighted by its probability of occurrence.
- NA = not applicable. No density estimate was calculated because the patch lies outside the geographic breeding range of the species.

SESPdens = Seaside Sparrow density (birds/ha). Density was calculated for all patches south of 42.9185 degrees latitude (see SESP_info); "9999" was recorded when the field did not apply.

SESPdens_s = standard deviation of Seaside Sparrow expected density (birds/ha) for the patch. This field only applies to patches where density was calculated using a Bayesian network model (see SESP_info); "9999" was recorded when the field did not apply.

SESPstate = most probable Seaside Sparrow density state for the patch: 0–<10^{-5} birds/ha, 10^{-5}–<1 birds/ha, or ≥1 bird/ha. This field only applies to patches where density was calculated using a Bayesian network model (see SESP_info); "NA" was recorded when the field did not apply.

SESPdens_0 = probability of the patch being in the 0–<10^{-5} birds/ha density state for Seaside Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see SESP_info); "9999" was recorded when the field did not apply.

SESPdens_h = probability of the patch being in the 10^{-5}–<1 birds/ha density state for Seaside Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see SESP_info); "9999" was recorded when the field did not apply.

SESPdens_1 = probability of the patch being in the ≥1 bird/ha density state for Seaside Sparrow. This field only applies to patches where density was calculated using a Bayesian network model (see SESP_info); "9999" was recorded when the field did not apply.

SESPabun = Seaside Sparrow abundance for the patch (SESPdens multiplied by area_ha); "9999" was recorded when the field did not apply.

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