Supplement to Final Report BOEM 2021-051

Atlantic Marine Assessment Program for Protected Species: 2015-2019

Appendix I
Generalize Additive Density-Habitat Models and Maps, by Species

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1 Study Area

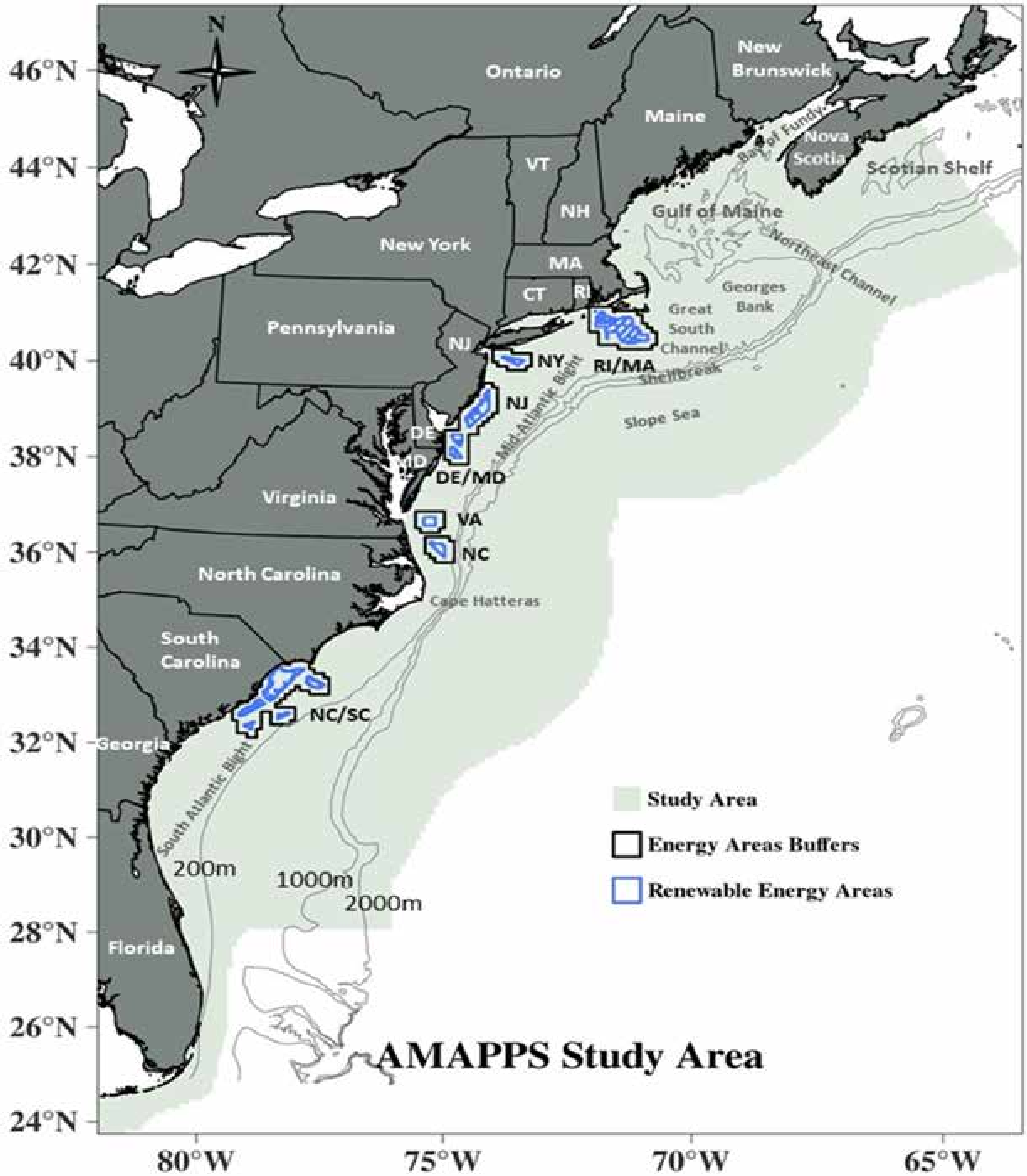

Figure 1-1 AMAPPS study area and Massachusetts to North Carolina wind-energy study areas
We identified the locations of the offshore wind energy areas (blue line) along with a 10 km buffer (black line) in relationship to the AMAPPS study area (green shaded).

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2 Humpback Whale (*Megaptera novaeangliae*)

Figure 2-1 Humpback Whale
Image collected under MMPA Research permit #17355. Credit: NOAA/NEFSC/Tim Cole

2.1 Data Collection

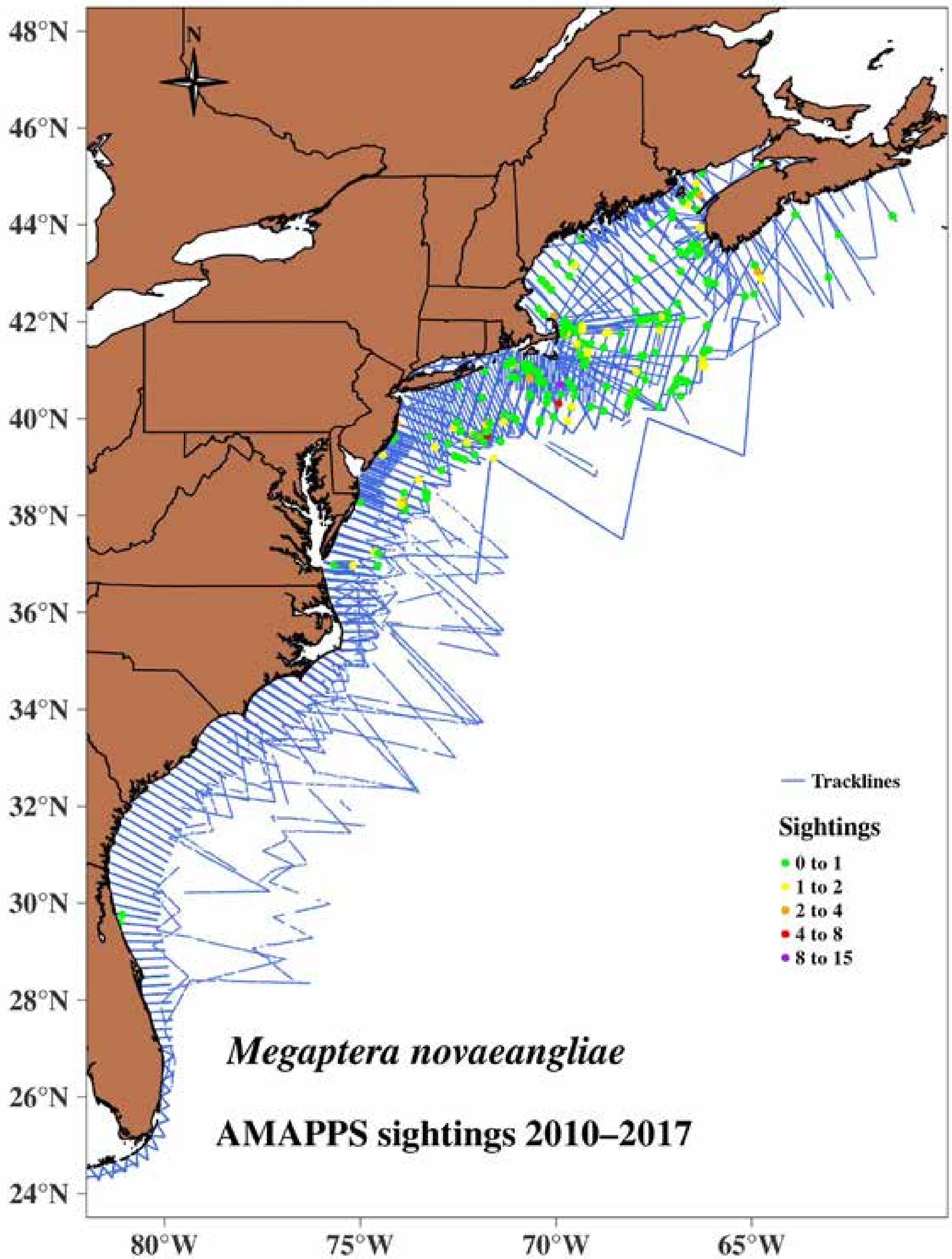

Figure 2-2 Distribution of track lines and humpback whale sightings 2010 to 2017

Table 2-1 AMAPPS research effort 2010 to 2017 and humpback whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	157	370
NE Shipboard	Fall	1,065	0	0
NE Aerial	Spring	13,314	13	20
NE Aerial	Summer	25,867	68	88
NE Aerial	Fall	37,850	75	101
NE Aerial	Winter	12,179	7	10
SE Shipboard	Spring	8,853	45	76
SE Shipboard	Summer	12,968	1	1
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	8	9
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	3	6
SE Aerial	Winter	8,950	2	2

2.2 Mark-Recapture Distance Sampling Analysis

Table 2-2 Intermediate parameters in humpback whale mark-recapture distance sampling models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 4	distance * observer + sea state + glare	300	distance	LT43- 300	HR	0.86	0.18	0.98	0.96	0.95
NE–aerial group 3	distance + group size	1500	distance + sea state + quality	1500	HR	0.67	0.09	0.06	0.87	0.94
NE–shipboard group 8	distance + time of day	7000	distance + glare	7000	HR	0.39	0.24	0.31	0.98	0.99
SE–shipboard group 5	distance * observer + group size	6000	distance + glare + time of day	6000	HR	0.57	0.11	0.24	0.61	0.65

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

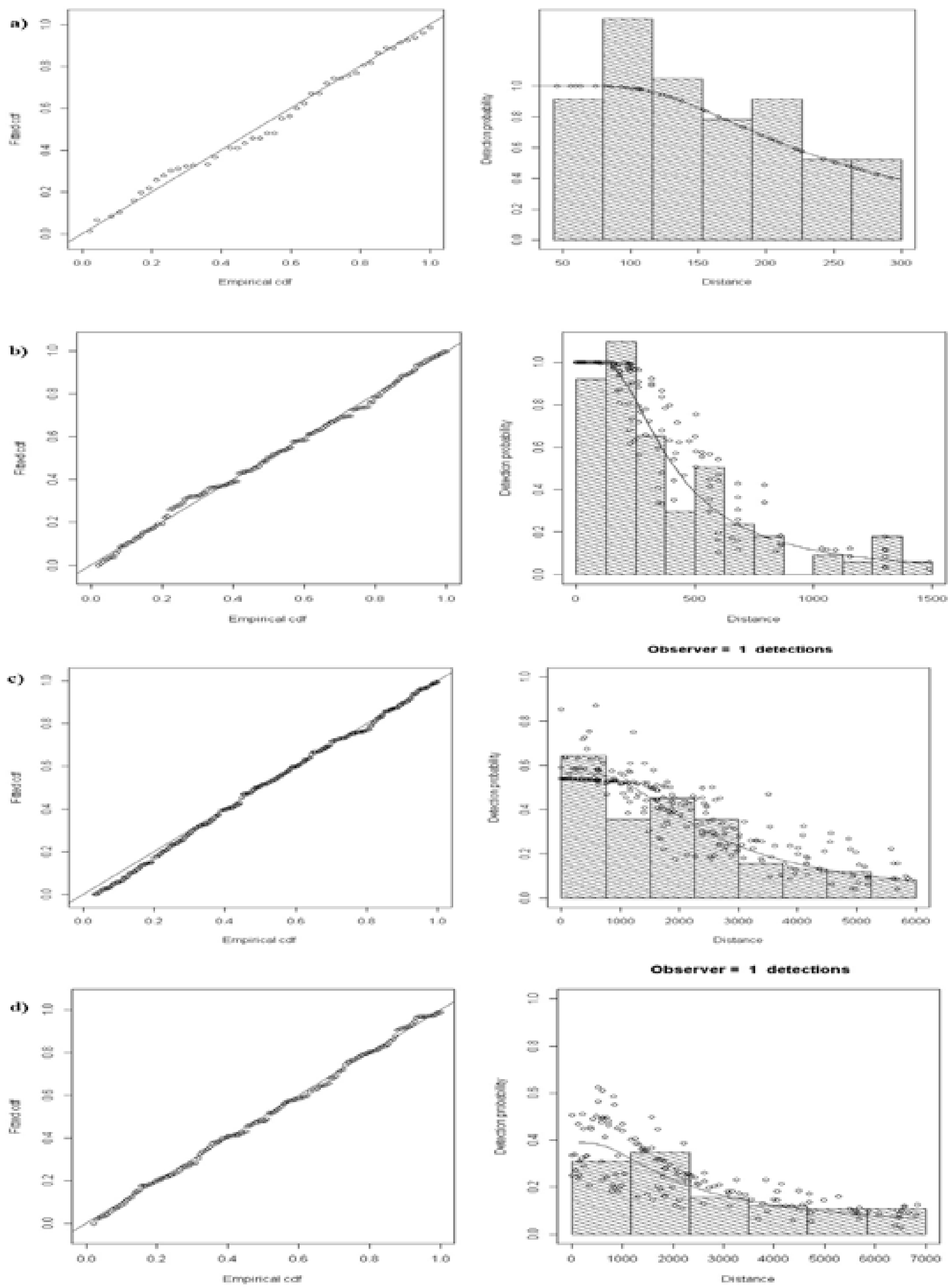

Figure 2-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 4; b) NE-aerial analysis set 3; c) NE-shipboard analysis set 8; d) SE-shipboard analysis set 5.

2.3 Generalized Additive Model Analysis

Table 2-3 2010 to 2017 density-habitat model output for humpback whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(sstmur)	2.89	4	10.58	2.95	<0.0001
s(mld)	0.93	4	3.34	1.96	0.0001
s(picma)	0.87	4	1.45	0.79	0.0094
s(pp)	2.72	4	16.04	8.07	<0.0001
s(dist125)	2.35	4	16.34	8.88	<0.0001
s(dist1000)	1.15	4	5.09	1.70	<0.0001
s(lat)	3.70	4	19.32	9.24	<0.0001
te(LY,chlfma)	10.02	24	2.86	8.13	<0.0001

Adjusted R^2 = 0.0328. Deviance explained = 41.7%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

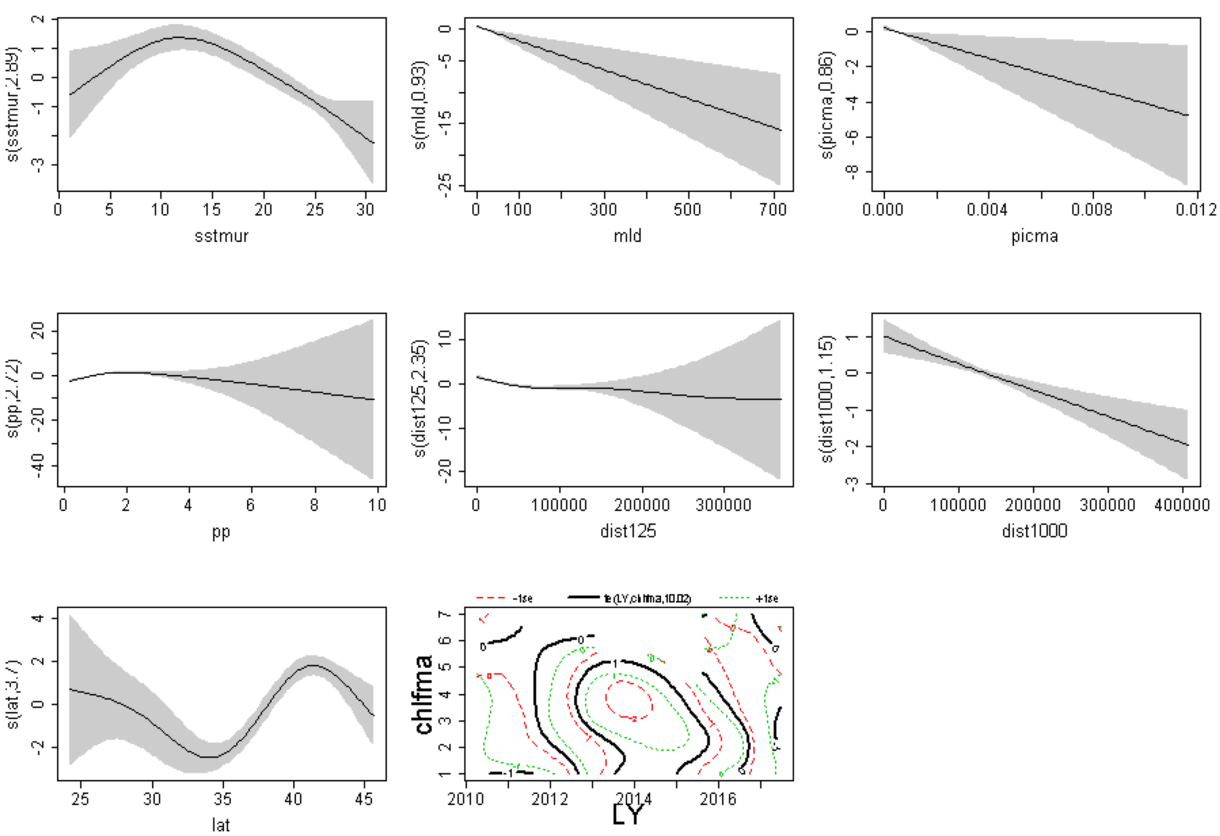

Figure 2-4 Humpback whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

2.4 Model Cross-Validation

Table 2-4 Diagnostic statistics from the humpback whale density-density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.272	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	90.700	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.107	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.001	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

2.5 Abundance Estimates for AMAPPS Study Area

Table 2-5 Humpback whale average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	581	0.44	238–1,238
Summer (June–August)	1,366	0.42	599–2,908
Fall (September–November)	414	0.42	184–892
Winter (December–February)	111	0.46	44–248
Summer 2011 U.S. surveys[1]	335	0.42	199–564
Summer 2016 U.S. surveys[1]	2,368	0.48	1,315–4,264

[1]Hayes et al. 2020

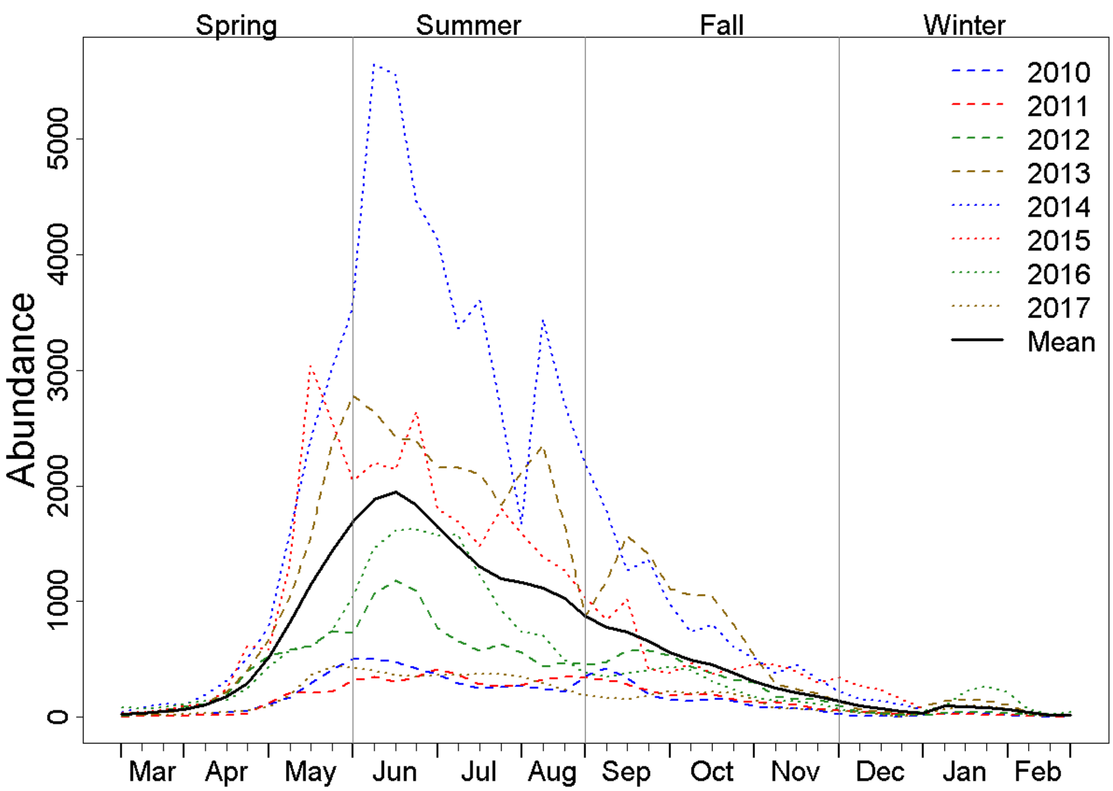

Figure 2-5 Annual abundance trends for humpback whales in the AMAPPS study area

2.6 Seasonal Prediction Maps

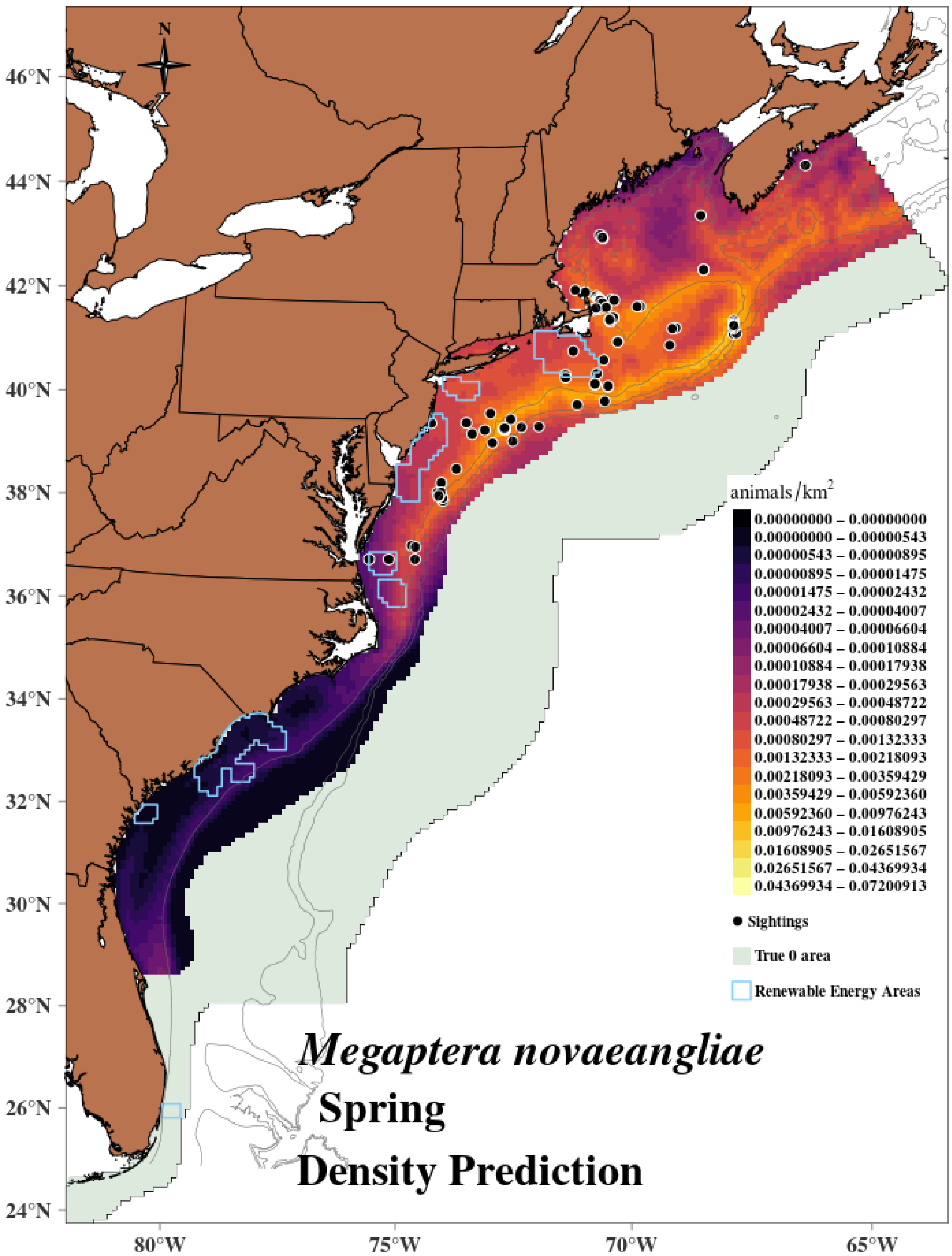

Figure 2-6 Humpback whale spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

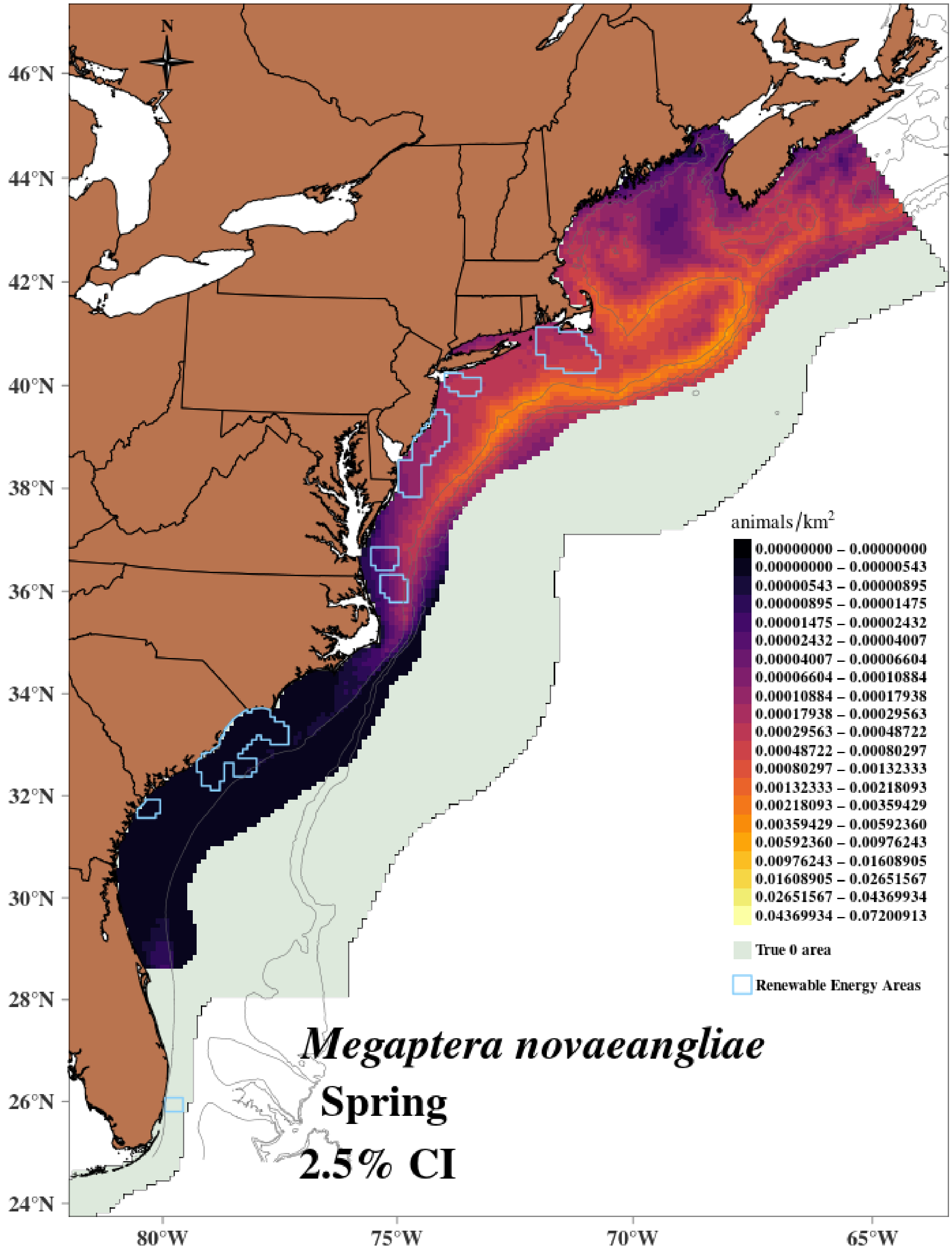

Figure 2-7 Lower 2.5% confidence interval of the spring humpback whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

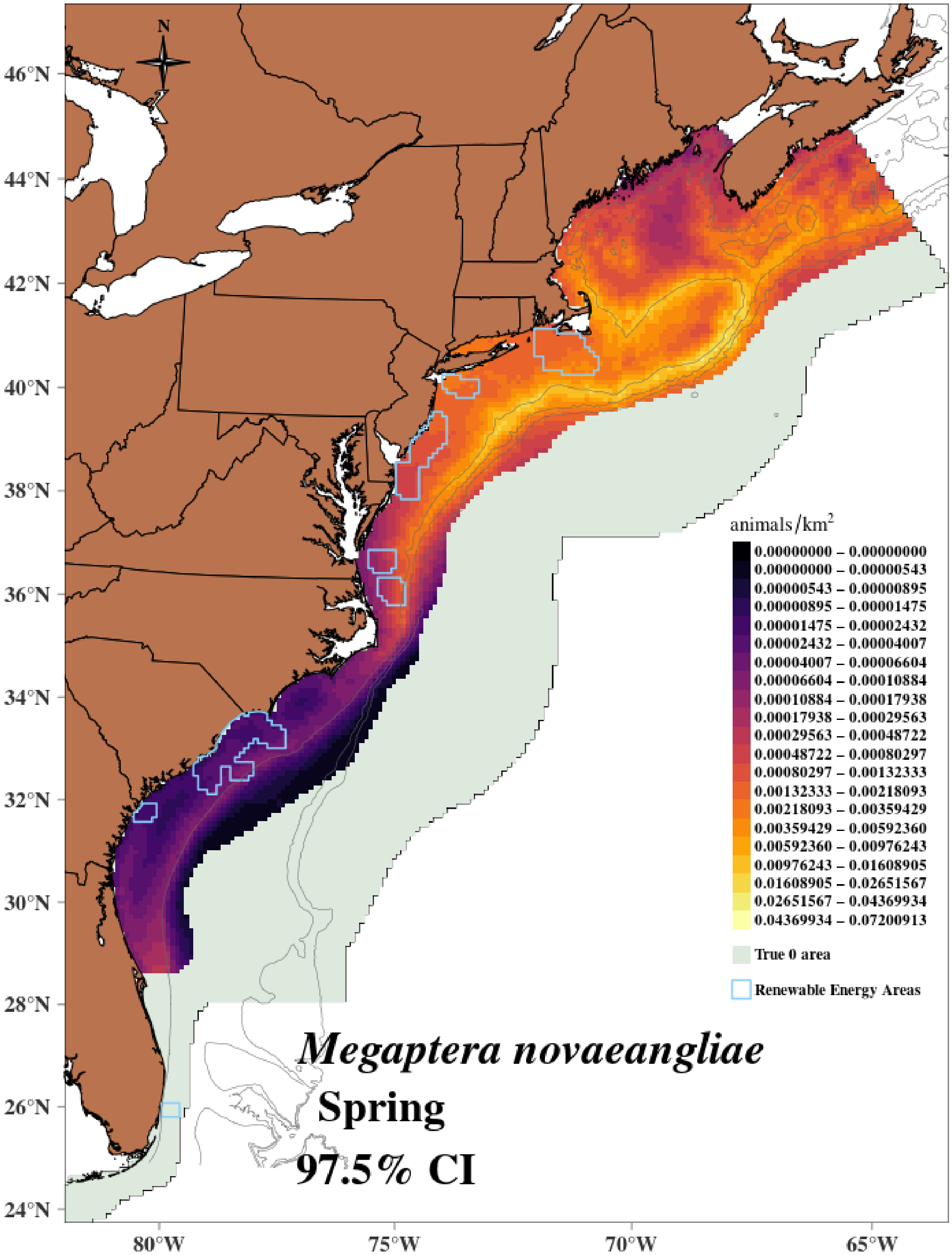

Figure 2-8 Upper 97.5% confidence interval of the spring humpback whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

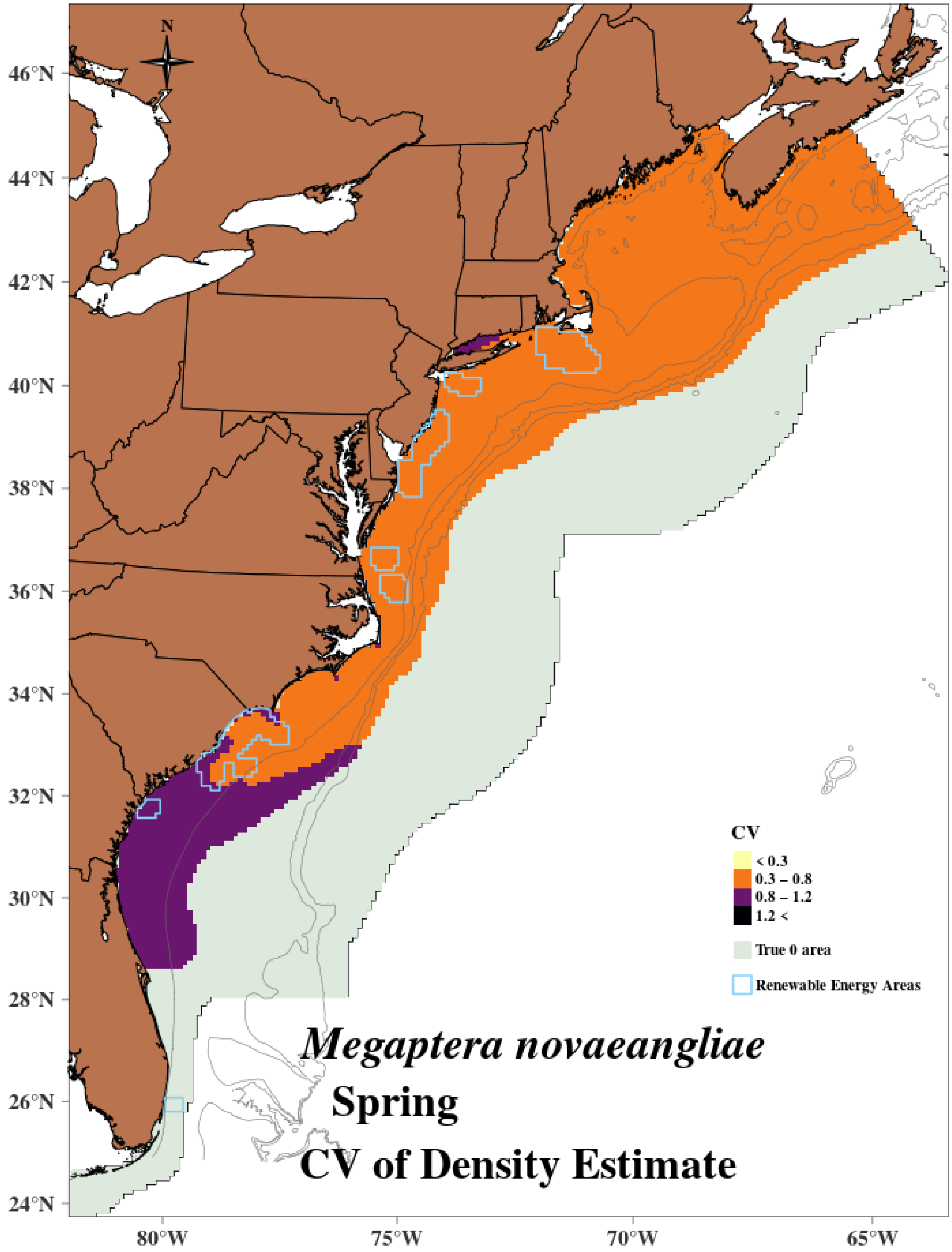

Figure 2-9 CV of spring humpback whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

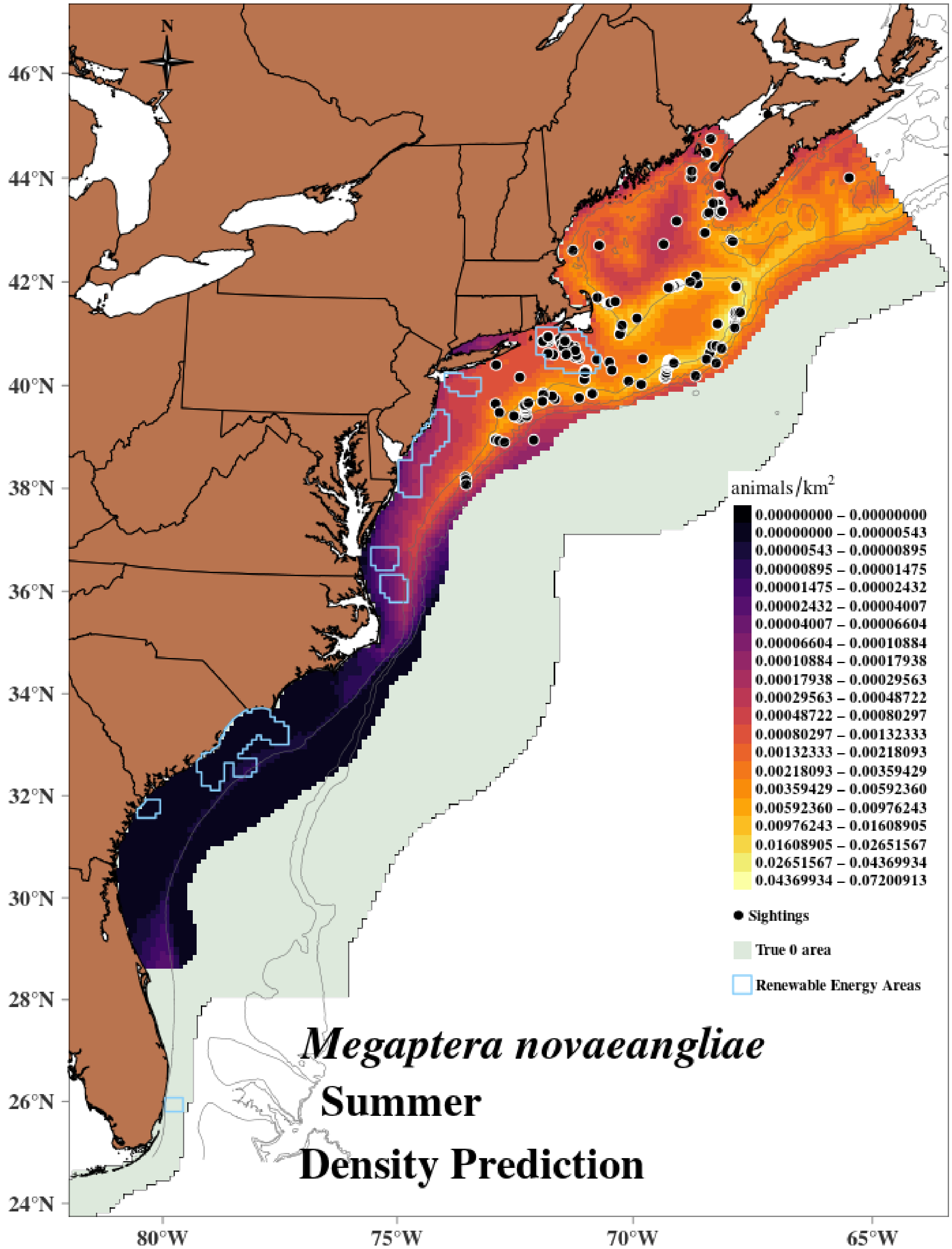

Figure 2-10 Humpback whale summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

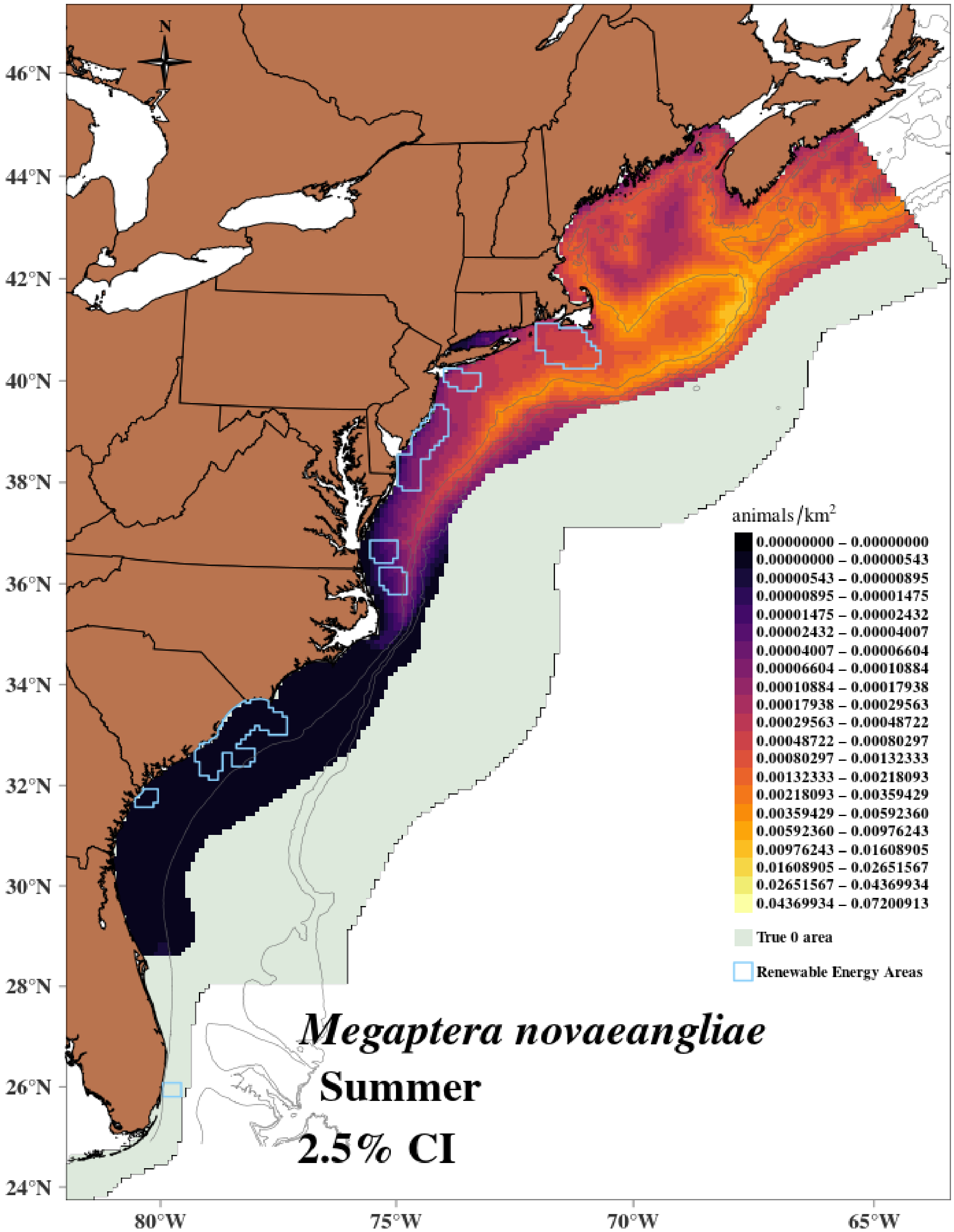

Figure 2-11 Lower 2.5% confidence interval of the summer humpback whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

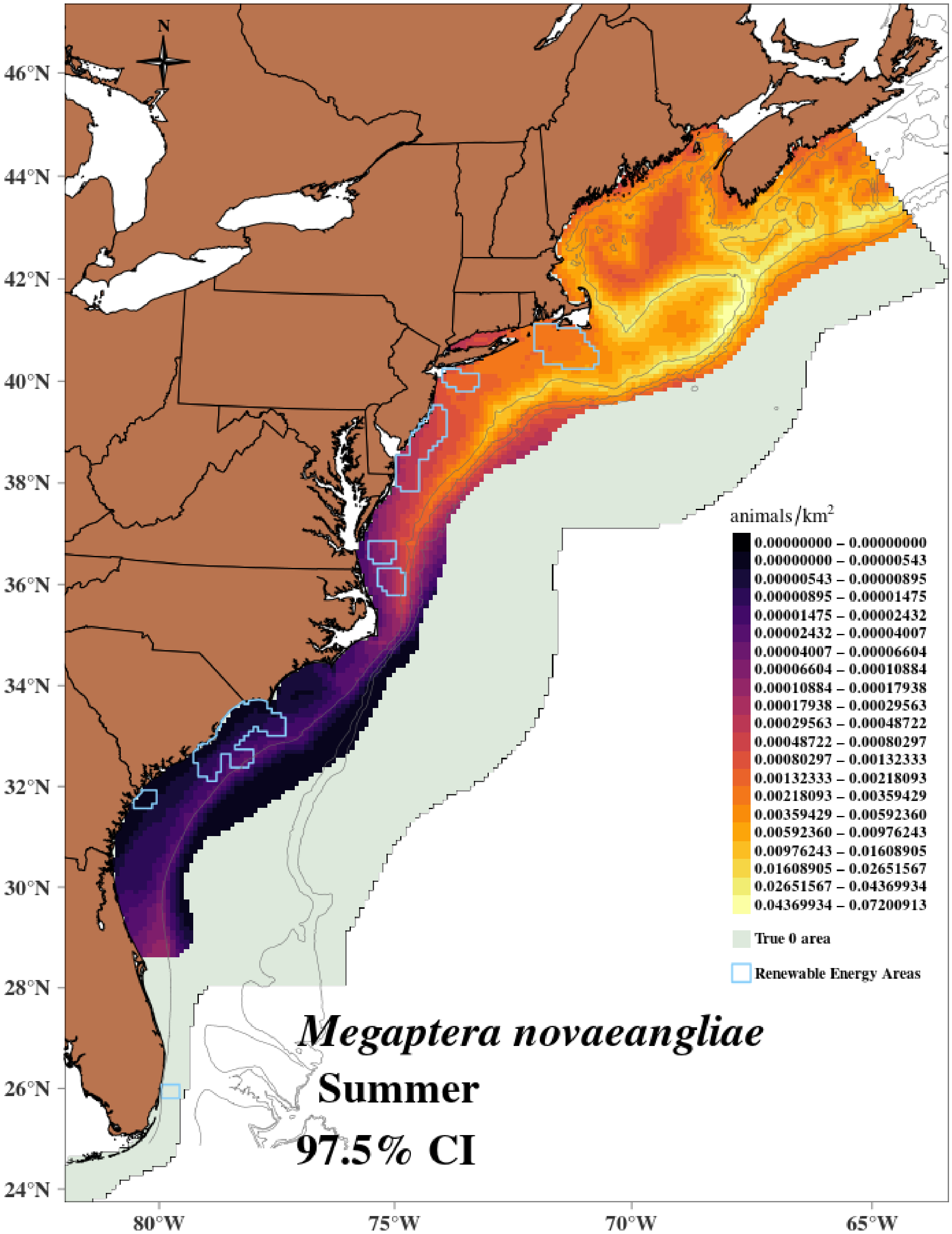

Figure 2-12 Upper 97.5% confidence interval of the summer humpback whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

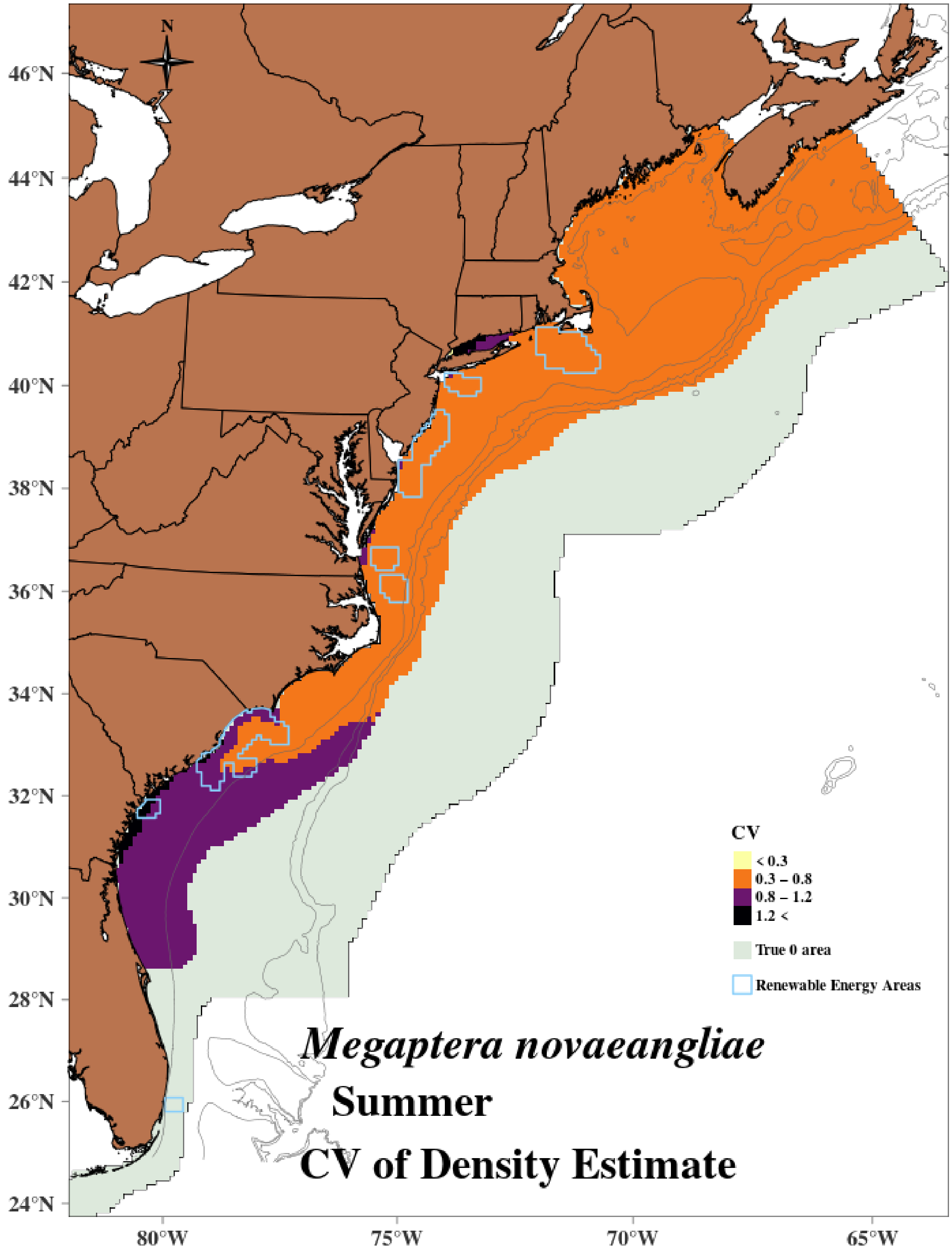

Figure 2-13 CV of summer humpback whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

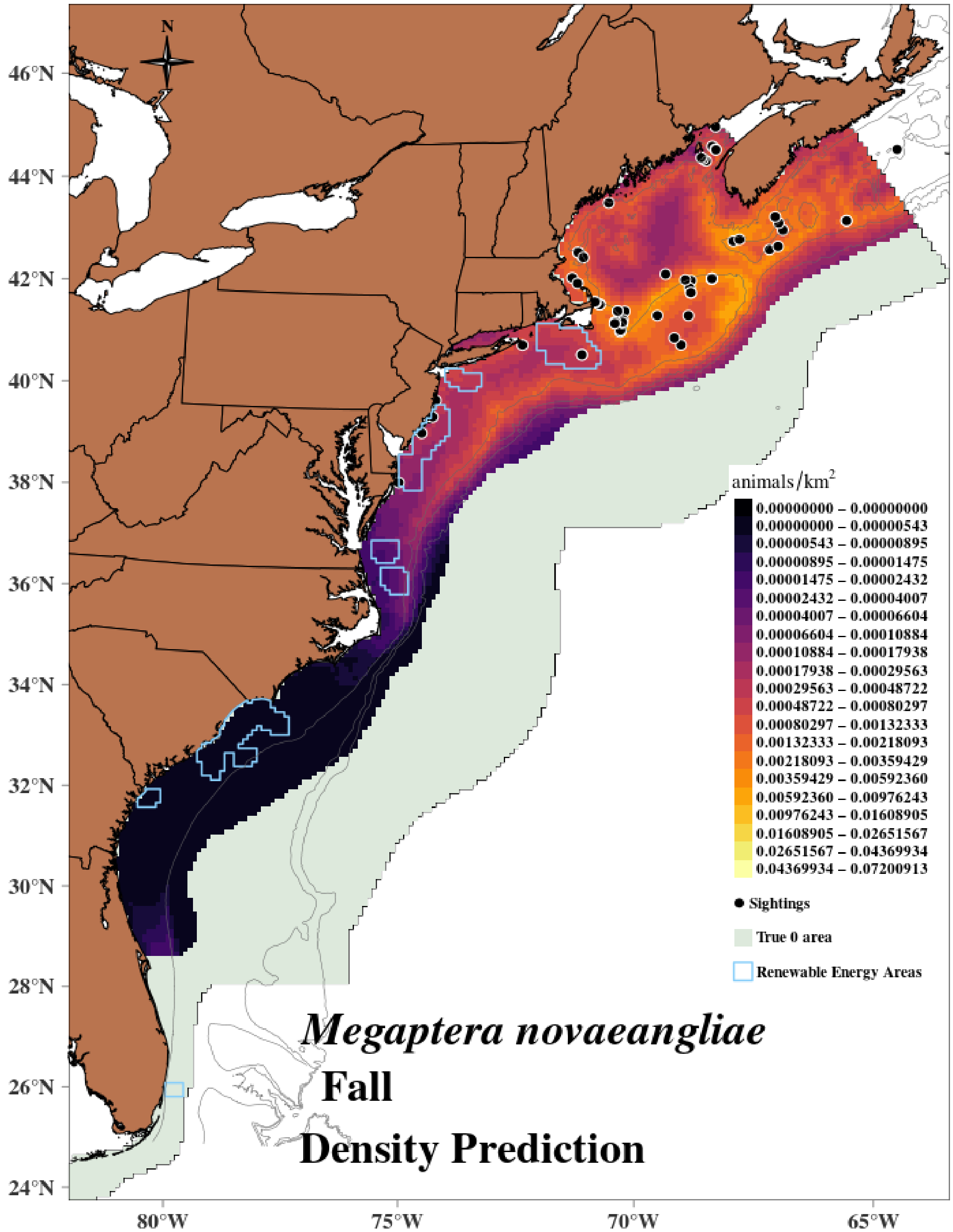

Figure 2-14 Humpback whale fall average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

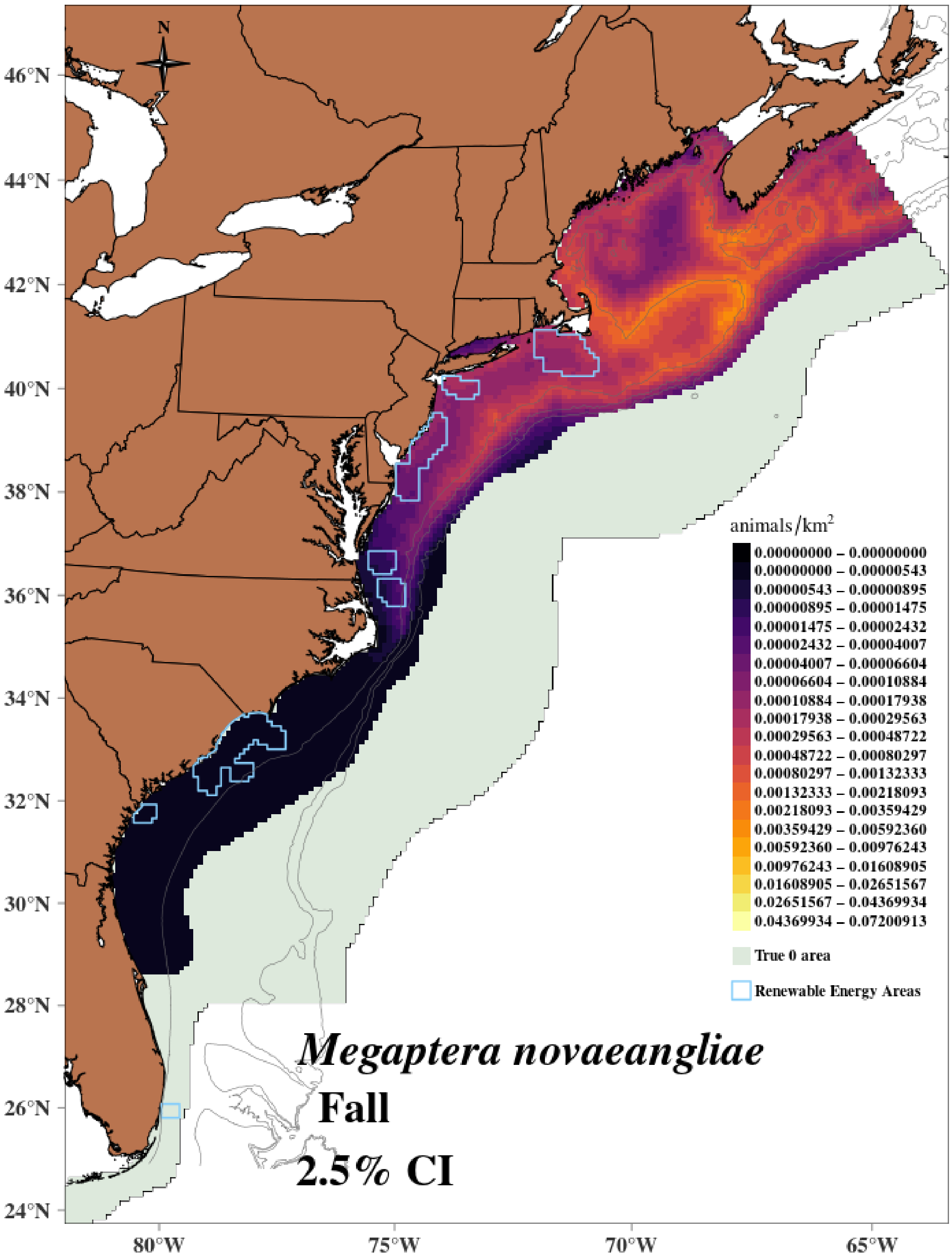

Figure 2-15 Lower 2.5% confidence interval of the fall humpback whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

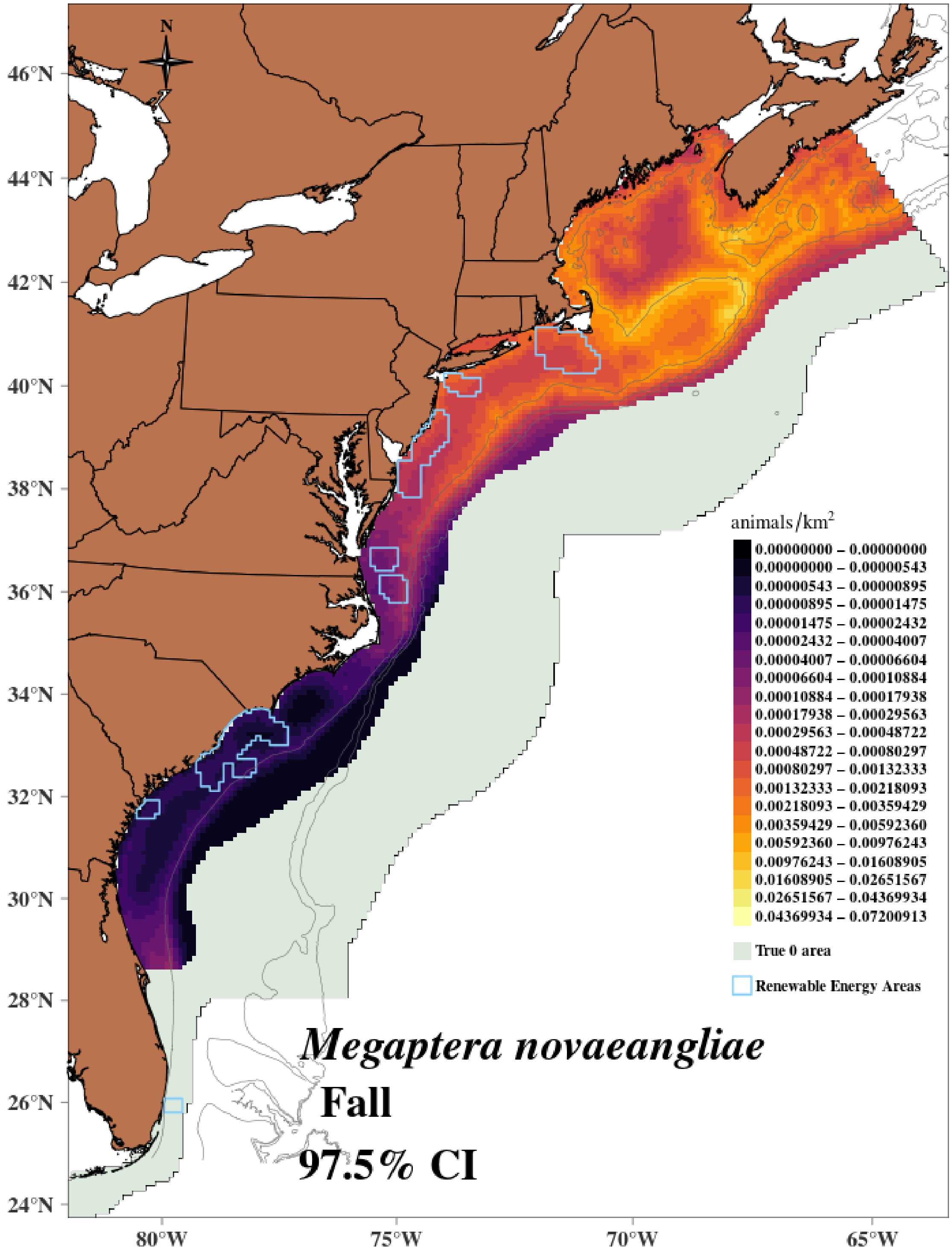

Figure 2-16 Upper 97.5% confidence interval of the fall humpback whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

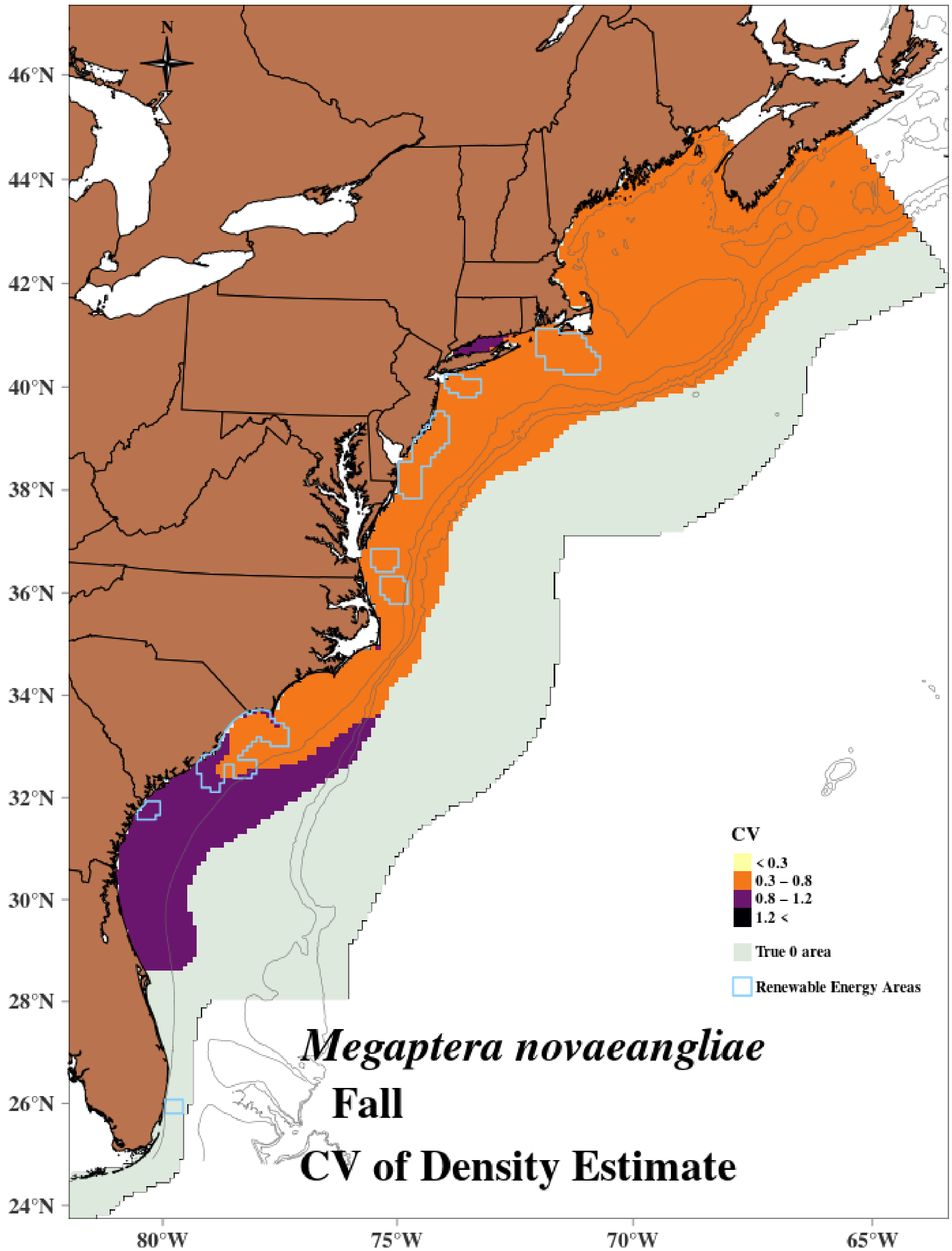

Figure 2-17 CV of fall humpback whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

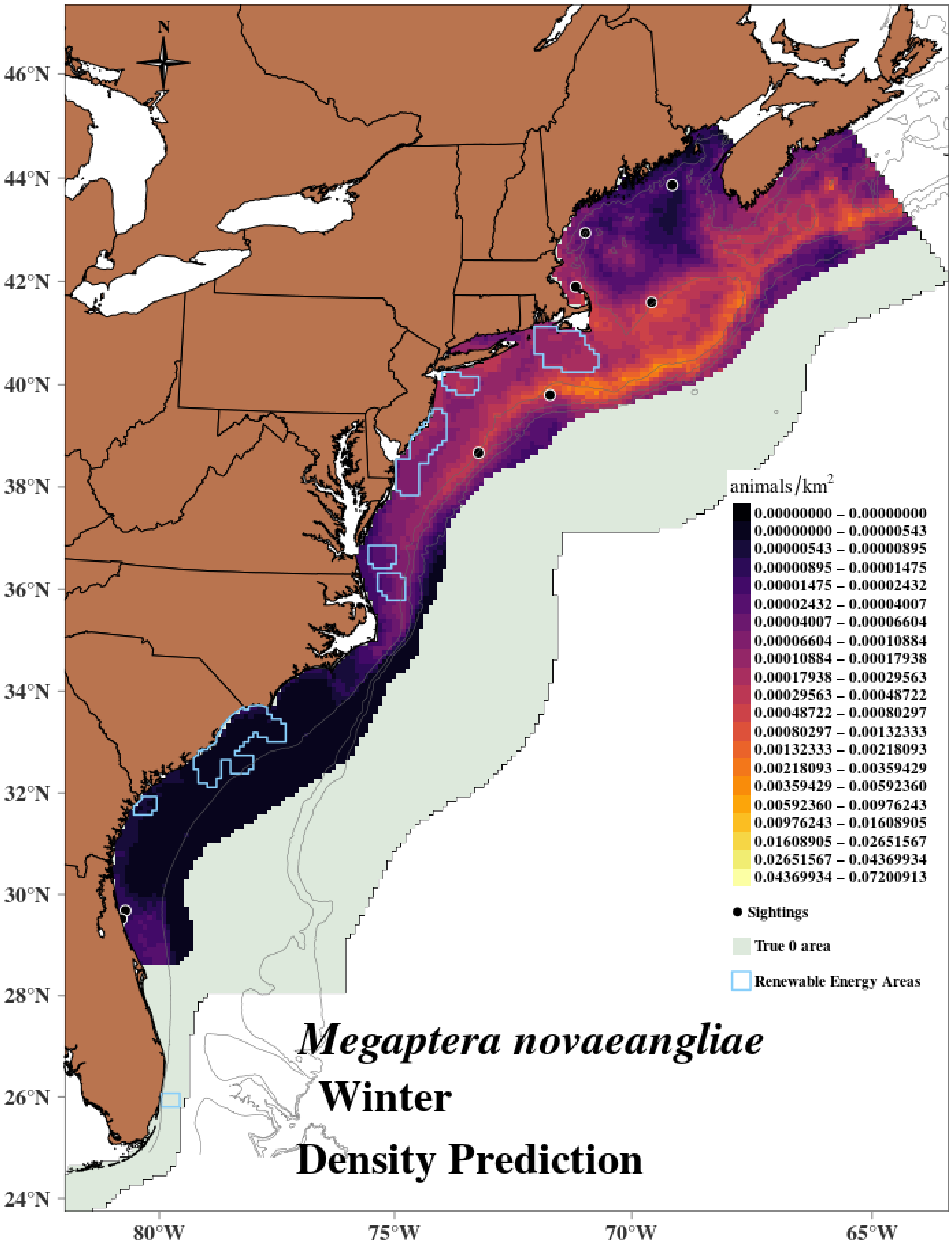

Figure 2-18 Humpback whale winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

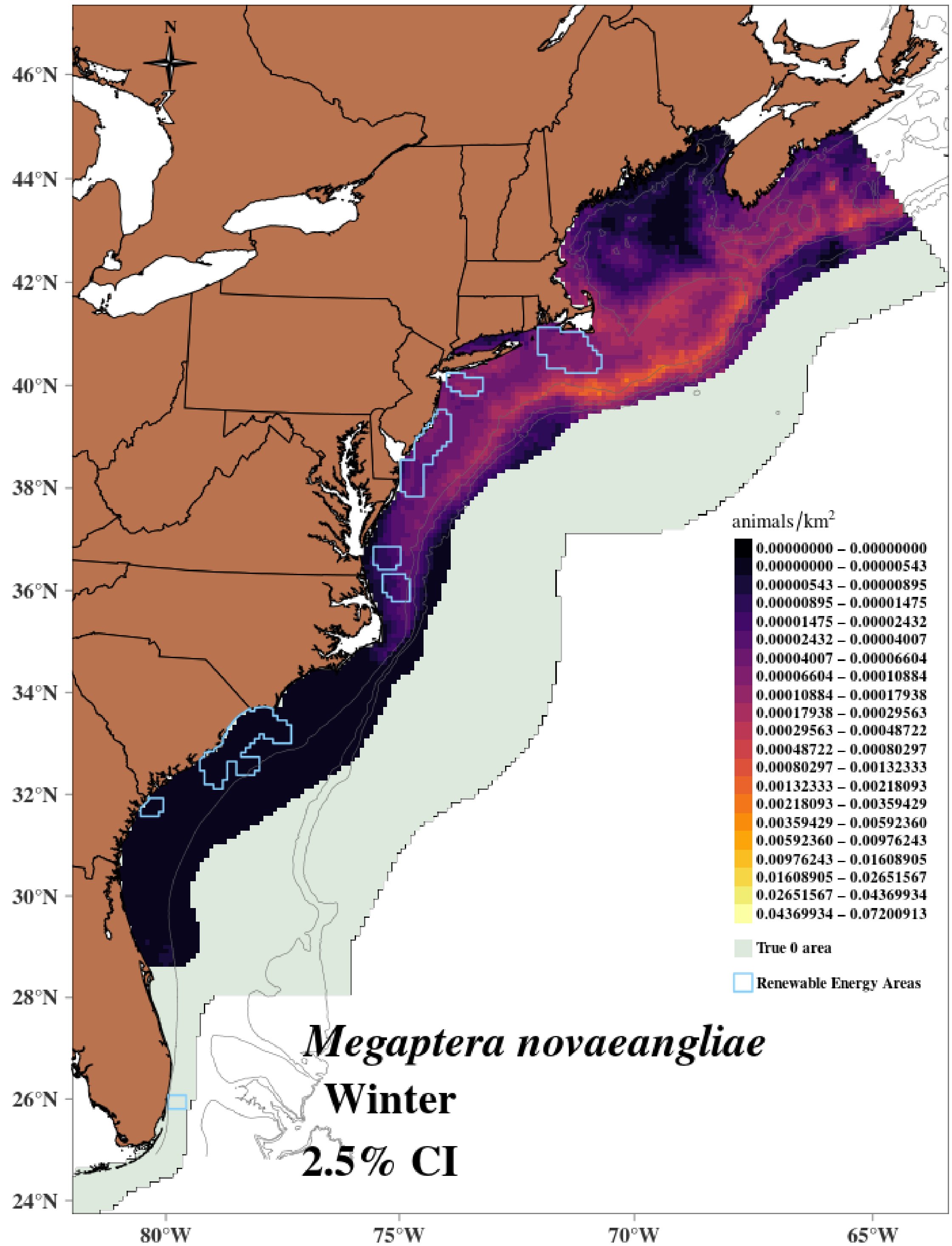

Figure 2-19 Lower 2.5% confidence interval of the winter humpback whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

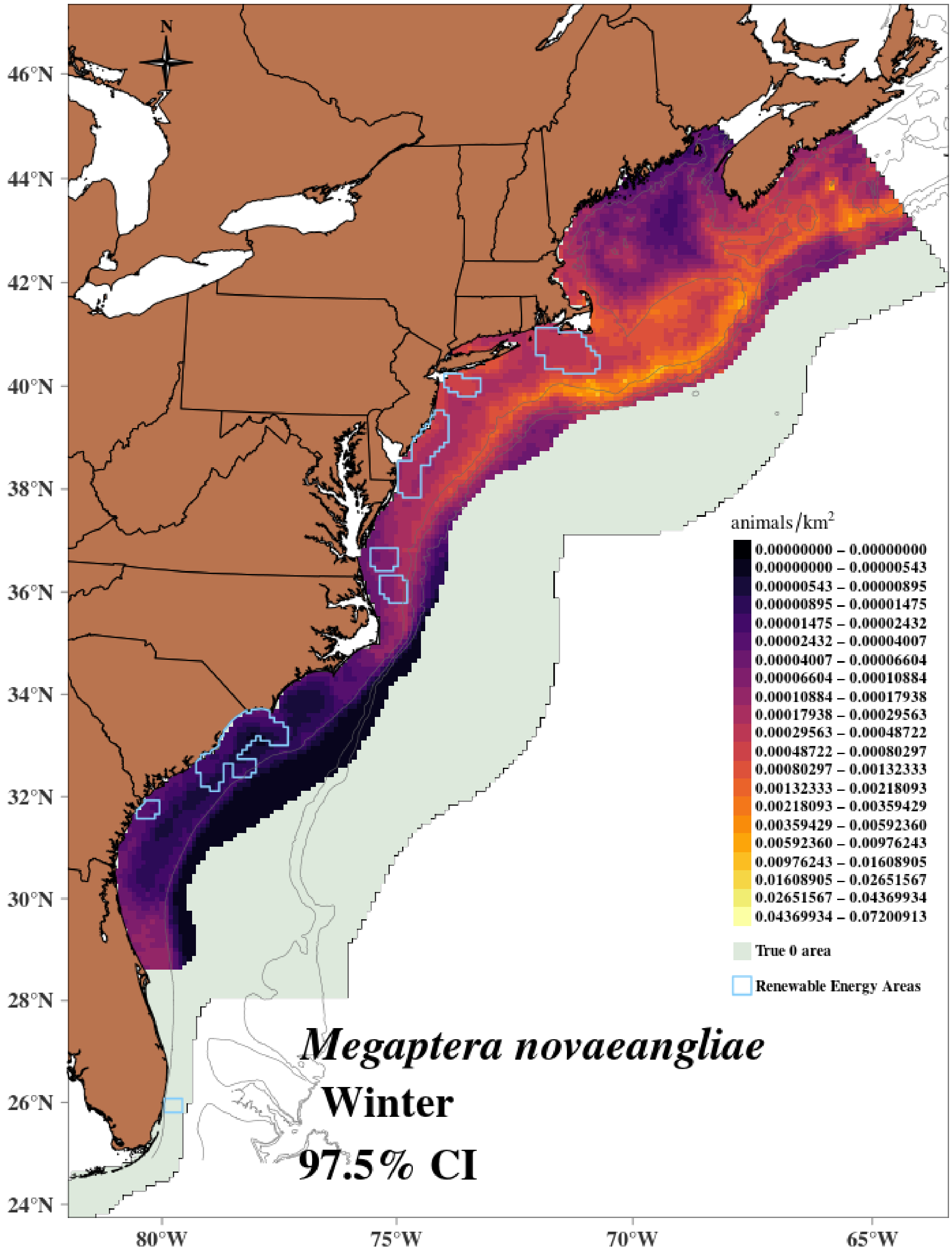

Figure 2-20 Upper 97.5% confidence interval of the winter humpback whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

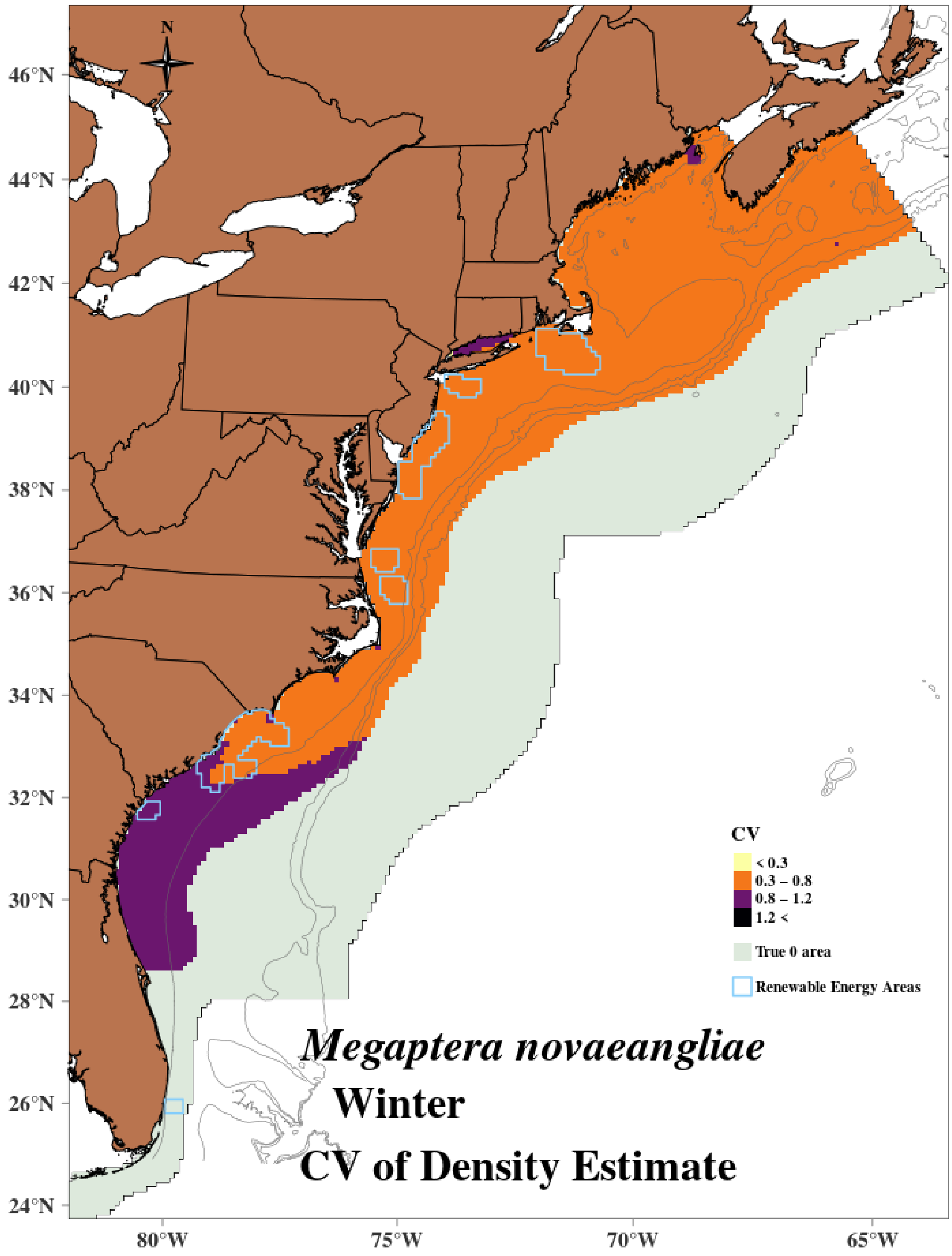

Figure 2-21 CV of winter humpback whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

2.7 Offshore Energy Development Areas

Table 2-6 Humpback whale abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	12.5	0.46	5.3–29.6
	NY	2.6	0.50	1.0–6.5
	NJ	3.3	0.49	1.3–8.2
	DE/MD	1.2	0.47	0.5–2.8
	VA	0.4	0.50	0.1–0.9
	NC	0.8	0.52	0.3–2.1
	NC/SC	0.1	0.77	0.0–0.5
Summer (Jun–Aug)	RI/MA	2.0	0.49	0.8–4.9
	NY	1.7	0.51	0.7–4.4
	NJ	0.6	0.49	0.2–1.5
	DE/MD	0.2	0.49	0.1–0.4
	VA	0.3	0.48	0.1–0.8
	NC	0.0	0.79	0.0–0.2
	NC/SC	0.0	1.09	0.0–0.0
Fall (Sep–Nov)	RI/MA	1.7	0.50	0.7–4.3
	NY	0.5	0.49	0.2–1.3
	NJ	0.1	0.49	0.0–0.2
	DE/MD	0.1	0.50	0.1–0.3
	VA	0.0	0.78	0.0–0.1
	NC	0.0	0.96	0.0–0.0
	NC/SC	1.8	0.45	0.8–4.3
Winter (Dec–Feb)	RI/MA	0.3	0.47	0.1–0.7
	NY	0.1	0.48	0–0.3
	NJ	0.2	0.50	0.1–0.6
	DE/MD	0.1	0.77	0.0–0.3
	VA	0.0	0.96	0.0–0.0
	NC	12.5	0.46	5.3–29.6
	NC/SC	2.6	0.50	1.0–6.5

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

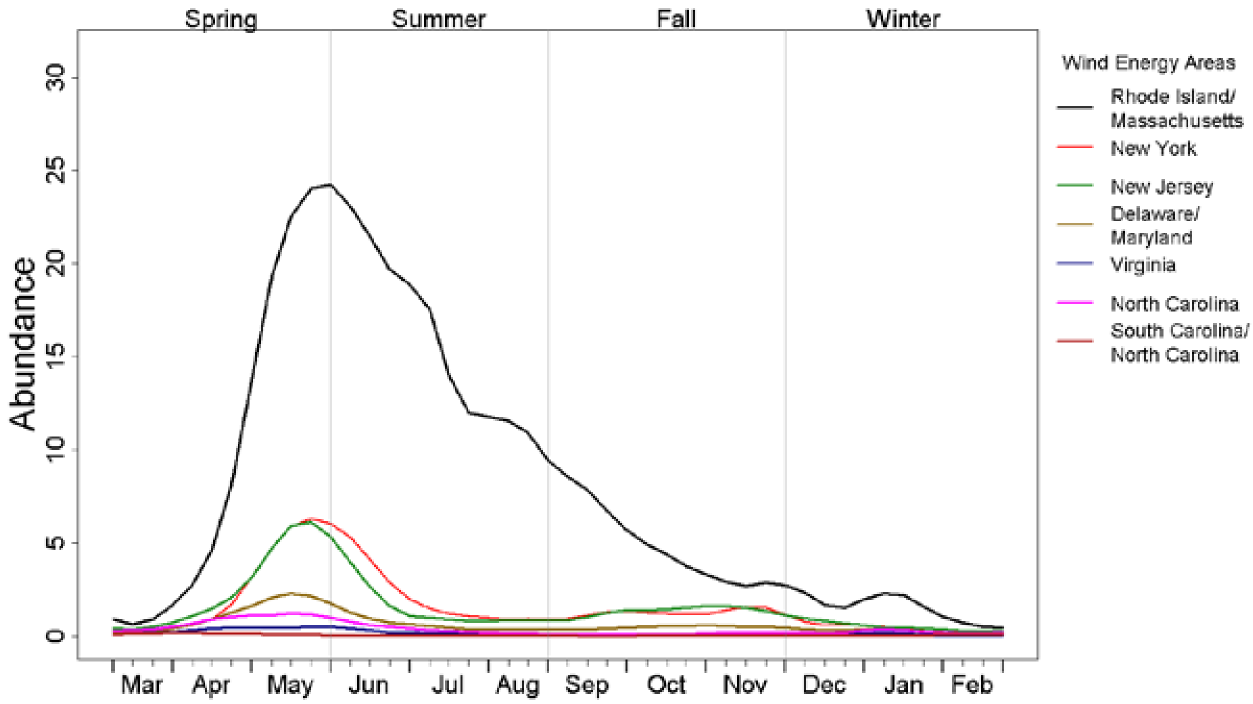

Figure 2-22 Average seasonal abundance of humpback whales in the wind-energy study areas

3 Fin Whale (*Balaenoptera physalus*)

Figure 3-1 Fin whale
Image collected under MMPA Research permit #17355. Credit: NOAA/NEFSC/Brenda Rhone.

3.1 Data Collection

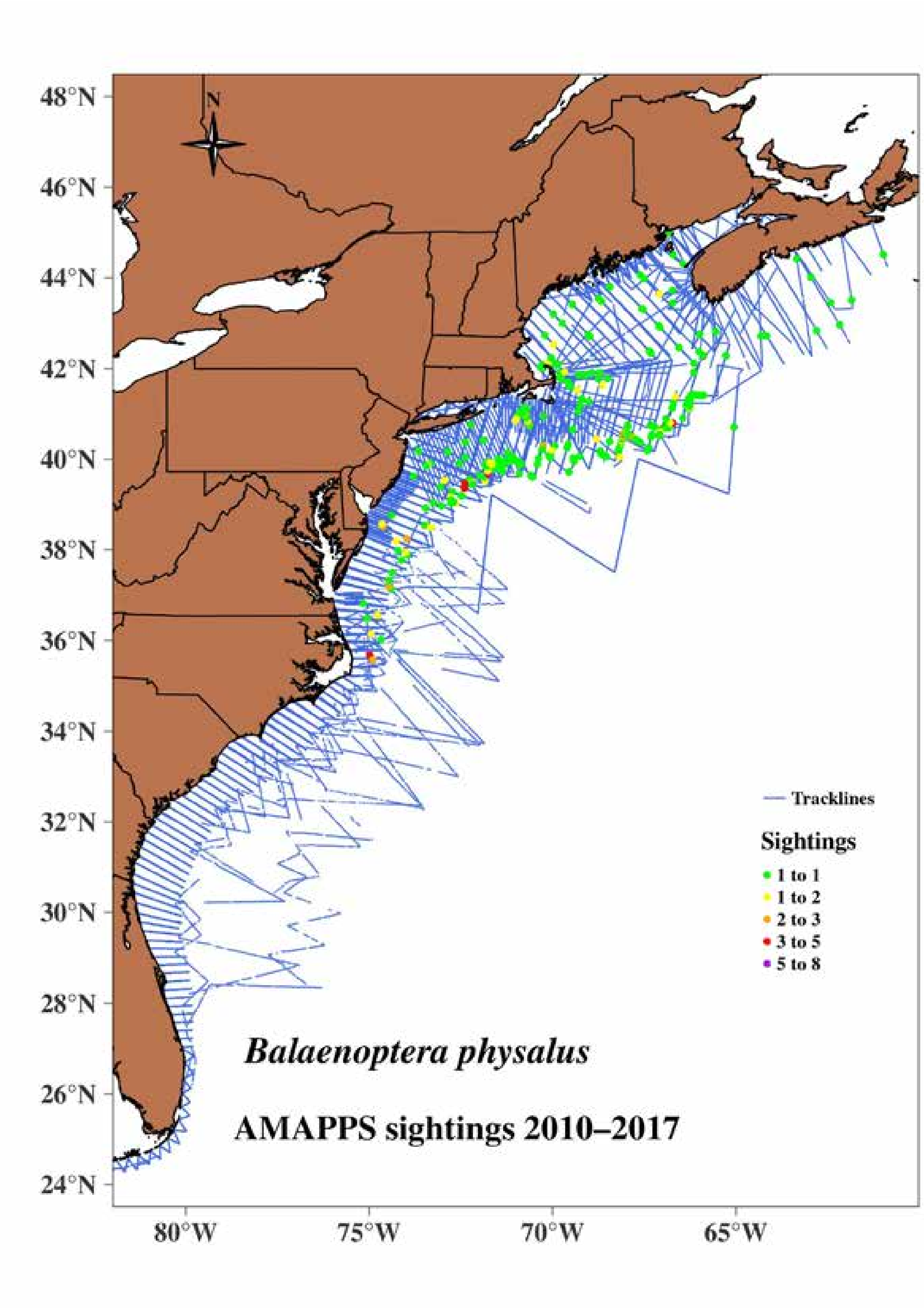

Figure 3-2 Distribution of track lines and fin whale sightings 2010–2017

Table 3-1 AMAPPS research effort 2010–2017 and fin whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	345	533
NE Shipboard	Fall	1,065	1	1
NE Aerial	Spring	13,314	25	36
NE Aerial	Summer	25,867	31	31
NE Aerial	Fall	37,850	55	60
NE Aerial	Winter	12,179	4	4
SE Shipboard	Spring	8,853	34	48
SE Shipboard	Summer	12,968	5	8
SE Shipboard	Fall	3,012	3	9
SE Aerial	Spring	41,293	16	21
SE Aerial	Summer	28,236	5	7
SE Aerial	Fall	18,974	6	10
SE Aerial	Winter	8,950	1	2

3.2 Mark-Recapture Distance Sampling Analysis

Table 3-2 Intermediate parameters in fin whale mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 4	distance * observer + sea state + glare	300	distance	LT43- 300	HR	0.86	0.18	0.98	0.96	0.95
NE–aerial group 1	distance * observer + quality	600	distance + sea state	600	HR	0.67	0.16	0.24	0.98	0.99
NE–shipboard group 10	distance * observer + group size + sea state	6000	distance + time of day + group size	6000	HR	0.48	0.10	0.28	0.92	0.95
SE–shipboard group 5	distance * observer + group size	6000	distance + glare + time of day	6000	HR	0.57	0.11	0.24	0.61	0.65

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

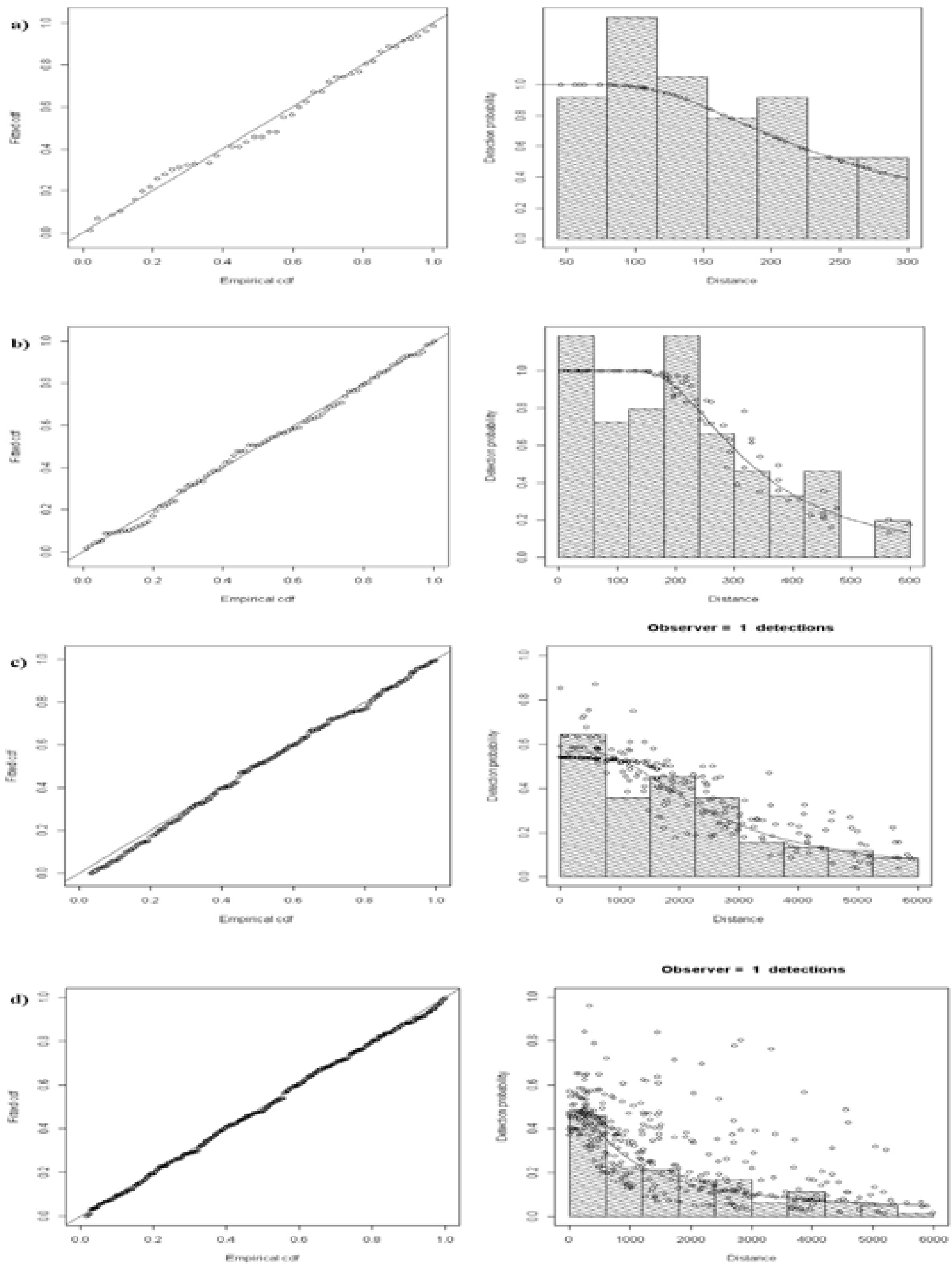

Figure 3-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 4; b) NE-aerial analysis set 1; c) NE-shipboard analysis set 10; d) SE-shipboard analysis set 5.

3.3 Generalized Additive Model Analysis

Table 3-3 2010 to 2017 density-habitat model output for fin whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(mlp)	0.86	4	1.39	1.78	0.0088
s(pp)	2.43	4	6.41	5.16	<0.0001
s(dist200)	1.14	4	30.98	16.40	<0.0001
s(lat)	2.23	4	14.70	4.51	<0.0001
te(LY,dist2GSNw)	12.27	24	4.70	14.38	<0.0001

Adjusted R^2 = 0.0563. Deviance explained = 42.2%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

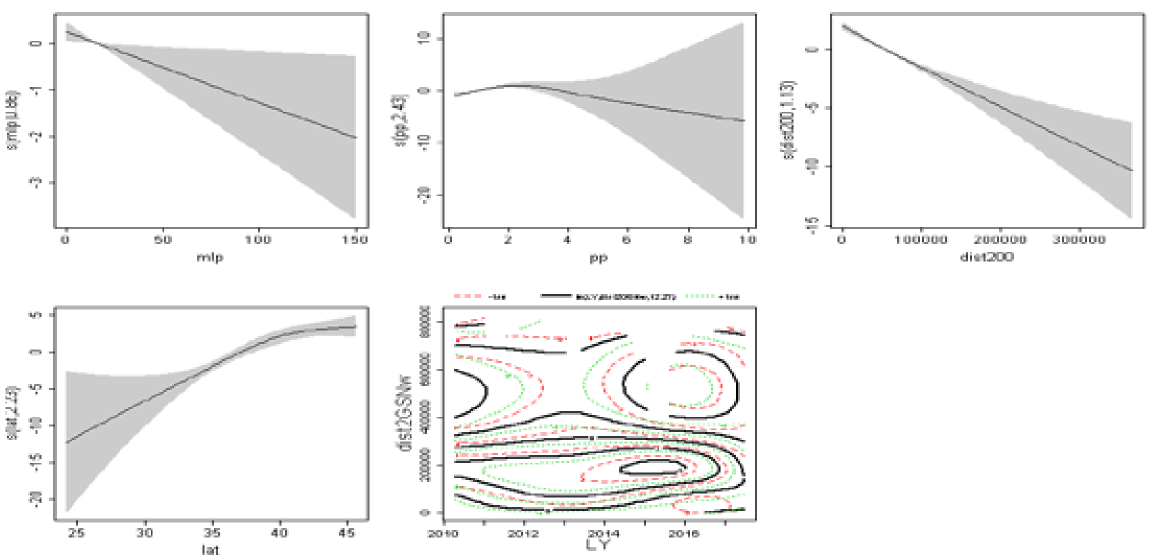

Figure 3-4 Fin whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

3.4 Model Cross-Validation

Table 3-4 Diagnostic statistics from the fin whale density-density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.190	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	86.900	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.124	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.002	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

3.5 Abundance Estimates for AMAPPS Study Area

Table 3-5 Fin whale average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	1,648	0.35	846–3,209
Summer (June–August)	2,285	0.34	1,195–4,369
Fall (September–November)	1,343	0.35	690–2,615
Winter (December–February)	613	0.34	321–1,172
Summer 2011 U.S. surveys[1]	1,618	0.33	
Summer 2016 U.S. surveys[1]	2,390	0.38	

[1]Hayes et al. 2020

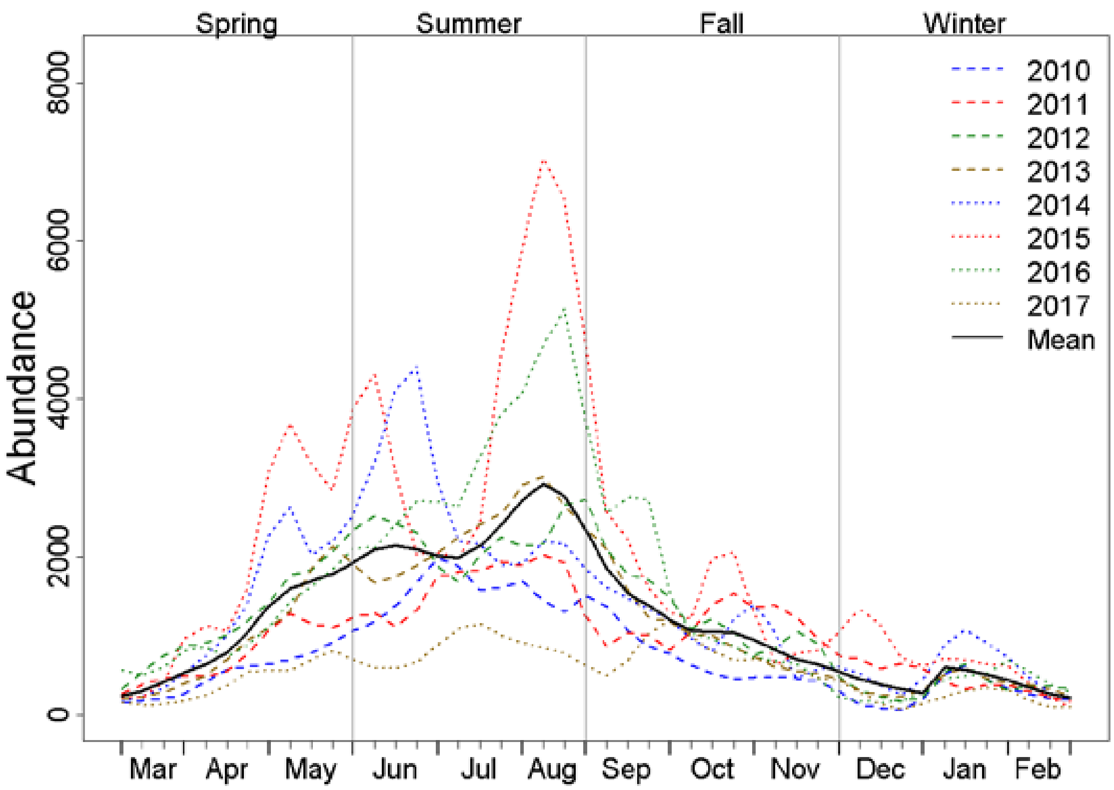

Figure 3-5 Annual abundance trends for fin whales in the AMAPPS study area

3.6 Seasonal Prediction Maps

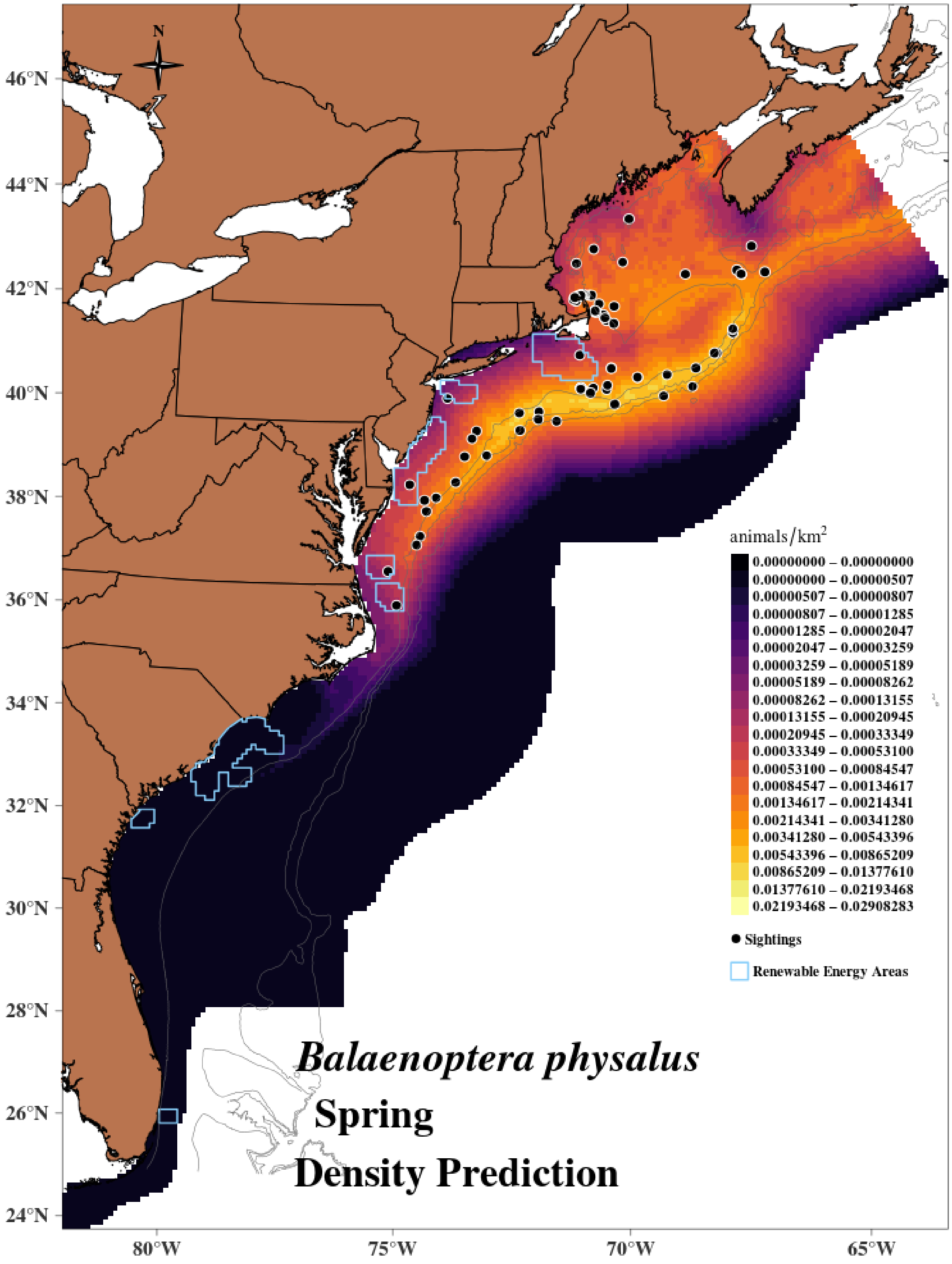

Figure 3-6 Fin whale spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

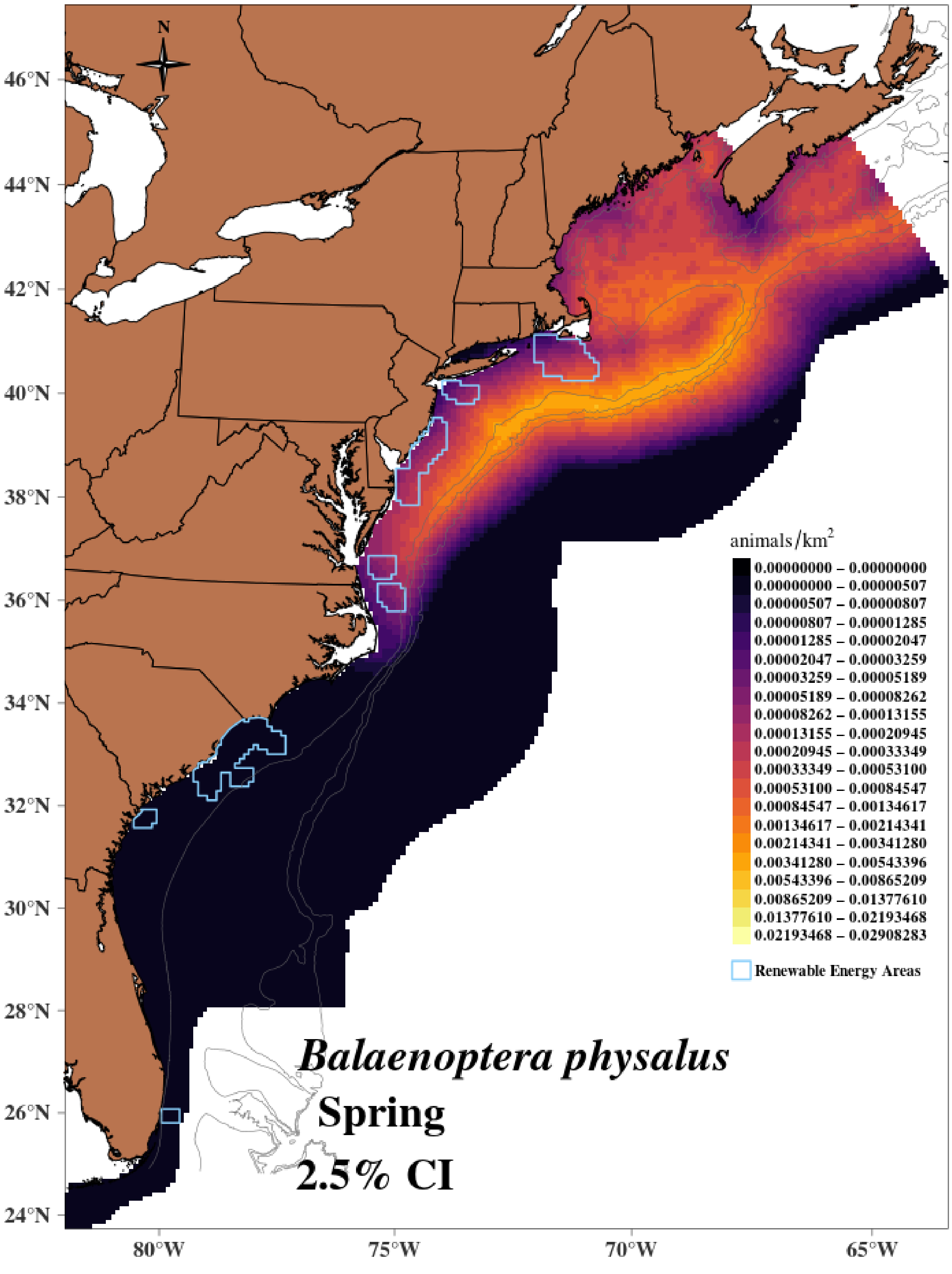

Figure 3-7 Lower 2.5% confidence interval of the spring fin whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

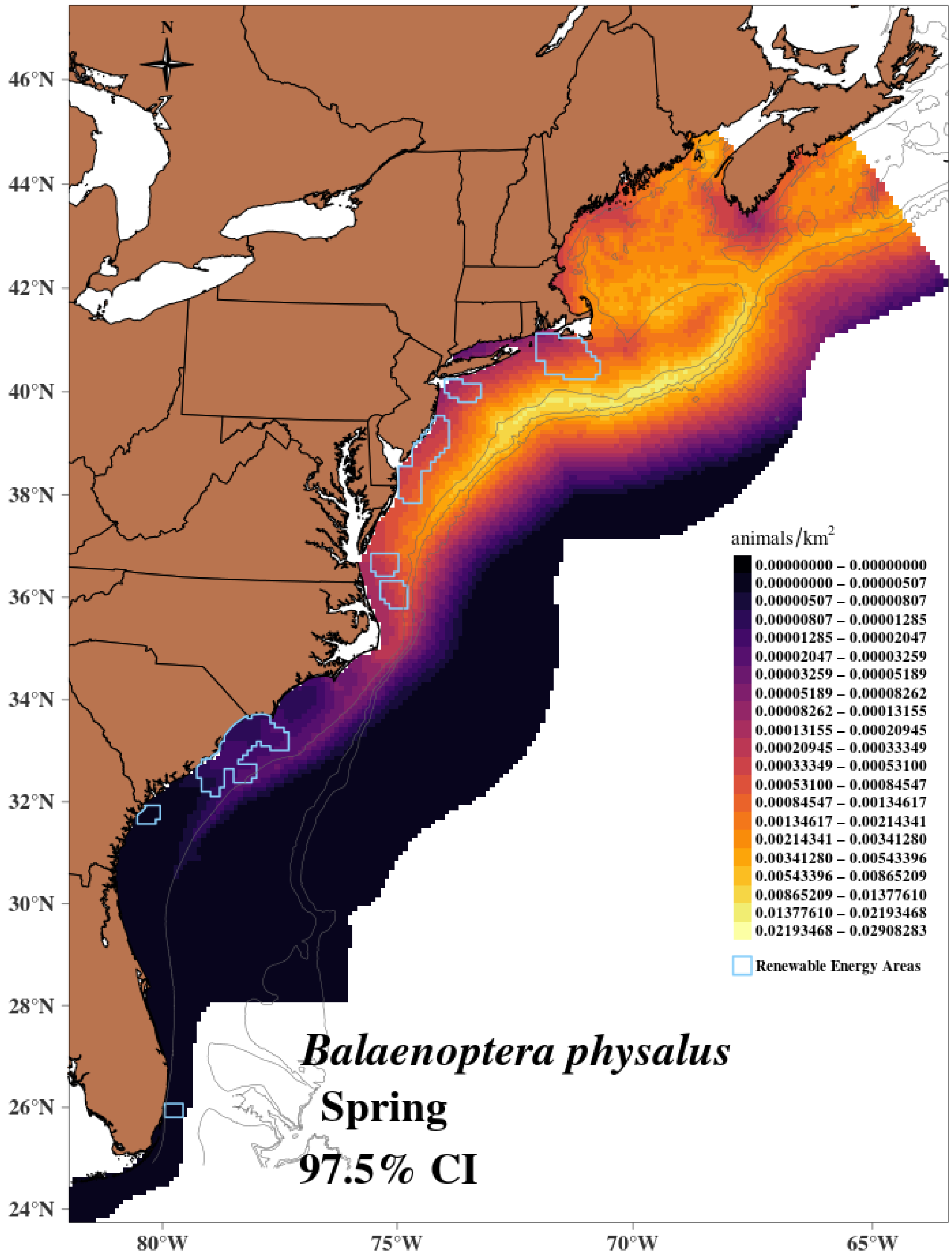

Figure 3-8 Upper 97.5% confidence interval of the spring fin whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

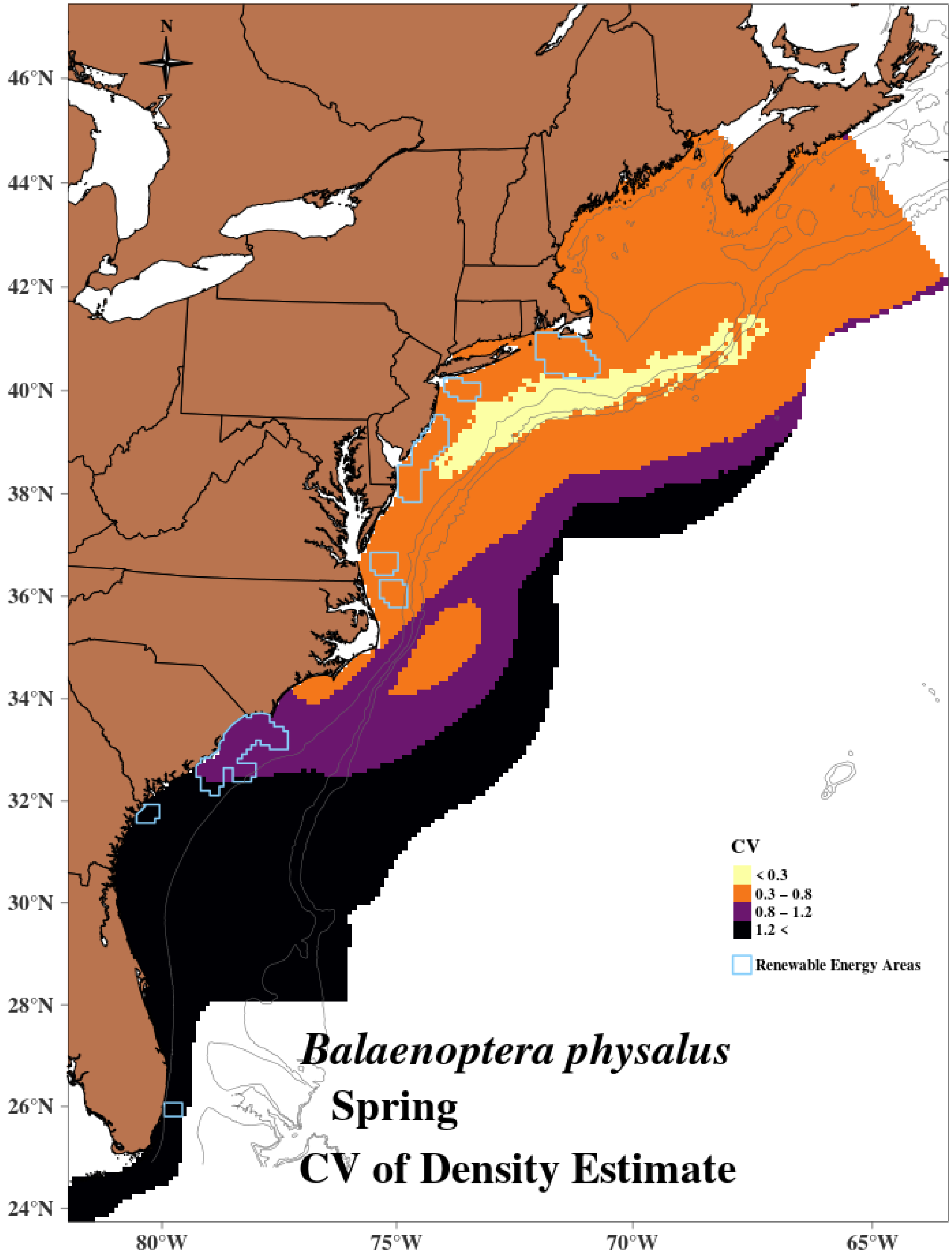

Figure 3-9 CV of spring fin whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

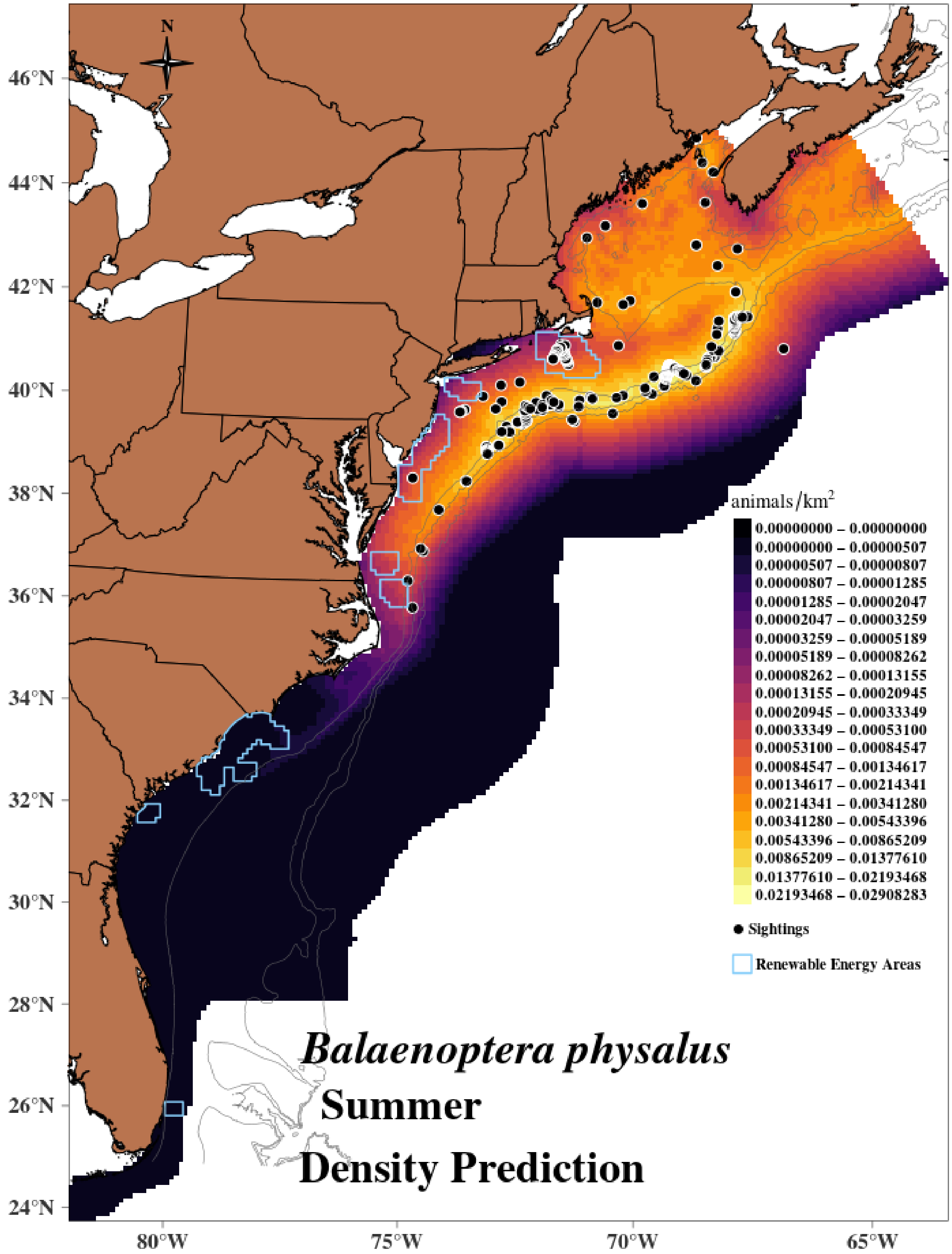

Figure 3-10 Fin whale summer average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

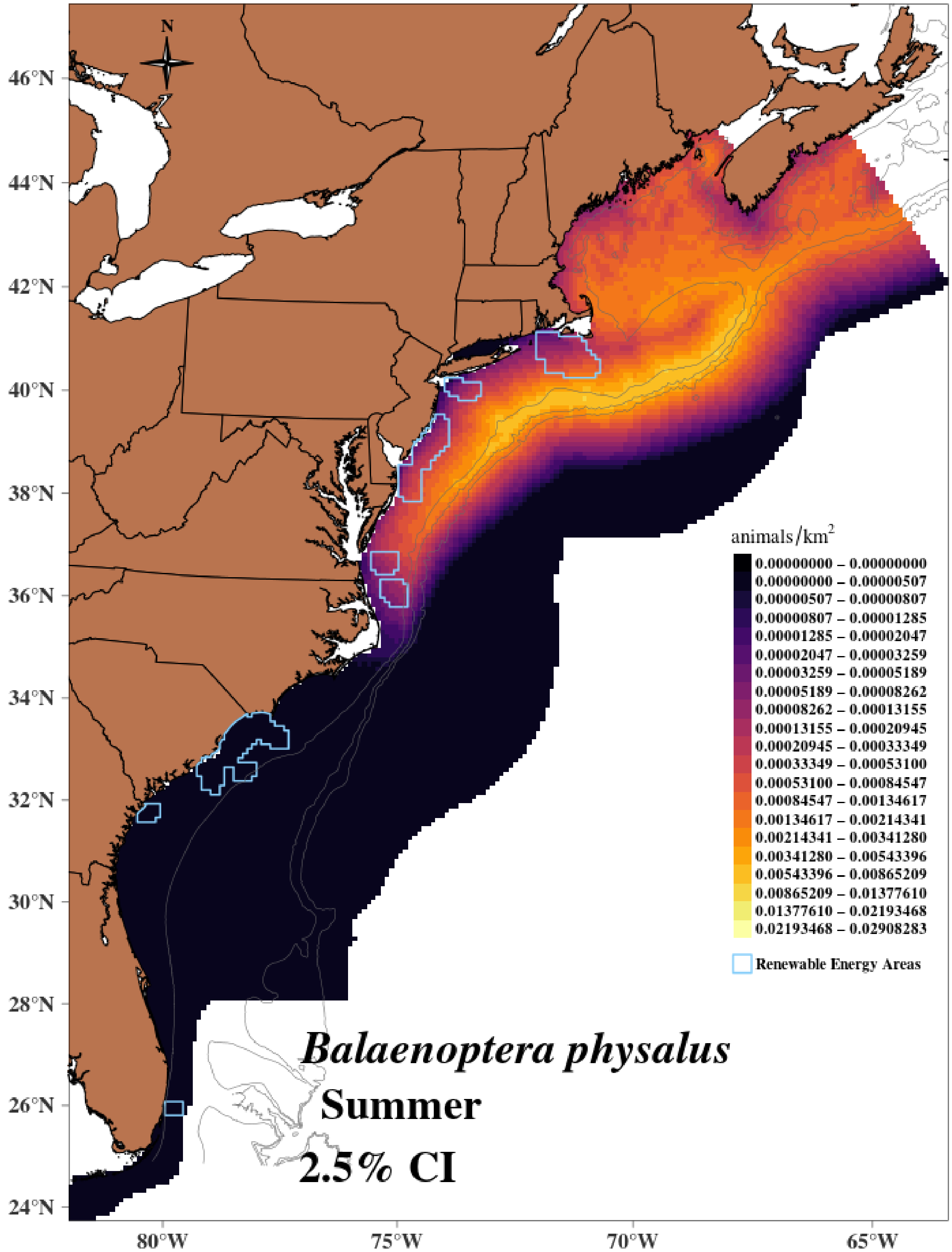

Figure 3-11 Lower 2.5% confidence interval of the summer fin whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

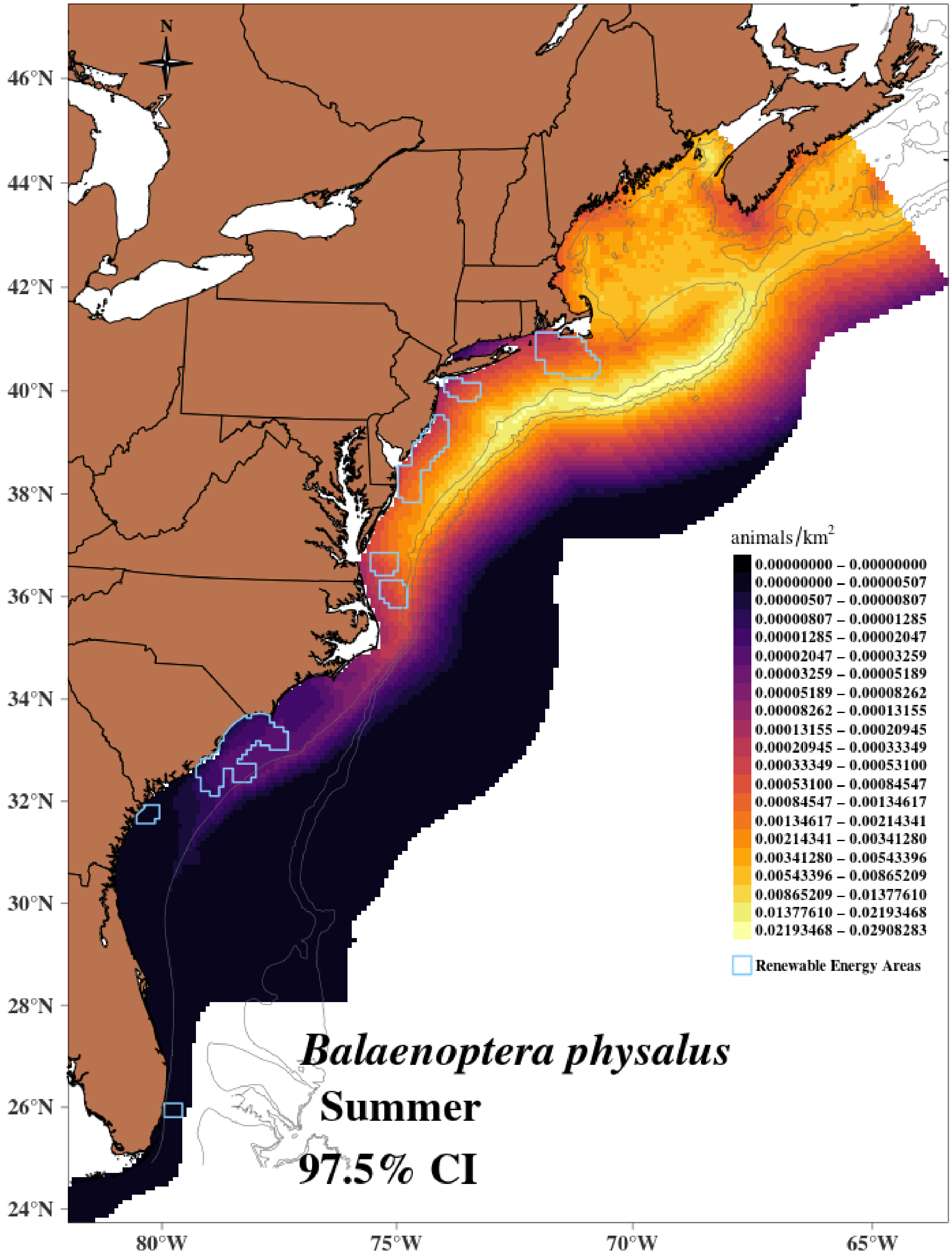

Figure 3-12 Upper 97.5% confidence interval of the summer fin whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

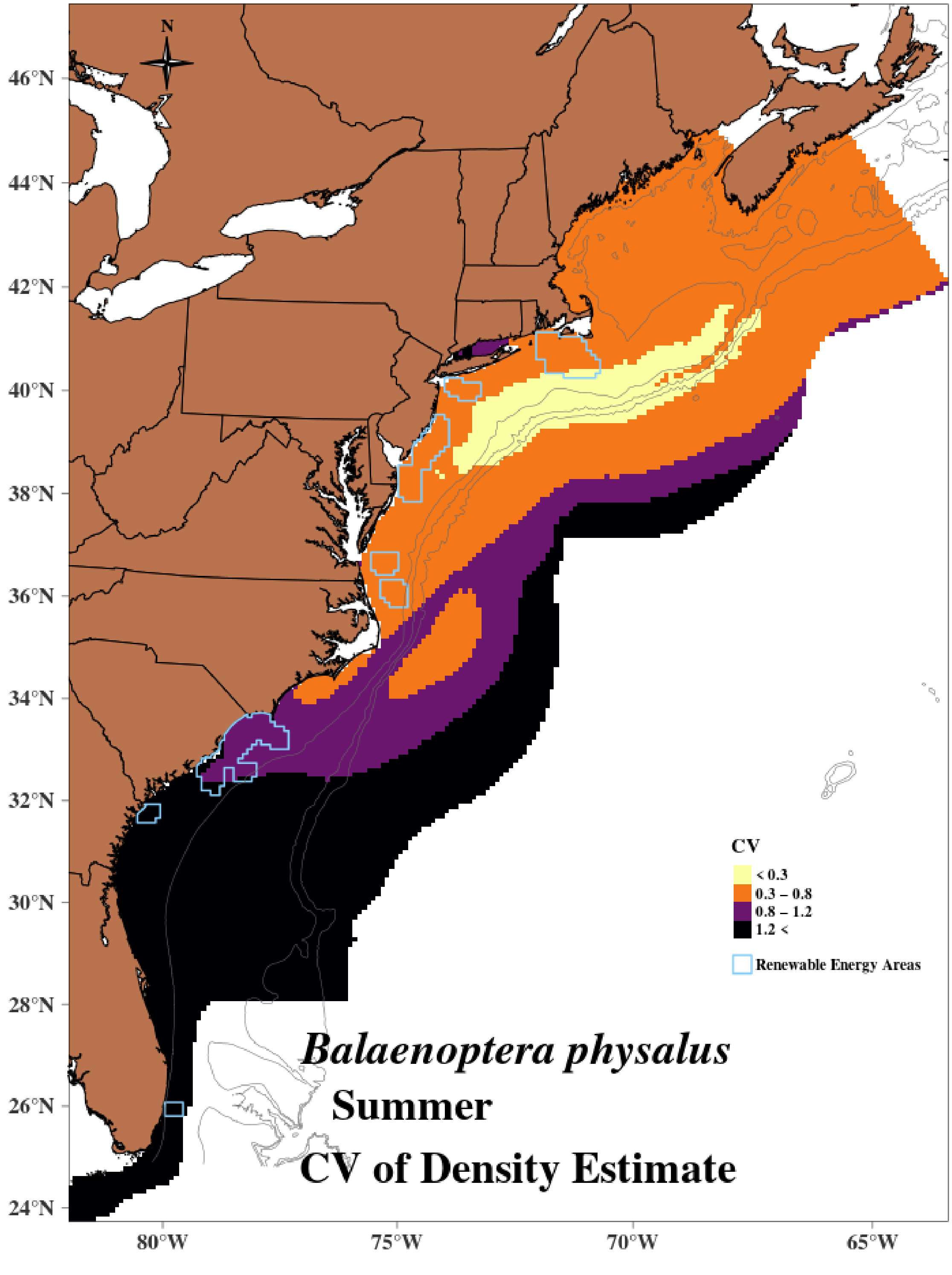

Figure 3-13 CV of summer fin whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

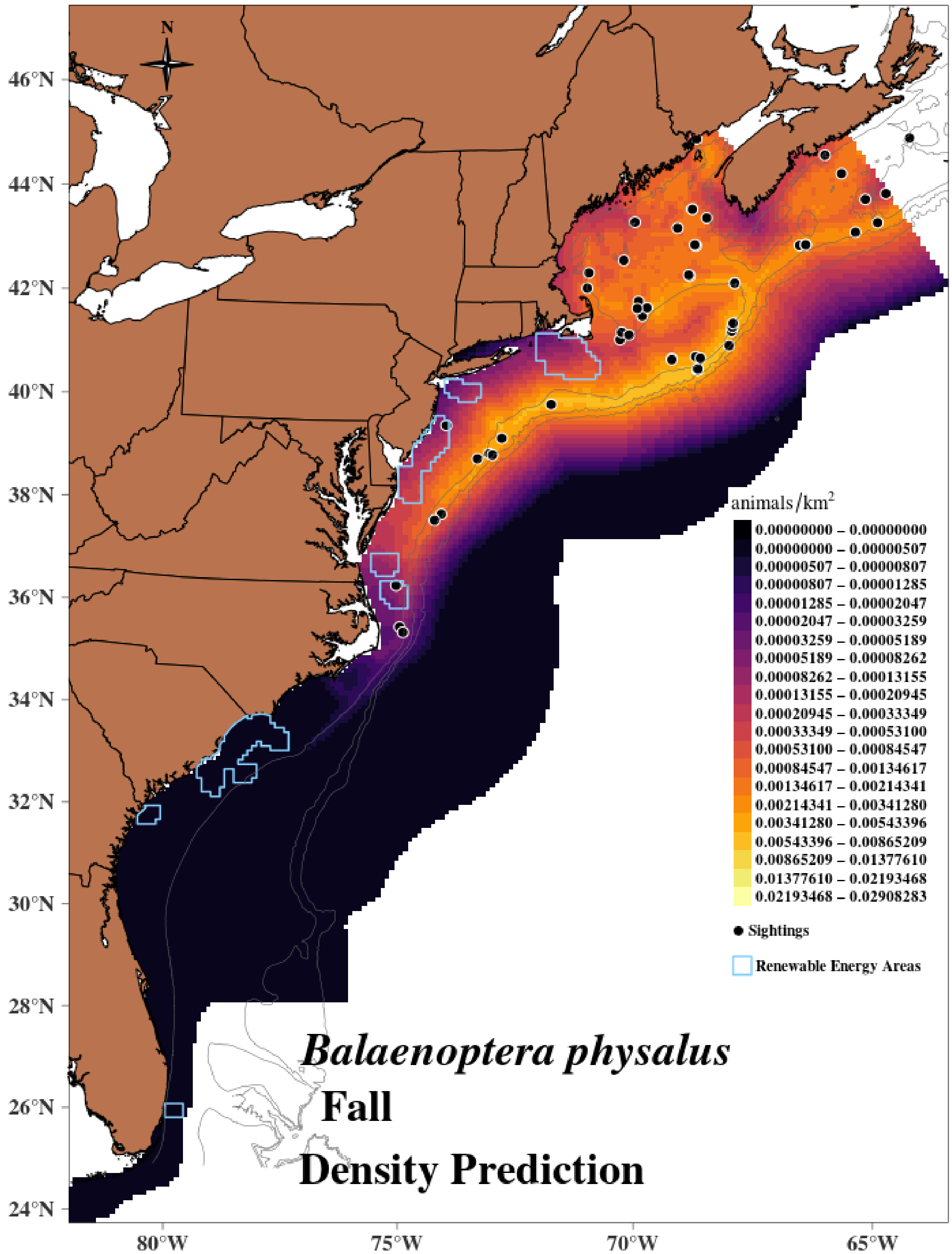

Figure 3-14 Fin whale fall average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

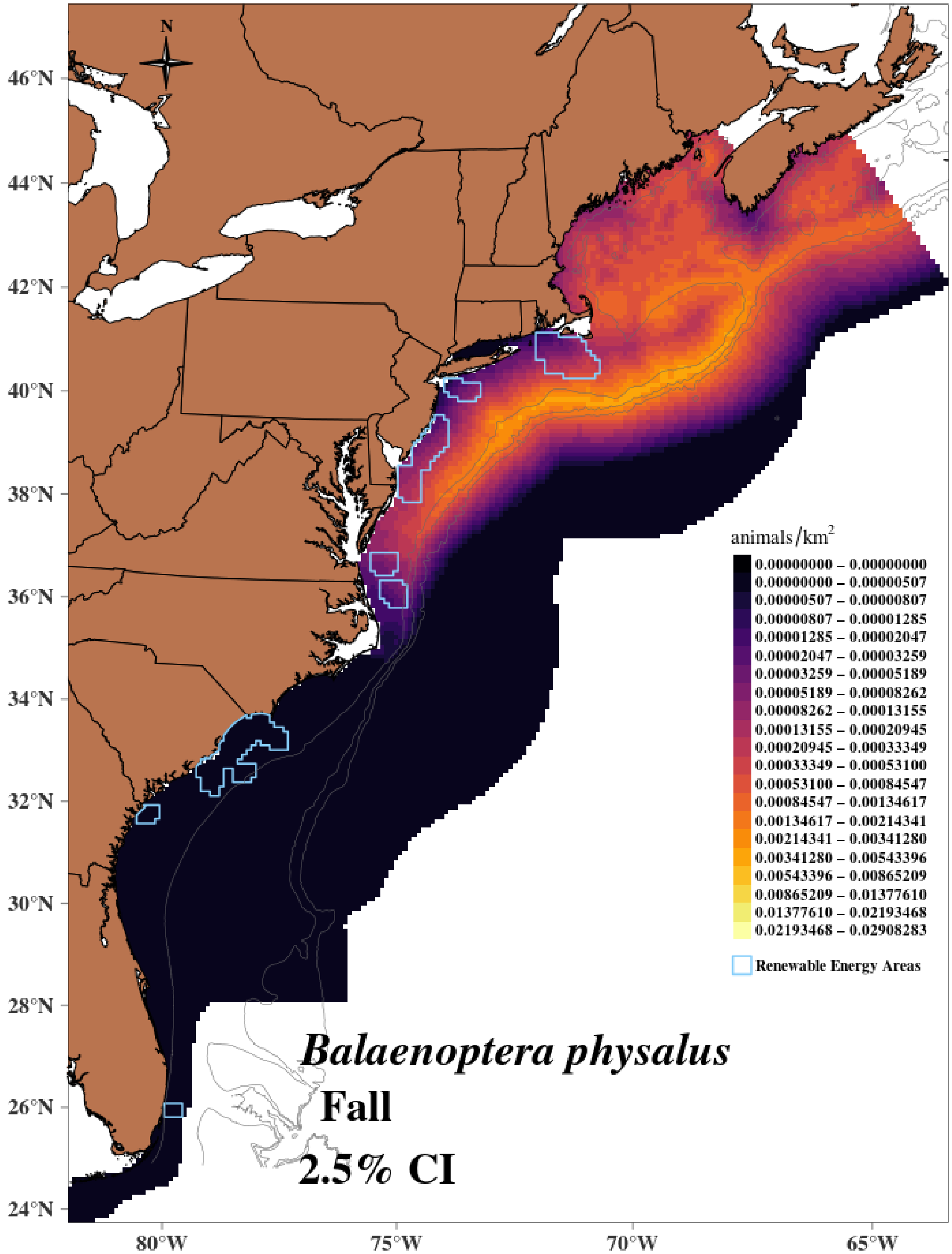

Figure 3-15 Lower 2.5% confidence interval of the fall fin whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

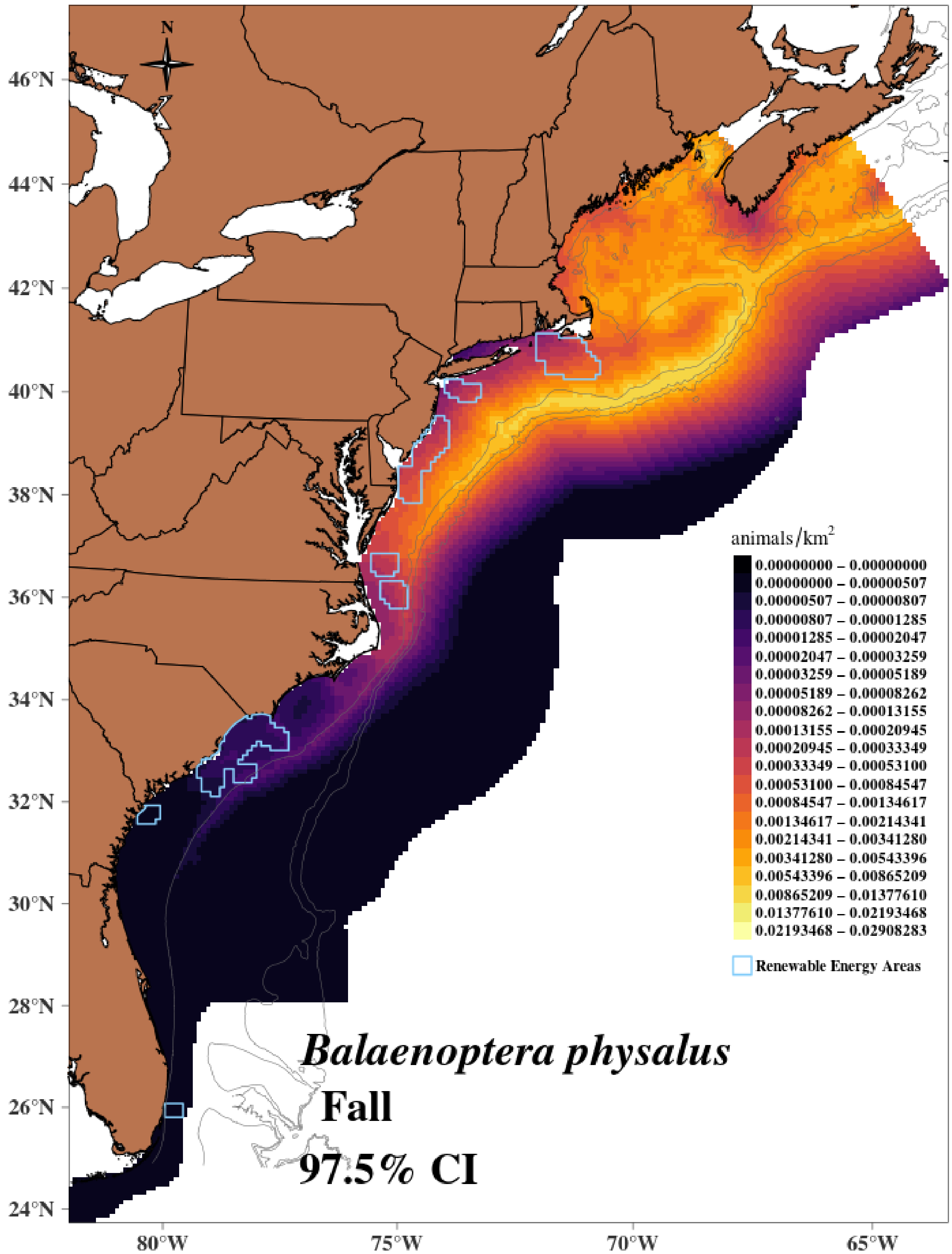

Figure 3-16 Upper 97.5% confidence interval of the fall fin whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

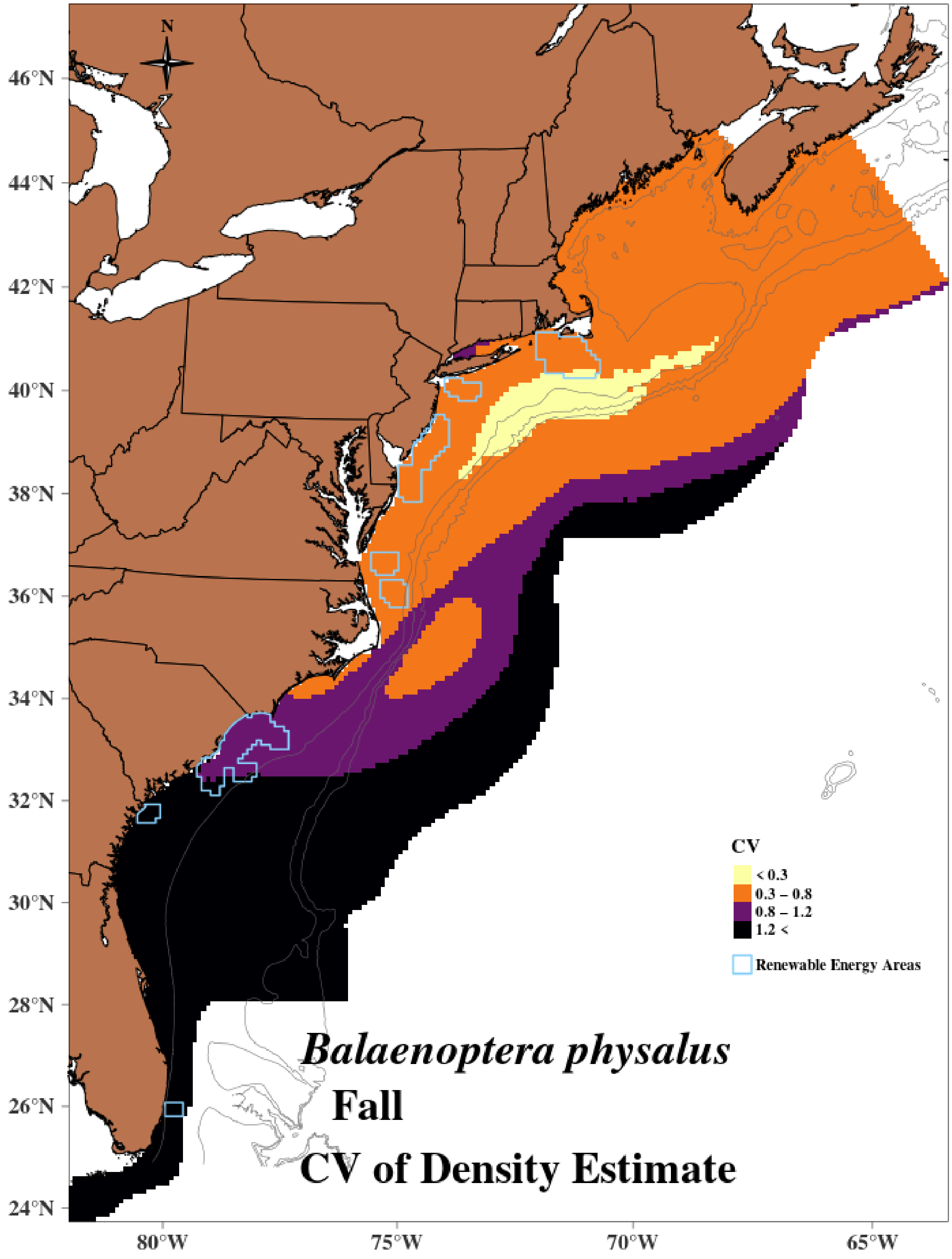

Figure 3-17 CV of fall fin whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

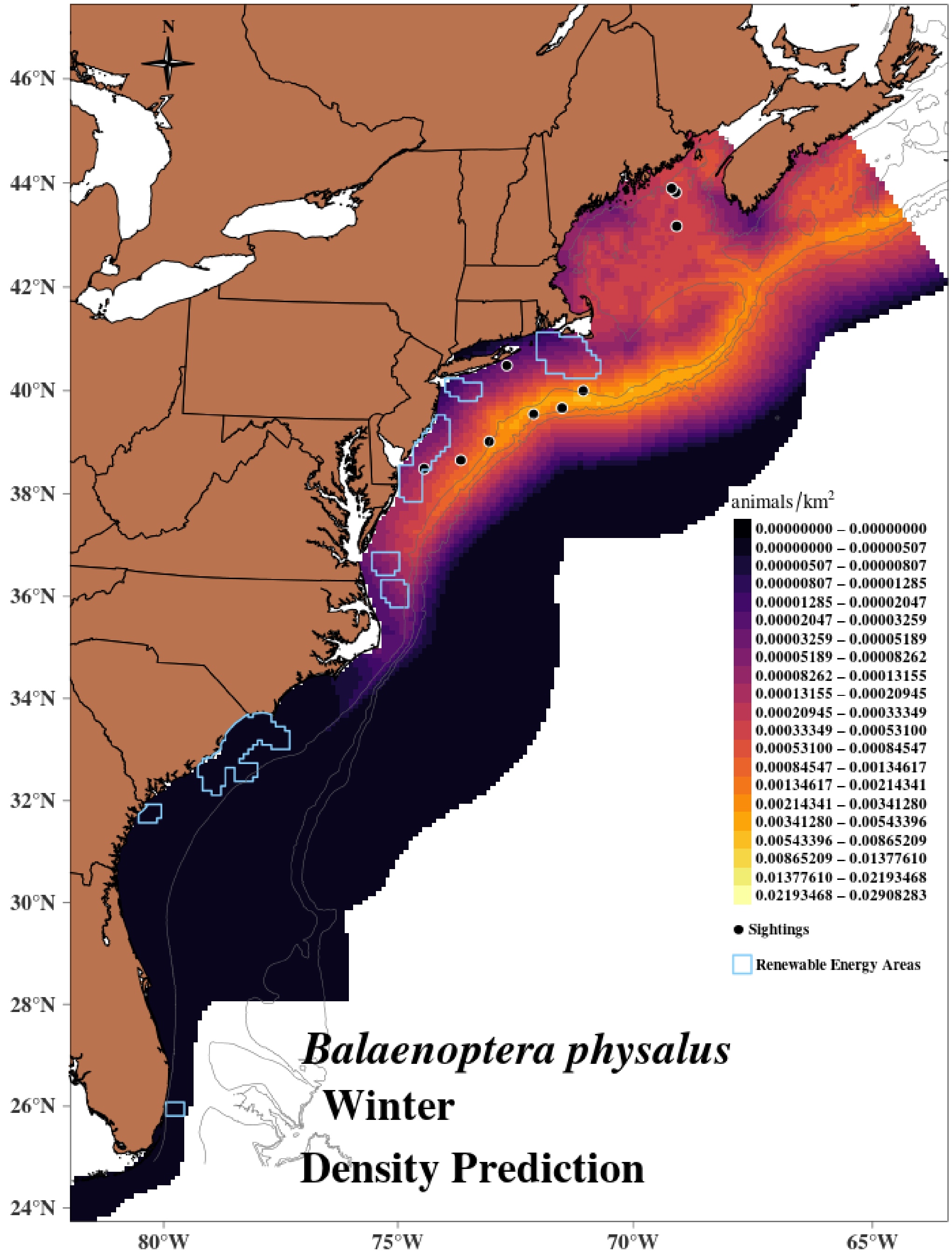

Figure 3-18 Fin whale winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

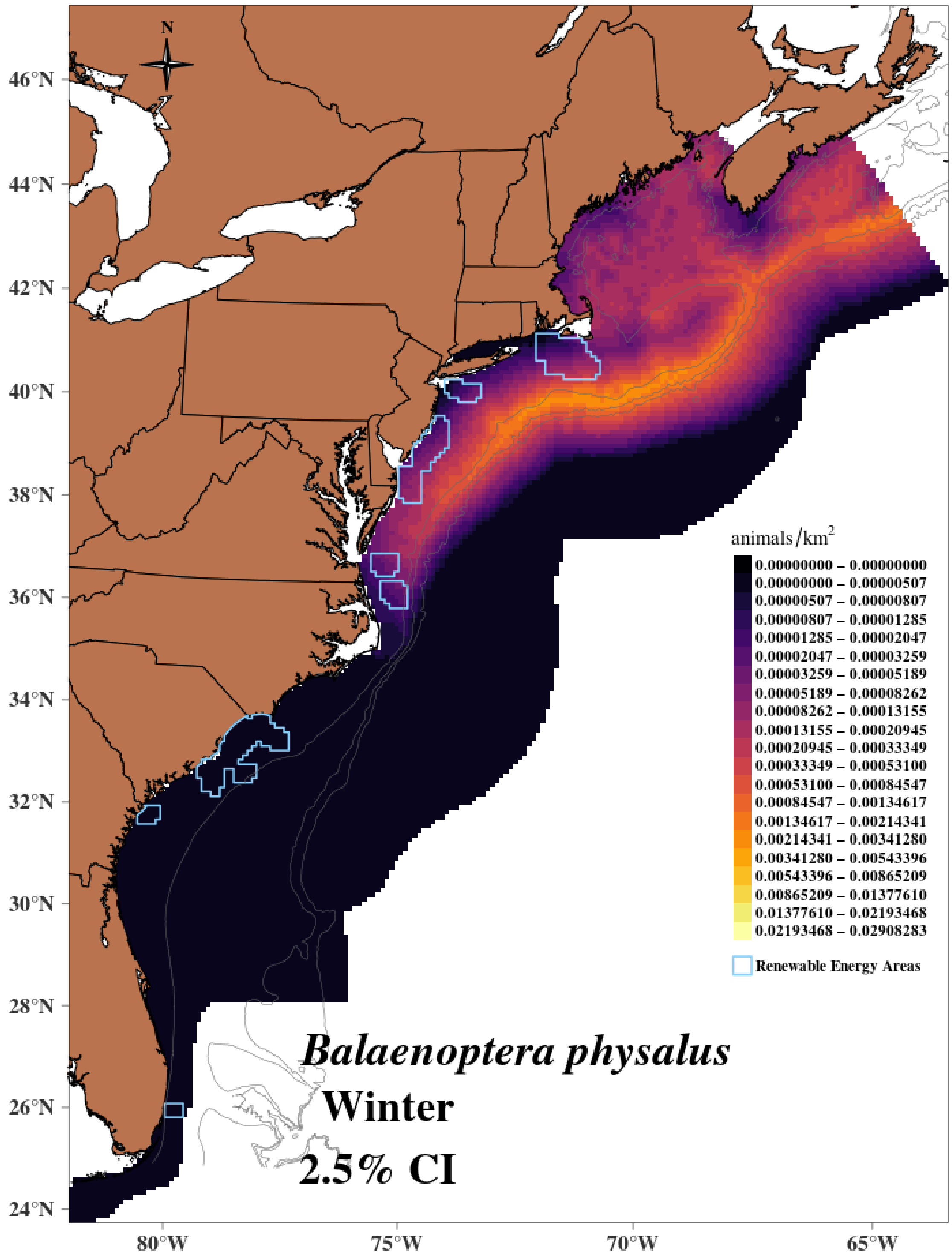

Figure 3-19 Lower 2.5% confidence interval of the winter fin whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

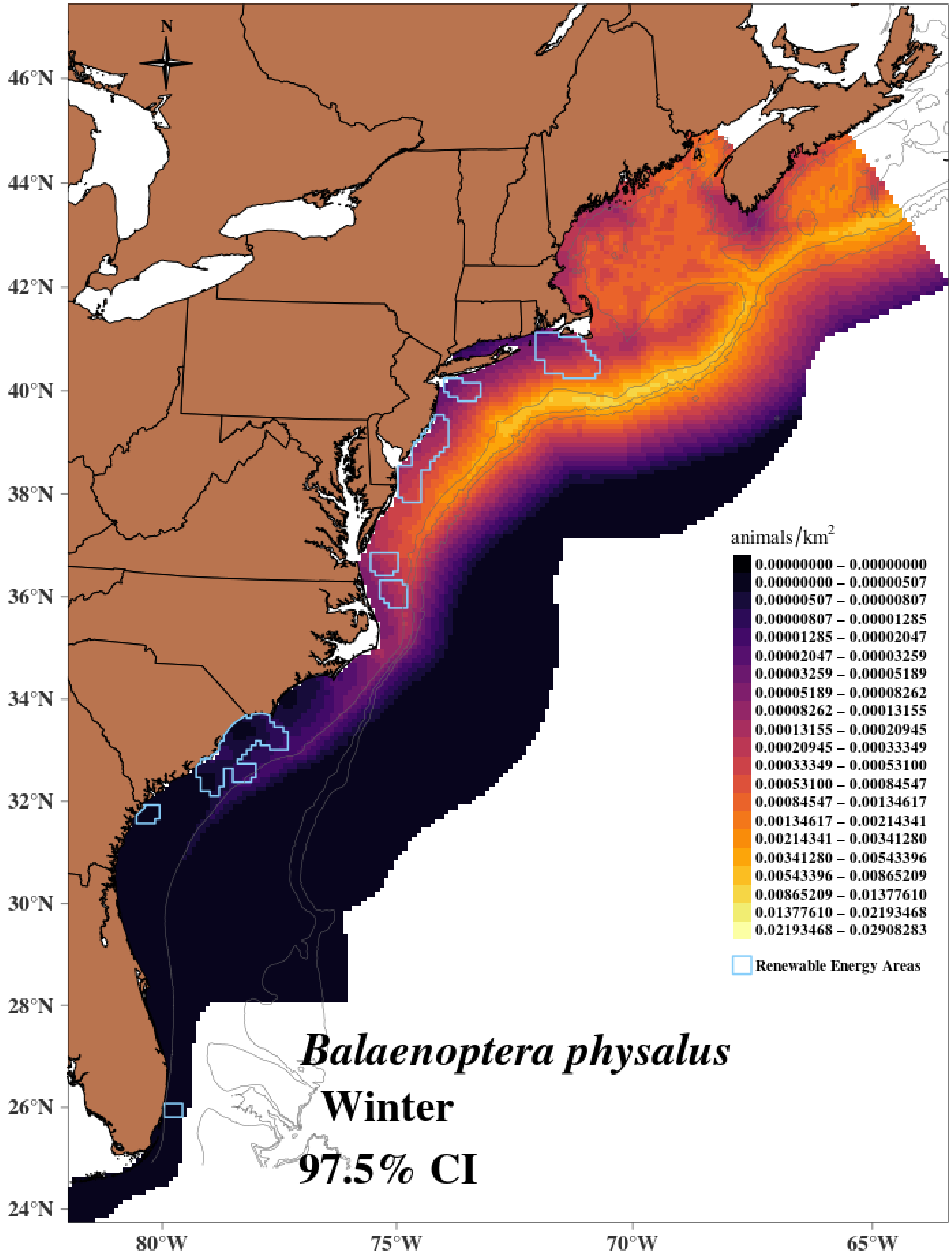

Figure 3-20 Upper 97.5% confidence interval of the winter fin whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

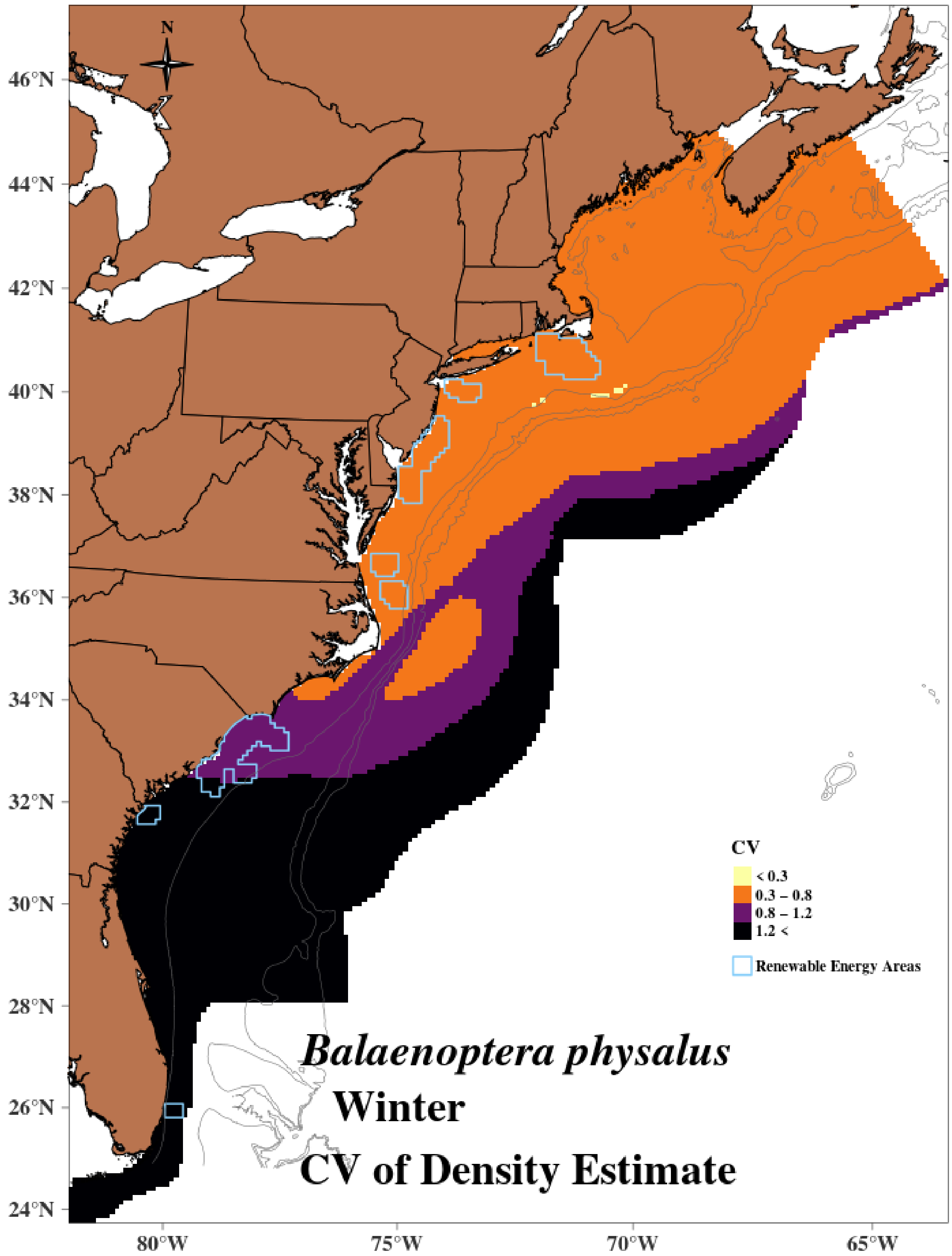

Figure 3-21 CV of winter fin whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

3.7 Offshore Energy Development Areas

Table 3-6 Fin whale abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	6.3	0.35	3.2–12.1
	NY	0.5	0.37	0.2–1.0
	NJ	1.6	0.36	0.8–3.1
	DE/MD	1.4	0.34	0.8–2.8
	VA	0.6	0.40	0.3–1.2
	NC	0.5	0.50	0.2–1.3
	NC/SC	0.0	1.05	0.0–0.2
Summer (Jun–Aug)	RI/MA	10.0	0.33	5.4–18.8
	NY	0.9	0.39	0.4–1.9
	NJ	2.7	0.39	1.3–5.6
	DE/MD	2.5	0.36	1.3–5.0
	VA	1.0	0.42	0.5–2.2
	NC	0.8	0.51	0.3–2.0
	NC/SC	0.1	1.07	0.0–0.3
Fall (Sep–Nov)	RI/MA	4.2	0.33	2.2–8.0
	NY	0.3	0.40	0.2–0.7
	NJ	1.3	0.38	0.6–2.7
	DE/MD	1.3	0.36	0.7–2.6
	VA	0.4	0.40	0.2–0.9
	NC	0.3	0.54	0.1–0.7
	NC/SC	0.0	1.05	0.0–0.2
Winter (Dec–Feb)	RI/MA	1.9	0.34	1.0–3.8
	NY	0.1	0.38	0.1–0.3
	NJ	0.6	0.36	0.3–1.3
	DE/MD	0.7	0.33	0.3–1.3
	VA	0.2	0.41	0.1–0.5
	NC	0.2	0.53	0.1–0.5
	NC/SC	0.0	1.05	0.0–0.1

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

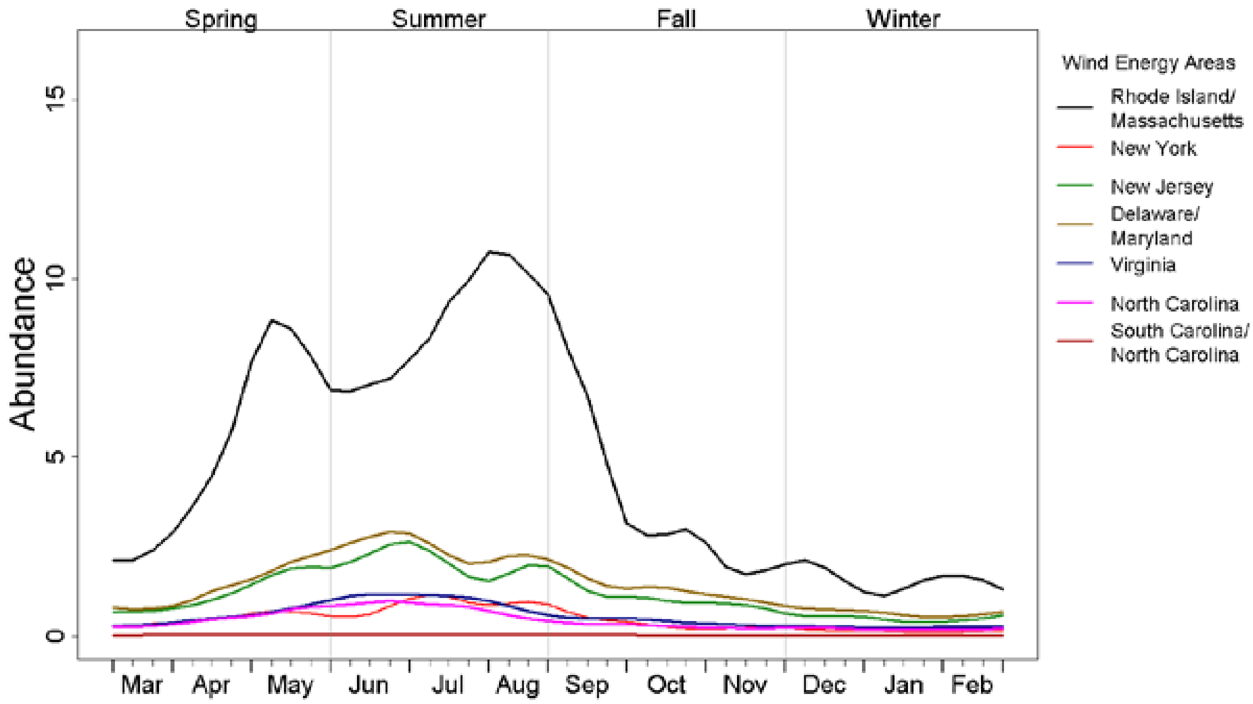

Figure 3-22 Average seasonal abundance of fin whales in the wind-energy study areas

4 Sei Whale (*Balaenoptera borealis*)

Figure 4-1 Sei whale
Image collected under MMPA Research permit #775-1875 Credit: NOAA/NEFSC/Genevieve Davis.

4.1 Data Collection

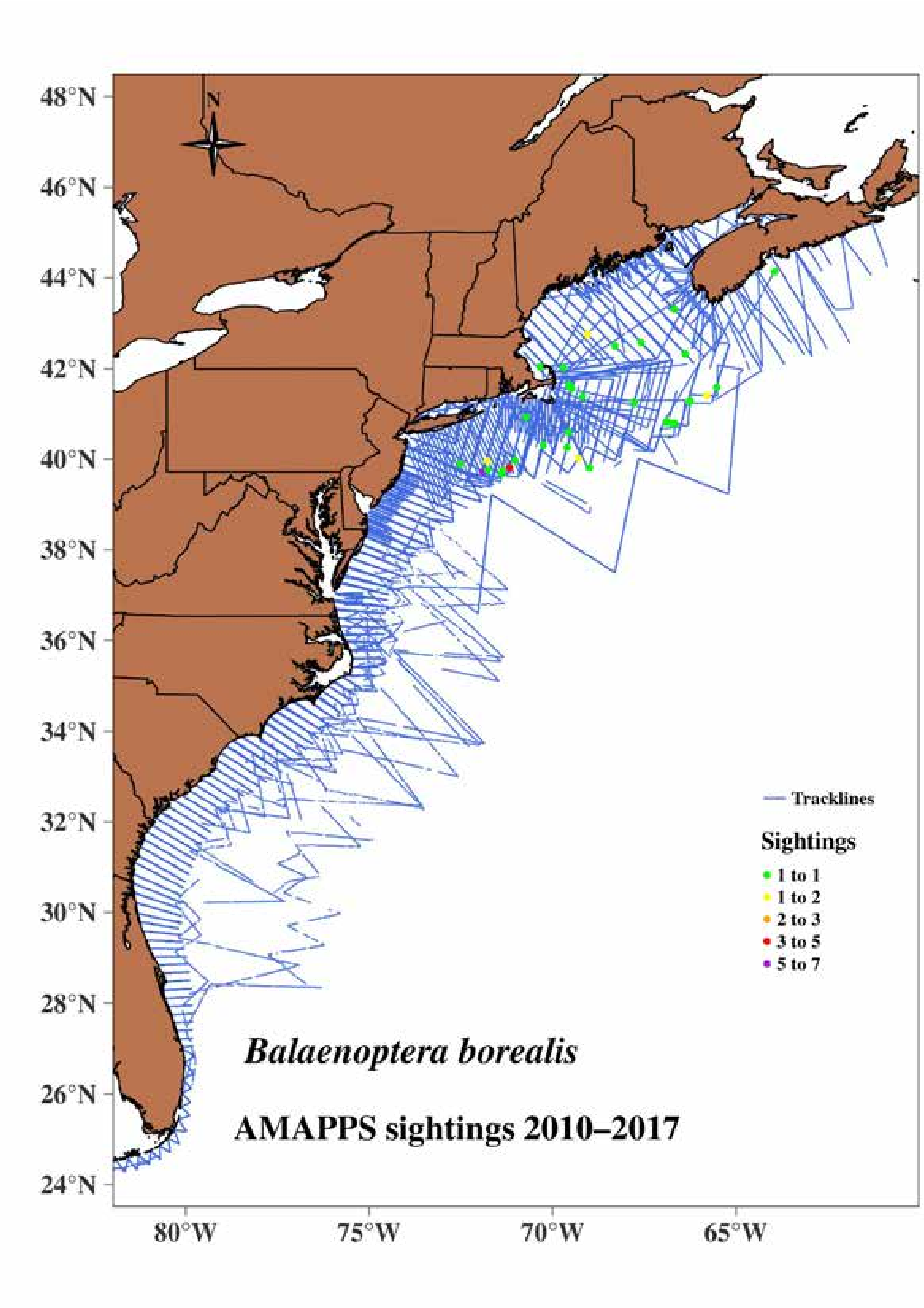

Figure 4-2 Distribution of track lines and sei whale sightings 2010 to 2017

Table 4-1 AMAPPS research effort 2010 to 2017 and sei whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	20	28
NE Shipboard	Fall	1,065	0	0
NE Aerial	Spring	13,314	13	33
NE Aerial	Summer	25,867	5	6
NE Aerial	Fall	37,850	6	12
NE Aerial	Winter	12,179	2	5
SE Shipboard	Spring	8,853	28	33
SE Shipboard	Summer	12,968	0	0
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	0	0
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

4.2 Mark-Recapture Distance Sampling Analysis

Table 4-2 Intermediate parameters in sei whale mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
NE–aerial group 1	distance * observer + quality	600	distance + sea state	600	HR	0.67	0.16	0.24	0.98	0.99
NE–shipboard group 10	distance * observer + group size + sea state	6000	distance + time of day + group size	6000	HR	0.48	0.10	0.28	0.92	0.95
SE–shipboard group 5	distance * observer + group size	6000	distance + glare + time of day	6000	HR	0.57	0.11	0.24	0.61	0.65

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

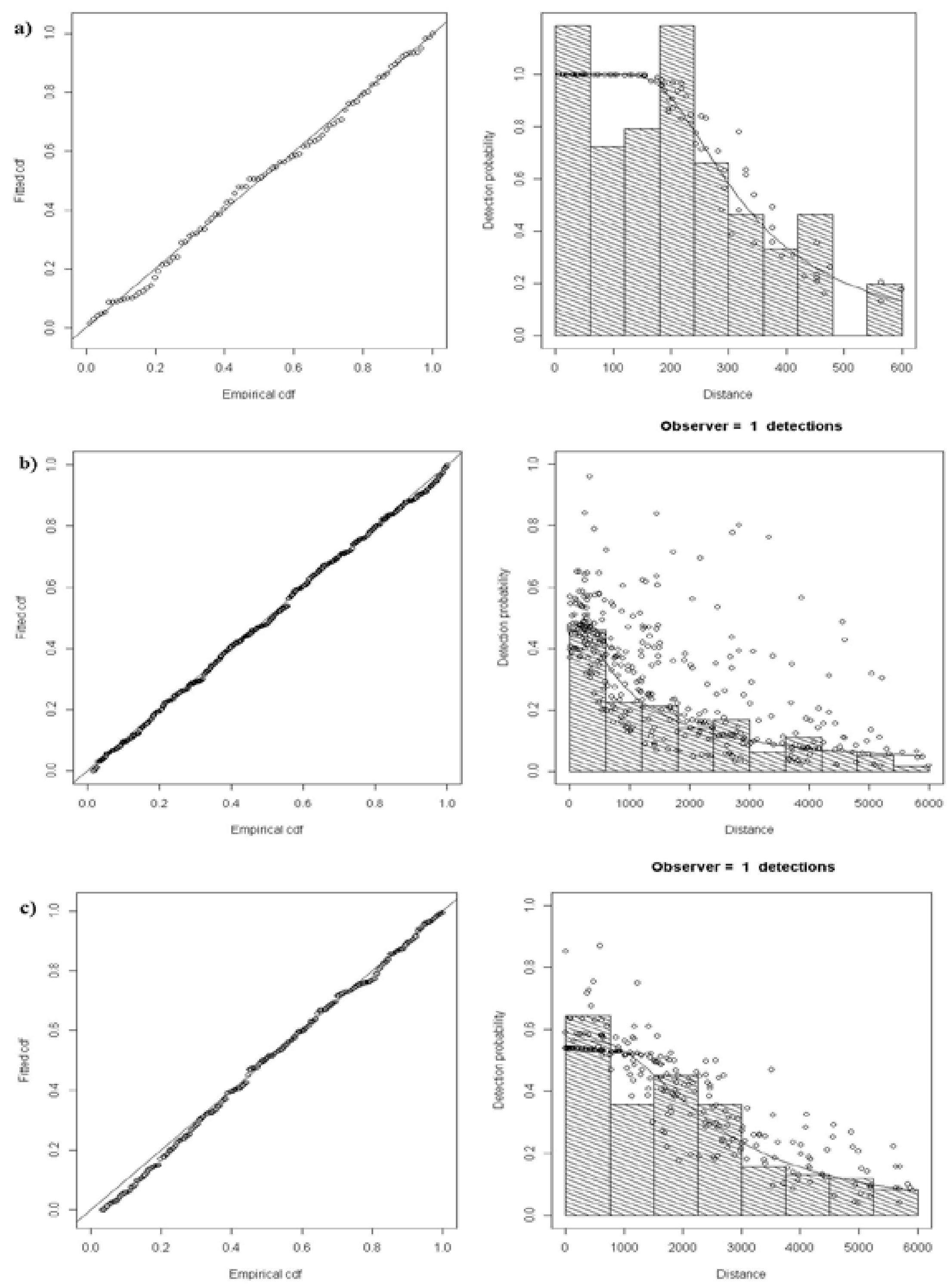

Figure 4-3 Q-Q plots and detection functions from the MRDS analyses
a) NE-aerial analysis set 1; b) NE-shipboard analysis set 10; c) SE-shipboard analysis set 5.

4.3 Generalized Additive Model Analysis

Table 4-3 2010 to 2017 density-habitat model output for sei whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(sstfmt)	0.95	4	2.59	9.51	0.0008
s(picma)	0.89	4	1.54	3.24	0.0084
te(LY,lat)	4.73	23	1.37	26.37	<0.0001

Adjusted R^2 = 0.00299. Deviance explained = 39.1%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

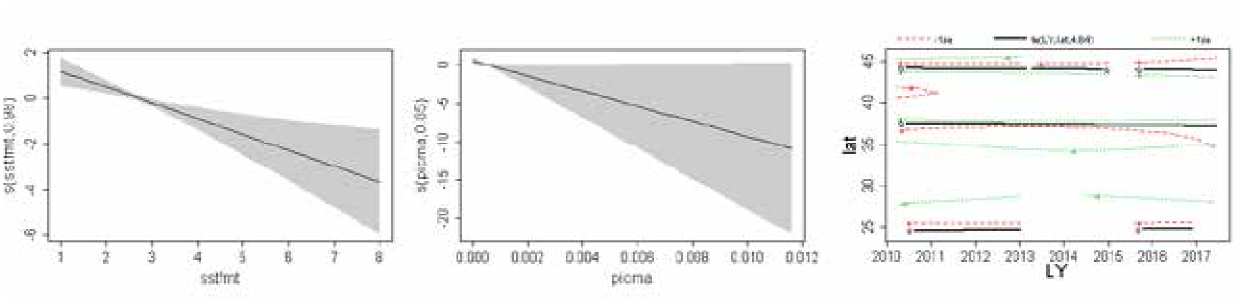

Figure 4-4 Sei whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

4.4 Model Cross-Validation

Table 4-4 Diagnostic statistics from the sei whale density-density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.335	Excellent
MAPE	Mean absolute percentage error	Non-zero density	98.750	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.0634	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.0001	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

4.5 Abundance Estimates for AMAPPS Study Area

Table 4-5 Sei whale average abundance estimates for the AMAPPS study area

Season	Time Period	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	2010–2013	243	0.45	
	2014–2017	43	0.47	
	2010–2017	142	0.46	
Summer (June–August)	2010–2013	208	0.45	
	2014–2017	32	0.50	
	2010–2017	121	0.45	
Fall (September–November)	2010–2013	192	0.45	
	2014–2017	28	0.50	
	2010–2017	110	0.45	
Winter (December–February)	2010–2013	258	0.47	
	2014–2017	42	0.48	
	2010–2017	150	0.47	
Summer 2011 U.S. surveys[1]		357	0.52	
Summer 2016 U.S. surveys[1]		52	0.53	

[1]Hayes et al. 2020

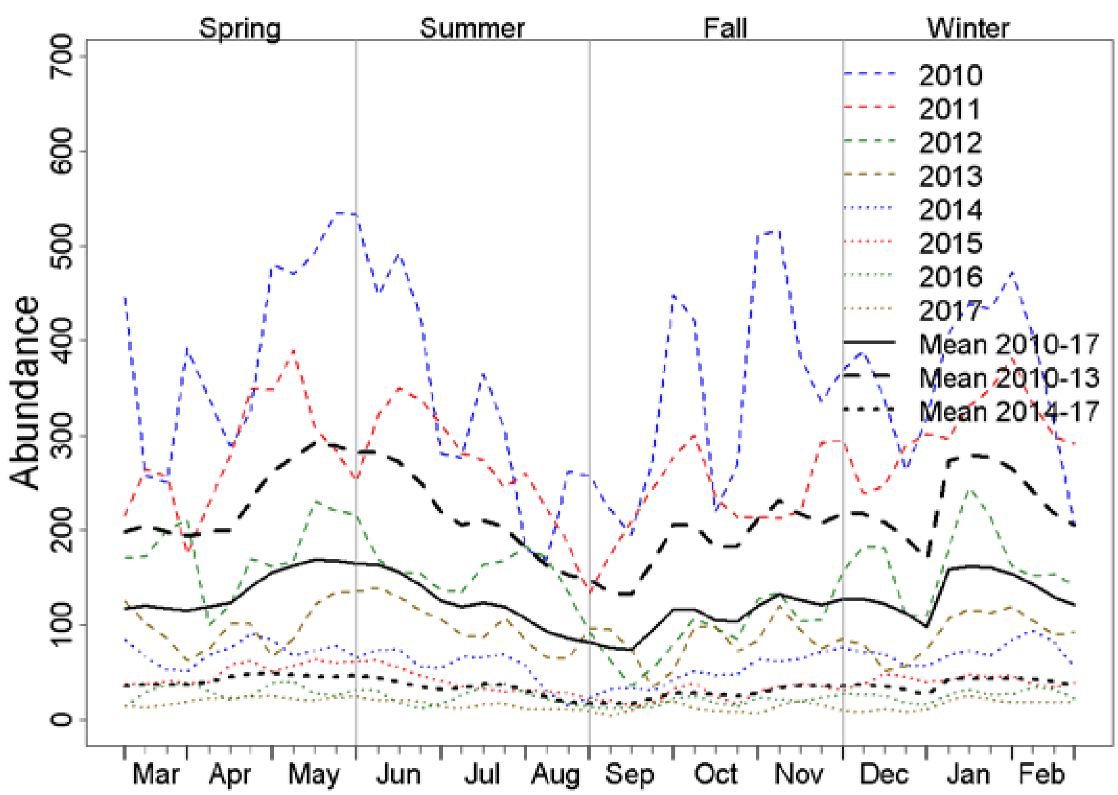

Figure 4-5 Annual abundance trends for sei whales in the AMAPPS study area

4.6 Seasonal Prediction Maps

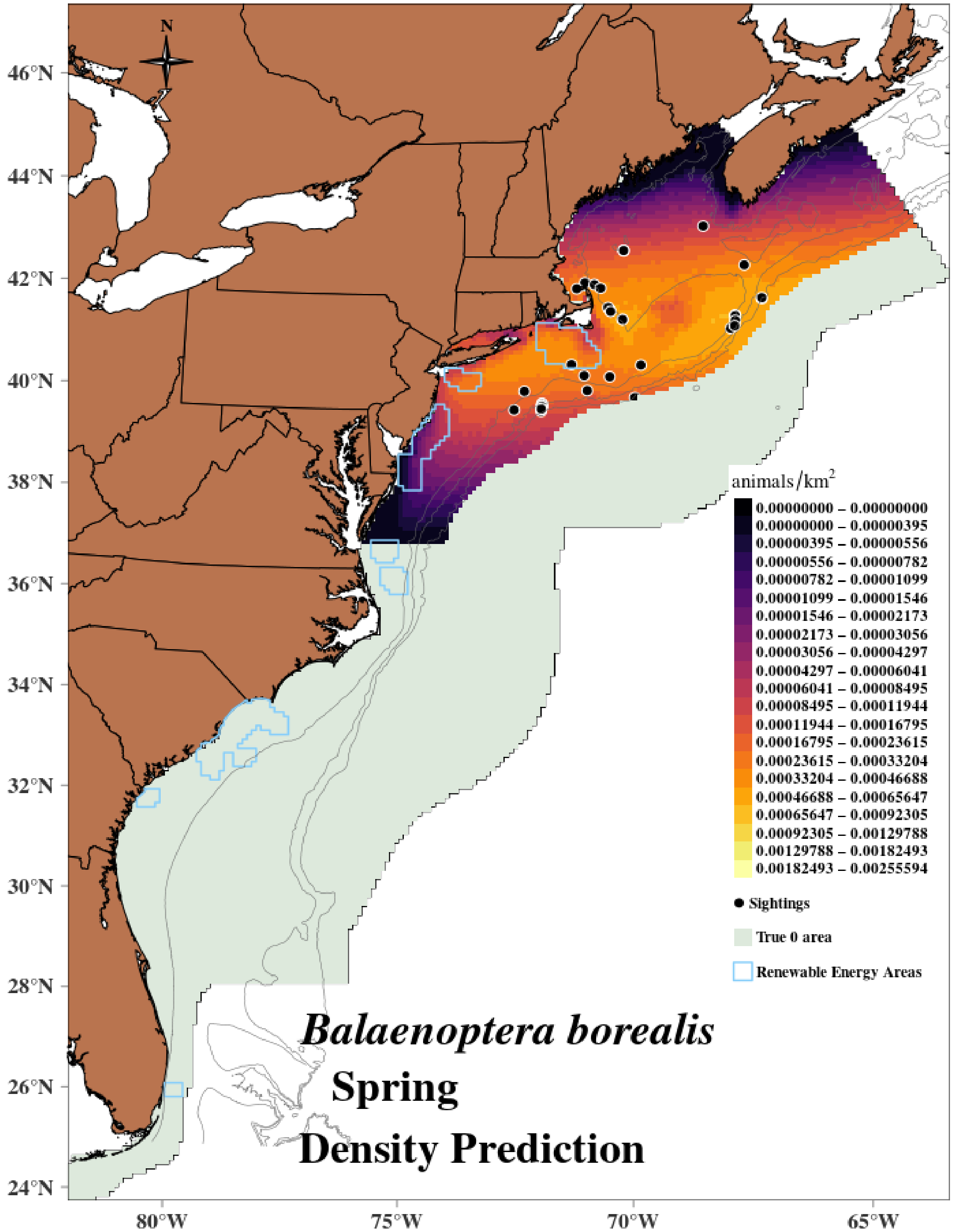

Figure 4-6 Sei whale spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

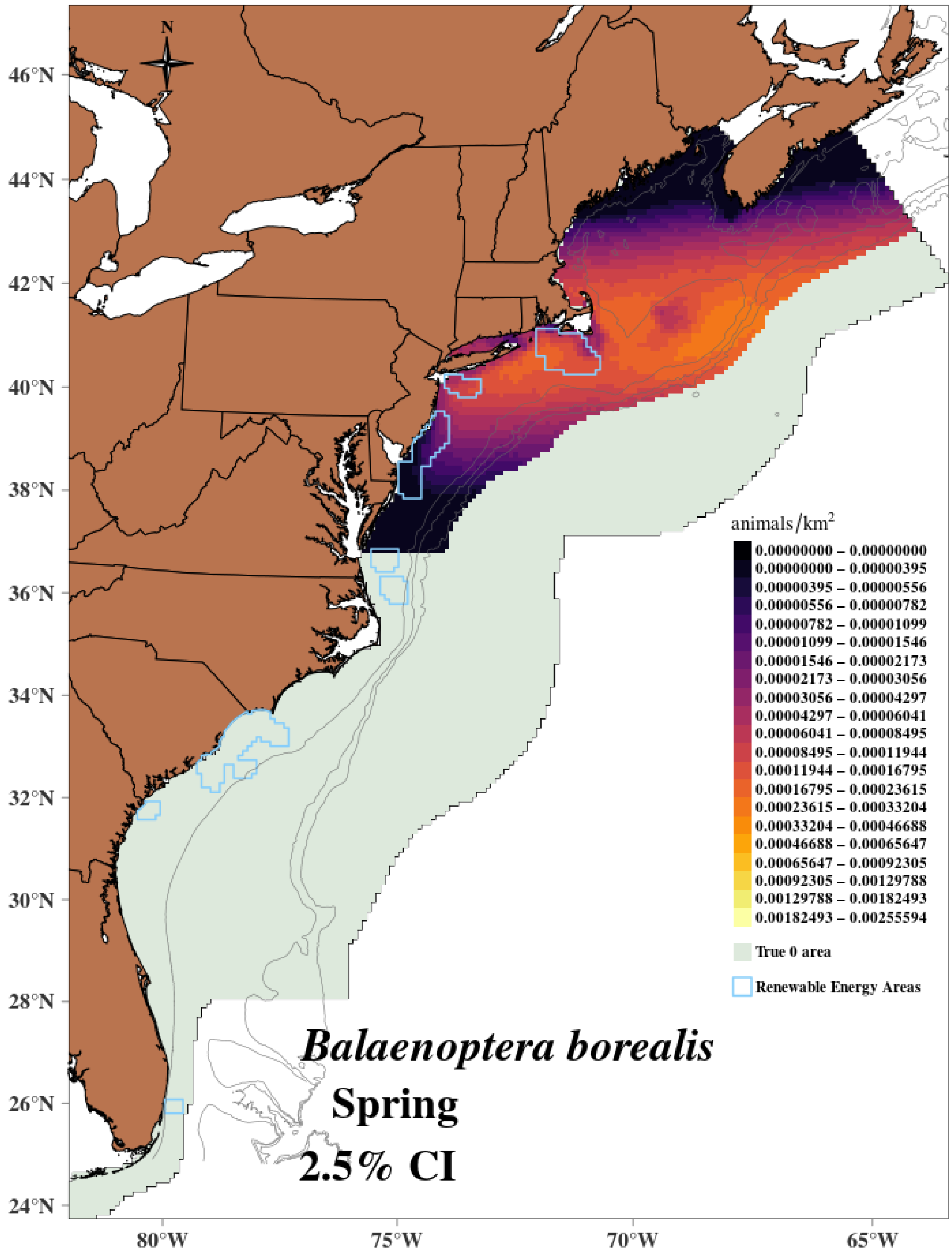

Figure 4-7 Lower 2.5% confidence interval of the spring sei whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

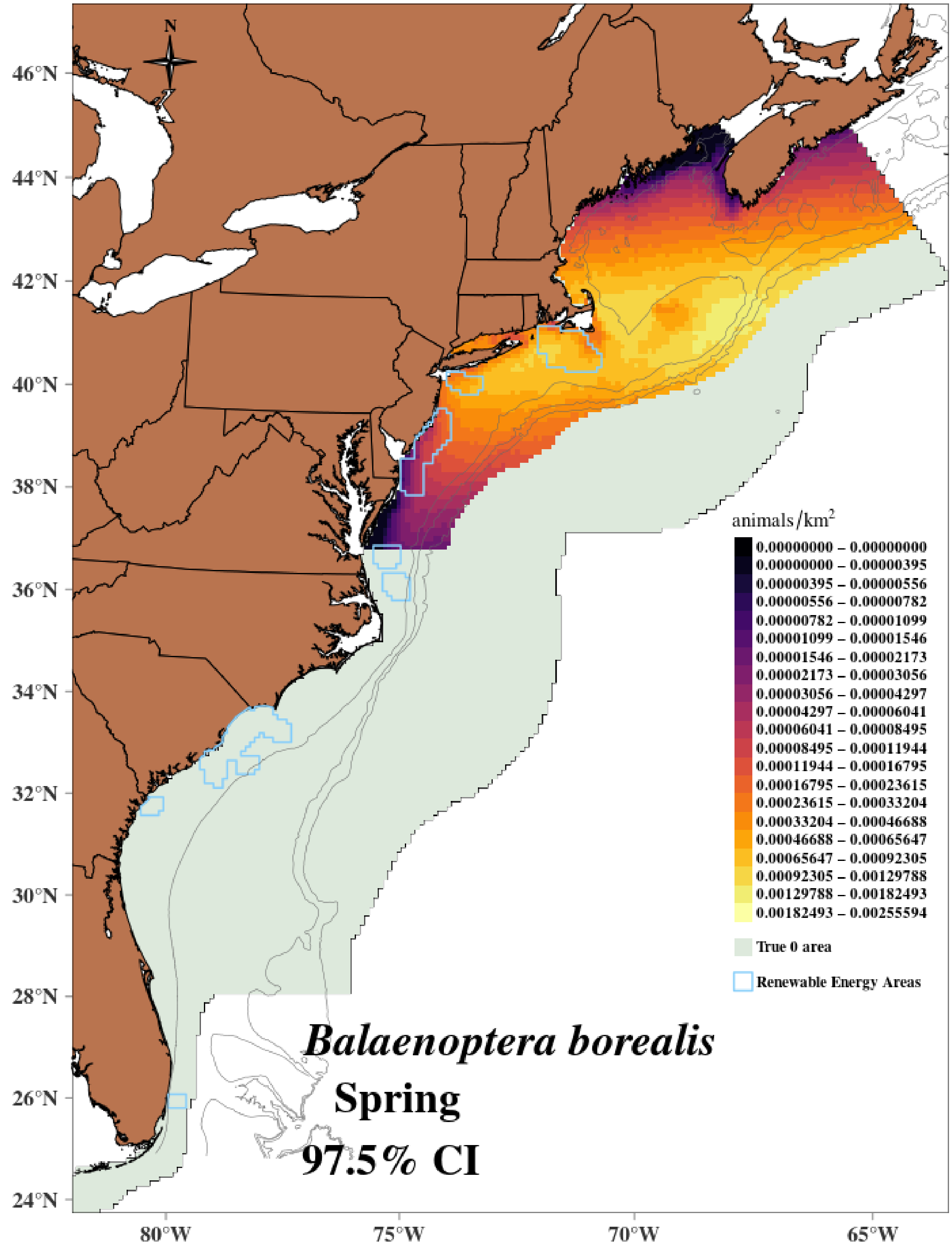

Figure 4-8 Upper 97.5% confidence interval of the spring sei whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

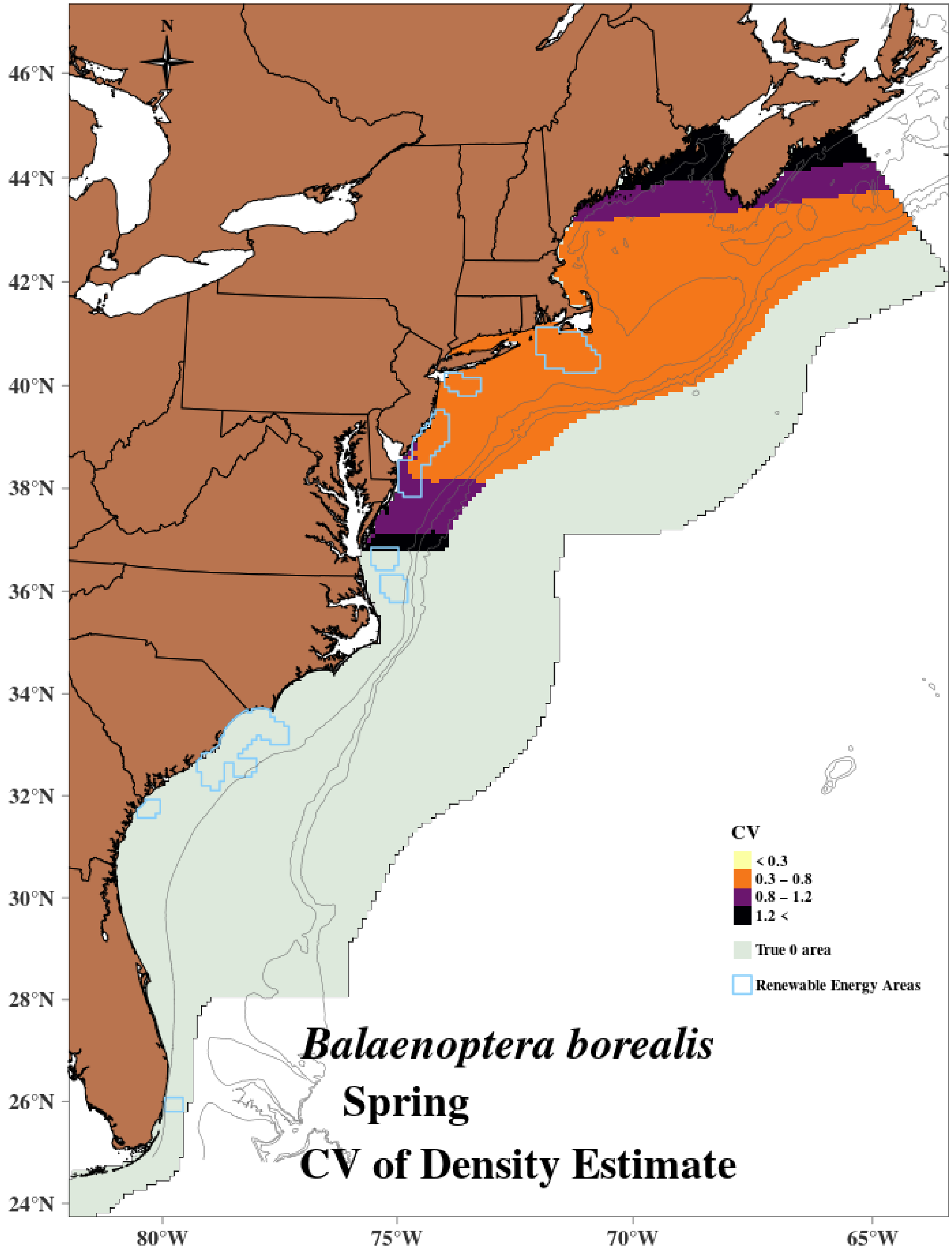

Figure 4-9 CV of spring sei whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

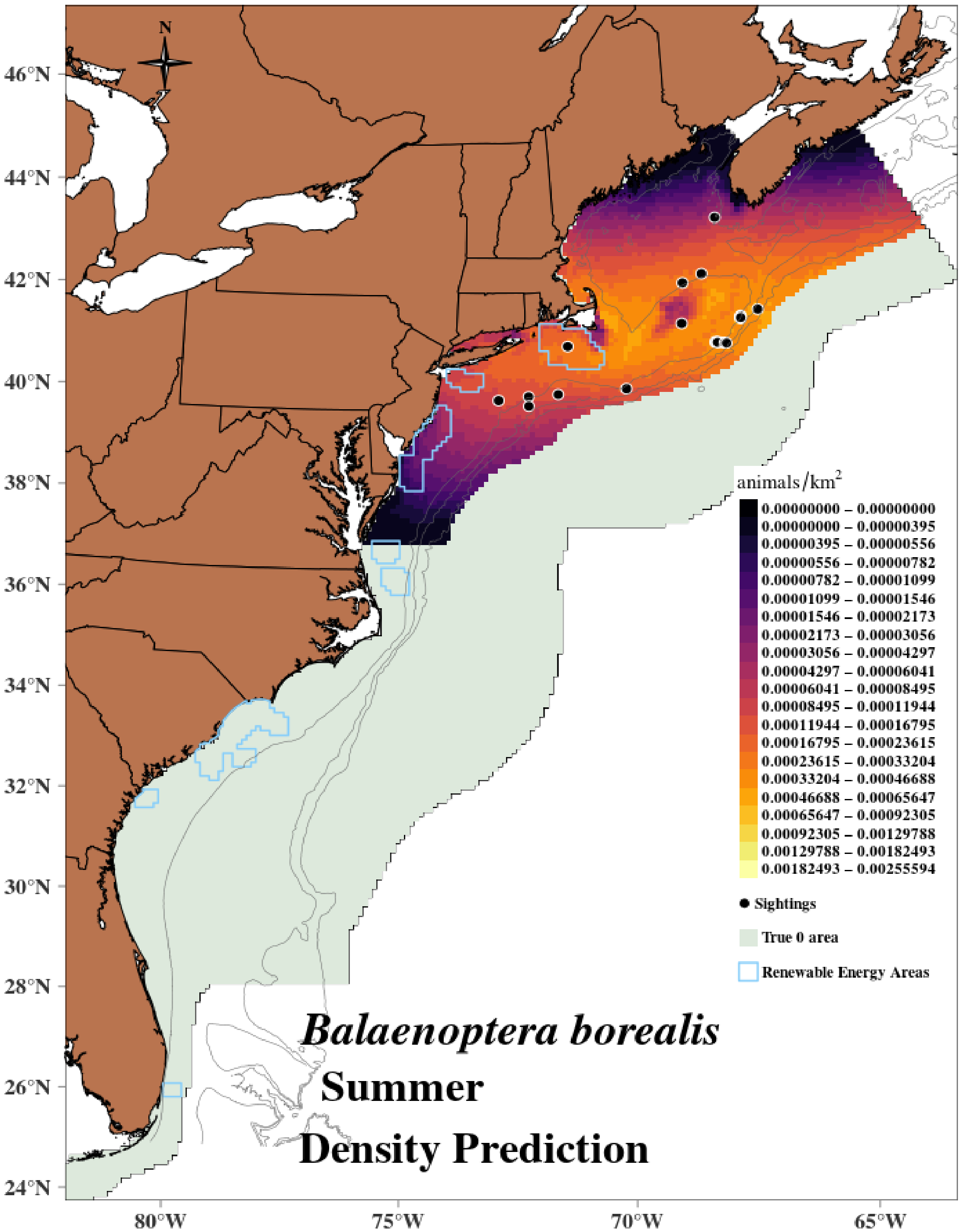

Figure 4-10 Sei whale summer average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

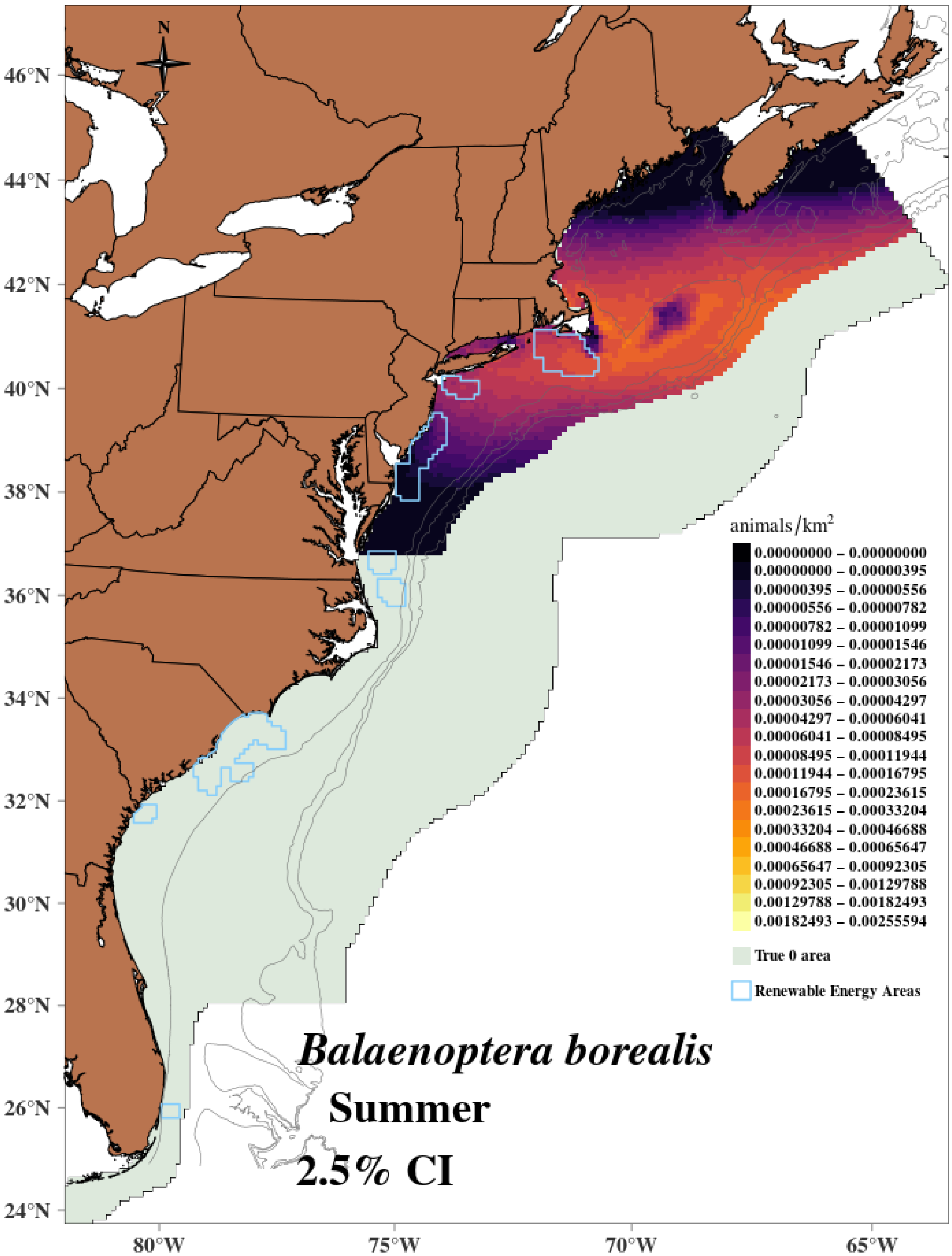

Figure 4-11 Lower 2.5% confidence interval of the summer sei whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

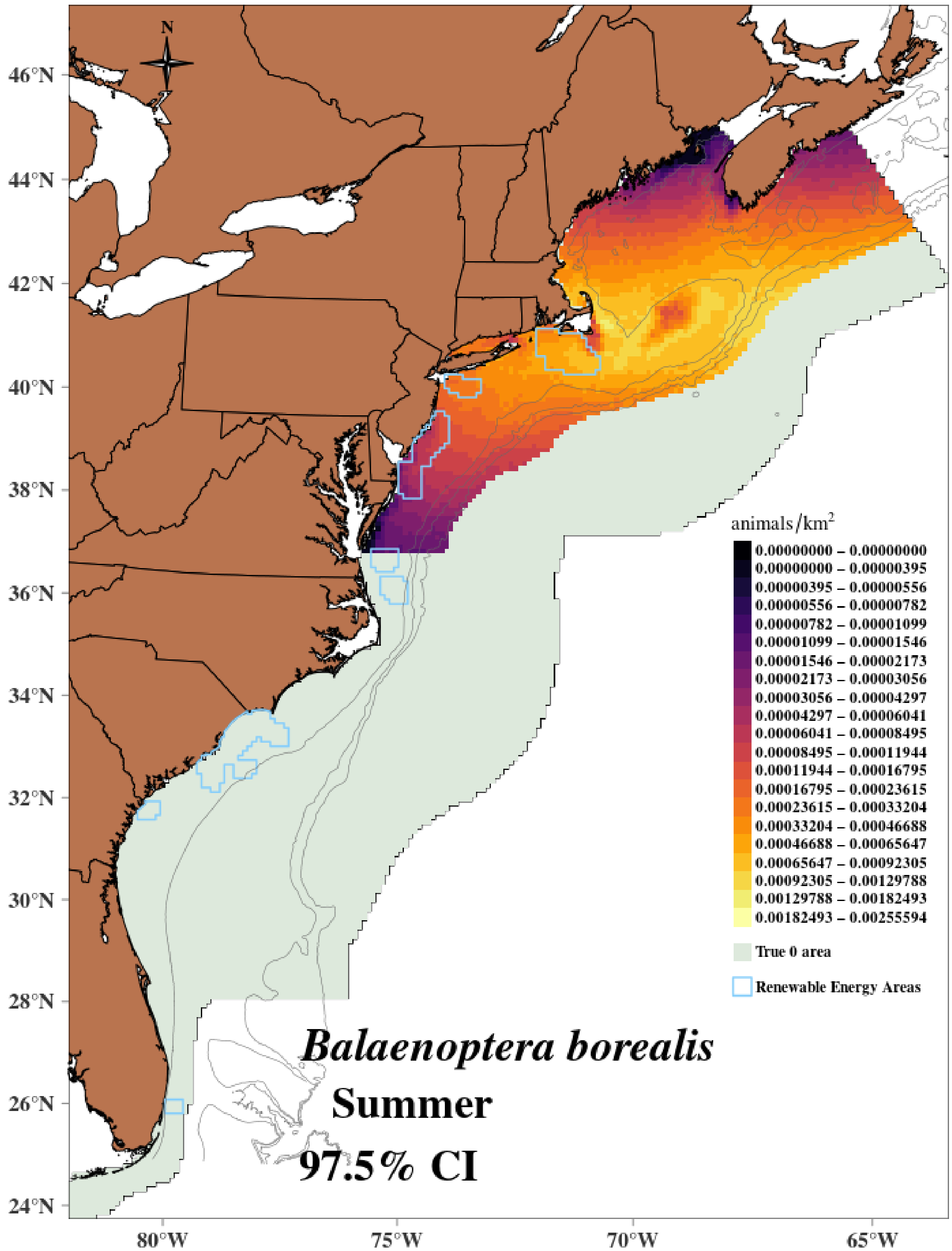

Figure 4-12 Upper 97.5% confidence interval of the summer sei whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

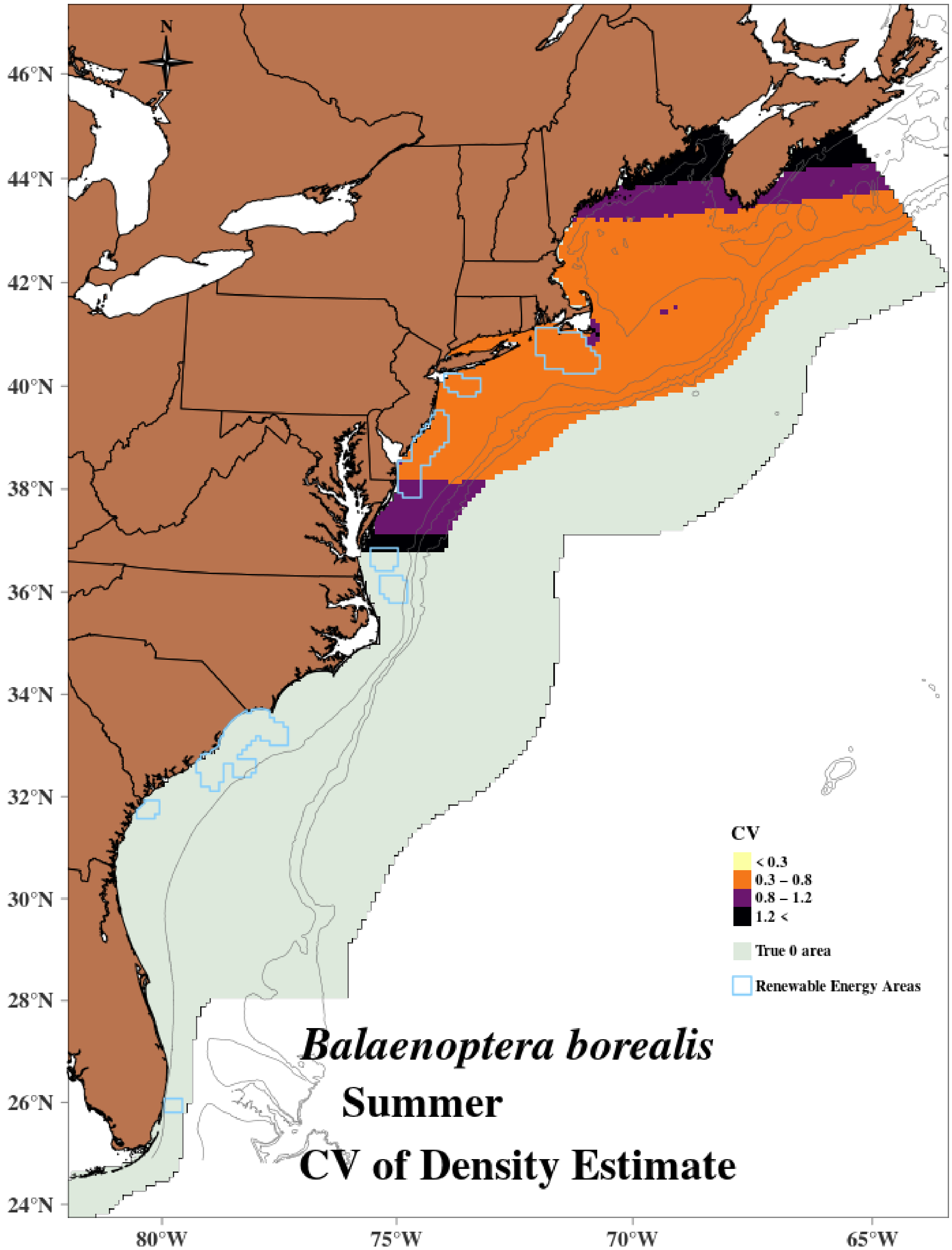

Figure 4-13 CV of summer sei whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

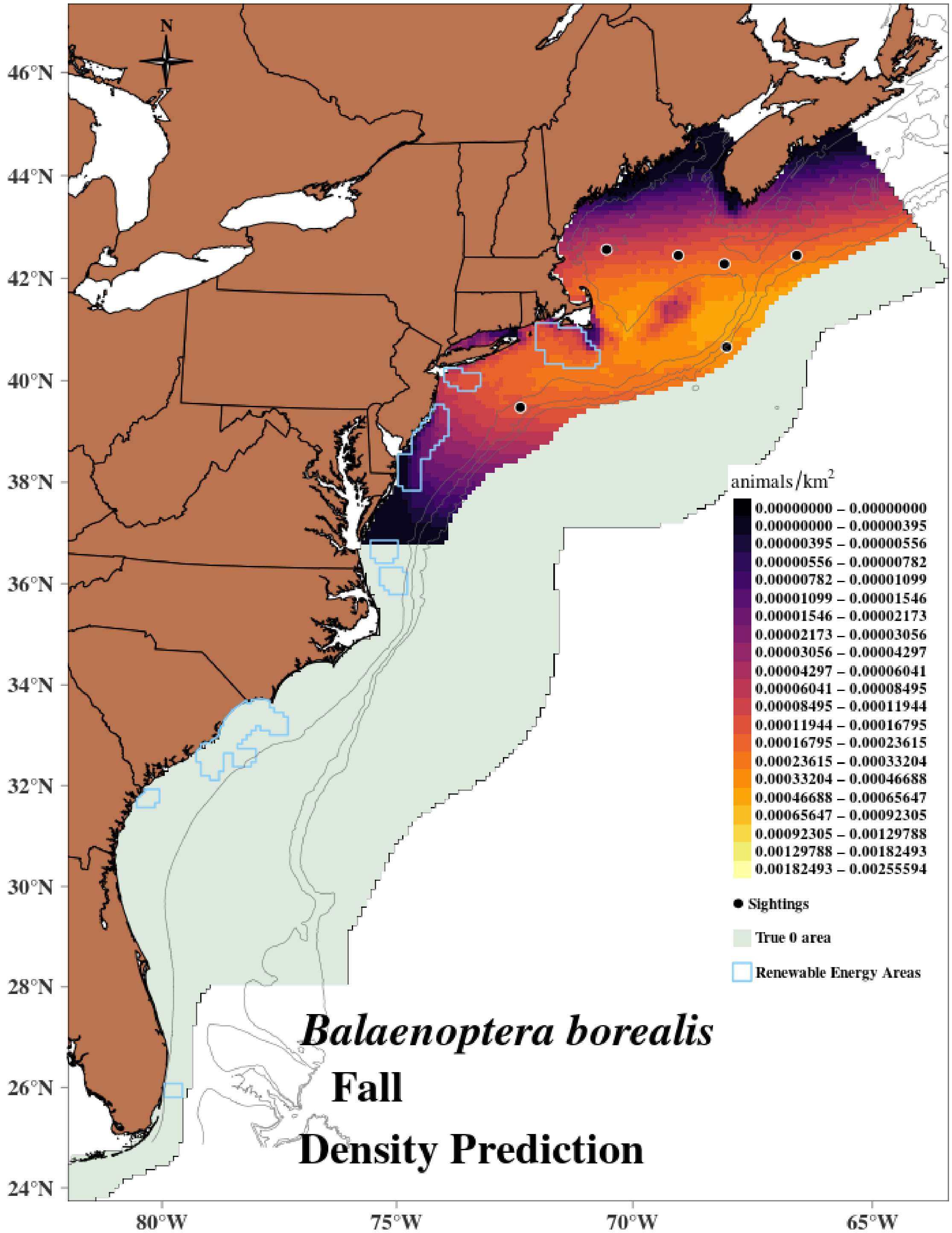

Figure 4-14 Sei whale fall average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

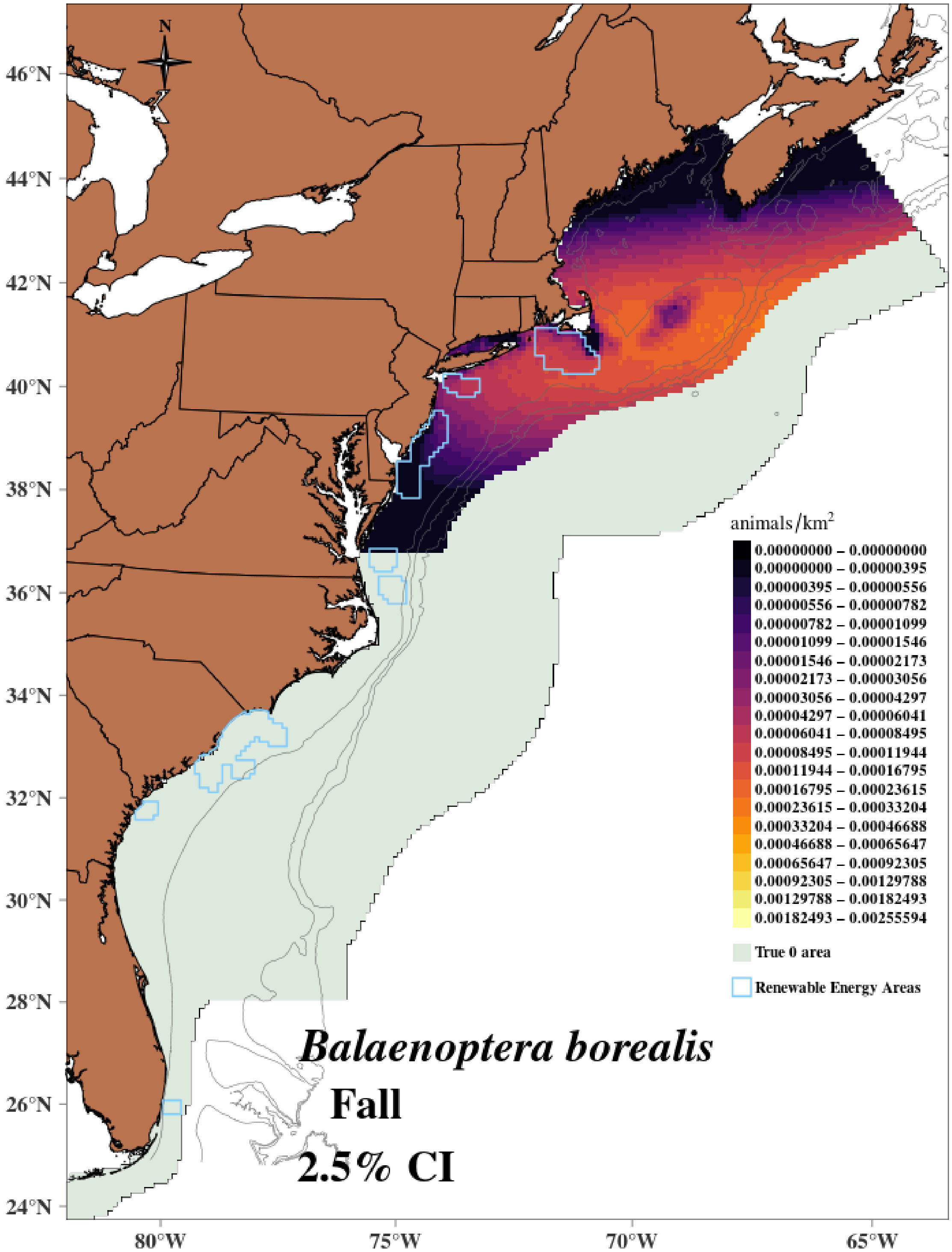

Figure 4-15 Lower 2.5% confidence interval of the fall sei whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

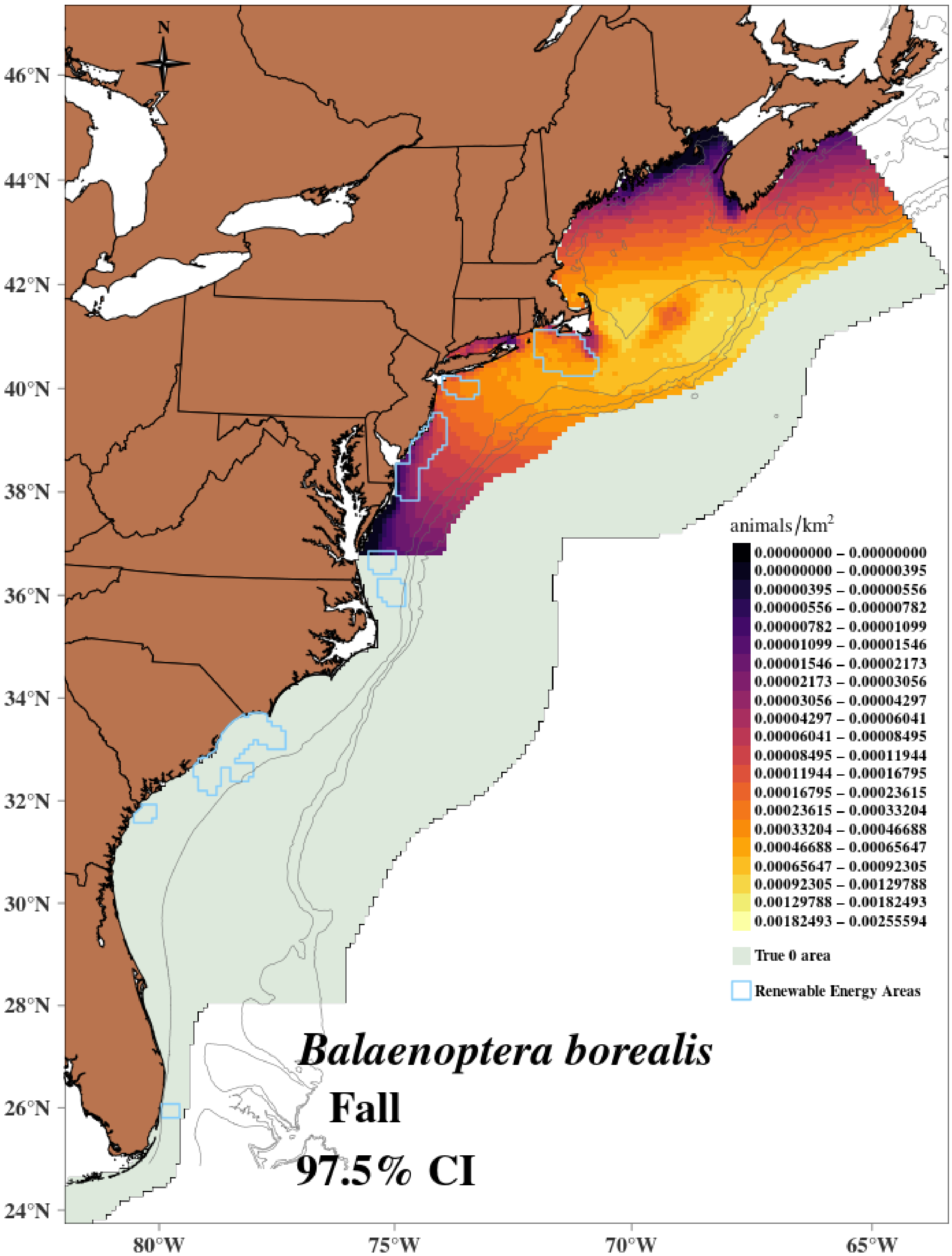

Figure 4-16 Upper 97.5% confidence interval of the fall sei whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

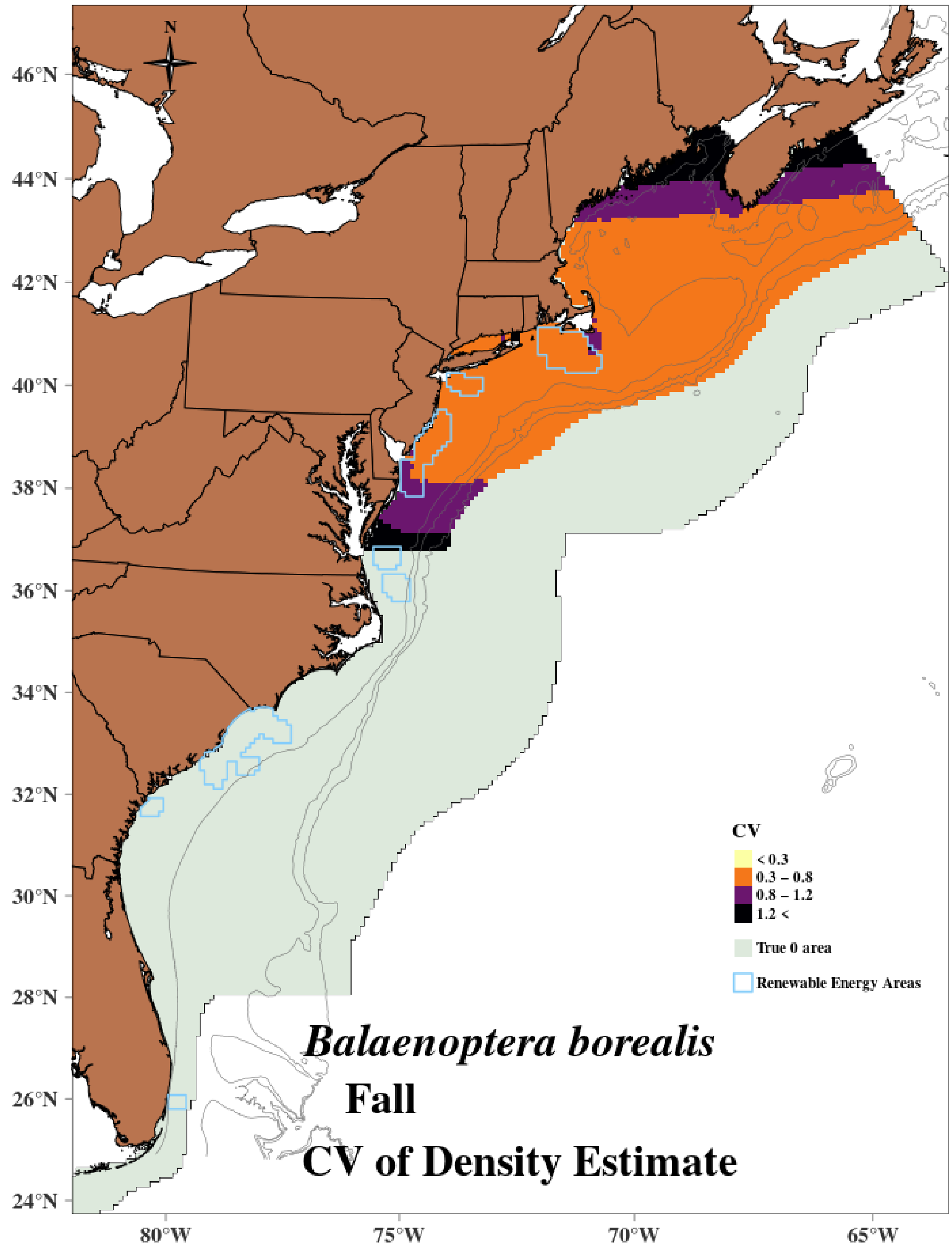

Figure 4-17 CV of fall sei whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

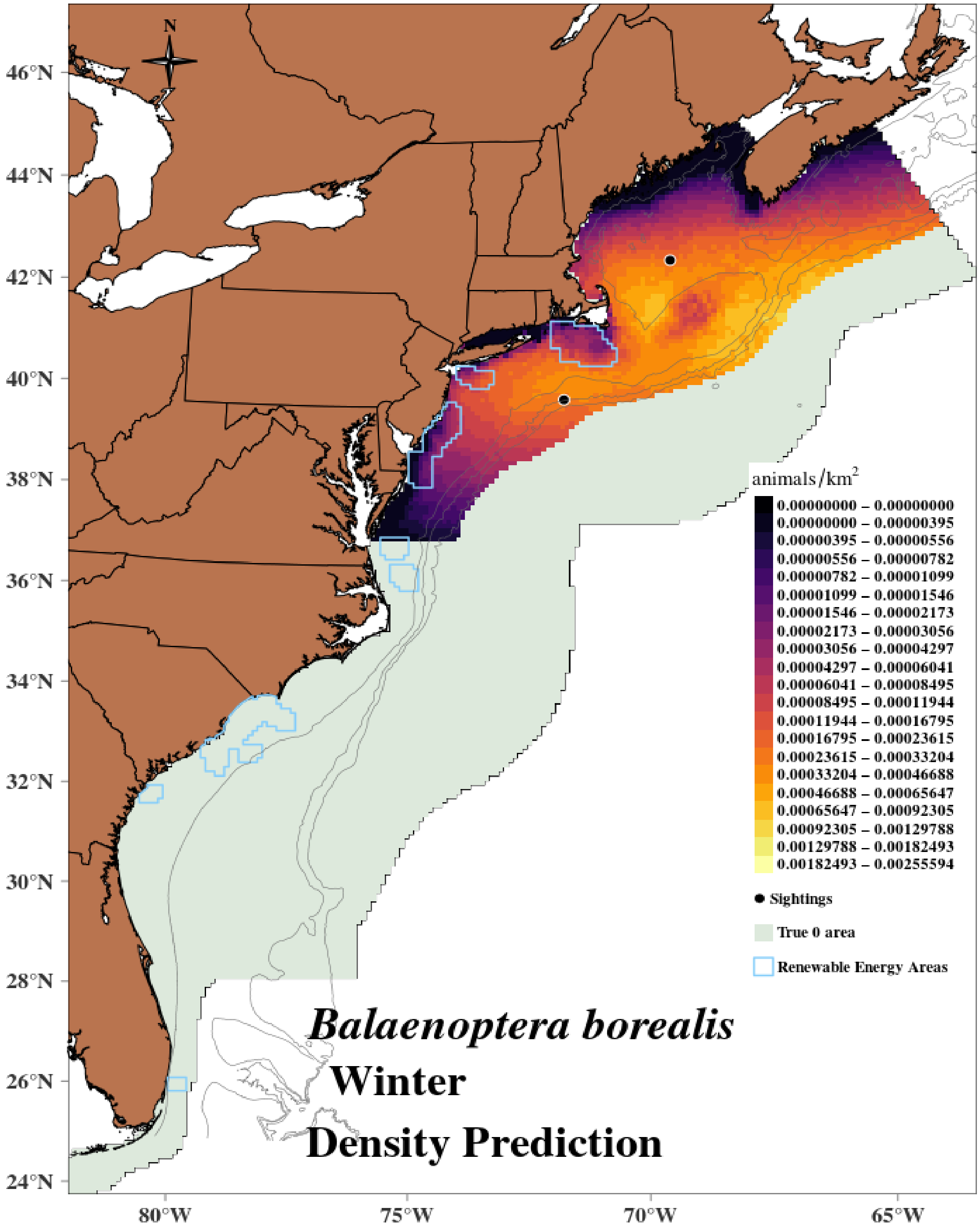

Figure 4-18 Sei whale winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

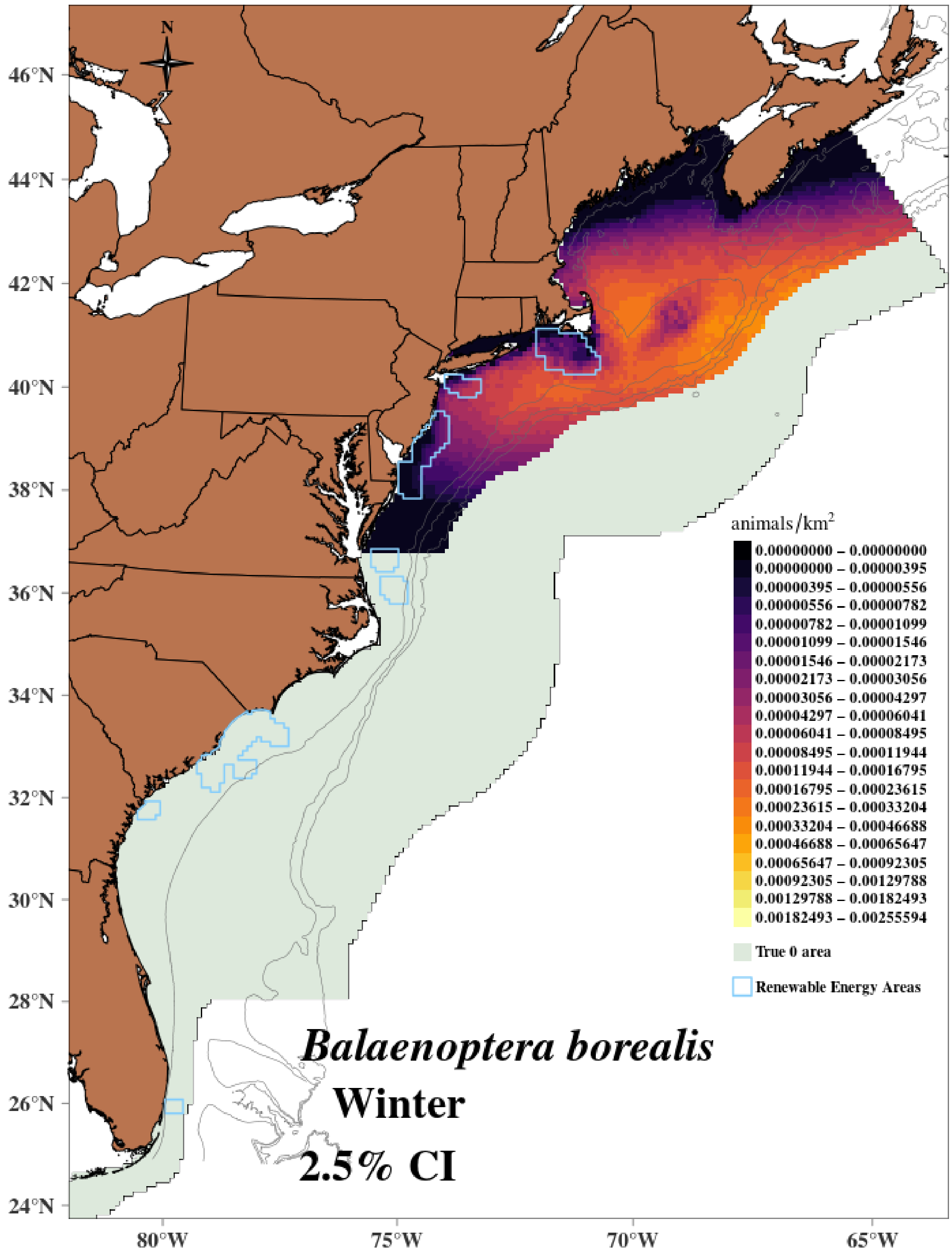

Figure 4-19 Lower 2.5% confidence interval of the winter sei whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

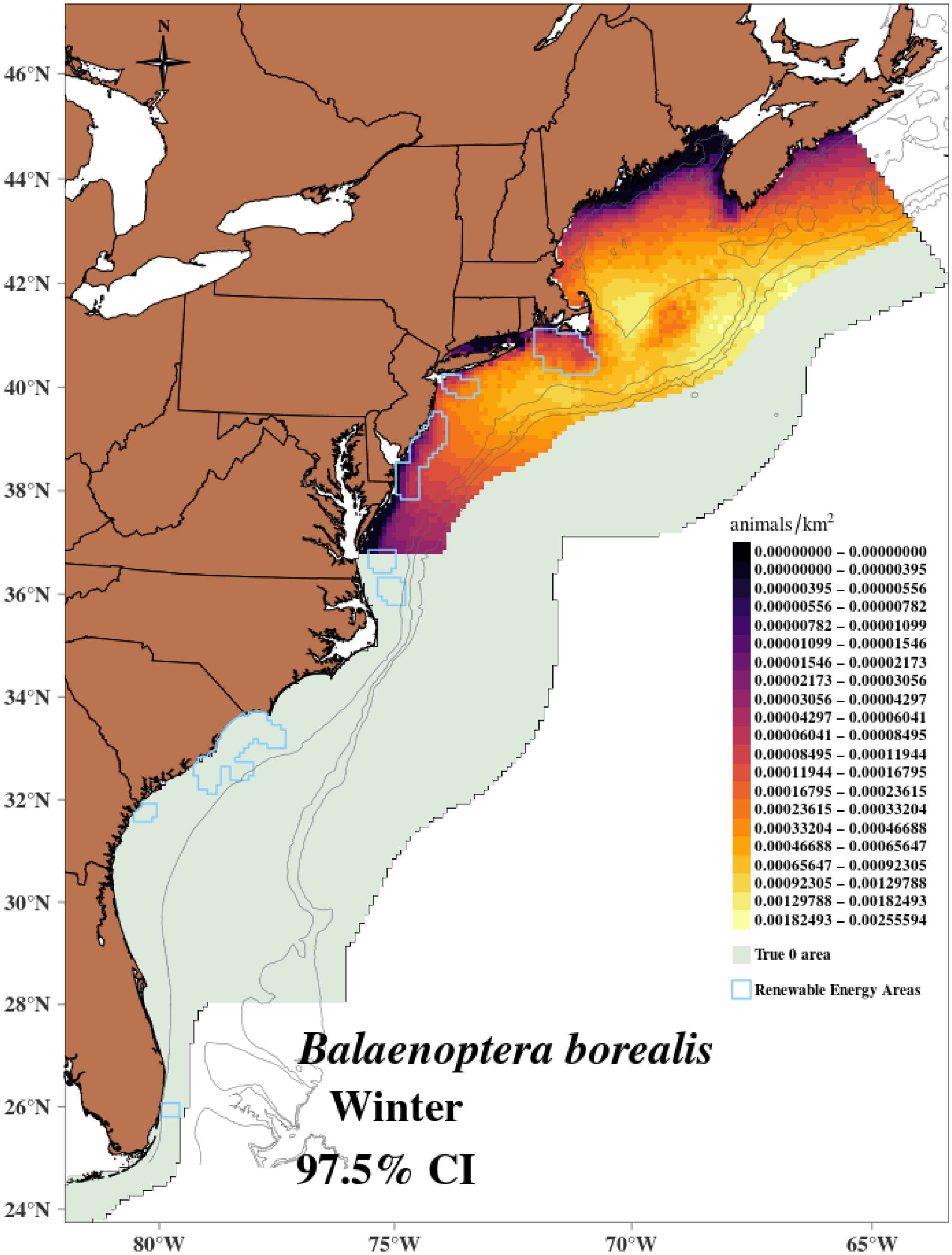

Figure 4-20 Upper 97.5% confidence interval of the winter sei whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

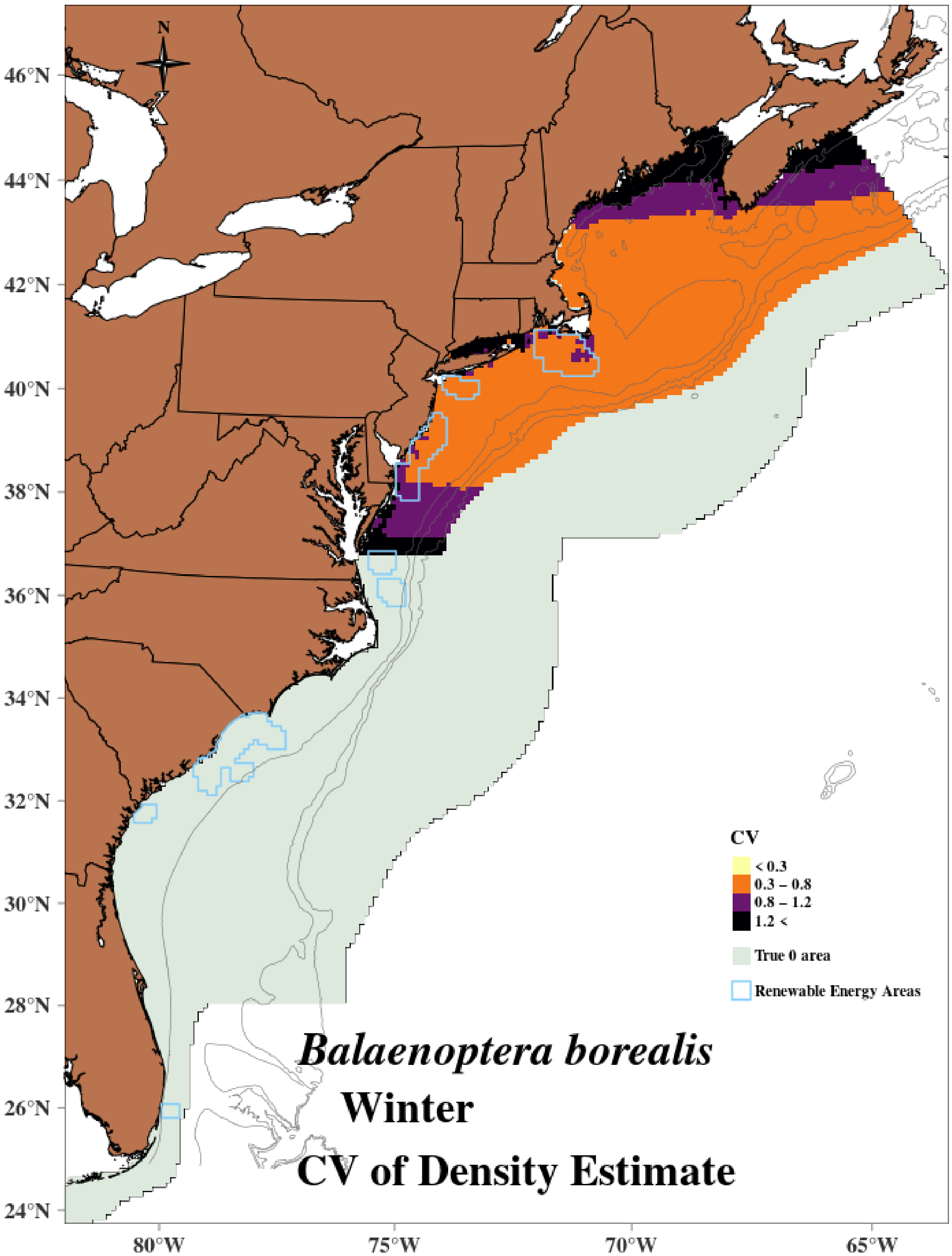

Figure 4-21 CV of winter sei whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

4.7 Offshore Energy Development Areas

Table 4-6 Sei whale abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	11.1	0.43	5.0–24.7
	NY	1.3	0.46	0.6–3.1
	NJ	0.3	0.66	0.1–1.0
	DE/MD	0.0	0.94	0.0–0.1
	VA	0.0	2.25	0.0–0.0
Summer (Jun–Aug)	RI/MA	9.0	0.41	4.1 - 19.5
	NY	0.7	0.43	0.3 - 1.7
	NJ	0.2	0.66	0.1 - 0.7
	DE/MD	0.0	0.91	0.0 - 0.1
	VA	9.0	0.41	4.1 - 19.5
Fall (Sep–Nov)	RI/MA	5.9	0.43	2.6 - 13.4
	NY	0.7	0.45	0.3 - 1.5
	NJ	0.2	0.67	0.1 - 0.5
	DE/MD	0.0	0.93	0.0 - 0.1
	VA	0.0	2.29	0.0 – 0.0
Winter (Dec–Feb)	RI/MA	4.8	0.54	1.7 - 12.9
	NY	0.8	0.46	0.3 - 1.9
	NJ	0.2	0.68	0.1 - 0.7
	DE/MD	0.0	0.96	0.0 - 0.1
	VA	0.0	2.32	0.0 – 0.0

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

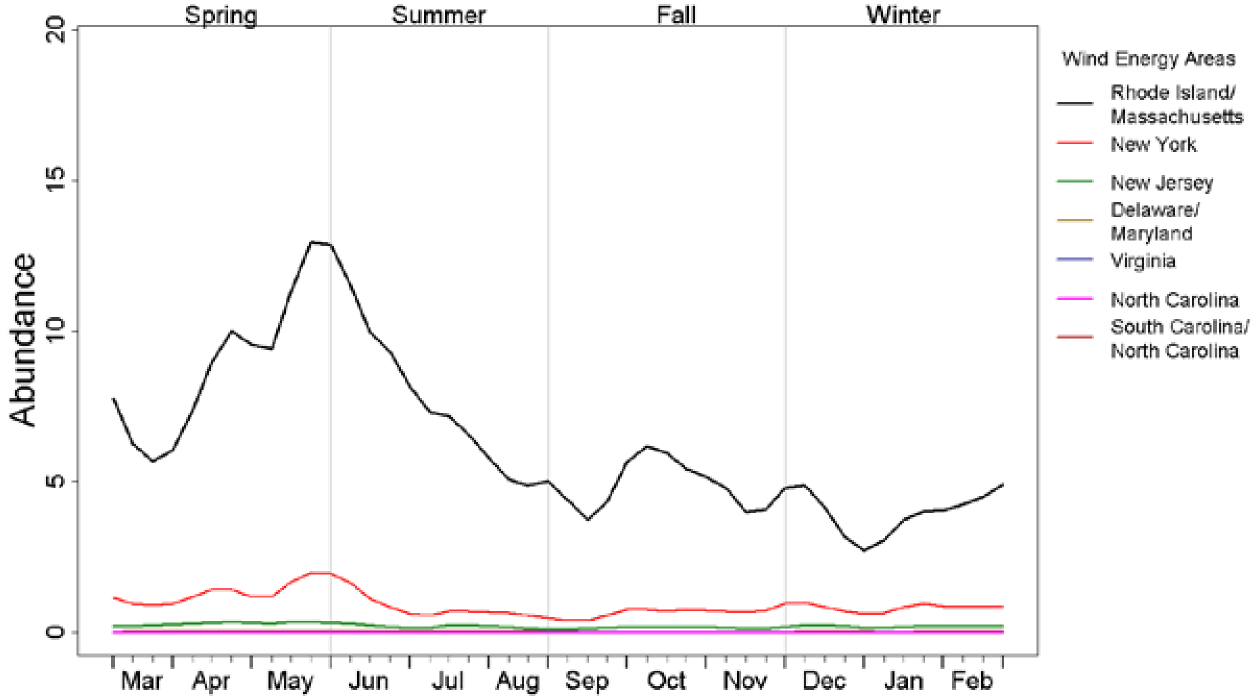

Figure 4-22 Average seasonal abundance of sei whales in the wind-energy study areas

5 Minke Whale (*Balaenoptera acutorostrata*)

Figure 5-1 Minke whale
Image collected under MMPA Research permit #17355. Credit: NOAA/NEFSC/Leah Crowe

5.1 Data Collection

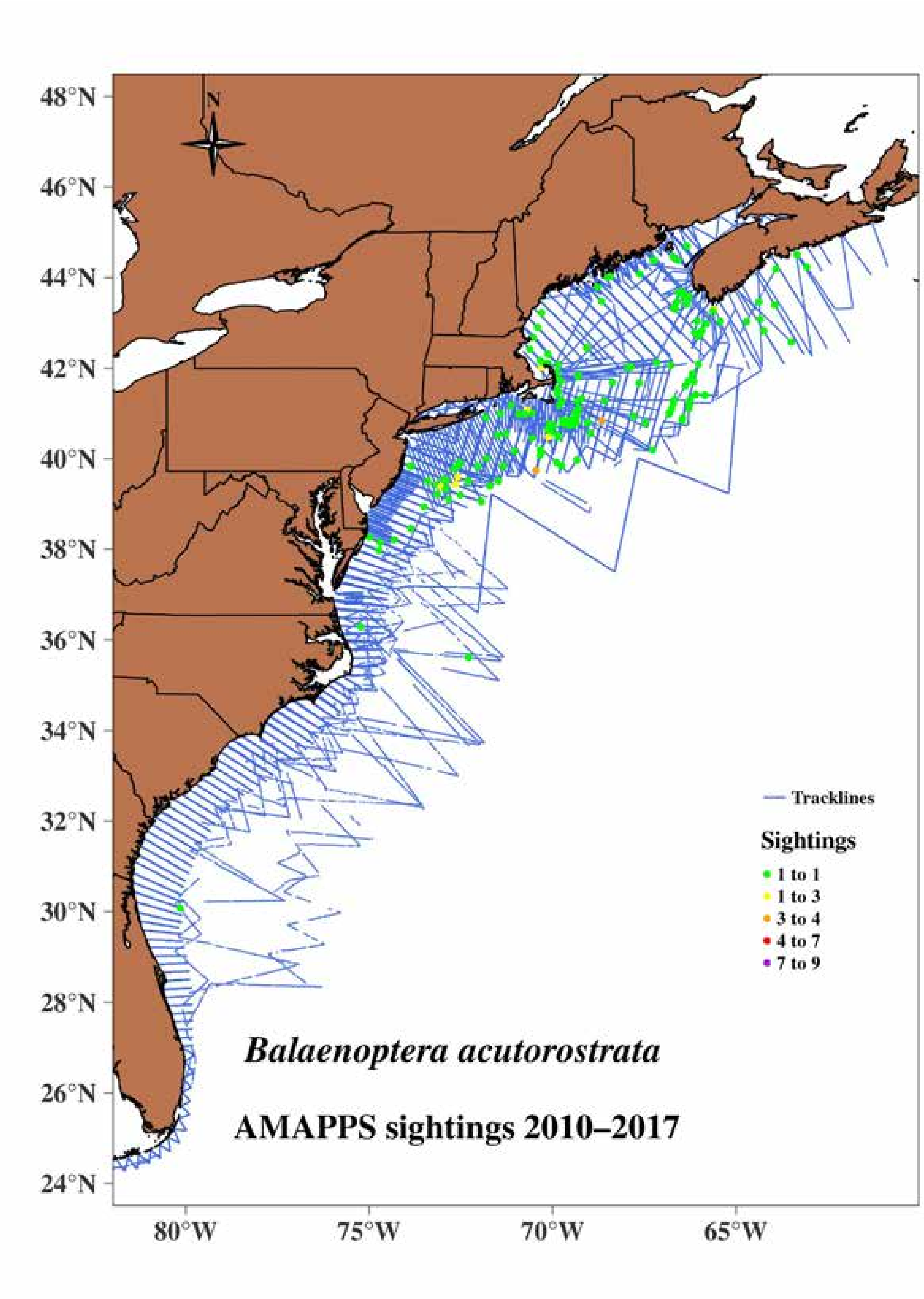

Figure 5-2 Distribution of track lines and minke whale sightings 2010 to 2017

Table 5-1 AMAPPS research effort 2010 to 2017 and minke whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	32	32
NE Shipboard	Fall	1,065	0	0
NE Aerial	Spring	13,314	10	11
NE Aerial	Summer	25,867	60	65
NE Aerial	Fall	37,850	37	52
NE Aerial	Winter	12,179	5	5
SE Shipboard	Spring	8,853	8	11
SE Shipboard	Summer	12,968	1	1
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	11	14
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	3	3
SE Aerial	Winter	8,950	1	1

5.2 Mark-Recapture Distance Sampling Analysis

Table 5-2 Intermediate parameters in minke whale mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 4	distance * observer + sea state + glare	300	distance	LT43- 300	HR	0.86	0.18	0.98	0.96	0.95
NE–aerial group 2	distance * observer + sea state + quality + group size	600	distance + sea state	LT35-600	HR	0.62	0.19	0.86	0.89	0.91
NE–shipboard group 10	distance * observer + group size + sea state	6000	distance + time of day + group size	6000	HR	0.48	0.10	0.28	0.92	0.95
SE–shipboard group 5	distance * observer + group size	6000	distance + glare + time of day	6000	HR	0.57	0.11	0.24	0.61	0.65

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

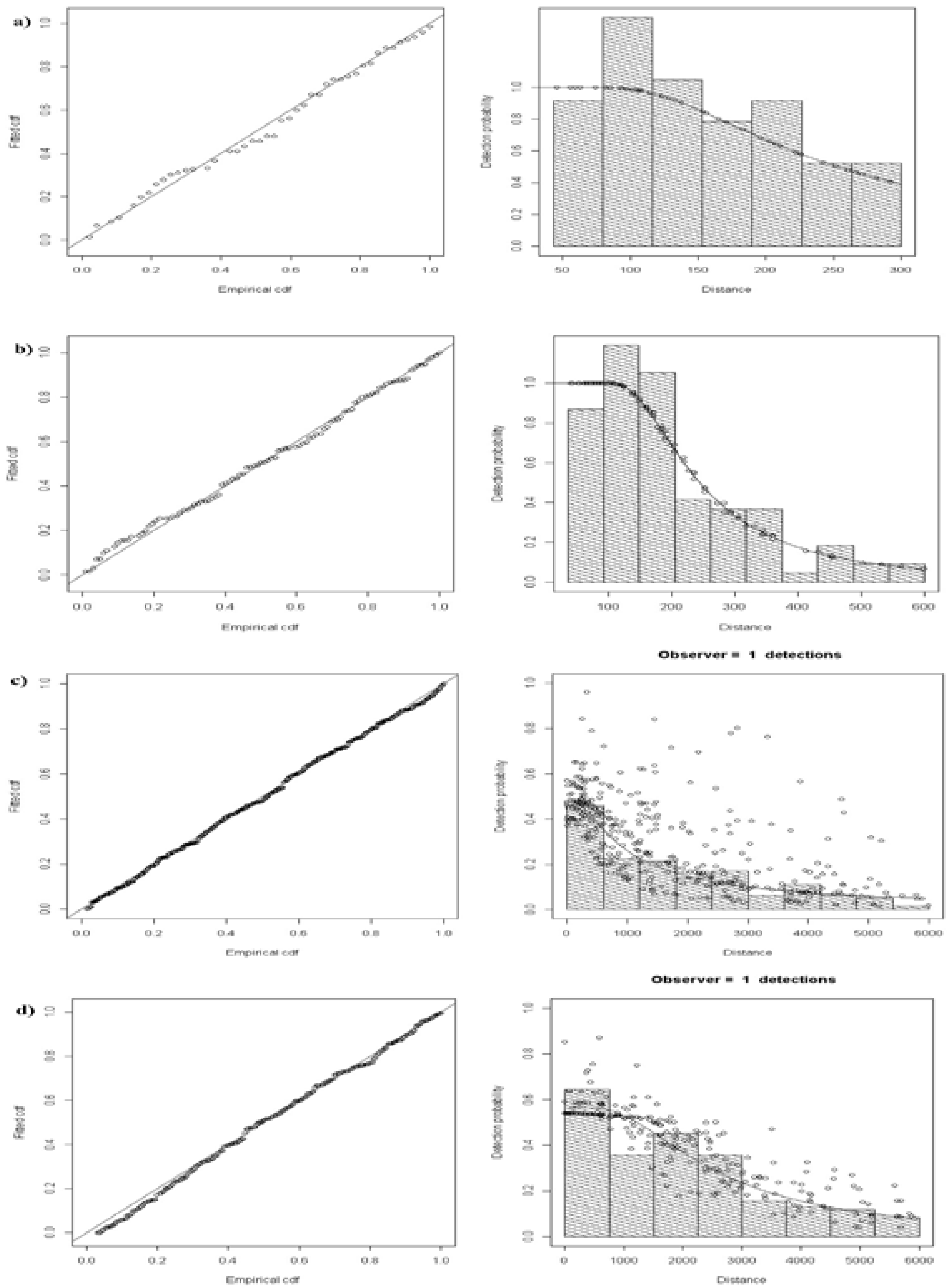

Figure 5-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 4; b) NE-aerial analysis set 2; c) NE-shipboard analysis set 10; d) SE-shipboard analysis set 5.

5.3 Generalized Additive Model Analysis

Table 5-3 2010 to 2017 density-habitat model output for minke whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(sstmur)	2.12	4	6.00	4.90	<0.0001
s(mld)	0.93	4	2.76	4.59	0.0005
s(chlfma)	0.80	4	0.87	1.06	0.0352
s(pocma)	0.88	4	1.60	0.67	0.0061
s(pp)	0.88	4	1.77	1.35	0.0039
s(dist200)	2.98	4	3.62	4.27	0.0012
s(dist1000)	0.86	4	1.16	2.73	0.0158
s(lat)	2.27	4	8.05	9.95	<0.0001

Adjusted R^2 = 0.00682. Deviance explained = 29.5%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

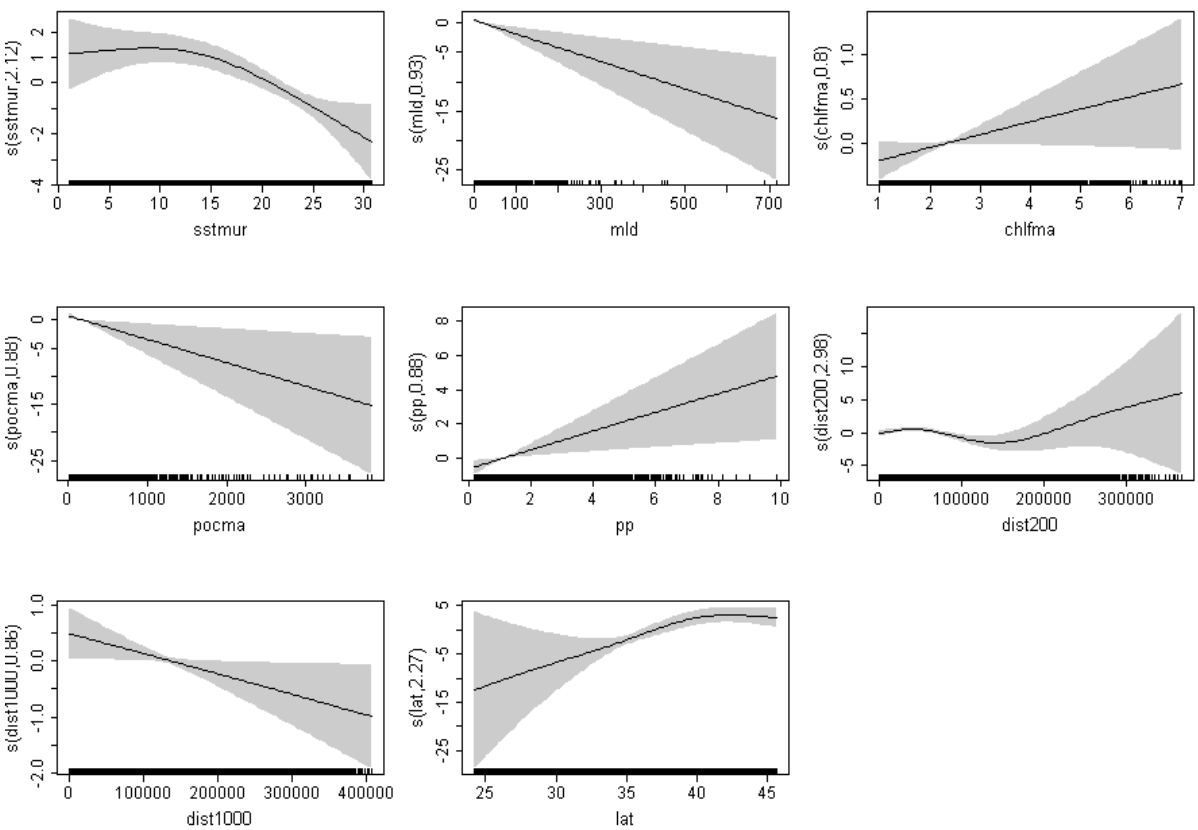

Figure 5-4 Minke whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

5.4 Model Cross-Validation

Table 5-4 Diagnostic statistics from the minke whale density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.153	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	97.410	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.121	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.001	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

5.5 Abundance Estimates for AMAPPS Study Area

Table 5-5 Minke whale average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	1,334	0.43	595–2,991
Summer (June–August)	1,197	0.33	637– 2,248
Fall (September–November)	616	0.32	334–1,136
Winter (December–February)	24	0.39	11– 50
Summer 2011 U.S. surveys[1]	2,591	0.81	
Summer 2016 U.S. surveys[1]	2,802	0.81	

[1]Hayes et al. 2020

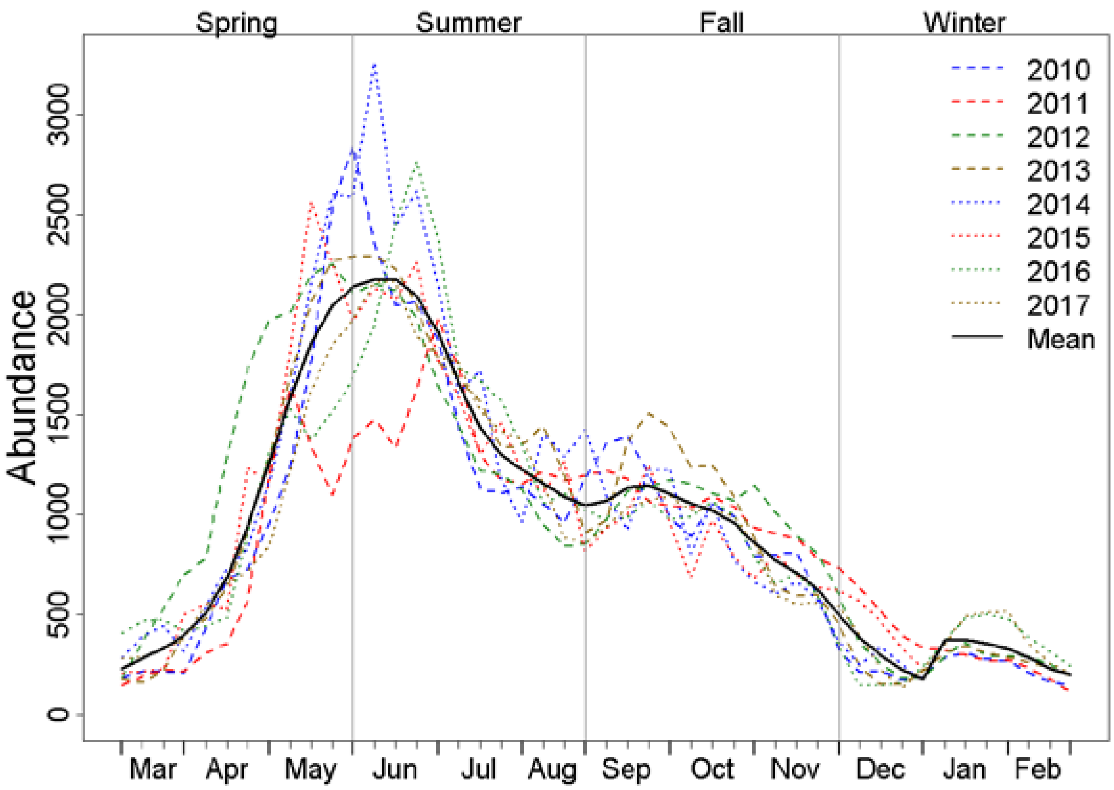

Figure 5-5 Annual abundance trends for minke whales in the AMAPPS study area

5.6 Seasonal Prediction Maps

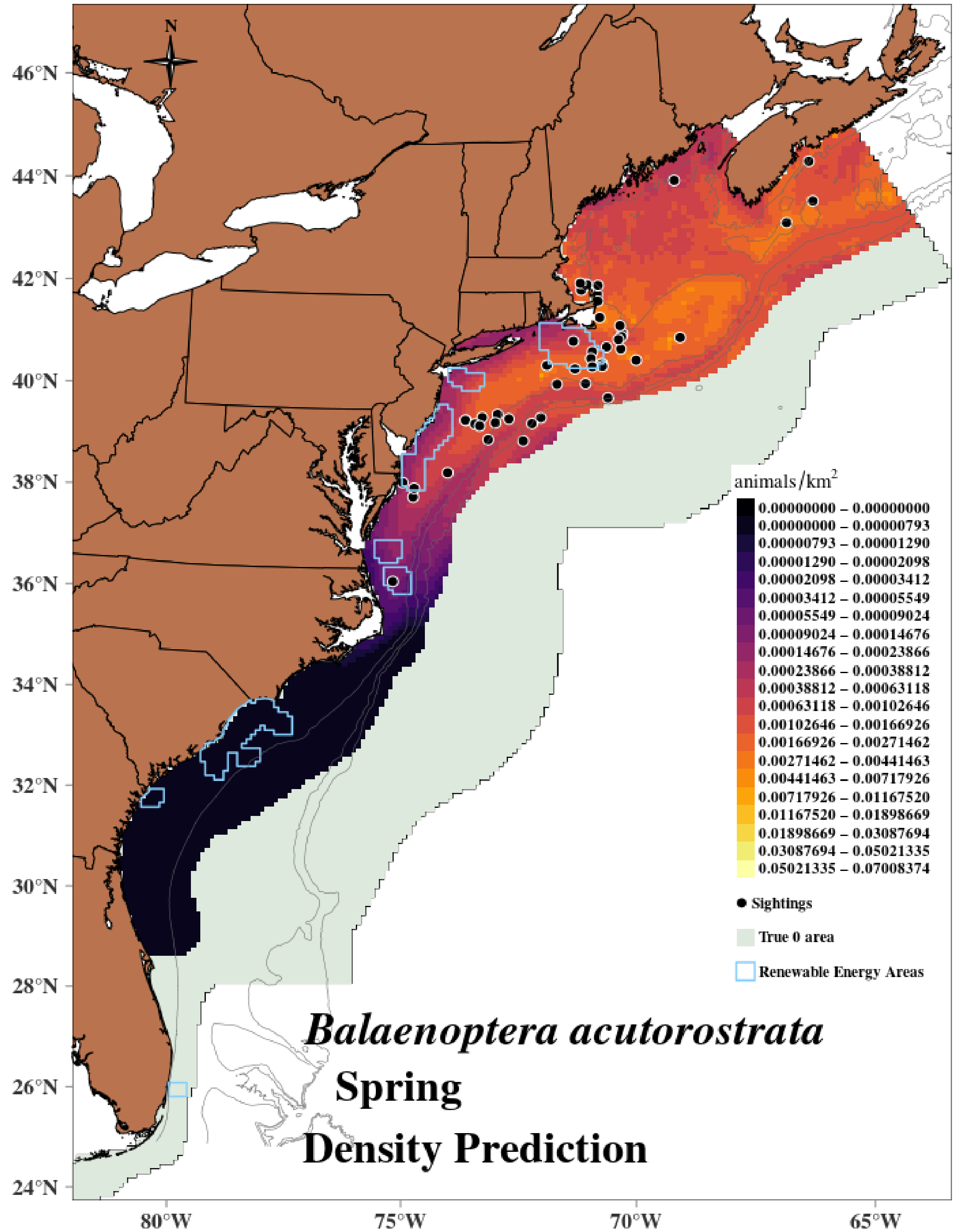

Figure 5-6 Minke whale spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

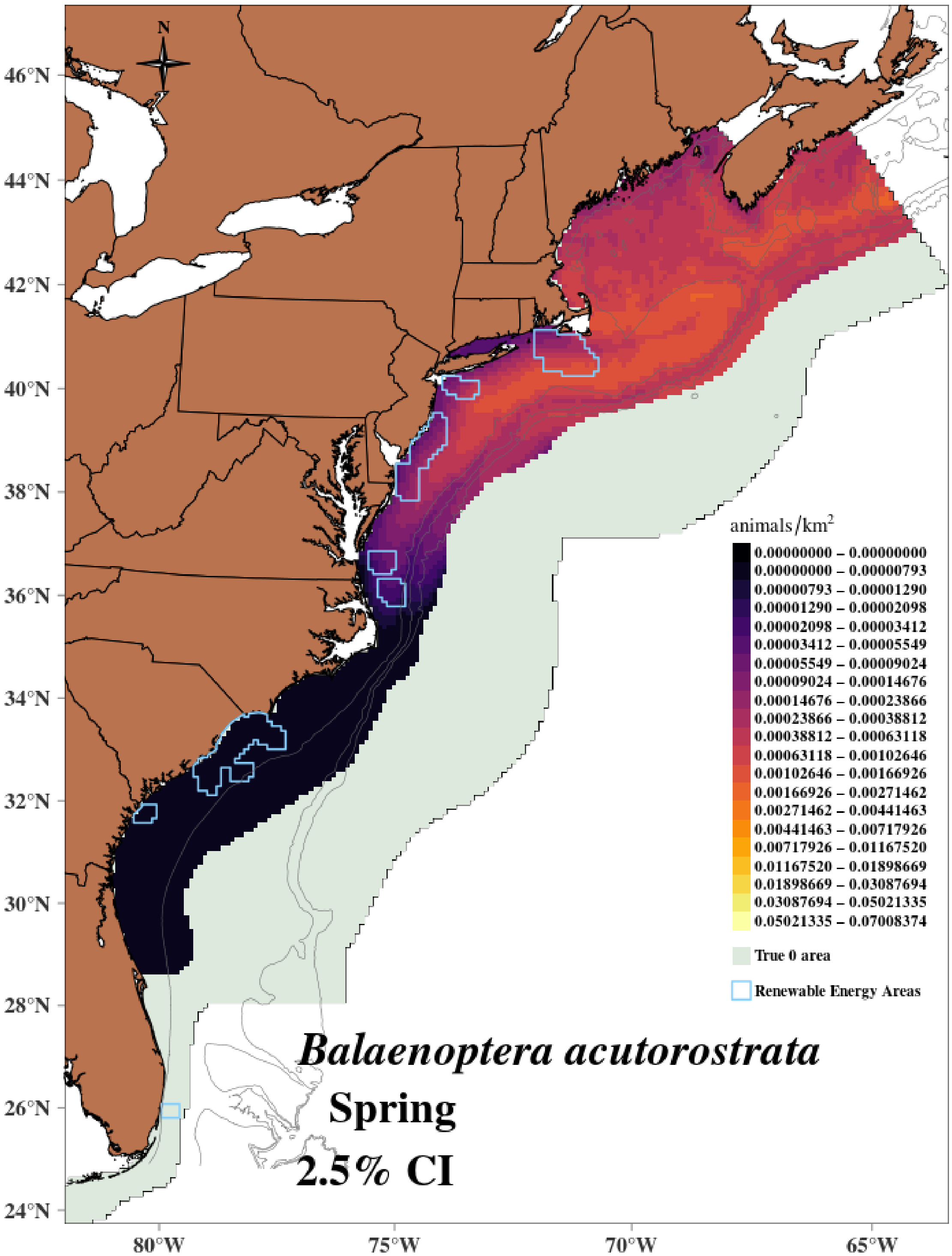

Figure 5-7 Lower 2.5% confidence interval of the spring minke whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

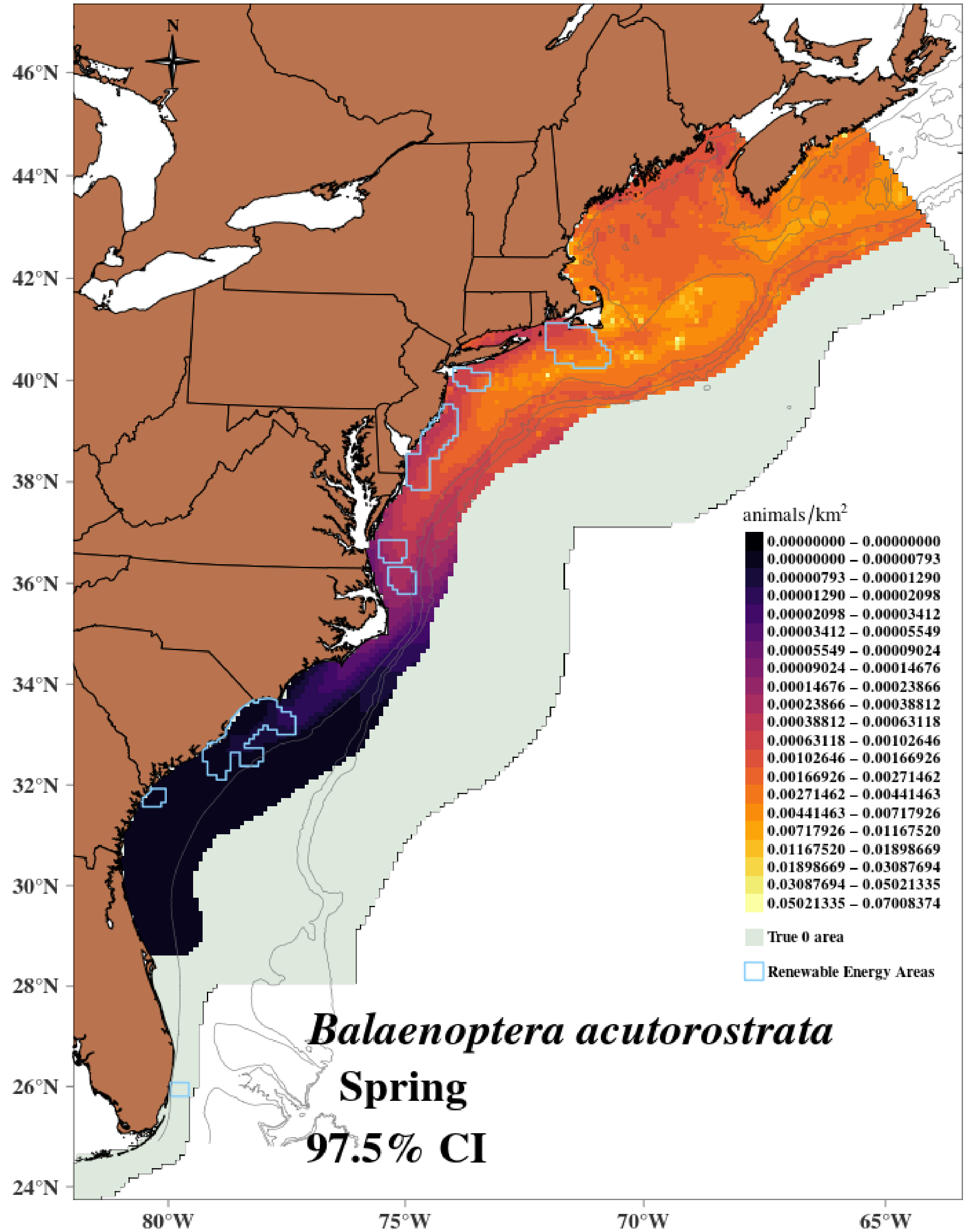

Figure 5-8 Upper 97.5% confidence interval of the spring minke whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

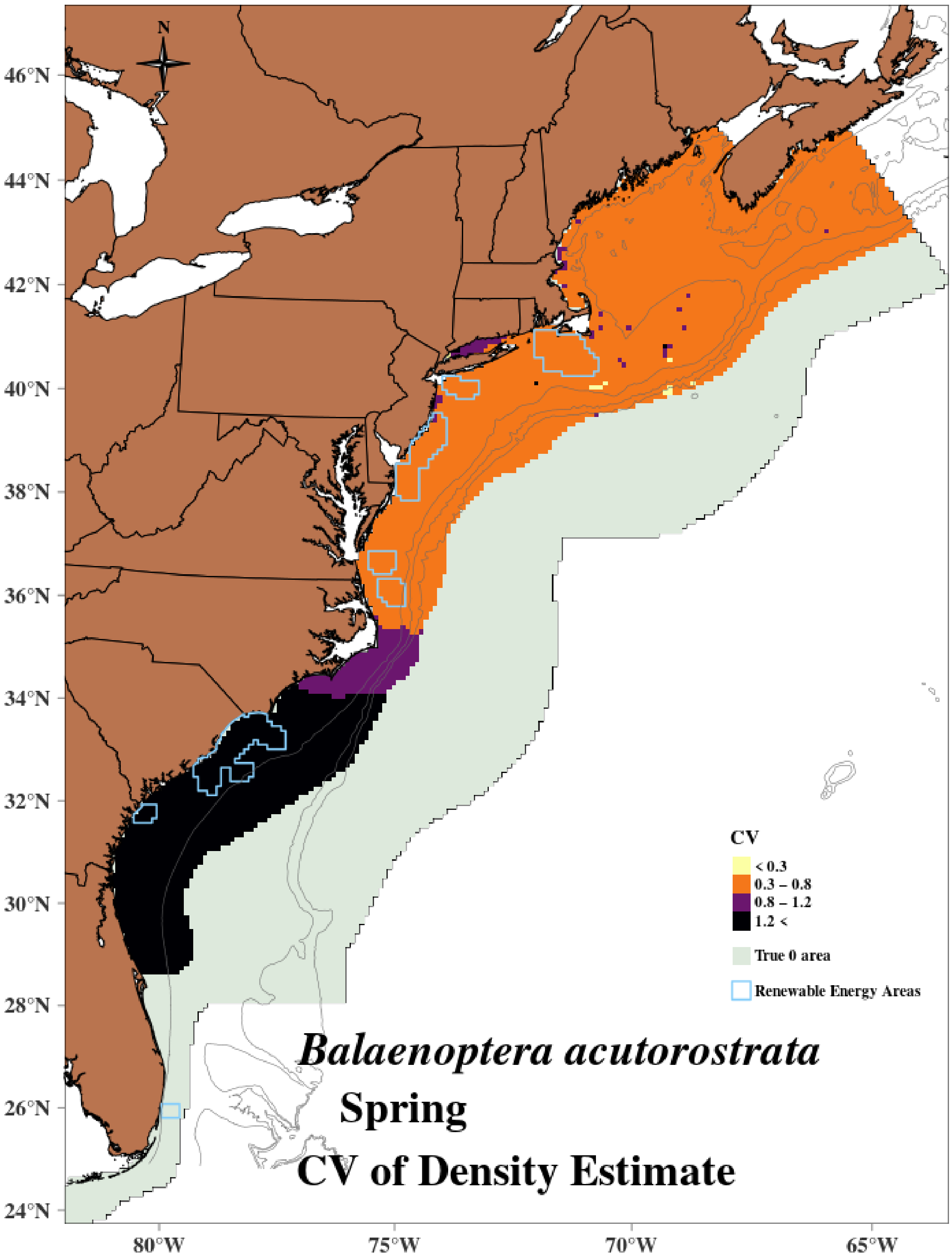

Figure 5-9 CV of spring minke whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

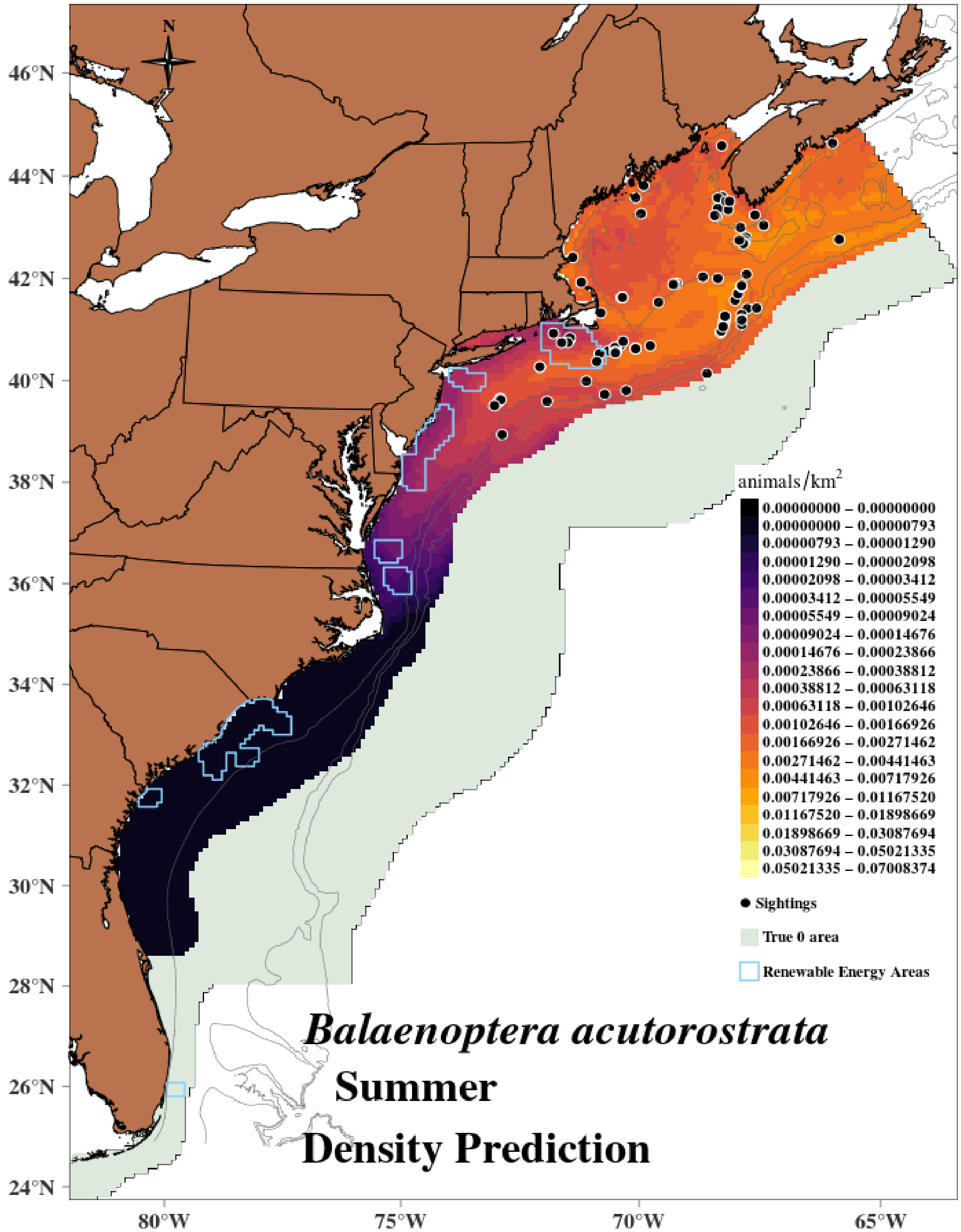

Figure 5-10 Minke whale summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

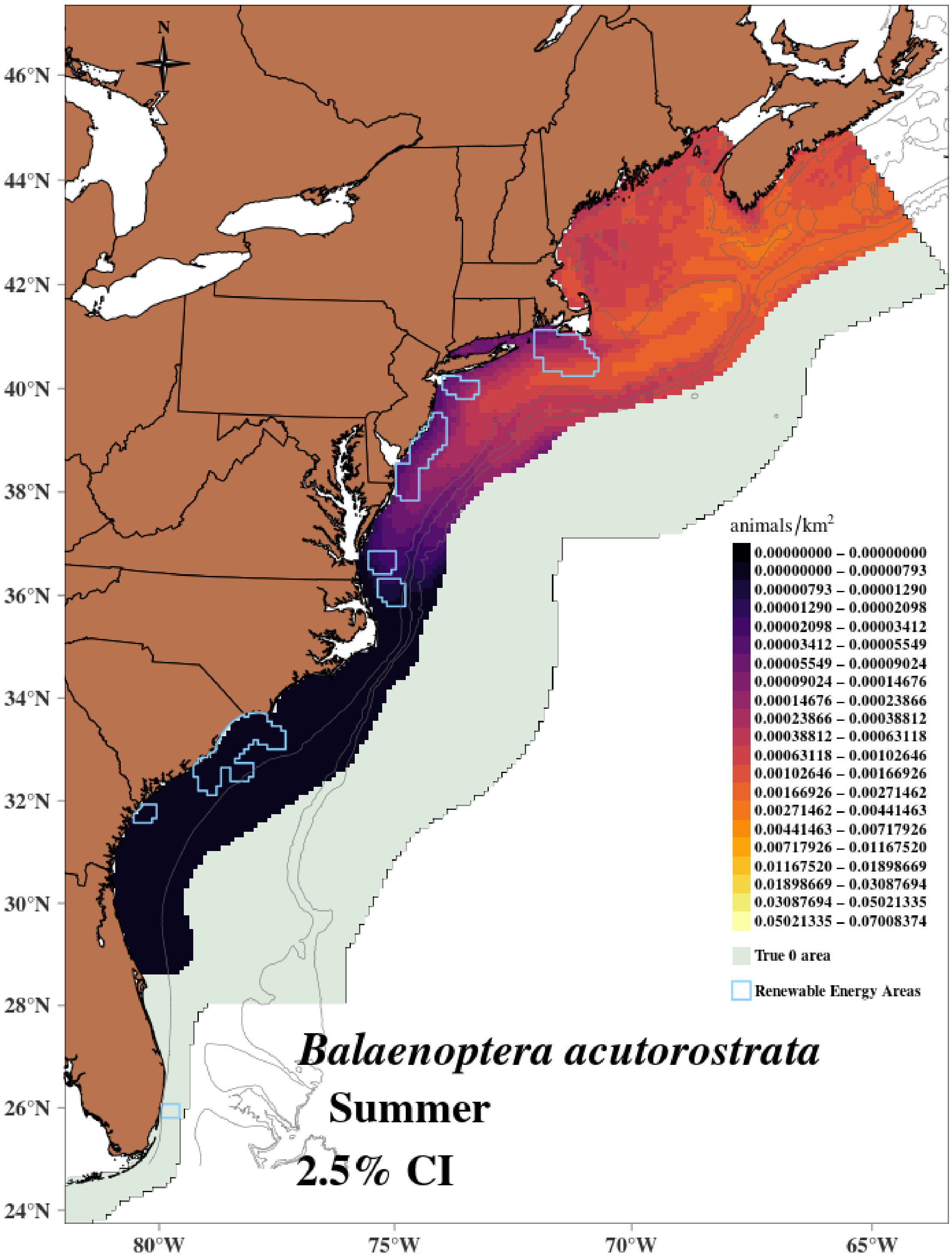

Figure 5-11 Lower 2.5% confidence interval of the summer minke whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

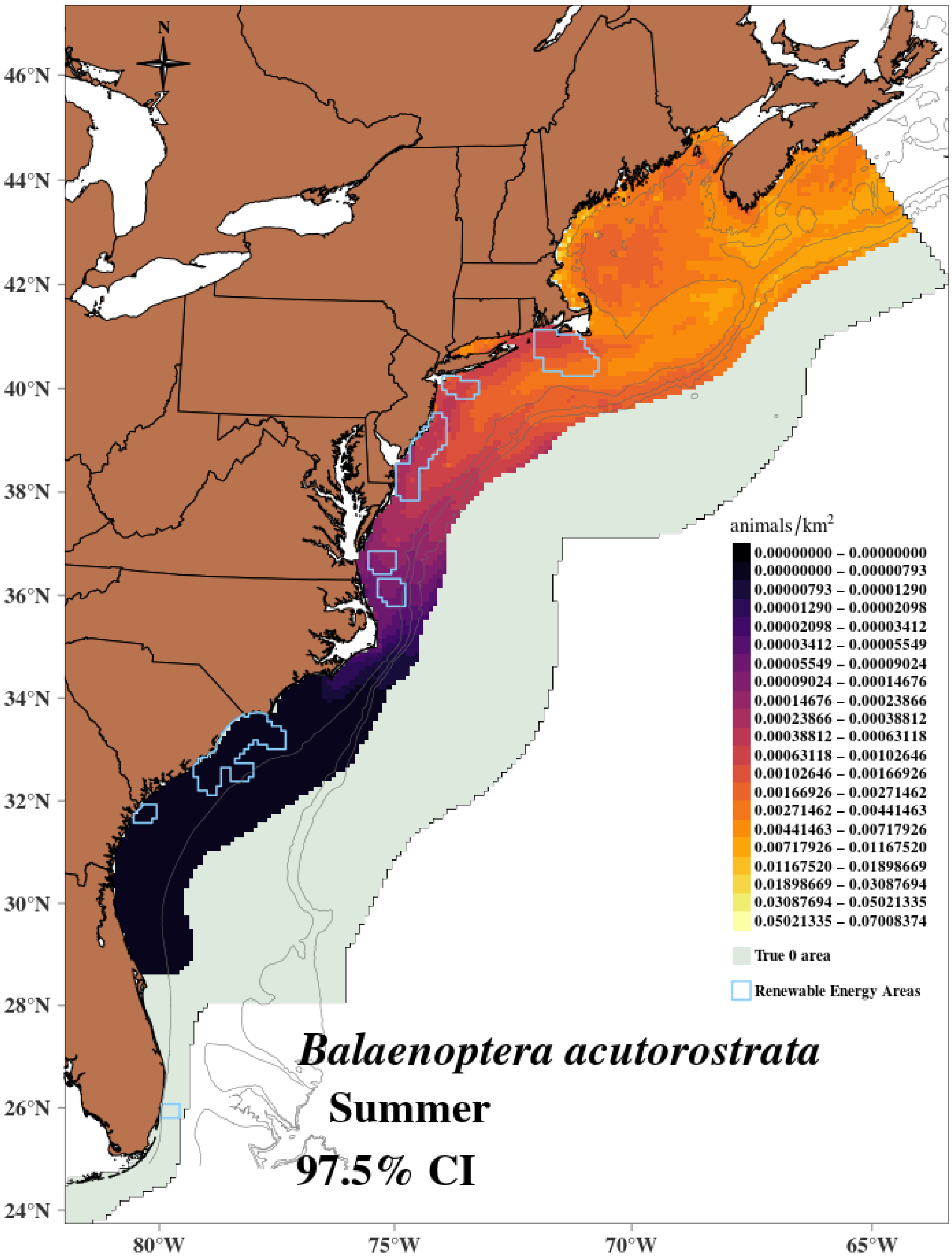

Figure 5-12 Upper 97.5% confidence interval of the summer minke whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

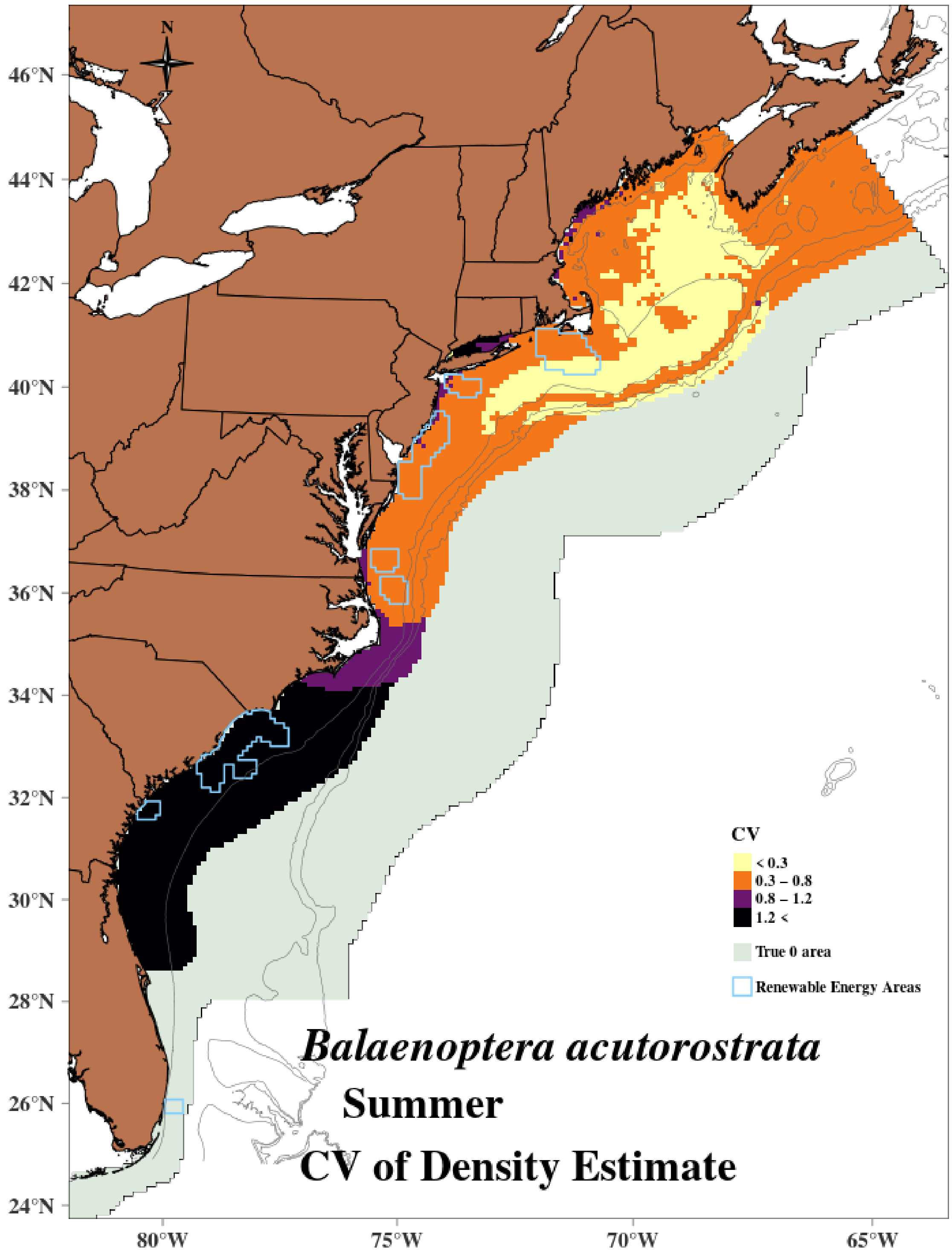

Figure 5-13 CV of summer minke whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

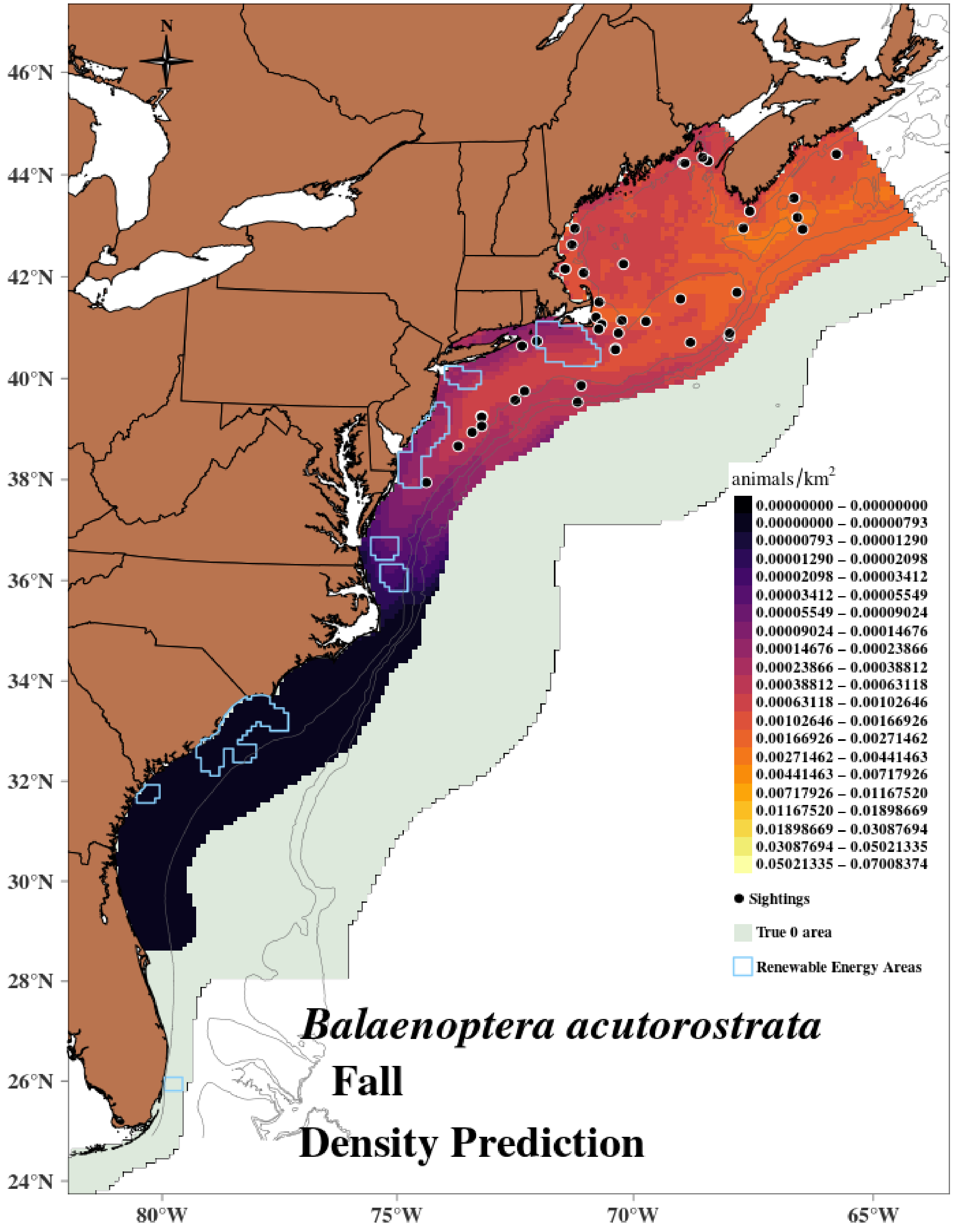

Figure 5-14 Minke whale fall average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

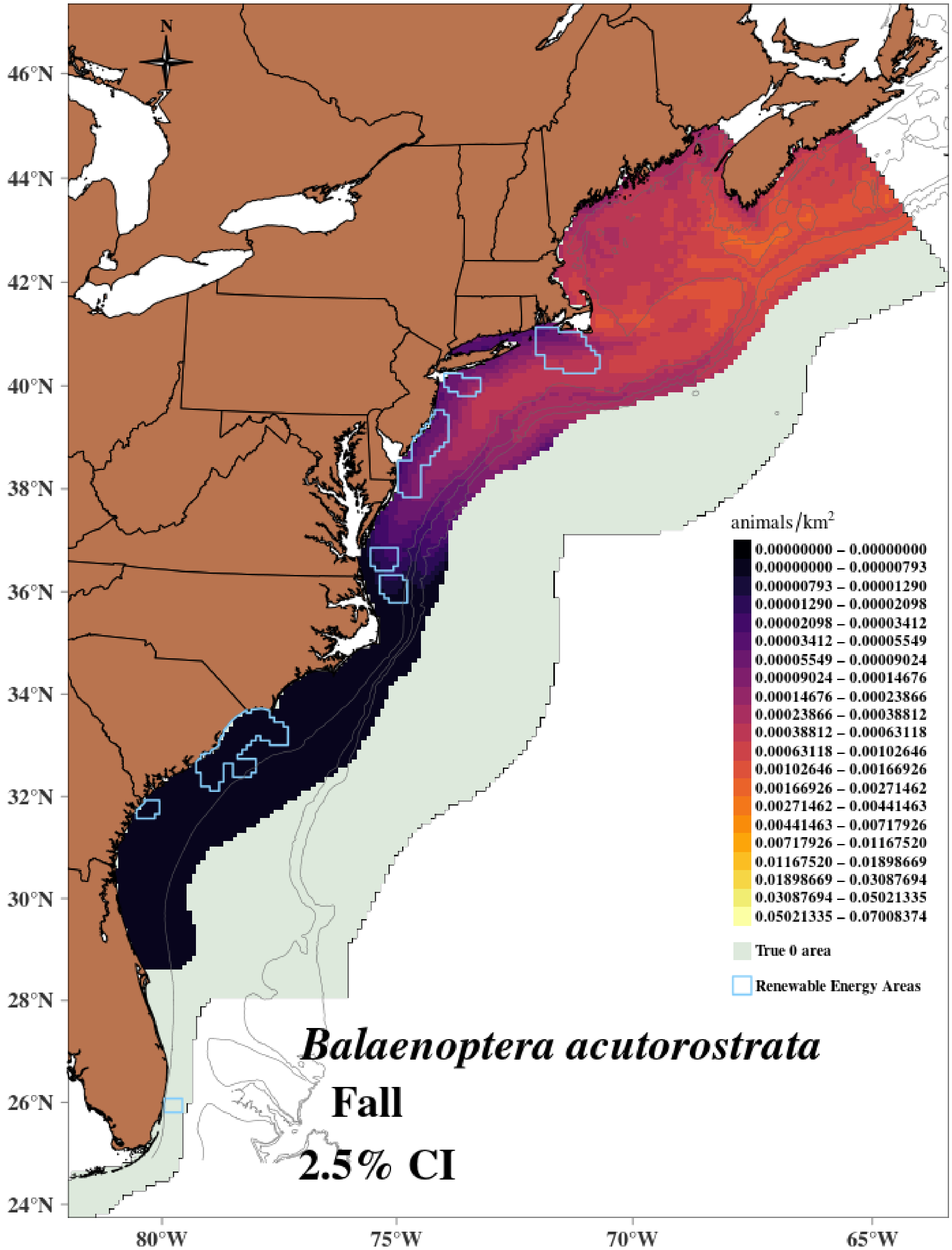

Figure 5-15 Lower 2.5% confidence interval of the fall minke whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

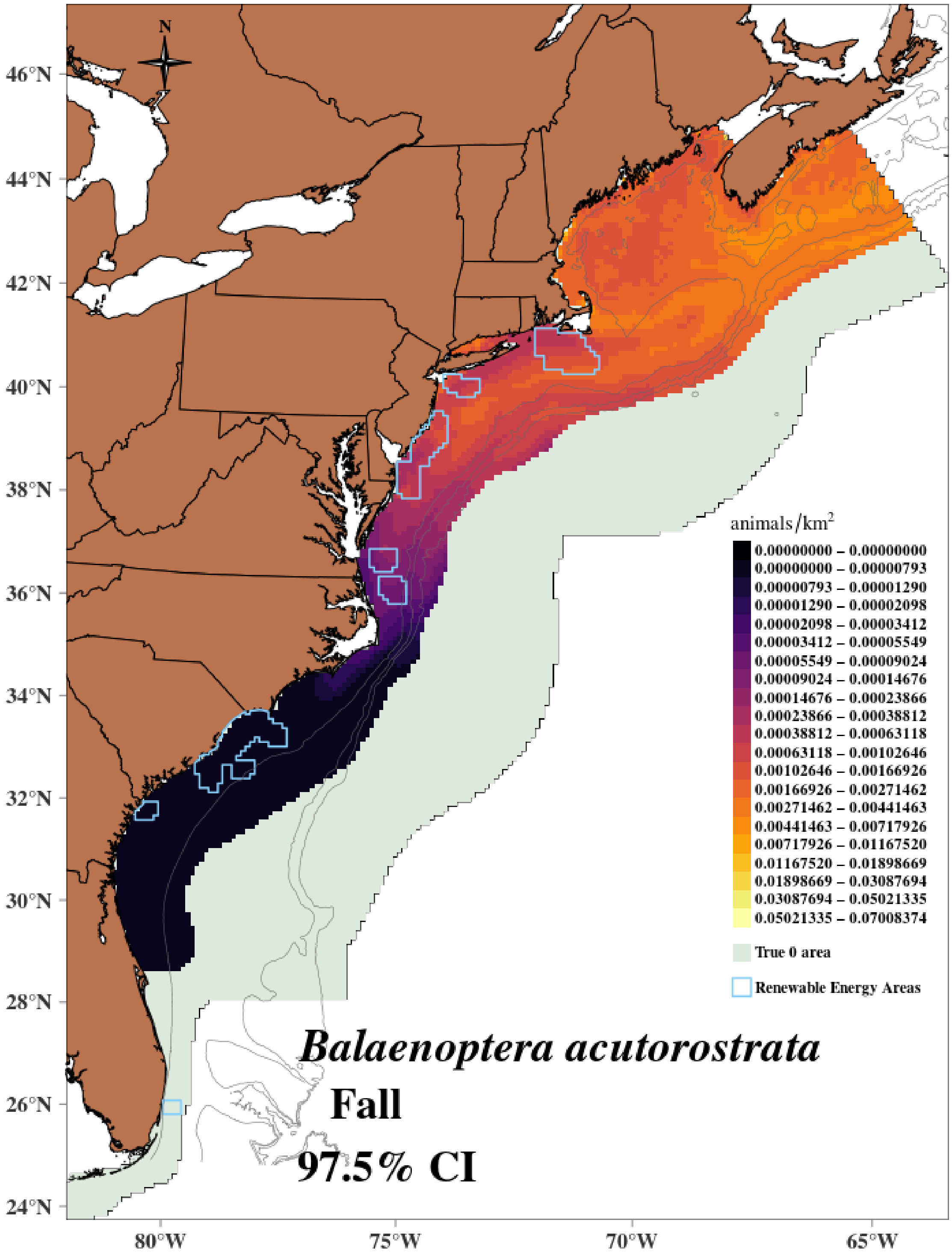

Figure 5-16 Upper 97.5% confidence interval of the fall minke whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

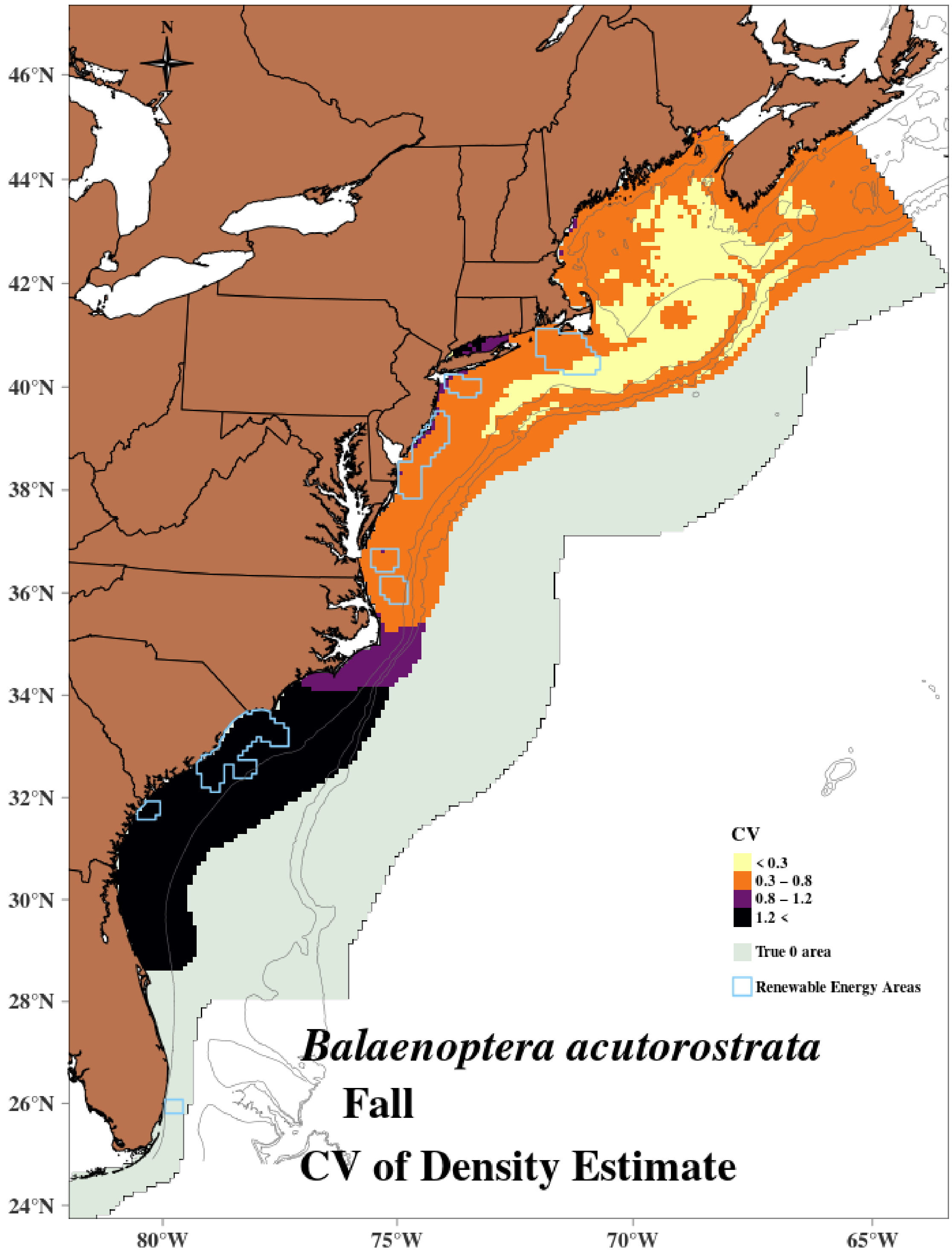

Figure 5-17 CV of fall minke whale density estimates

CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

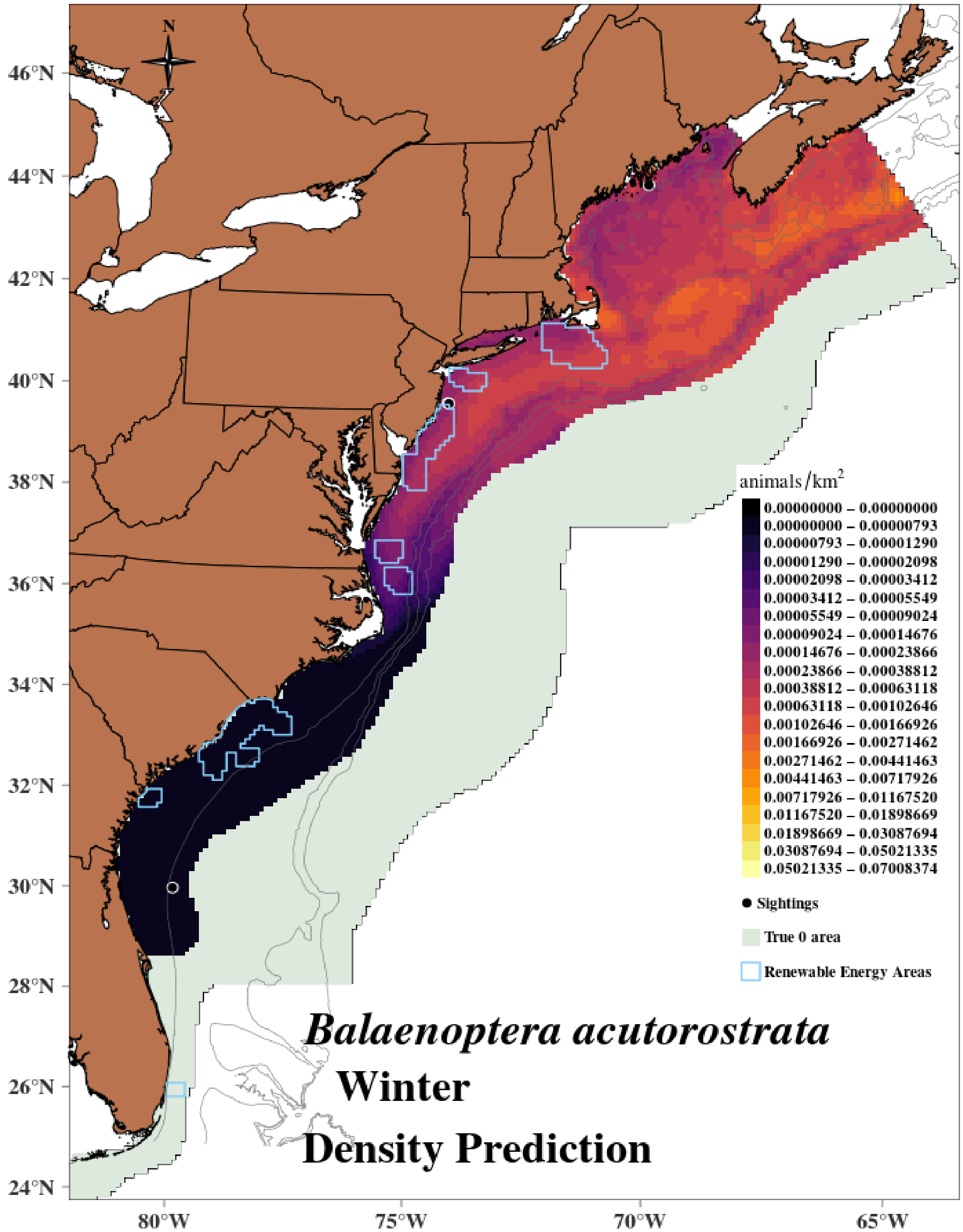

Figure 5-18 Minke whale winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

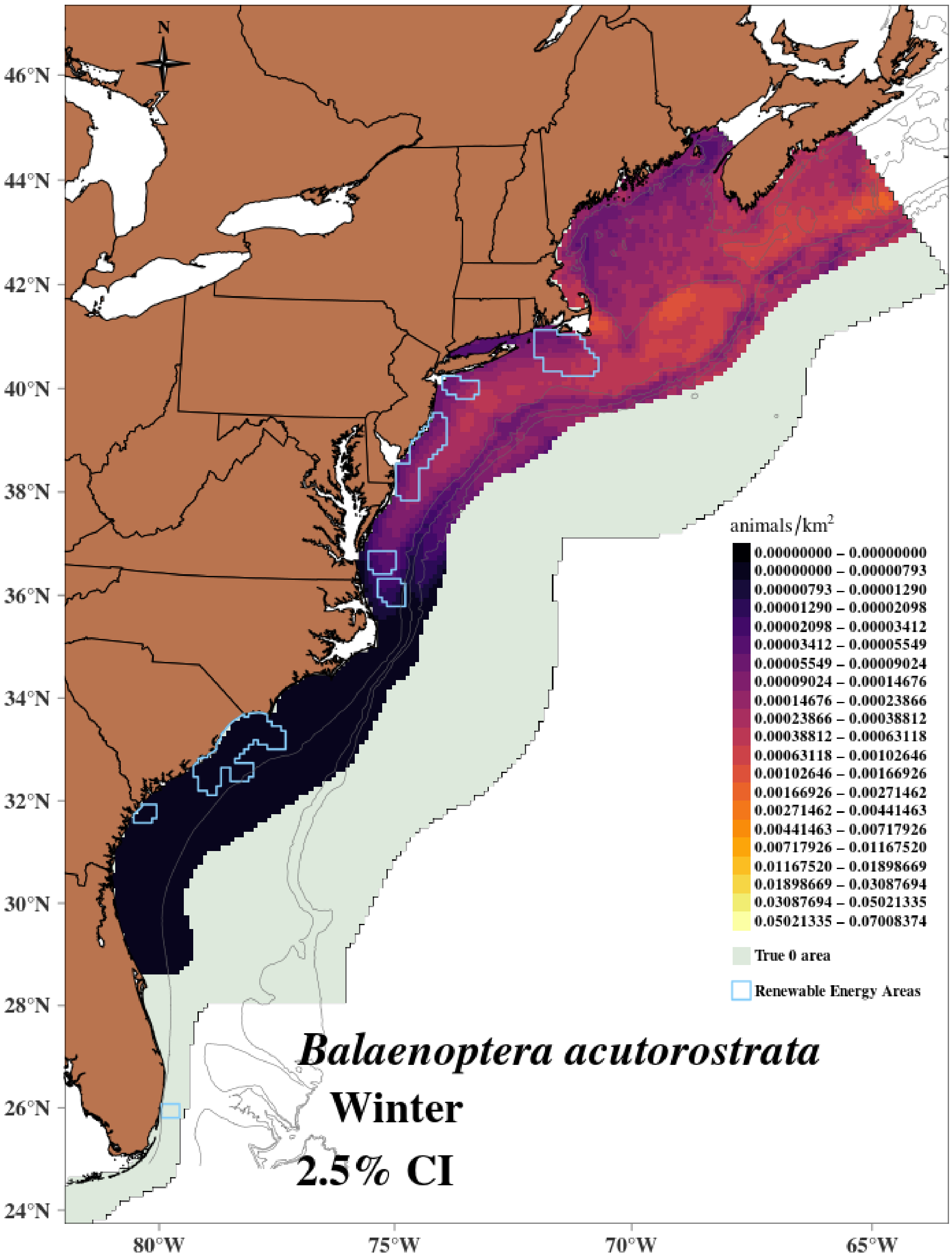

Figure 5-19 Lower 2.5% confidence interval of the winter minke whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

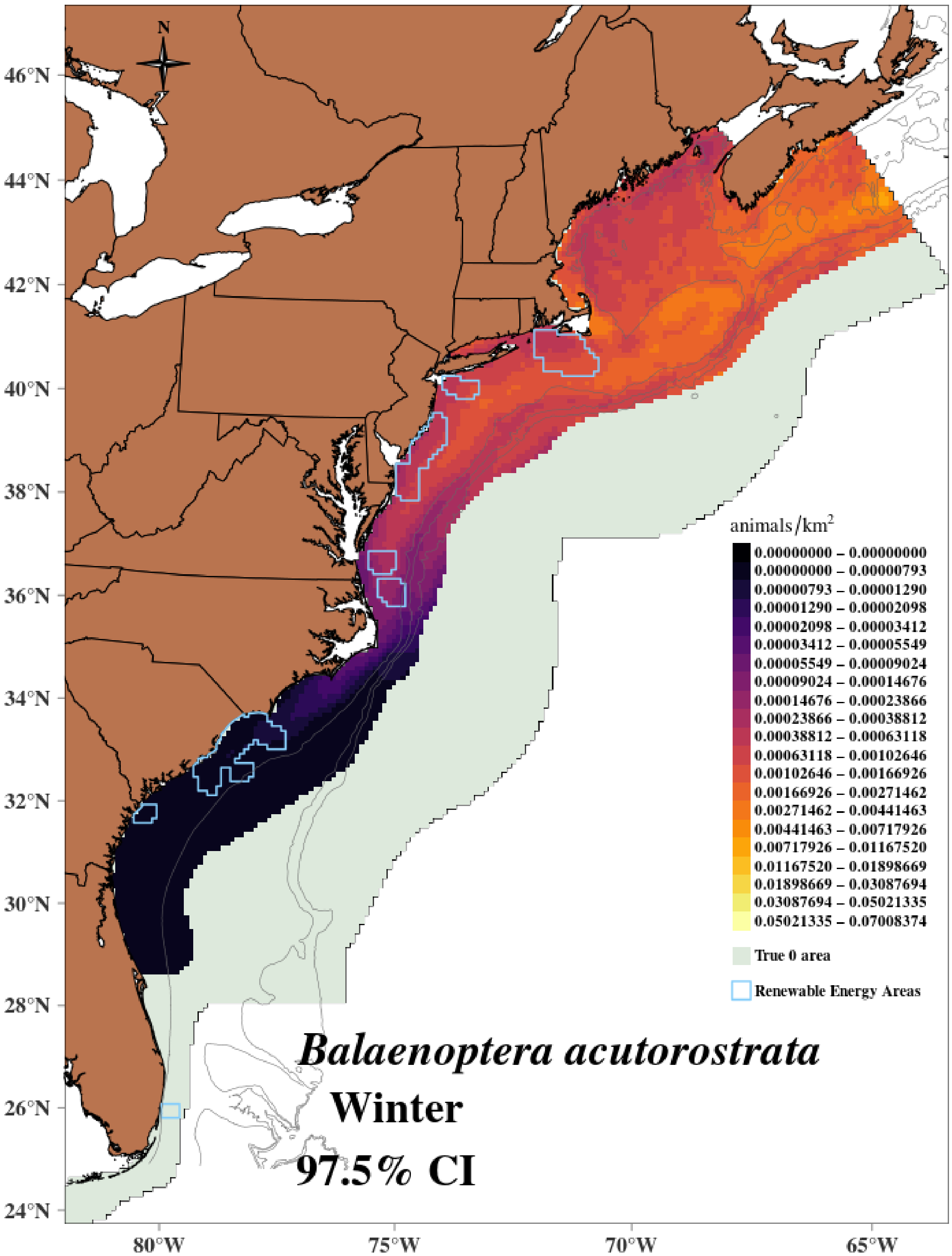

Figure 5-20 Upper 97.5% confidence interval of the winter minke whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

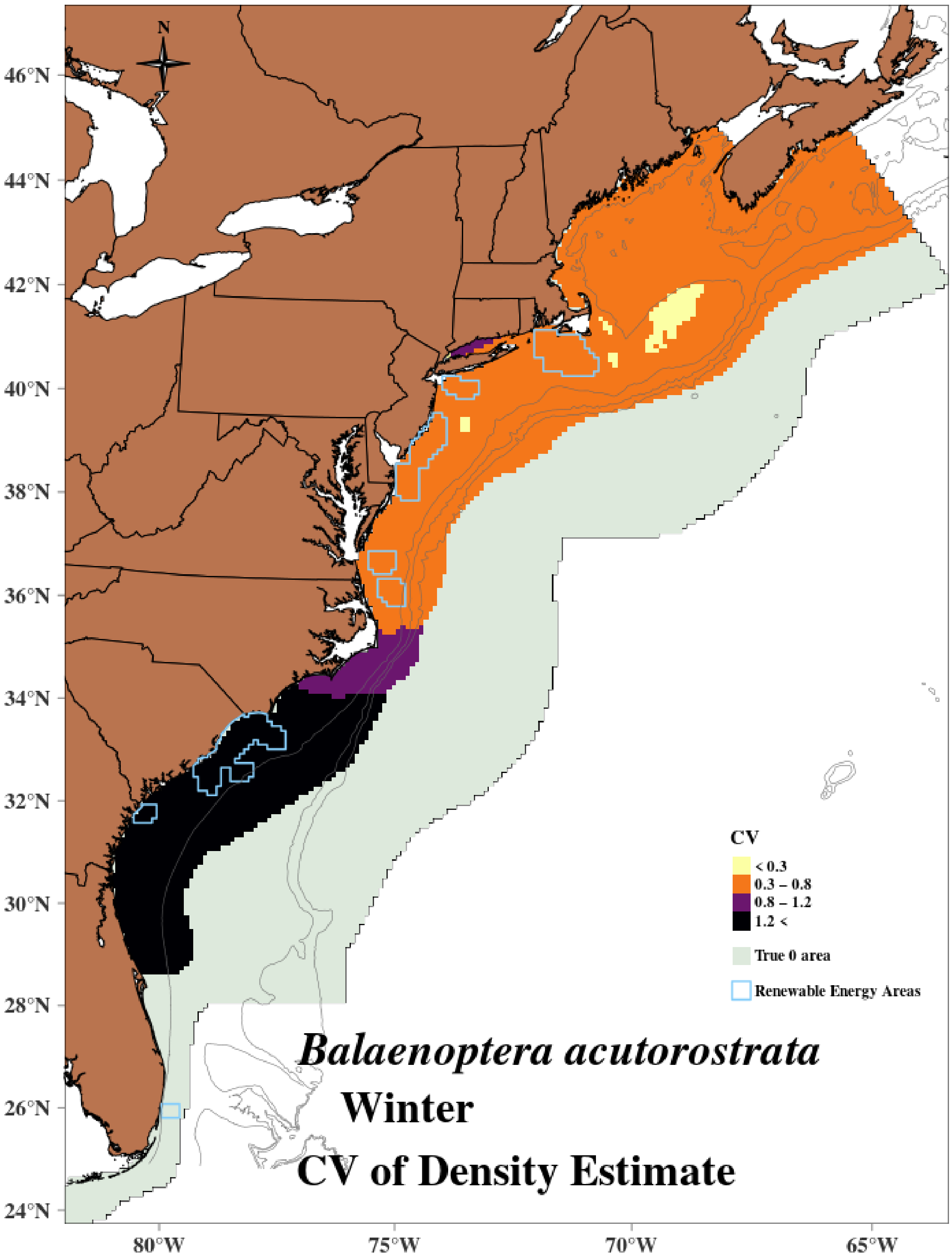

Figure 5-21 CV of winter minke whale density estimates

CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

5.7 Offshore Energy Development Areas

Table 5-6 Minke whale abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	15.7	0.44	6.9–35.8
	NY	1.8	0.44	0.8–4.0
	NJ	2.1	0.45	0.9–5.0
	DE/MD	1.3	0.44	0.6–3.0
	VA	0.4	0.56	0.1–1.0
	NC	0.3	0.65	0.1–0.8
	NC/SC	0.0	1.74	0.0–0.1
Summer (Jun–Aug)	RI/MA	13.1	0.34	6.9–24.8
	NY	1.3	0.50	0.5–3.2
	NJ	1.4	0.53	0.5–3.7
	DE/MD	0.7	0.46	0.3–1.6
	VA	0.1	0.56	0.0–0.4
	NC	0.1	0.64	0.0–0.3
	NC/SC	0.0	1.79	0.0–0.0
Fall (Sep–Nov)	RI/MA	6.7	0.36	3.4–13.3
	NY	1.0	0.50	0.4–2.5
	NJ	1.7	0.62	0.5–5.1
	DE/MD	0.7	0.53	0.3–2.0
	VA	0.1	0.57	0.0–0.4
	NC	0.1	0.64	0.0–0.3
	NC/SC	0.0	1.74	0.0–0.0
Winter (Dec–Feb)	RI/MA	5.3	0.40	2.5–11.2
	NY	1.0	0.42	0.4–2.1
	NJ	1.6	0.44	0.7–3.5
	DE/MD	0.9	0.42	0.4–2.0
	VA	0.3	0.55	0.1–0.7
	NC	0.2	0.64	0.1–0.5
	NC/SC	0.0	1.72	0.0–0.1

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

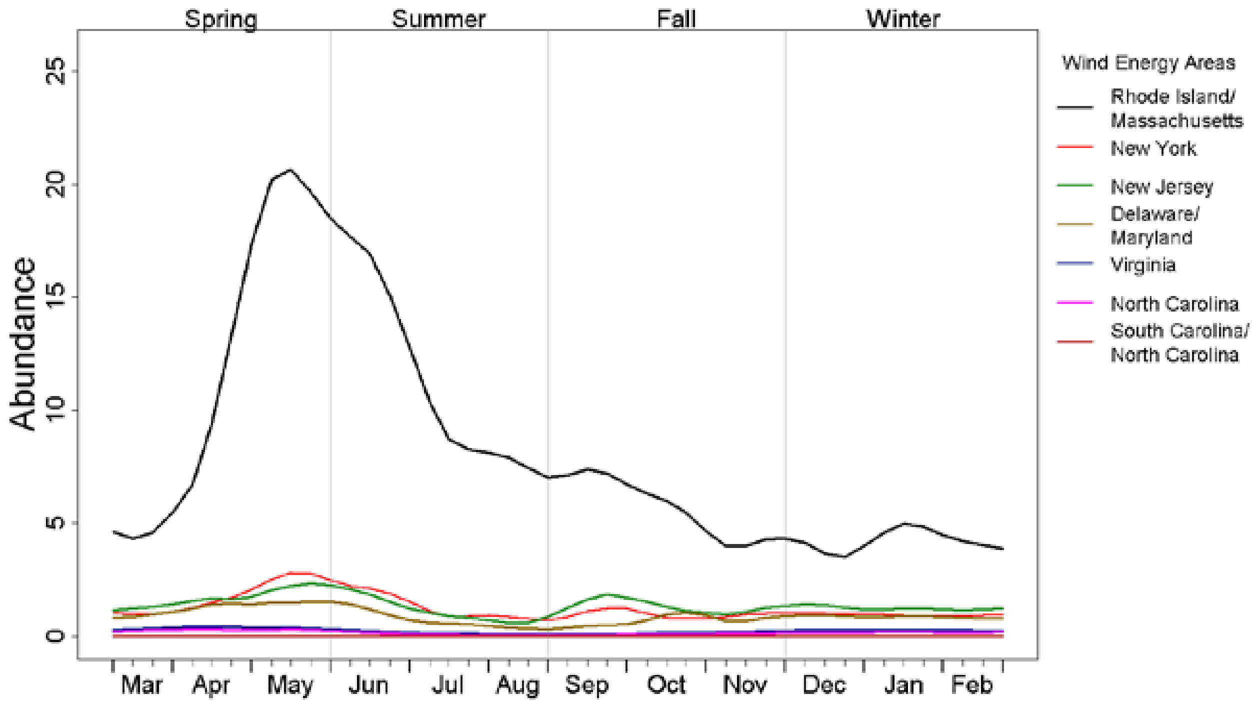

Figure 5-22 Average seasonal abundance of minke whales in the wind-energy study areas

6 Sperm Whale (*Physeter macrocephalus*)

Figure 6-1 Sperm whales
Image collected under MMPA Research permit #775-1875. Credit: NOAA/NEFSC

6.1 Data Collection

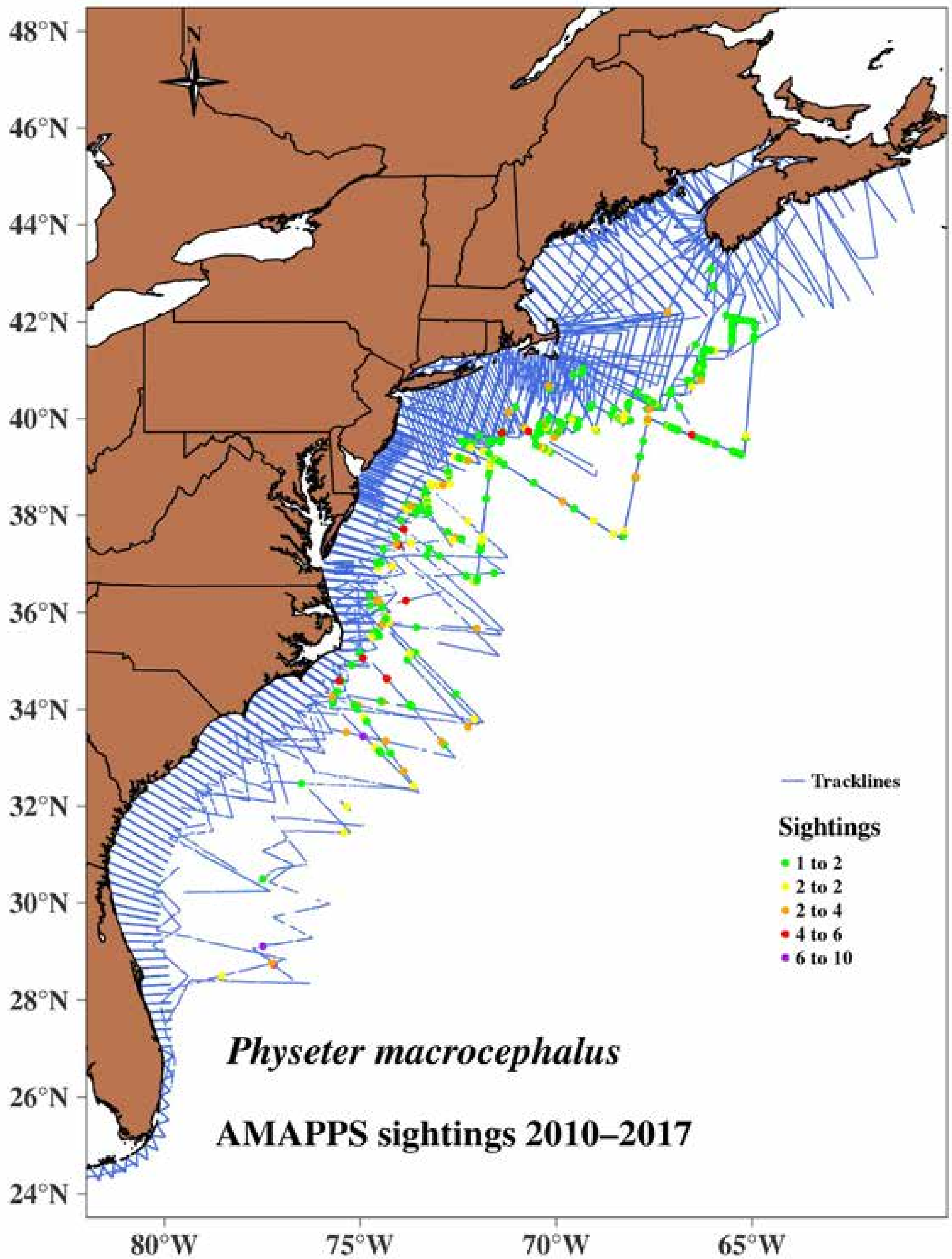

Figure 6-2 Distribution of track lines and sperm whale sightings 2010 to 2017

Table 6-1 AMAPPS research effort 2010 to 2017 and sperm whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	298	491
NE Shipboard	Fall	1,065	27	45
NE Aerial	Spring	13,314	3	3
NE Aerial	Summer	25,867	5	10
NE Aerial	Fall	37,850	6	9
NE Aerial	Winter	12,179	0	0
SE Shipboard	Spring	8,853	38	44
SE Shipboard	Summer	12,968	70	156
SE Shipboard	Fall	3,012	12	38
SE Aerial	Spring	41,293	7	7
SE Aerial	Summer	28,236	3	3
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

6.2 Mark-Recapture Distance Sampling Analysis

Table 6-2 Intermediate parameters in sperm whale mark-recapture distance sampling models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 4	distance * observer + sea state + glare	300	distance	LT43- 300	HR	0.86	0.18	0.98	0.96	0.95
NE–aerial group 3	distance + group size	1500	Distance + sea state + quality	1500	HR	0.67	0.09	0.06	0.87	0.94
NE–shipboard group 9	distance * observer + glare + group size	4600	distance + swell	4600	HR	0.58	0.11	0.12	0.90	0.97
SE–shipboard group 5	distance * observer + group size	6000	distance + glare + time of day	6000	HR	0.57	0.11	0.24	0.61	0.65

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

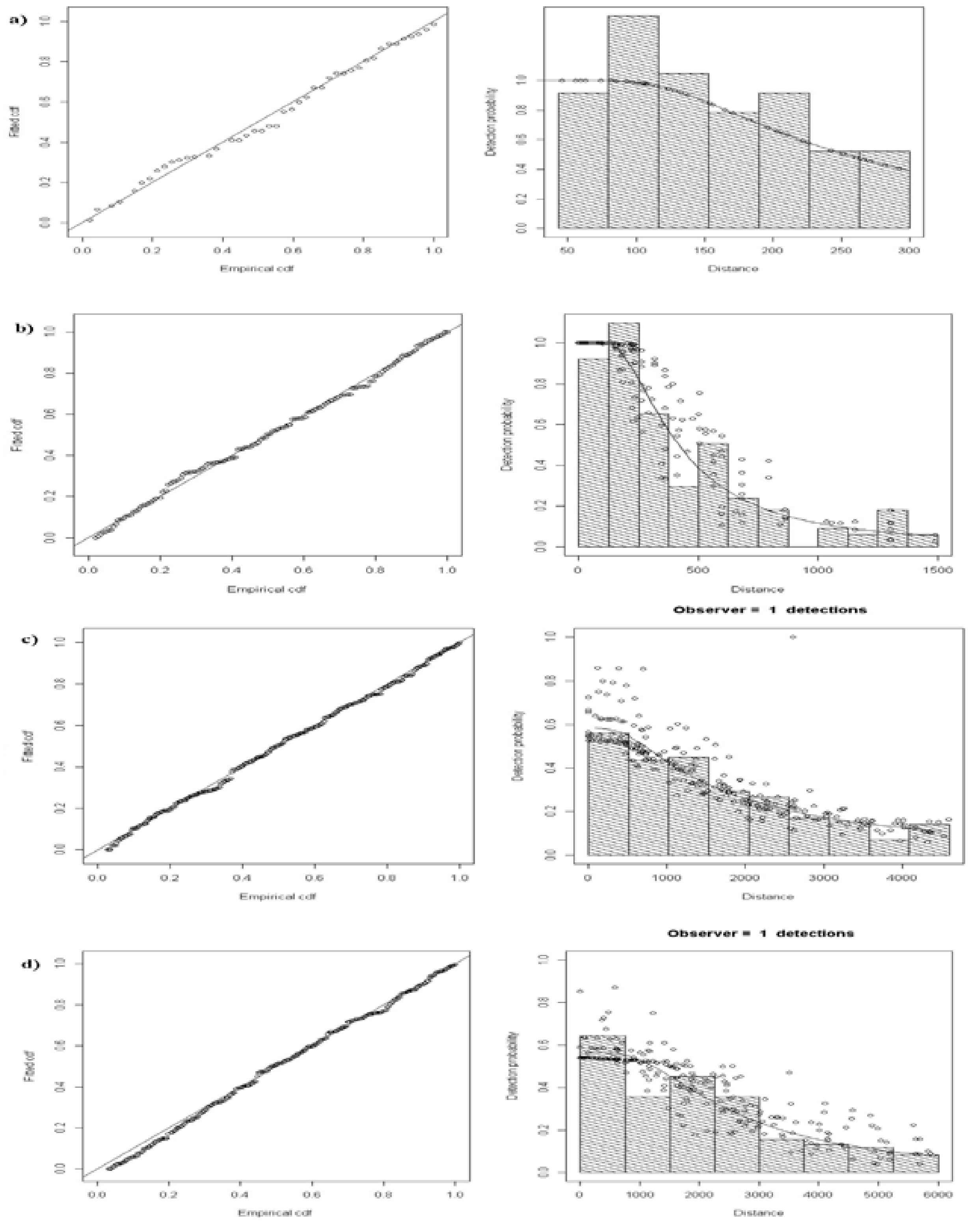

Figure 6-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 4; b) NE-aerial analysis set 3; c) NE-shipboard analysis set 9; d) SE-shipboard analysis set 5.

6.3 Generalized Additive Model Analysis

Table 6-3 2010 to 2017 density-habitat model output for sperm whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(sstmur)	1.18	4	7.91	10.79	<0.0001
s(btemp)	2.90	4	8.55	2.16	<0.0001
s(dist2GSNw)	2.64	4	2.86	0.52	0.0032
s(depth)	2.12	4	15.78	10.58	<0.0001
s(dist1000)	2.94	4	21.94	22.17	<0.0001
s(lat)	1.11	4	8.89	6.06	<0.0001

Adjusted R^2 = 0.0319 Deviance explained = 52.3%
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

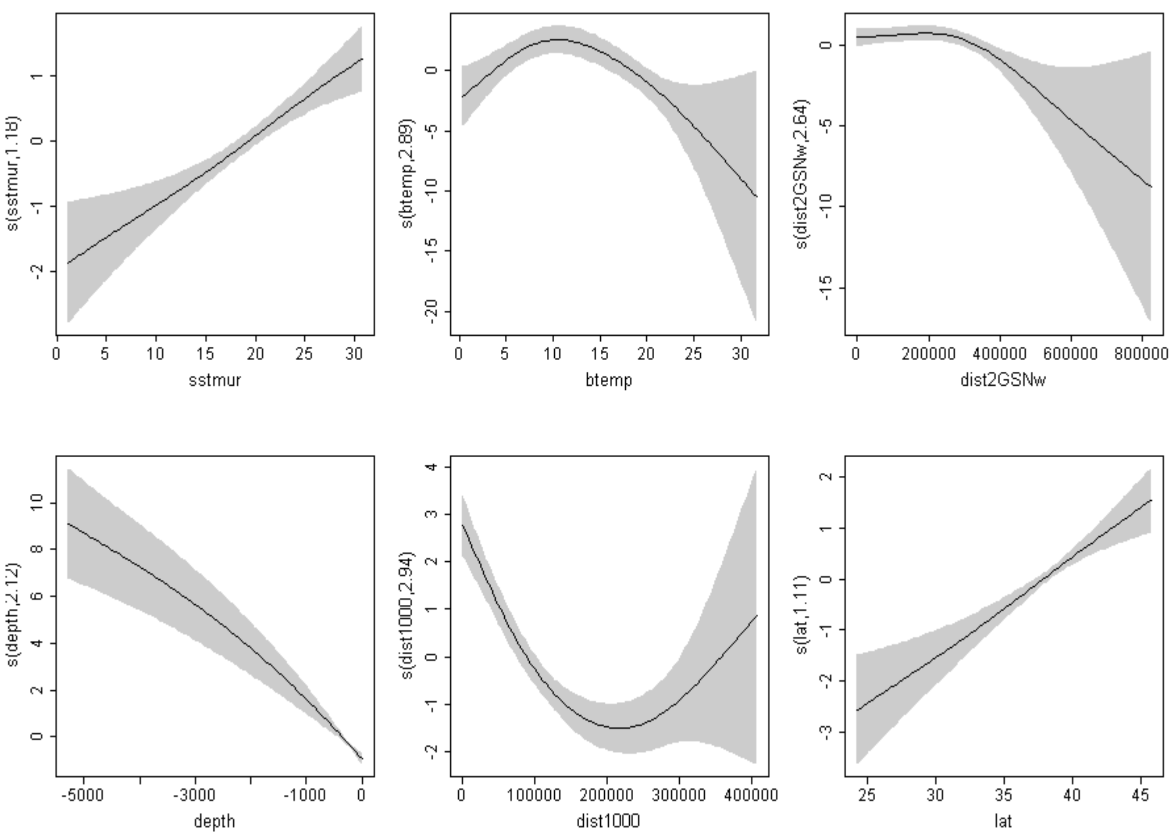

Figure 6-4 Sperm whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

6.4 Model Cross-Validation

Table 6-4 Diagnostic statistics from the sperm whale density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.191	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	86.680	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.149	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.003	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

6.5 Abundance Estimates for AMAPPS Study Area

Table 6-5 Sperm whale average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	2,576	0.35	1,323–5,015
Summer (June–August)	5,342	0.29	3,061–9,324
Fall (September–November)	4,641	0.30	2,611–8,251
Winter (December–February)	2,580	0.34	1,349–4,934
Summer 2011 U.S. surveys[1]	39	0.64	
Summer 2016 U.S. surveys[1]	4,349	0.28	

[1]Hayes et al. 2020

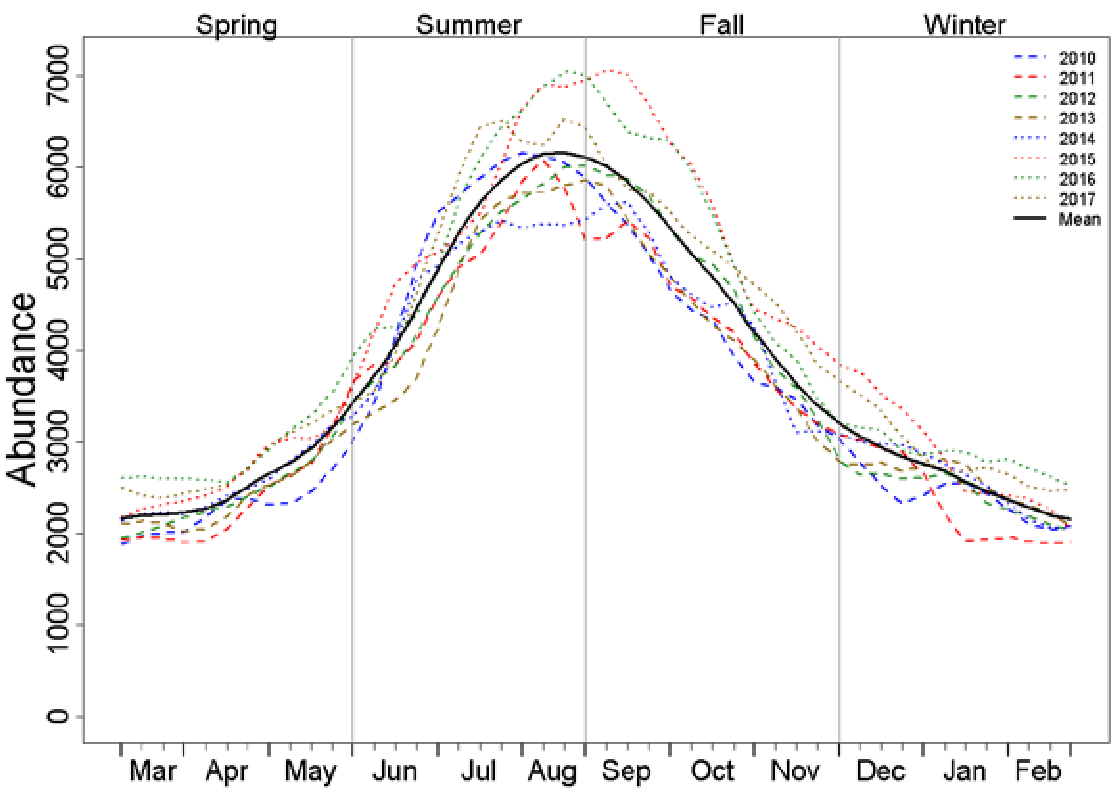

Figure 6-5 Annual abundance trends for sperm whales in the AMAPPS study area

6.6 Seasonal Prediction Maps

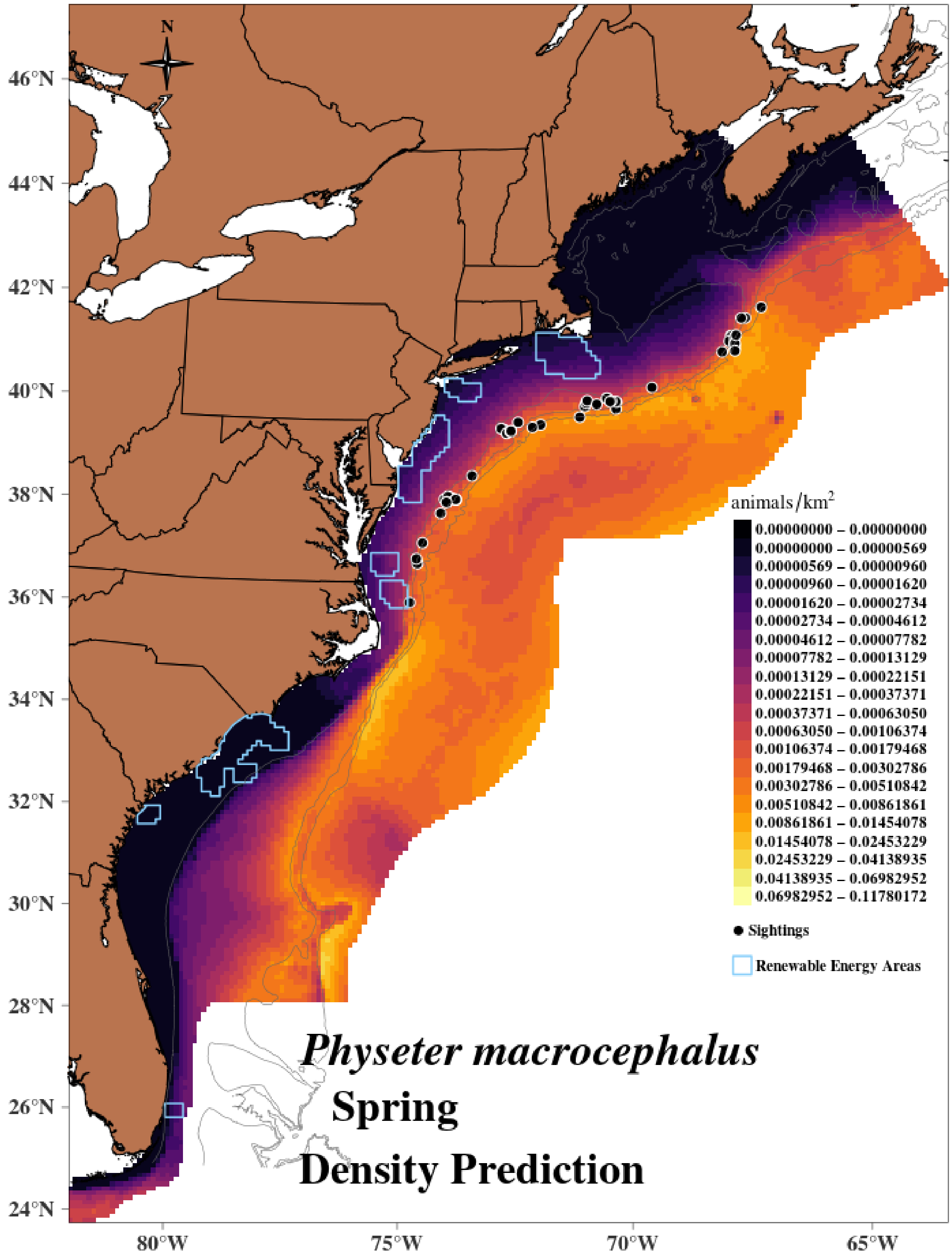

Figure 6-6 Sperm whale spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

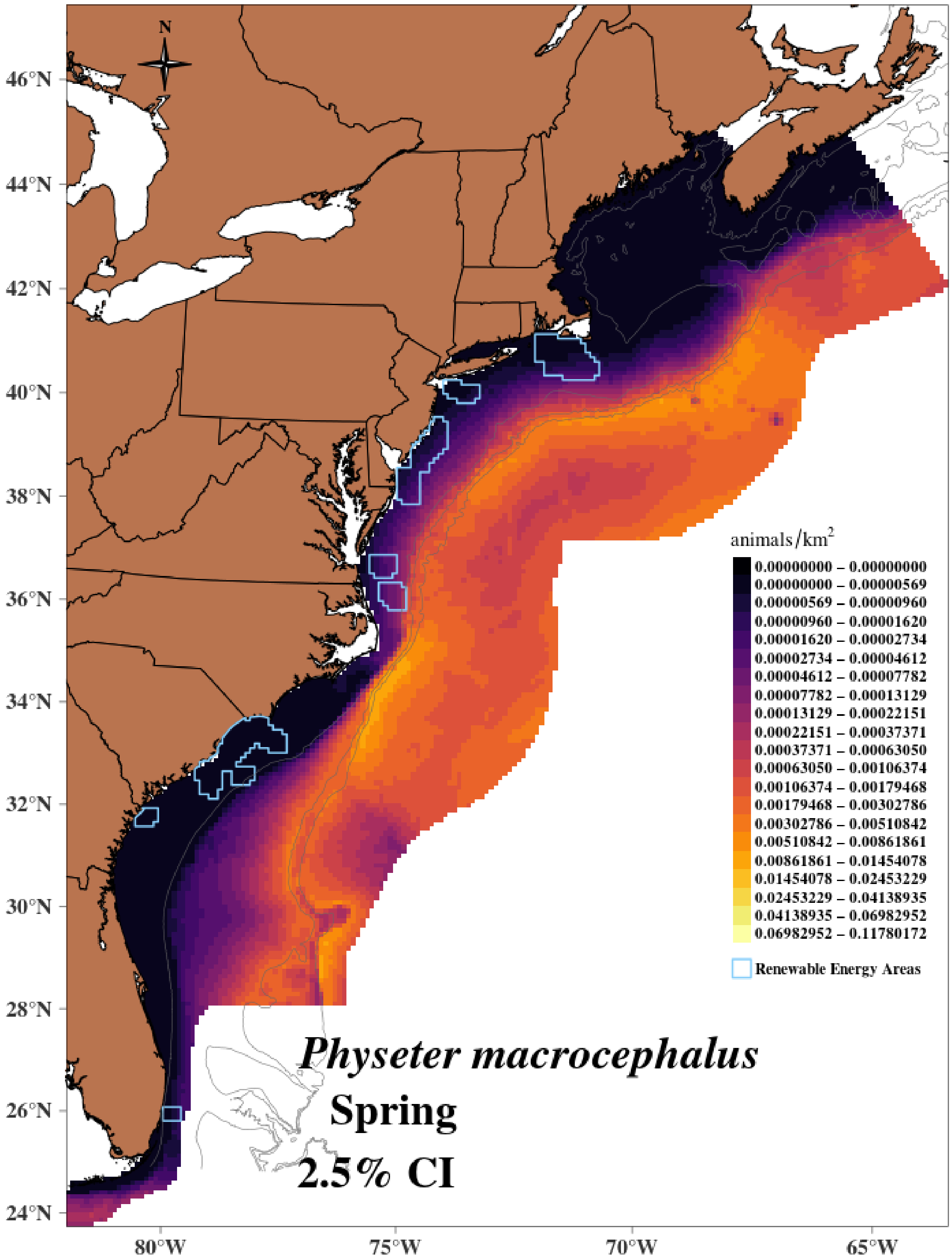

Figure 6-7 Lower 2.5% confidence interval of the spring sperm whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

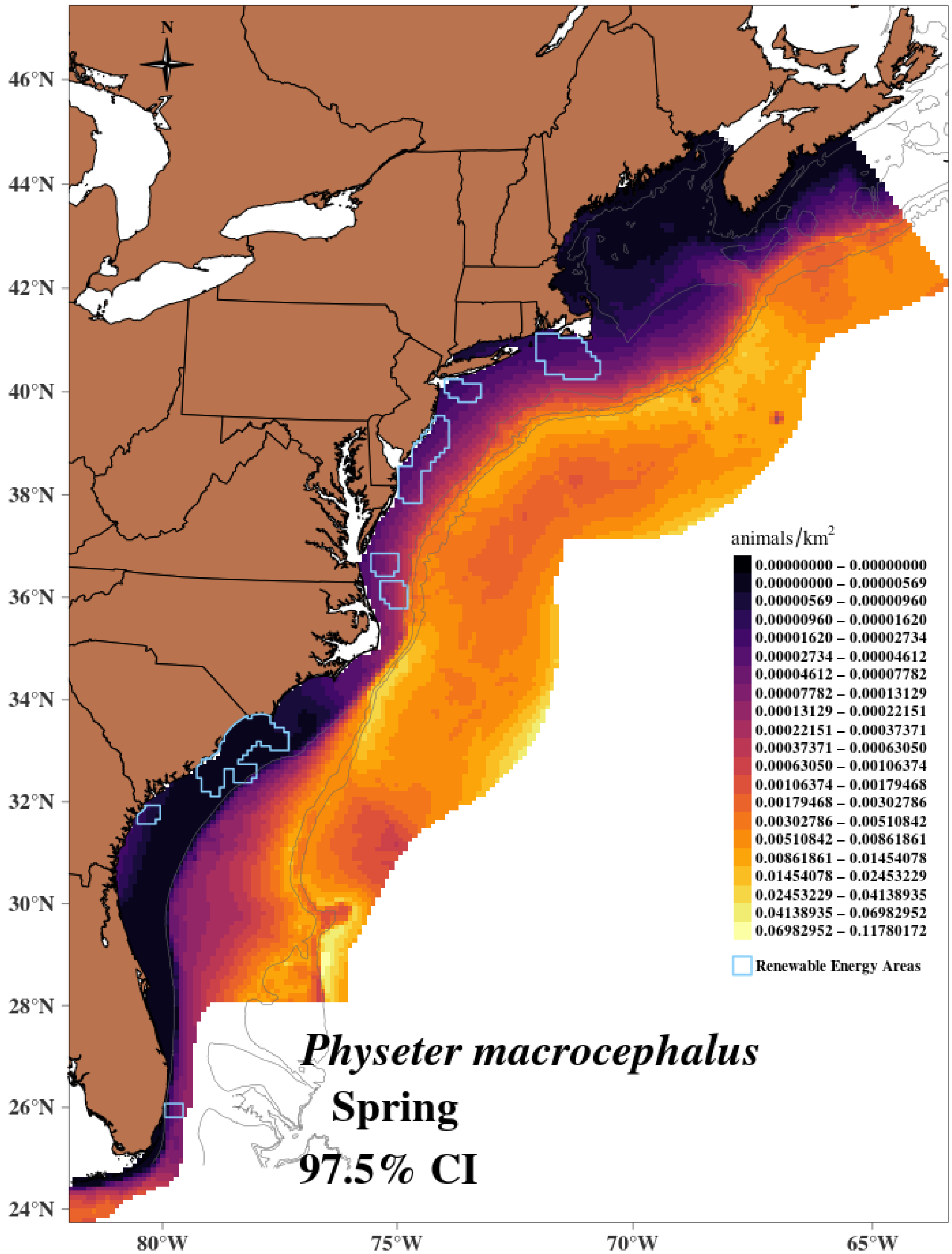

Figure 6-8 Upper 97.5% confidence interval of the spring sperm whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

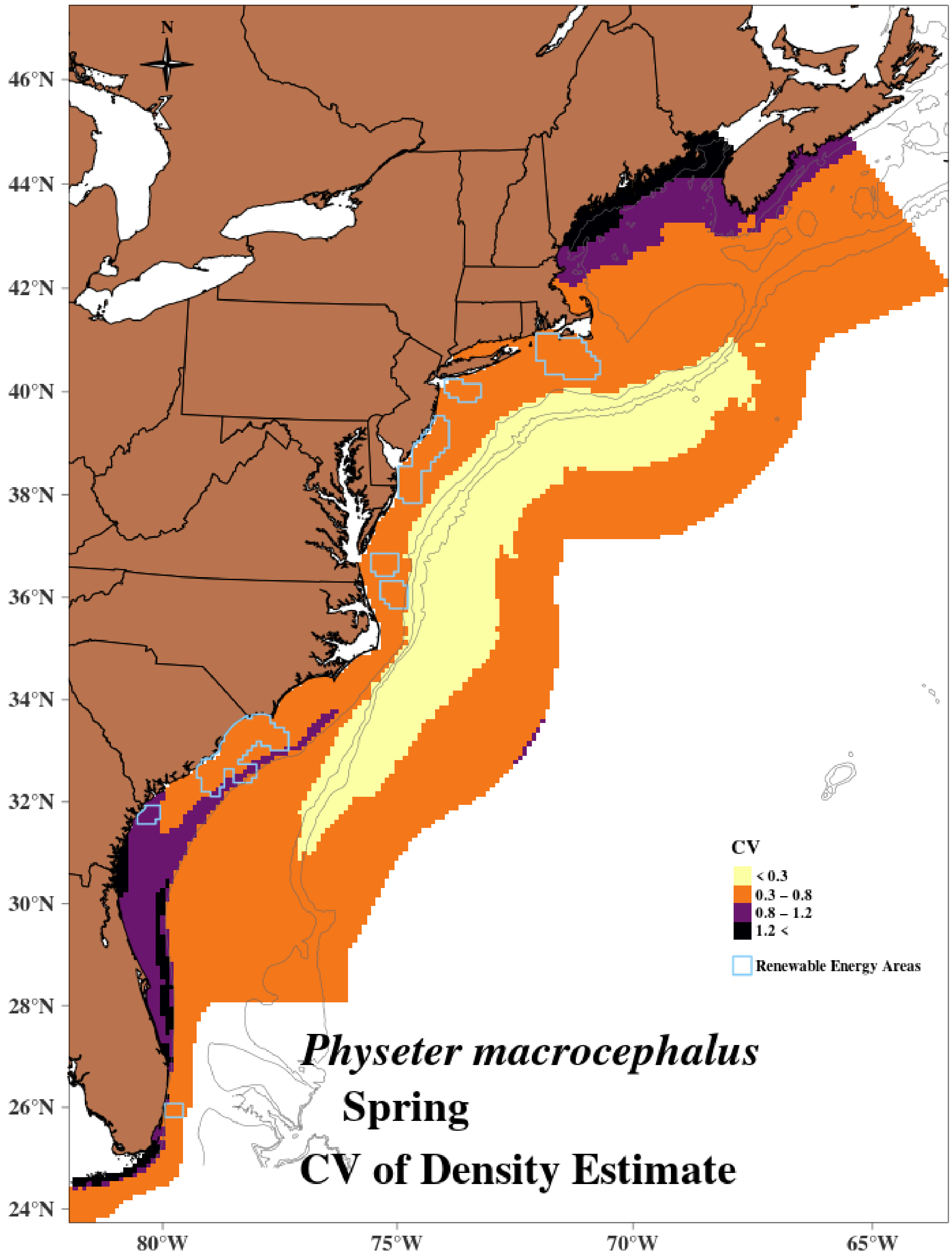

Figure 6-9 CV of spring sperm whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

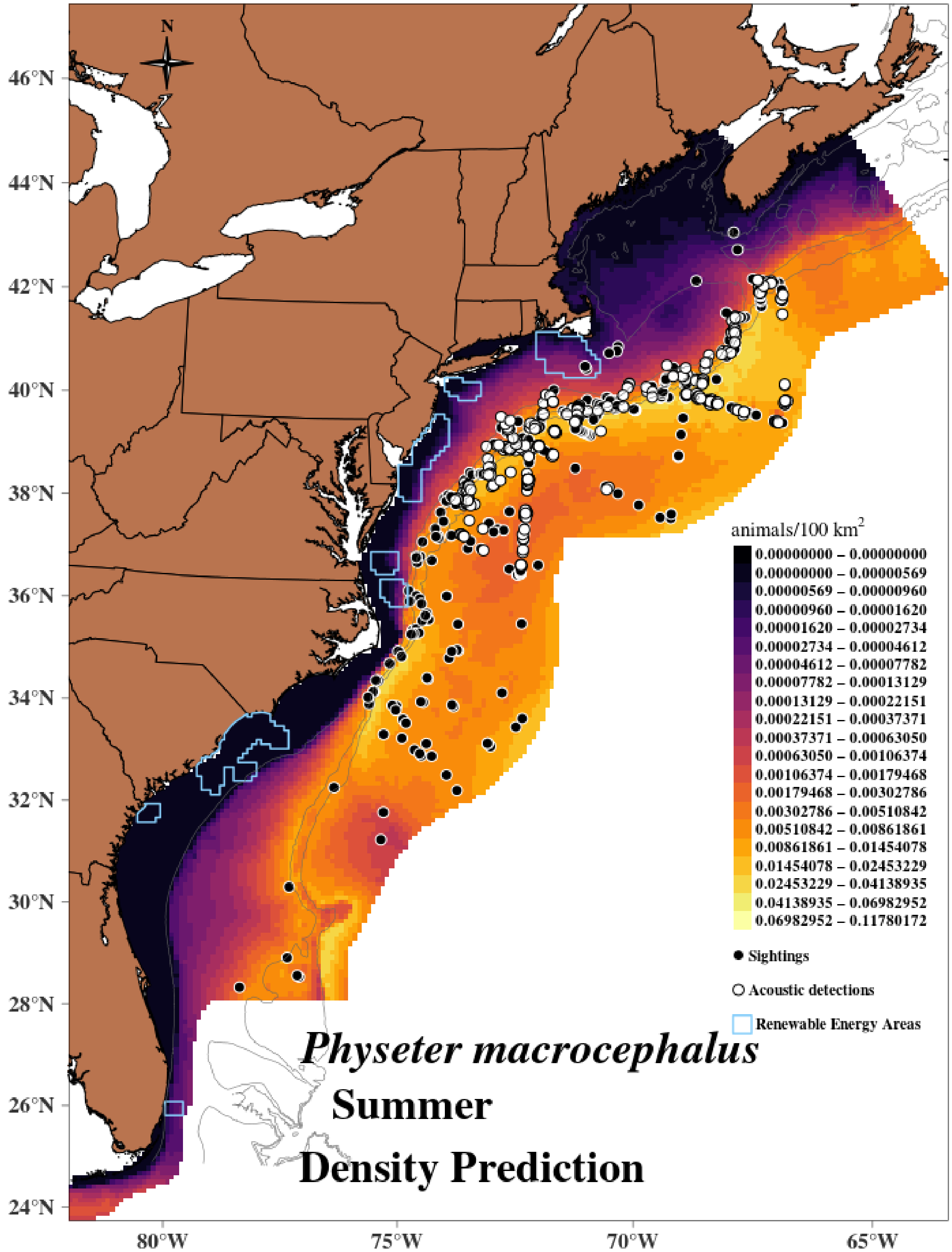

Figure 6-10 Sperm whale summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Black circles indicate locations of animal sightings. White circles are locations of sperm whale passive acoustic detections from the NEFSC 2011 and 2013 towed hydrophone arrays. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

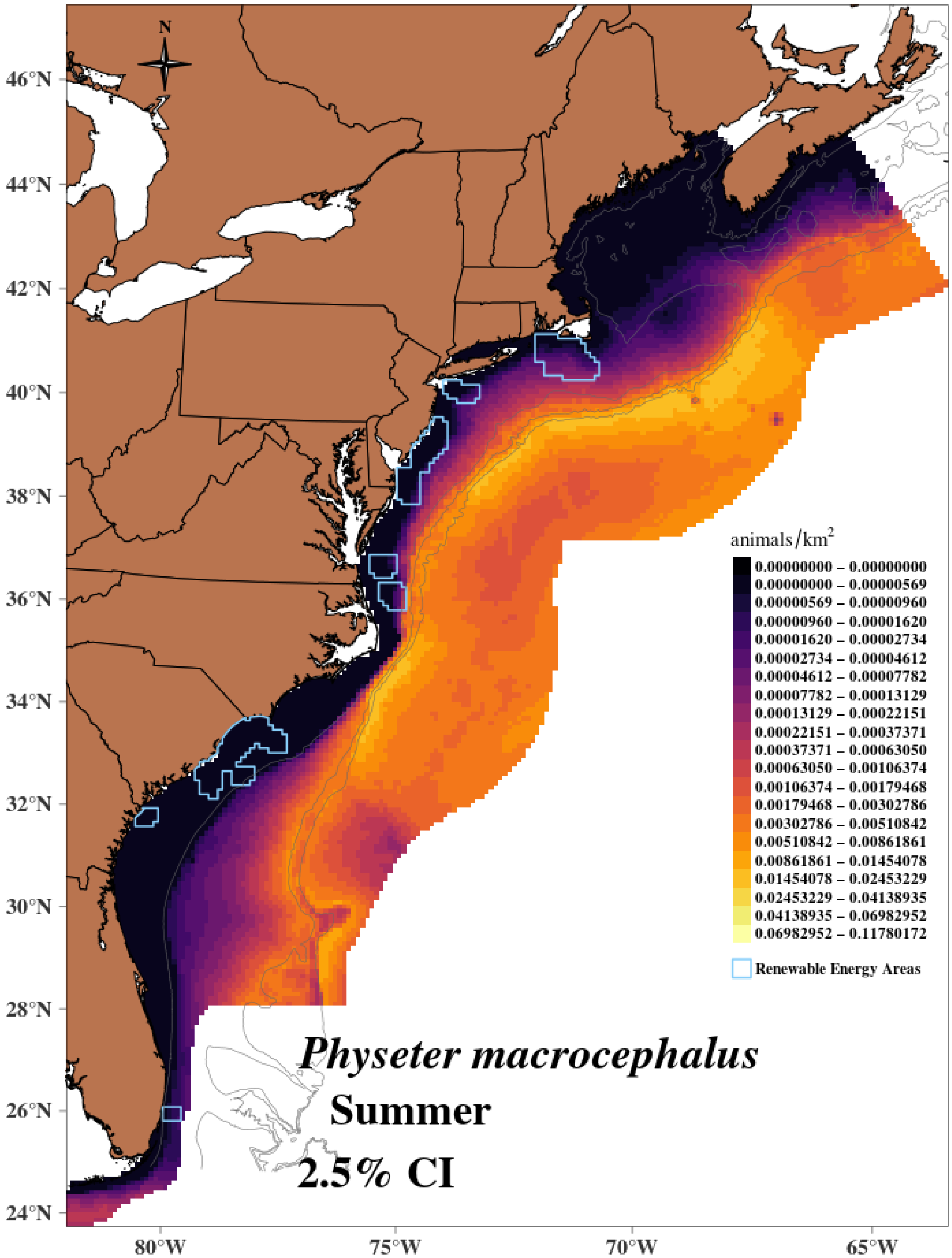

Figure 6-11 Lower 2.5% confidence interval of the summer sperm whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

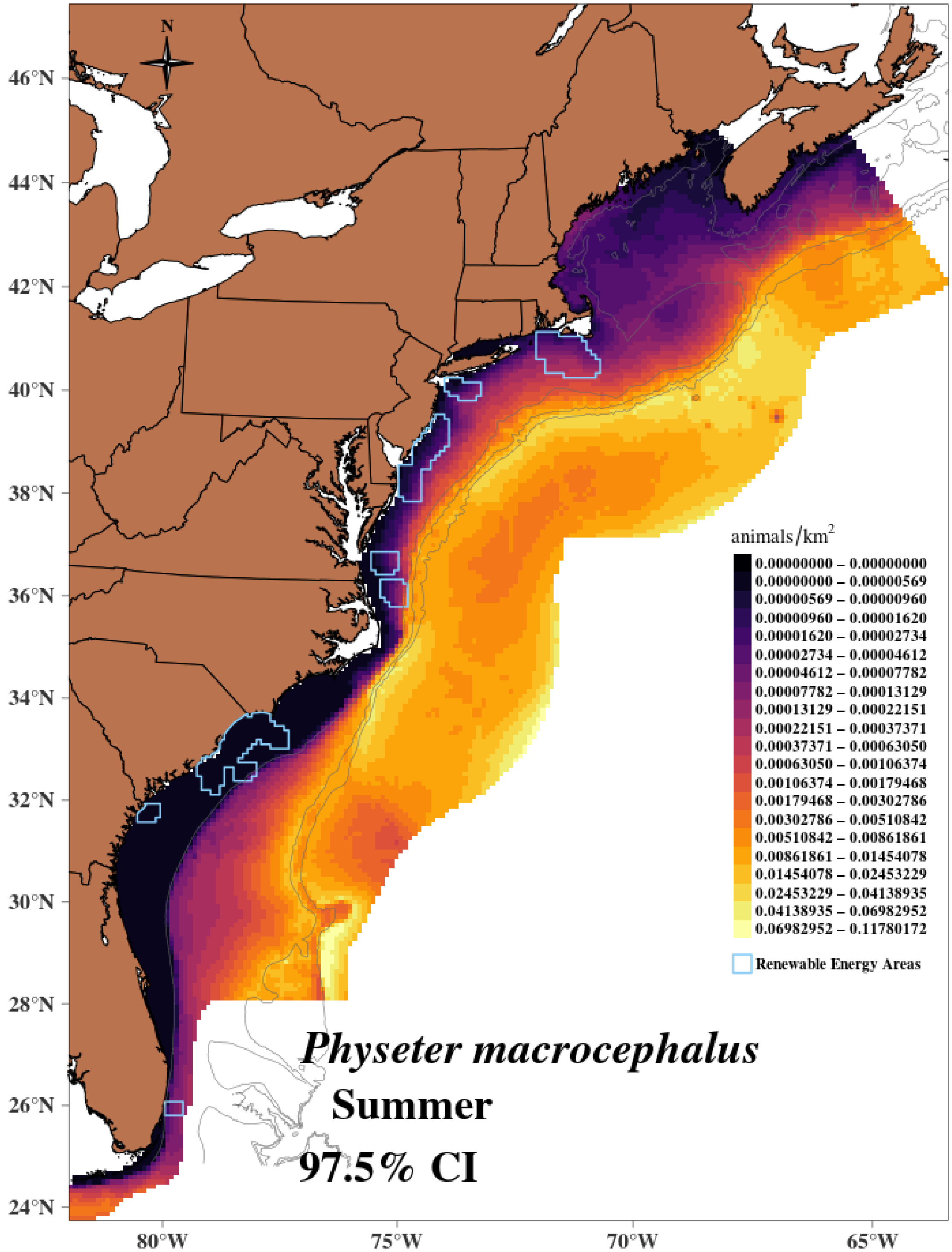

Figure 6-12 Upper 97.5% confidence interval of the summer sperm whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

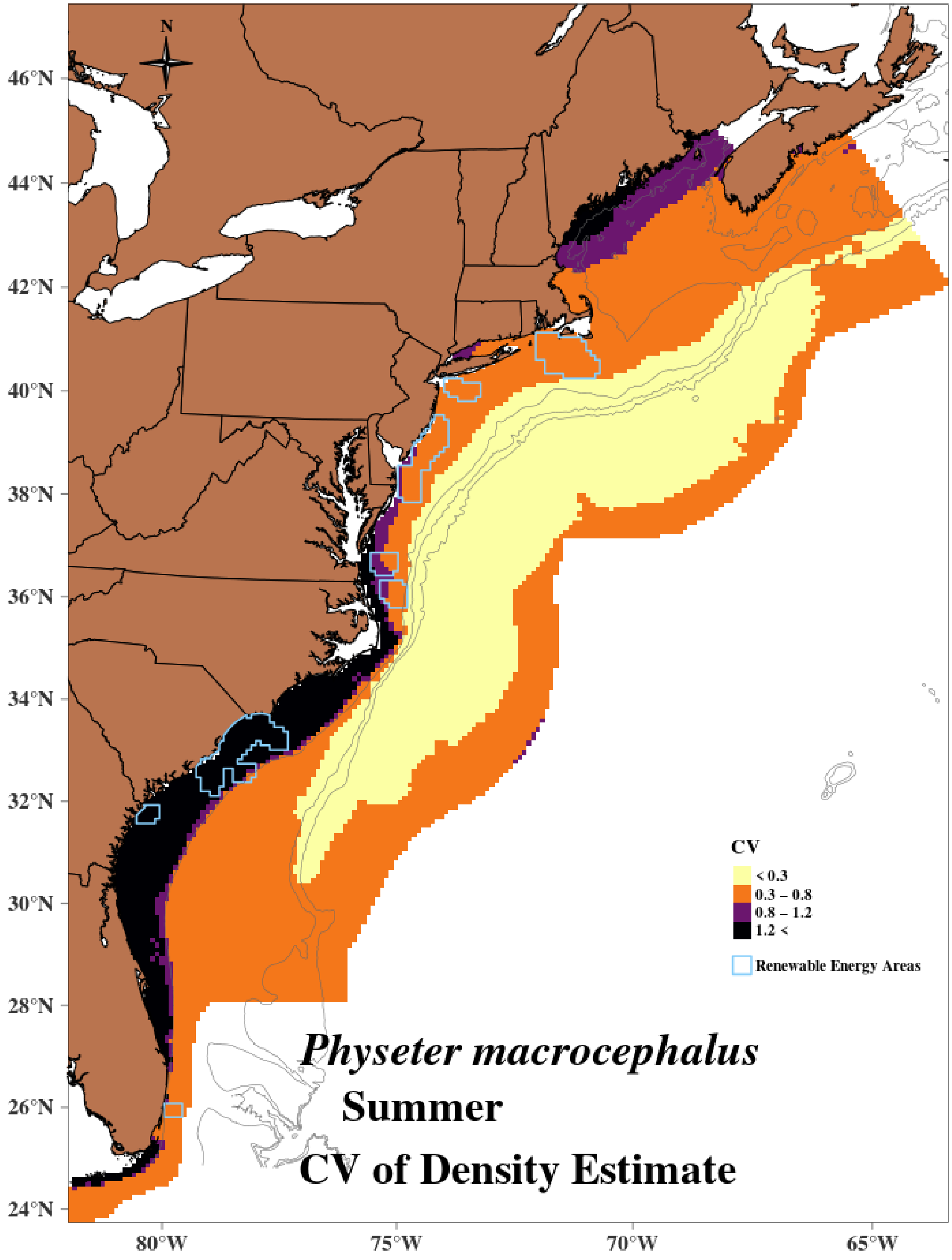

Figure 6-13 CV of summer sperm whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

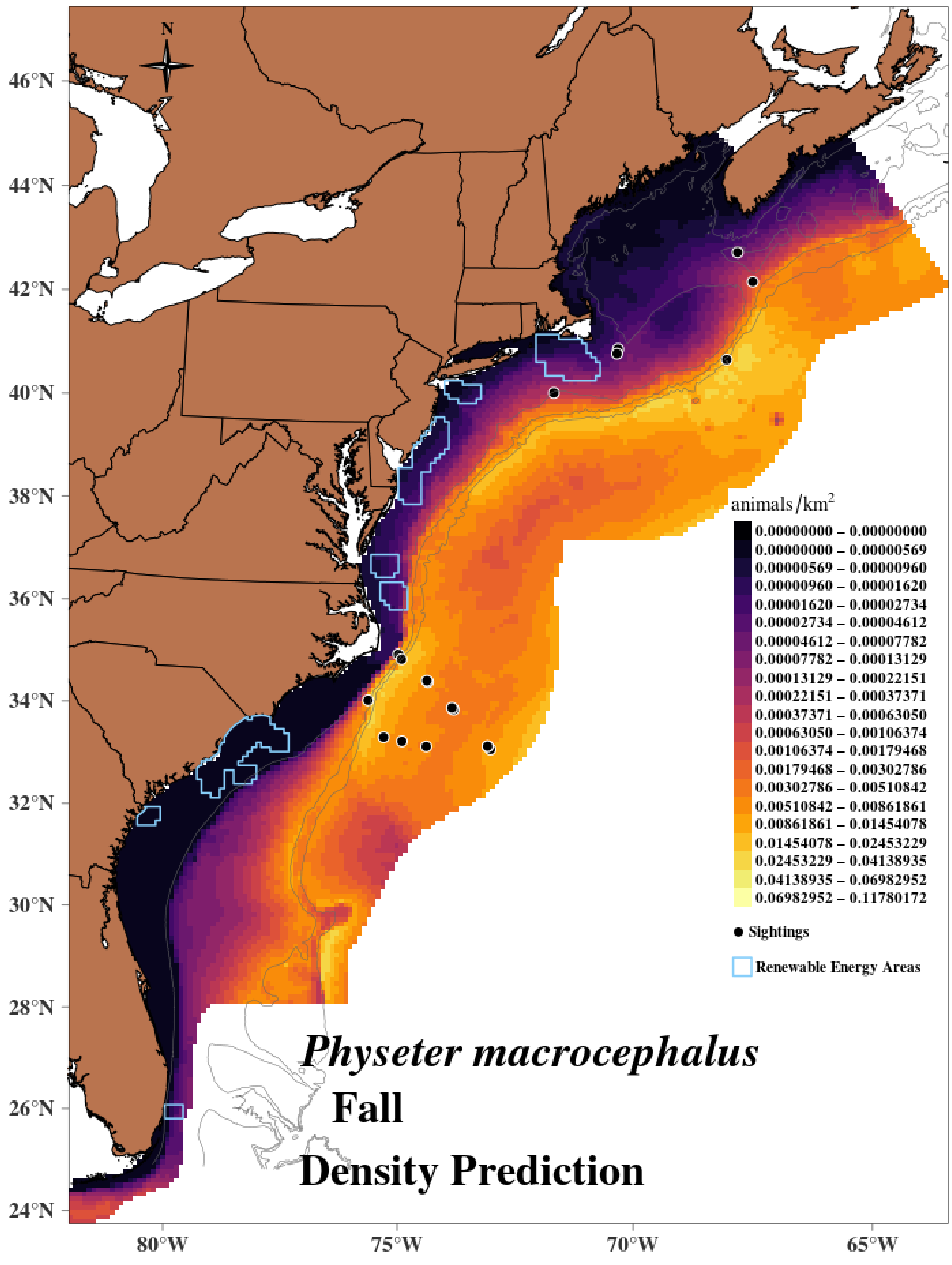

Figure 6-14 Sperm whale fall average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

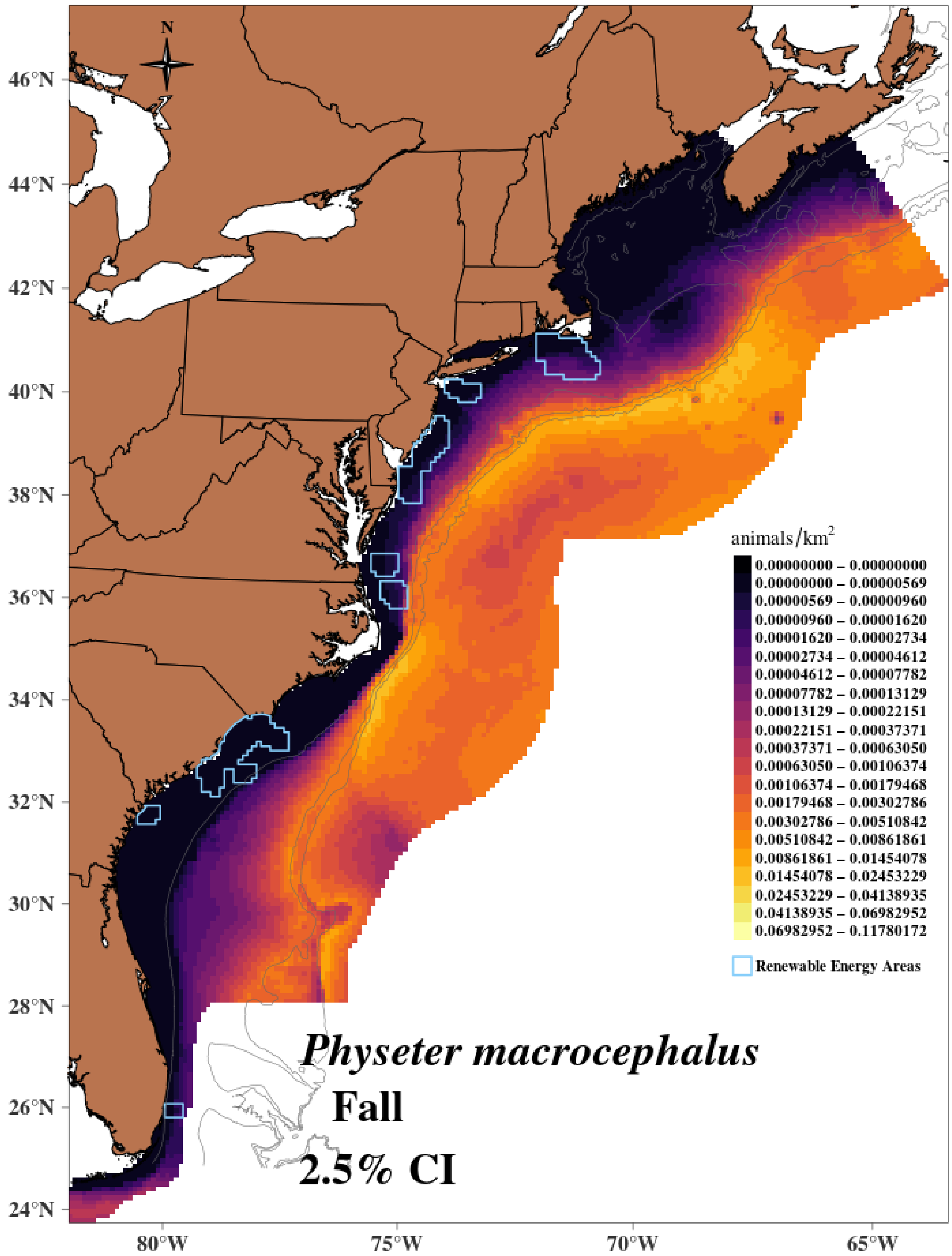

Figure 6-15 Lower 2.5% confidence interval of the fall sperm whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

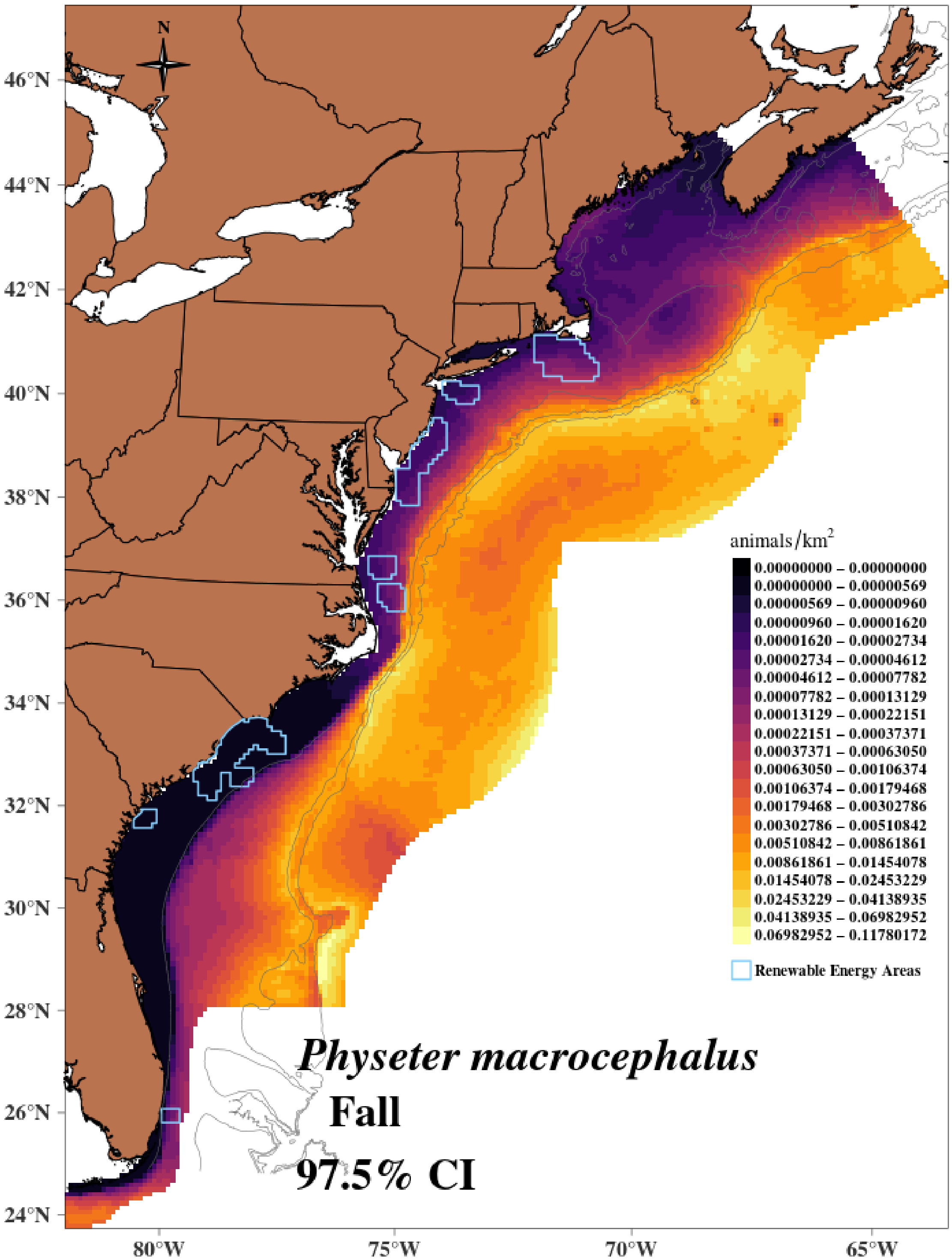

Figure 6-16 Upper 97.5% confidence interval of the fall sperm whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

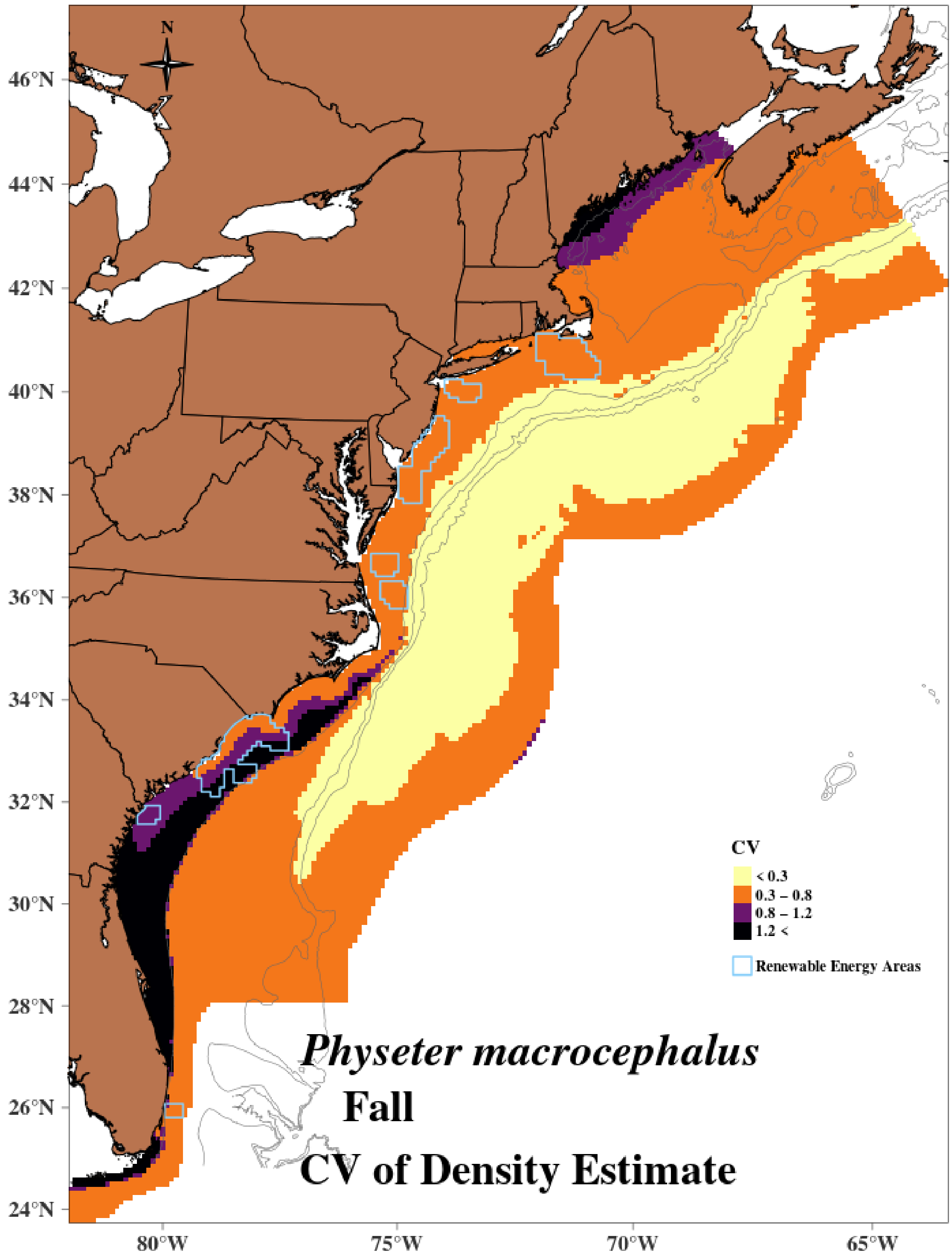

Figure 6-17 CV of fall sperm whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

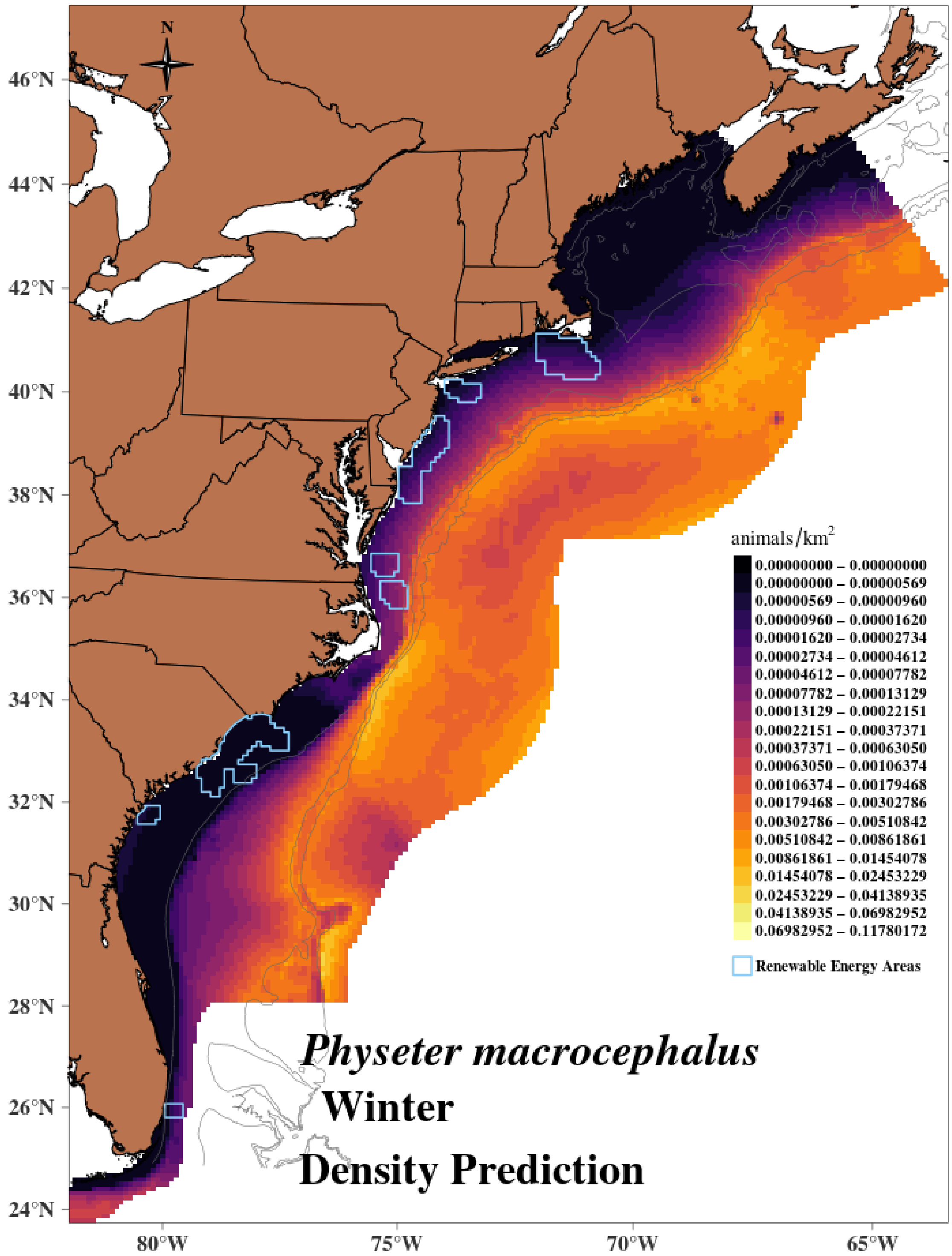

Figure 6-18 Sperm whale winter average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

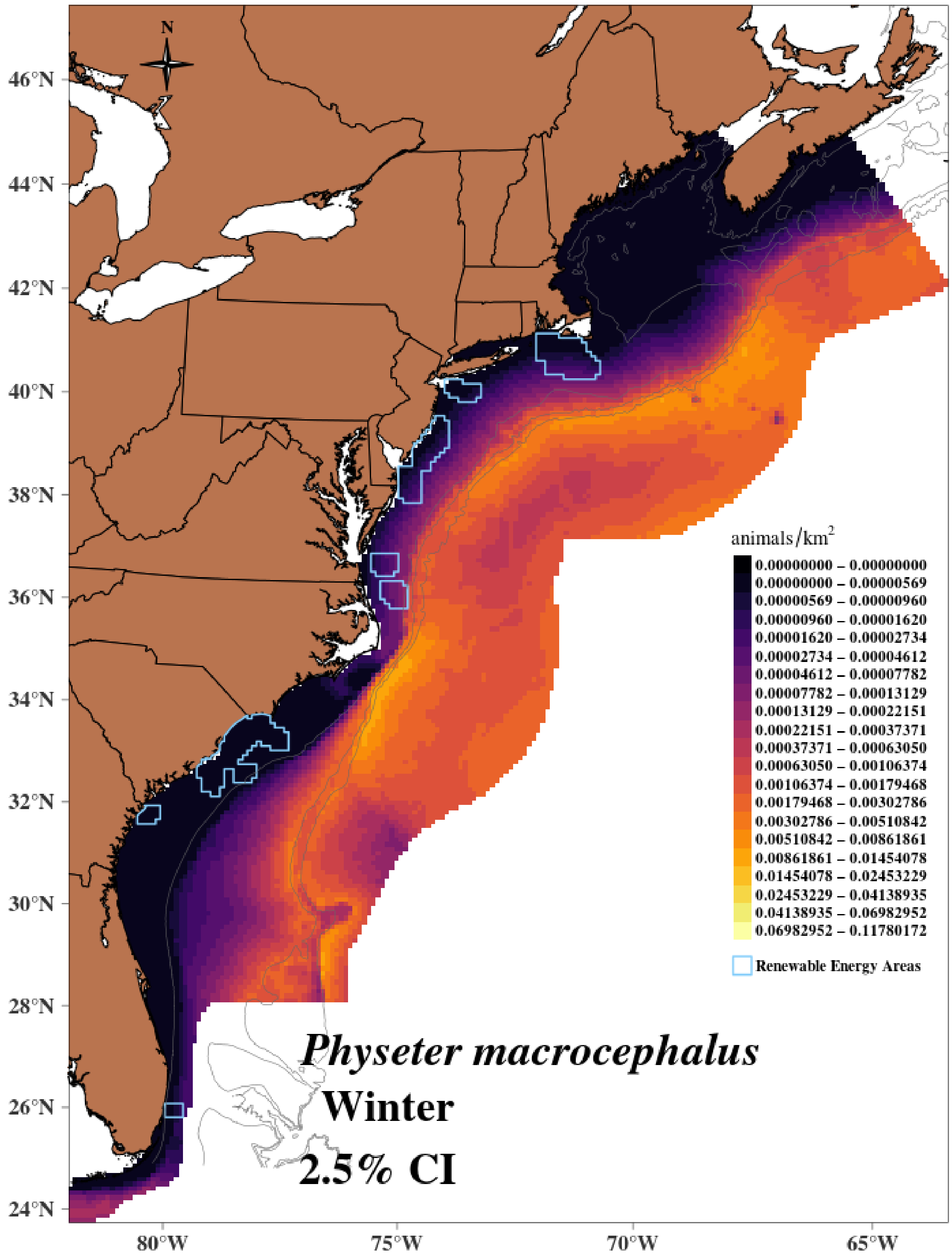

Figure 6-19 Lower 2.5% confidence interval of the winter sperm whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

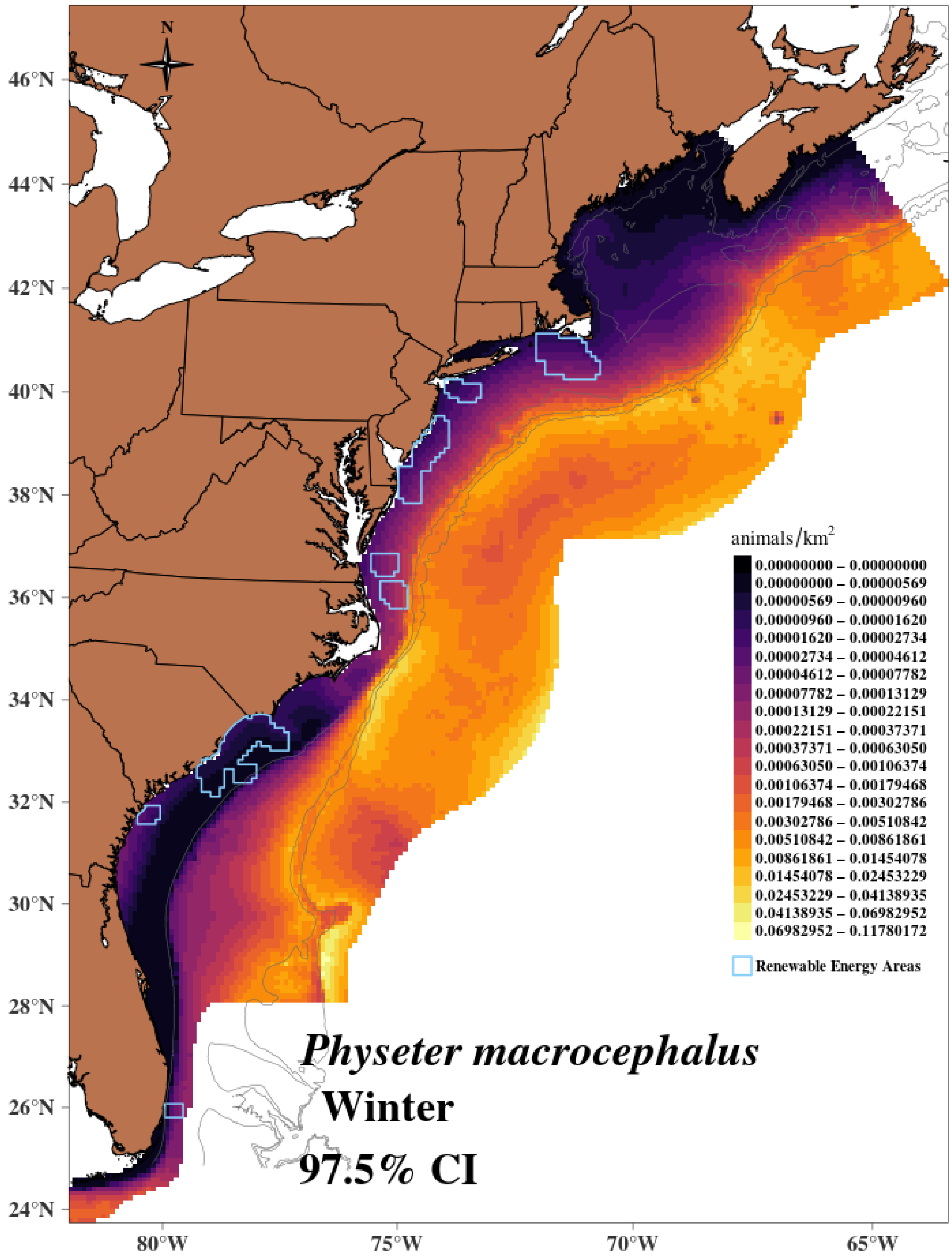

Figure 6-20 Upper 97.5% confidence interval of the winter sperm whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

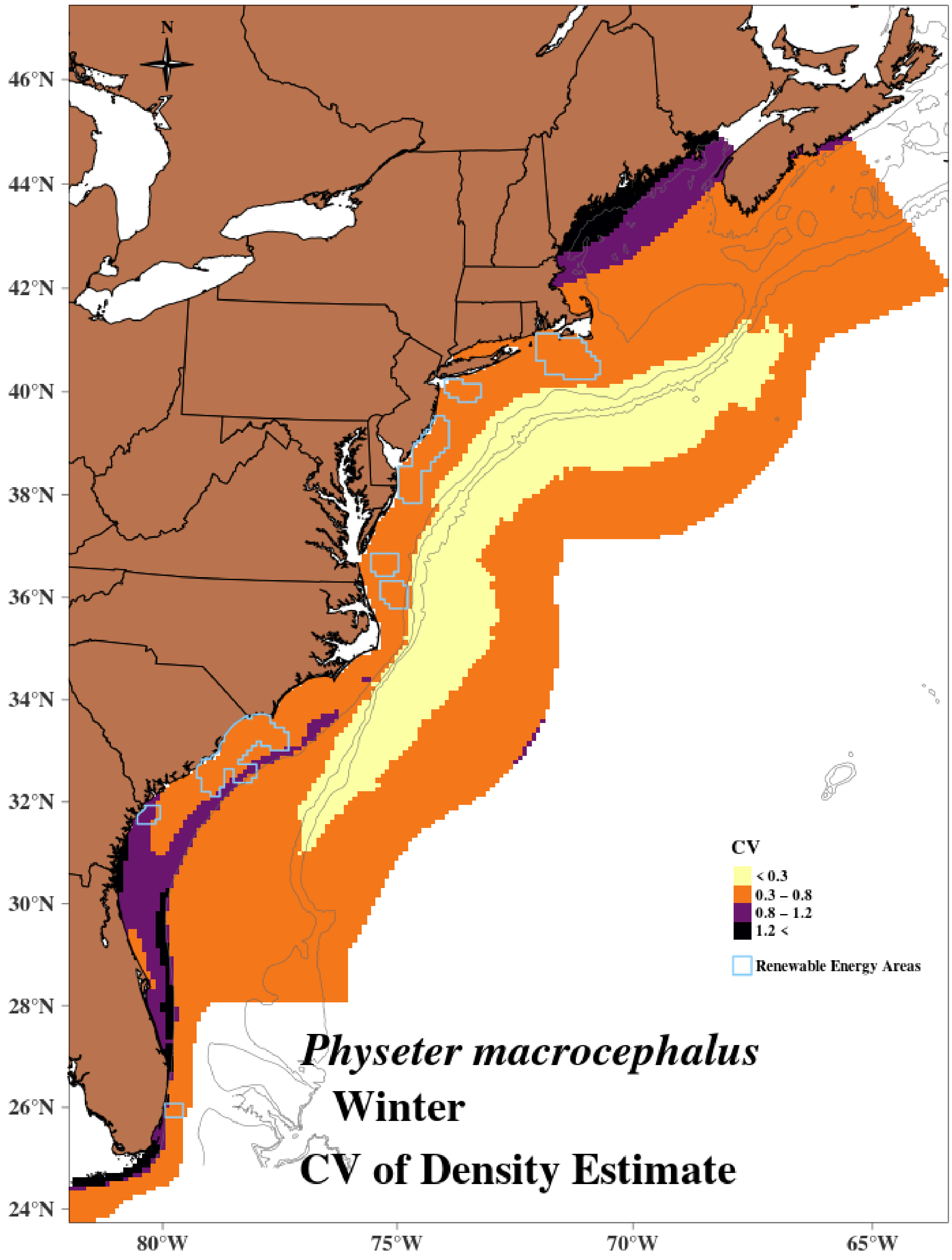

Figure 6-21 CV of winter sperm whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

6.7 Offshore Energy Development Areas

Table 6-6 Sperm whale abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	0.2	0.42	
	NY	0.0	0.44	0.0 0.1
	NJ	0.1	0.39	
	DE/MD	0.1	0.36	
	VA	0.2	0.36	
	NC	0.6	0.33	
	NC/SC	0.0	0.61	0.0 0.1
Summer (Jun–Aug)	RI/MA	1.0	0.35	.0
	NY	0.1	0.41	0.0 0.1
	NJ	0.0	0.52	0.0 0.1
	DE/MD	0.0	0.46	0.0 0.1
	VA	0.0	0.47	0.0 0.1
	NC	0.4	0.37	
	NC/SC	0.0	0.63	0.0 0.0
Fall (Sep–Nov)	RI/MA	0.5	0.37	.0
	NY	0.0	0.46	0.0 0.1
	NJ	0.1	0.44	0.0 0.2
	DE/MD	0.1	0.43	0.0 0.1
	VA	0.0	0.48	0.0 0.1
	NC	0.2	0.43	
	NC/SC	0.0	0.74	0.0 0.0
Winter (Dec–Feb)	RI/MA	0.3	0.38	
	NY	0.0	0.43	0.0 0.1
	NJ	0.1	0.40	
	DE/MD	0.1	0.38	
	VA	0.2	0.36	
	NC	0.5	0.36	
	NC/SC	0.0	0.57	0.0 0.1

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

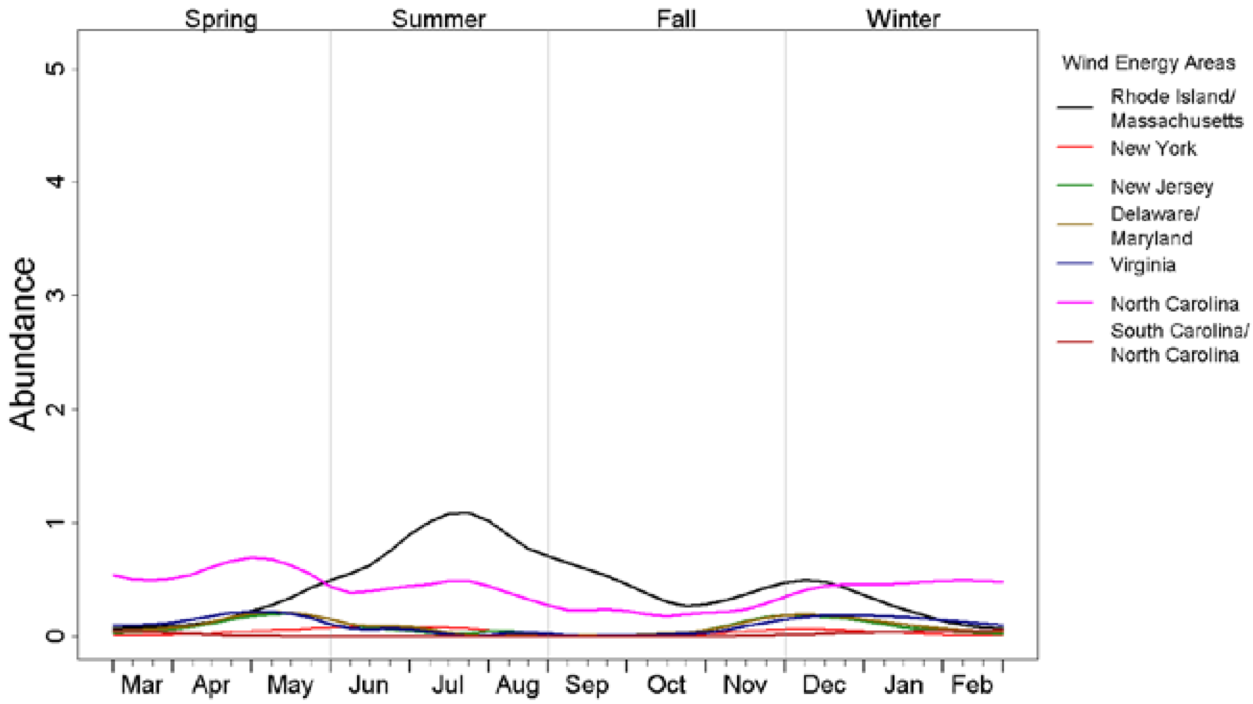

Figure 6-22 Average seasonal abundance of sperm whales in the wind-energy study areas

7 Cuvier's Beaked Whale (*Ziphius cavirostris*)

Figure 7-1 Cuvier's beaked whale
Image collected under MMPA research permit #779-1633. Credit:NOAA/SEFSC.

7.1 Data Collection

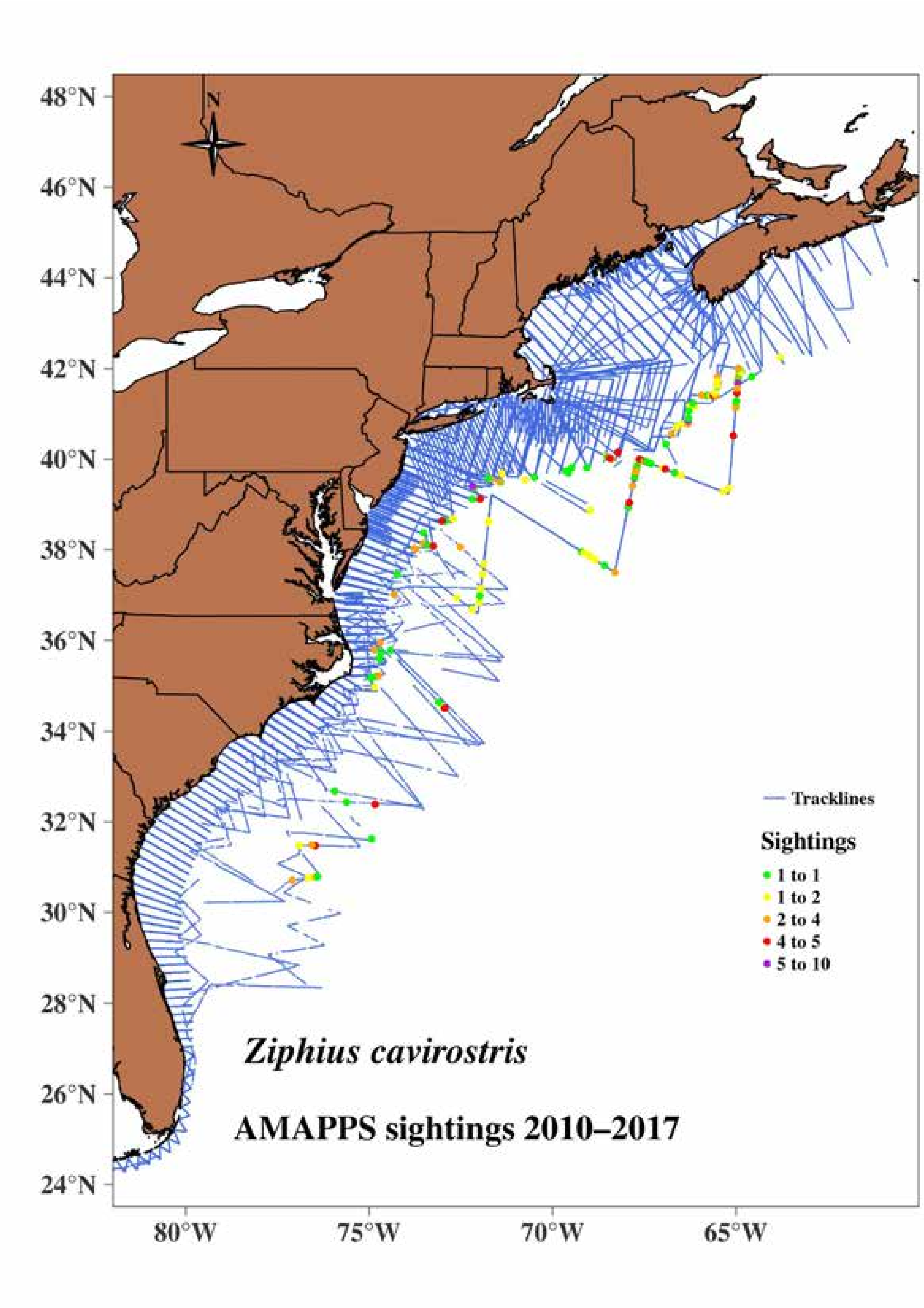

Figure 7-2 Distribution of track lines and Cuvier's beaked whale sightings 2010 to 2017

Table 7-1 AMAPPS research effort 2010 to 2017 and Cuvier's beaked whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	148	404
NE Shipboard	Fall	1,065	4	6
NE Aerial	Spring	13,314	1	4
NE Aerial	Summer	25,867	1	1
NE Aerial	Fall	37,850	0	0
NE Aerial	Winter	12,179	0	0
SE Shipboard	Spring	8,853	5	6
SE Shipboard	Summer	12,968	19	45
SE Shipboard	Fall	3,012	6	10
SE Aerial	Spring	41,293	3	6
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

7.2 Mark-Recapture Distance Sampling Analysis

Table 7-2 Intermediate parameters in Cuvier's beaked whale mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 4	distance * observer + sea state + glare	300	distance	LT43- 300	HR	0.86	0.18	0.98	0.96	0.95
NE–aerial group 2	distance * observer + group size + sea state + quality	600	distance + sea state	L35-600	HR	0.62	0.19	0.86	0.89	0.91
NE–shipboard group 6	distance * observer + group size	3800	distance + sea state + swell + time of day	3800	HR	0.42	0.13	0.22	0.31	0.88
SE–shipboard group 4	distance + group size	2800	distance	2800	HR	0.32	0.40	0.52	0.99	1.00

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

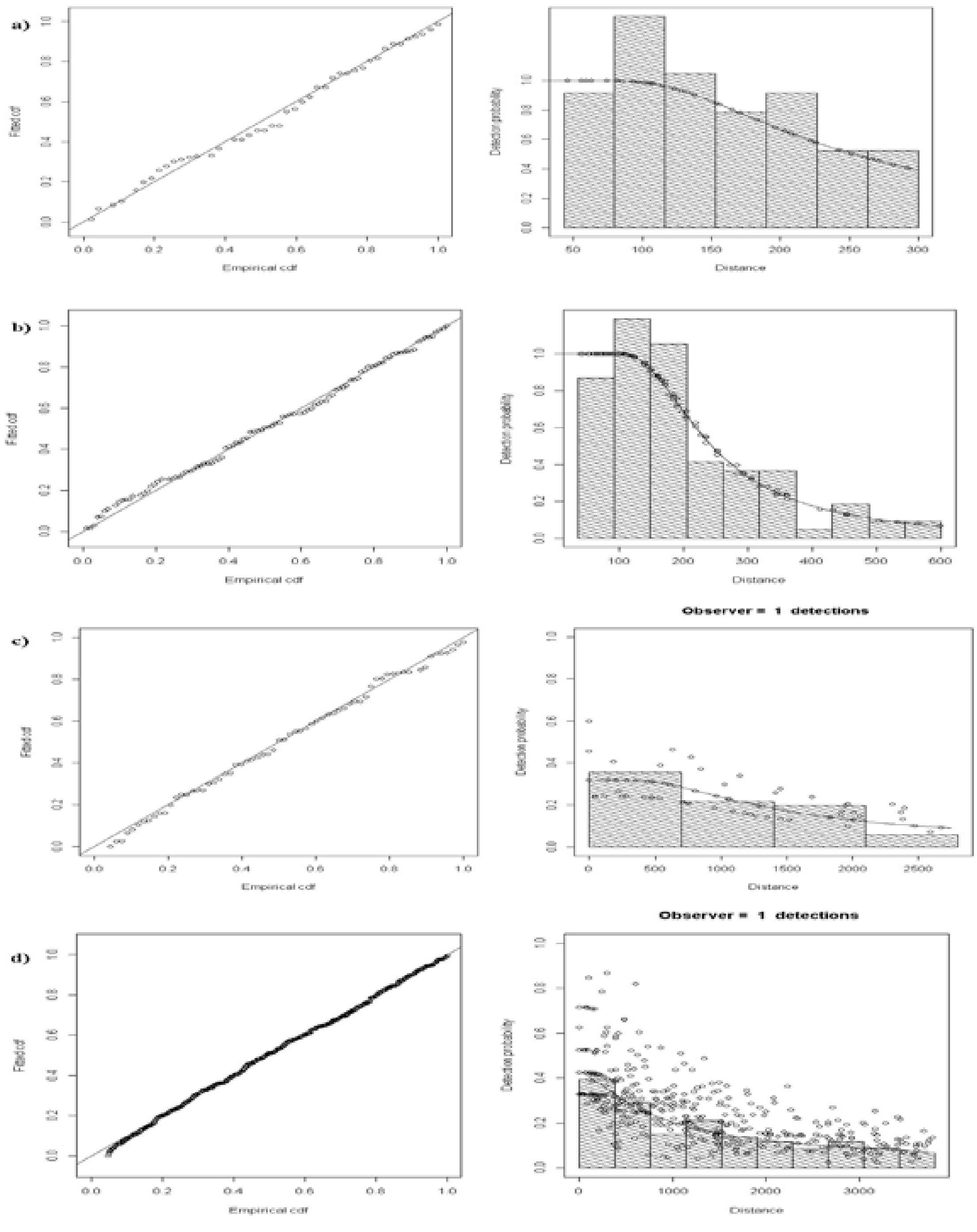

Figure 7-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 4; b) NE-aerial analysis set 2; c) NE-shipboard analysis set 6; d) SE-shipboard analysis set 4.

7.3 Generalized Additive Model Analysis

Table 7-3 2010 to 2017 density-habitat model output for Cuvier's beaked whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(chla)	0.89	4	1.95	2.96	0.0030
s(btemp)	1.00	4	5.76	6.25	<0.0001
s(depth)	1.24	4	2.21	1.66	0.0010
s(dist125)	2.52	4	3.28	2.70	<0.0001
s(lat)	1.81	4	10.58	18.4	<0.0001

Adjusted R^2 = 0.0396. Deviance explained = 32%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

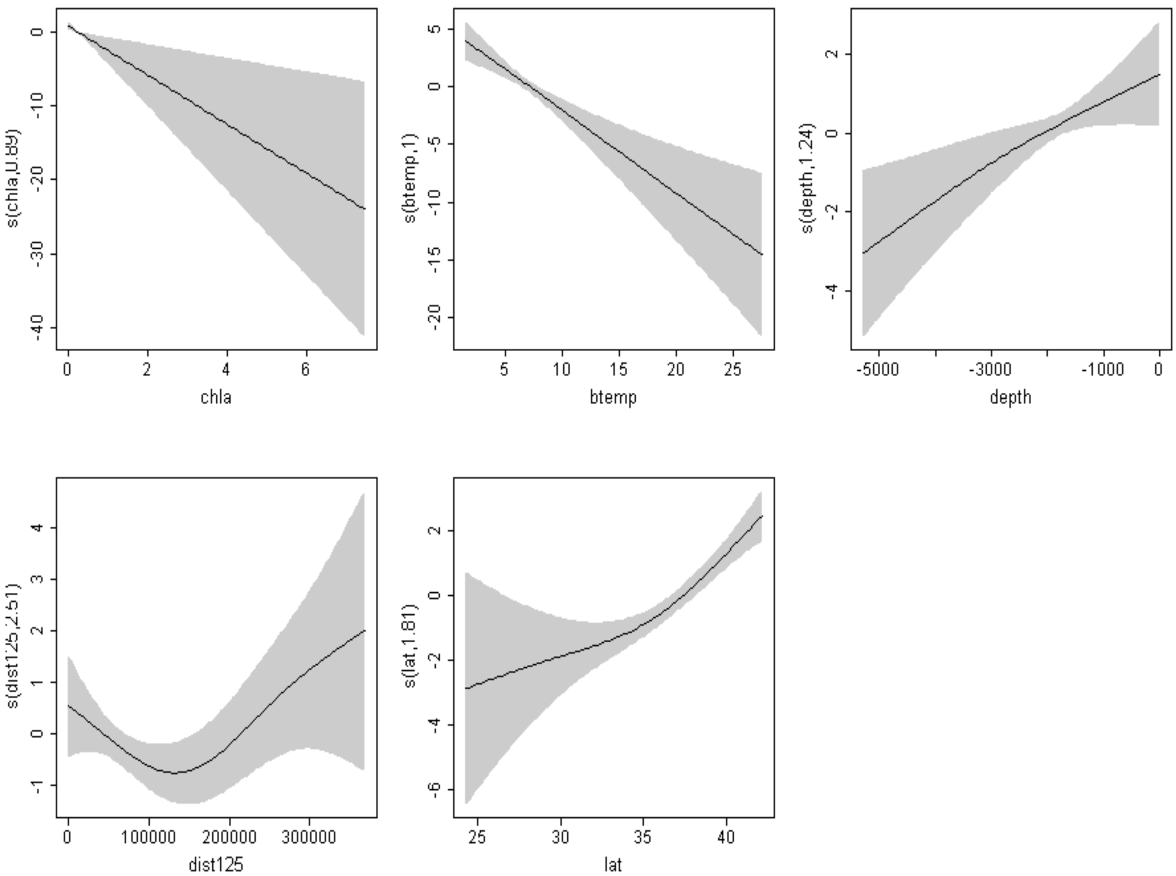

Figure 7-4 Cuvier's beaked whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

7.4 Model Cross-Validation

Table 7-4 Diagnostic statistics from the Cuvier's beaked whale density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.188	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	85.386	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.110	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.003	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

7.5 Abundance Estimates for AMAPPS Study Area

Table 7-5 Cuvier's beaked whale average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Summer (June–August)	4,688	0.36	2,365–9,293
Summer 2011 U.S. surveys[1]	6,532	0.32	
Summer 2016 U.S. surveys[1]	5,744	0.36	

[1]Hayes et al. 2020

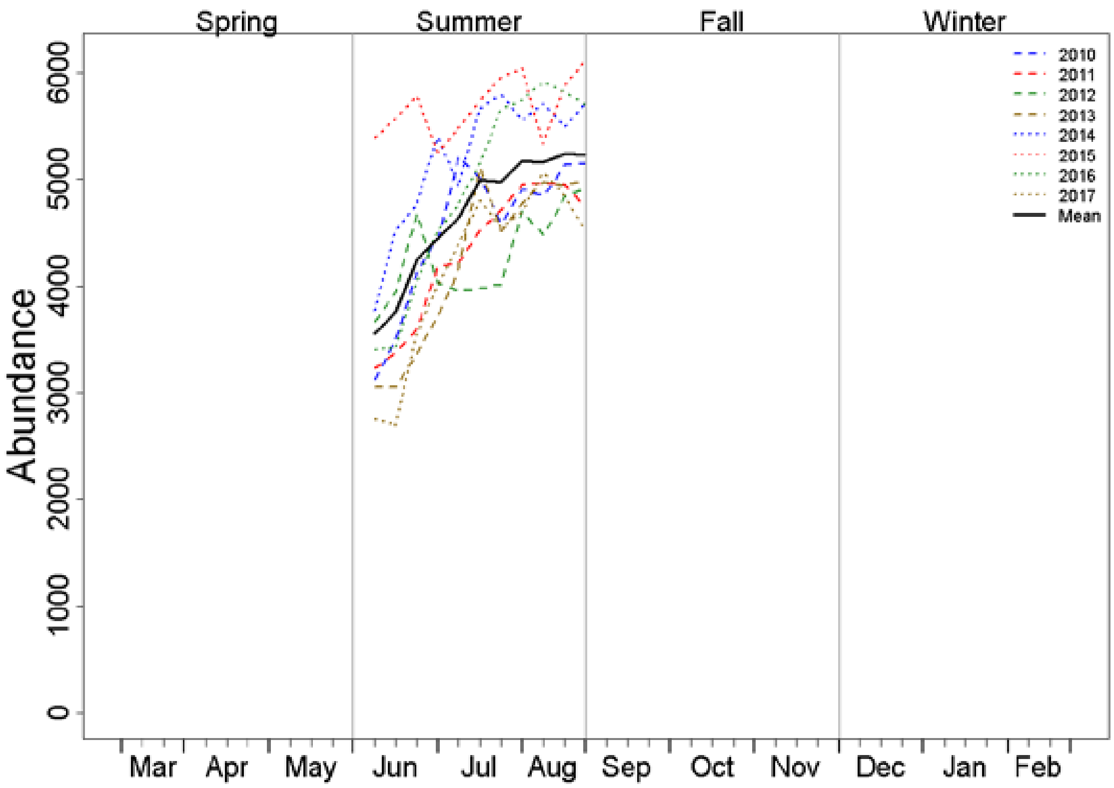

Figure 7-5 Annual abundance trends for Cuvier's beaked whales in the AMAPPS study area

7.6 Seasonal Prediction Maps

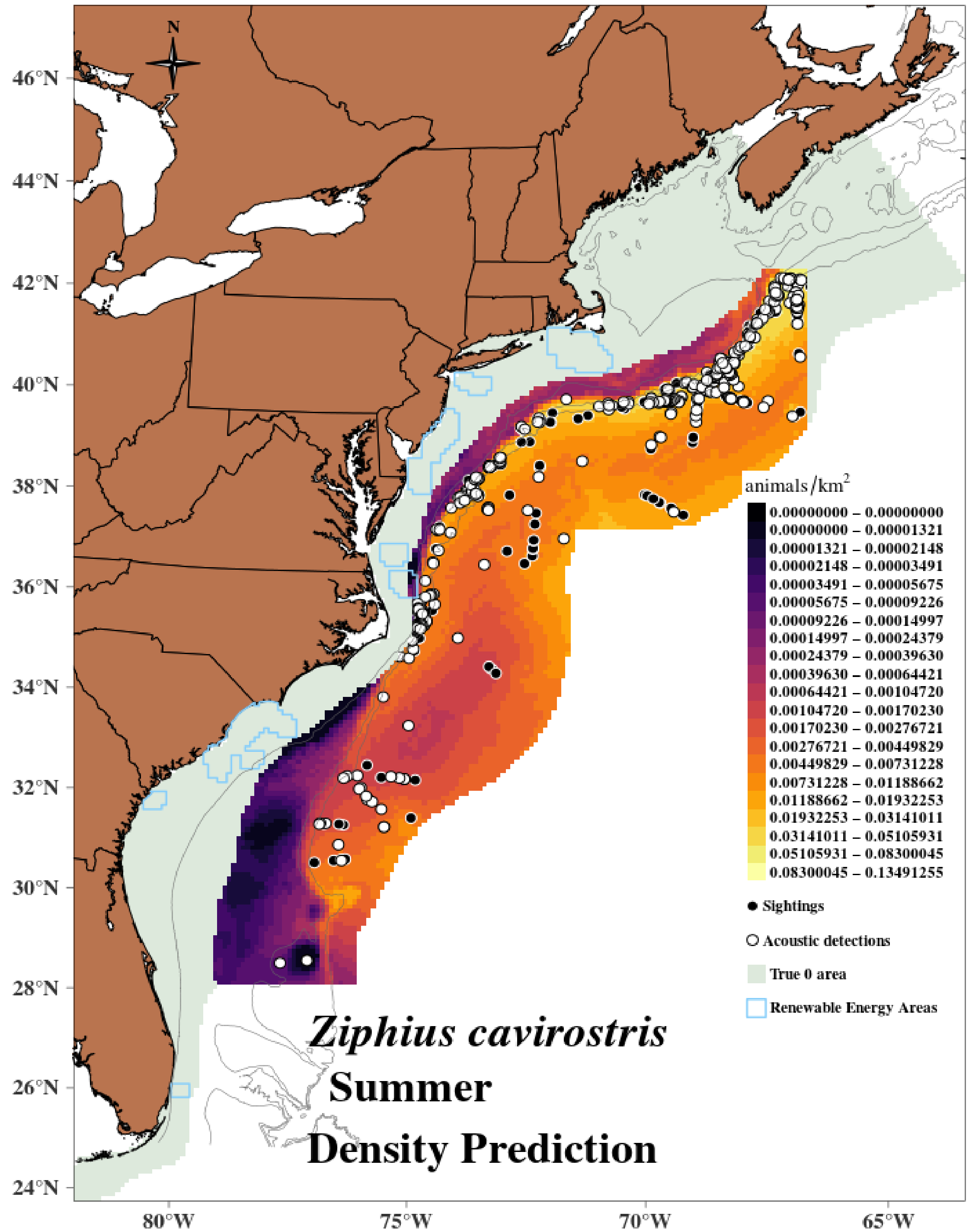

Figure 7-6 Cuvier's beaked whale summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Black circles indicate locations of animal sightings. White circles indicate locations of passive acoustic detections of Cuvier's beaked whales from the NEFSC and SEFSC 2013 and 2016 towed hydrophone arrays. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

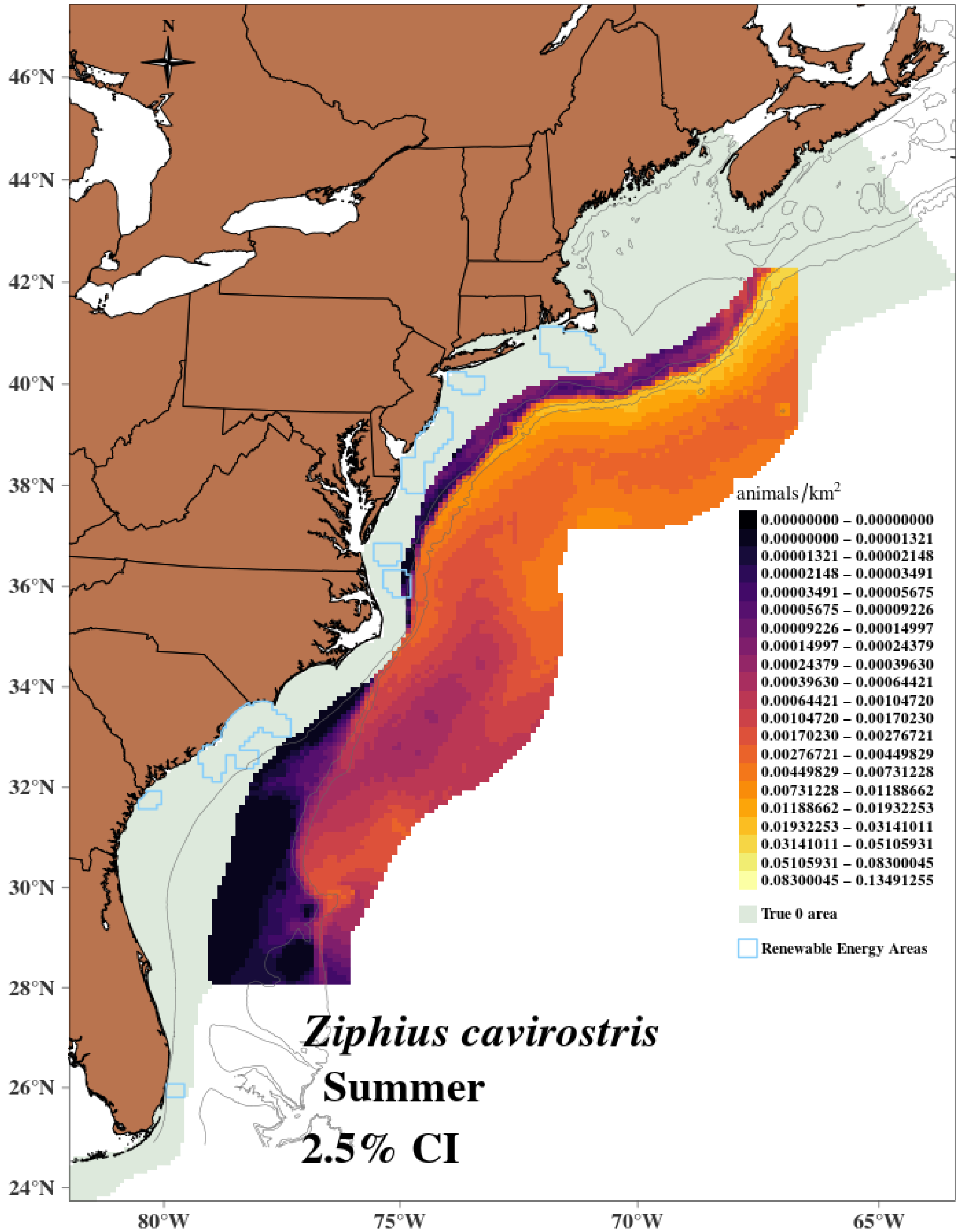

Figure 7-7 Lower 2.5% confidence interval of the summer Cuvier's beaked whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

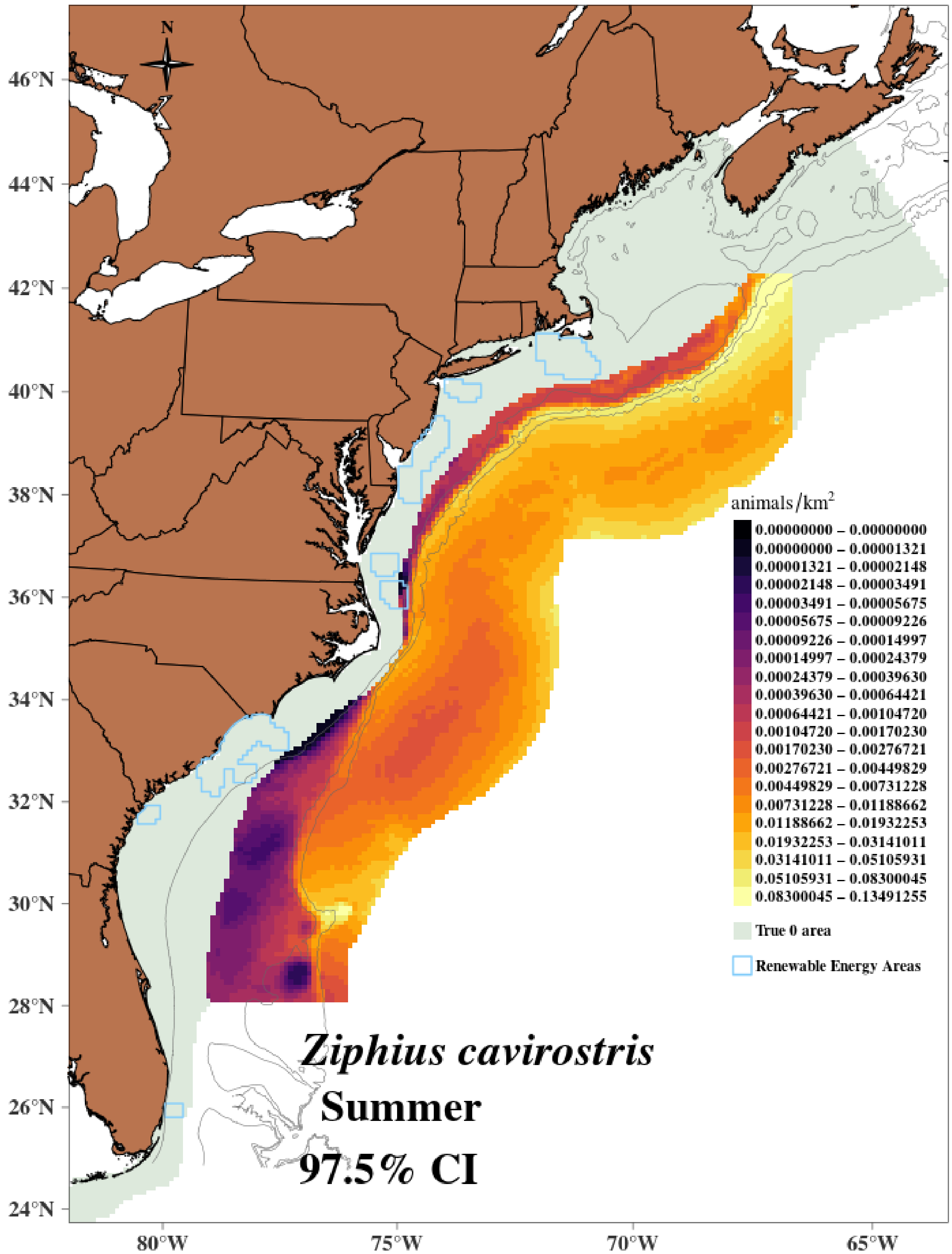

Figure 7-8 Upper 97.5% confidence interval of the summer Cuvier's beaked whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

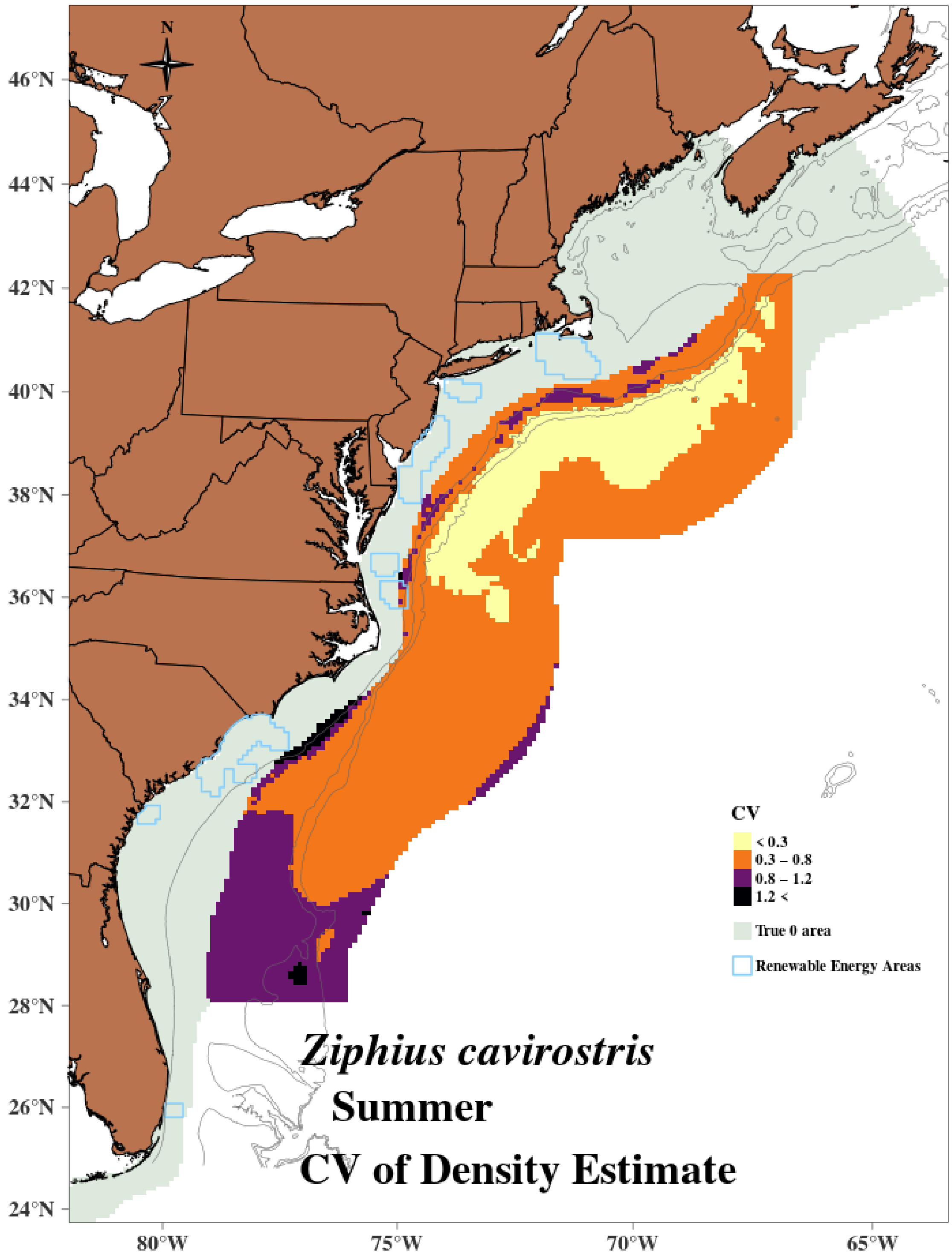

Figure 7-9 CV of summer Cuvier's beaked whale density estimates

CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

7.7 Offshore Energy Development Areas

Table 7-6 Cuvier's beaked whale abundance estimates for wind energy areas

Season	Area of interest	Abundance*	CV	95% Confidence Interval*
Summer (Jun–Aug)	NC	0.1	0.74	0.0–0.3

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

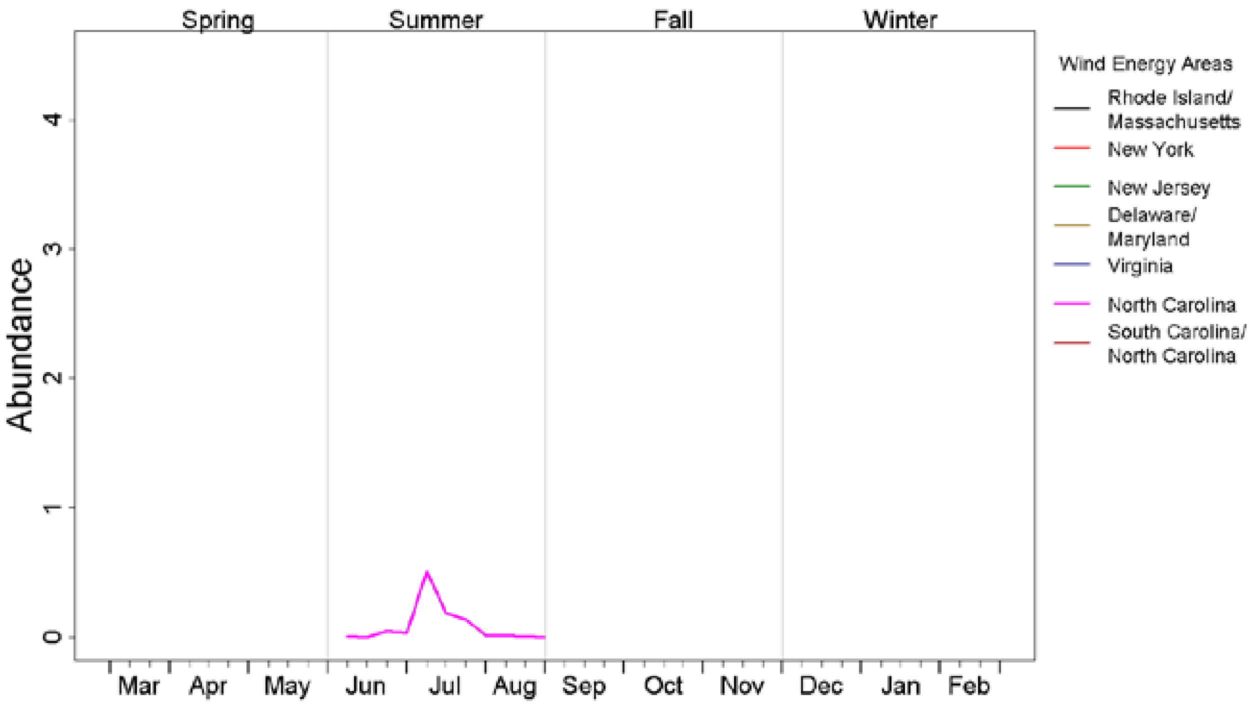

Figure 7-10 Average seasonal abundance of Cuvier's beaked whales in the wind-energy study areas

8 Sowerby’s Beaked Whale (*Mesoplodon bidens*)

Figure 8-1 Sowerby's beaked whale
Image collected under MMPA Research permit #17355. Credit: NOAA/NEFSC/Desray Reeb

8.1 Data Collection

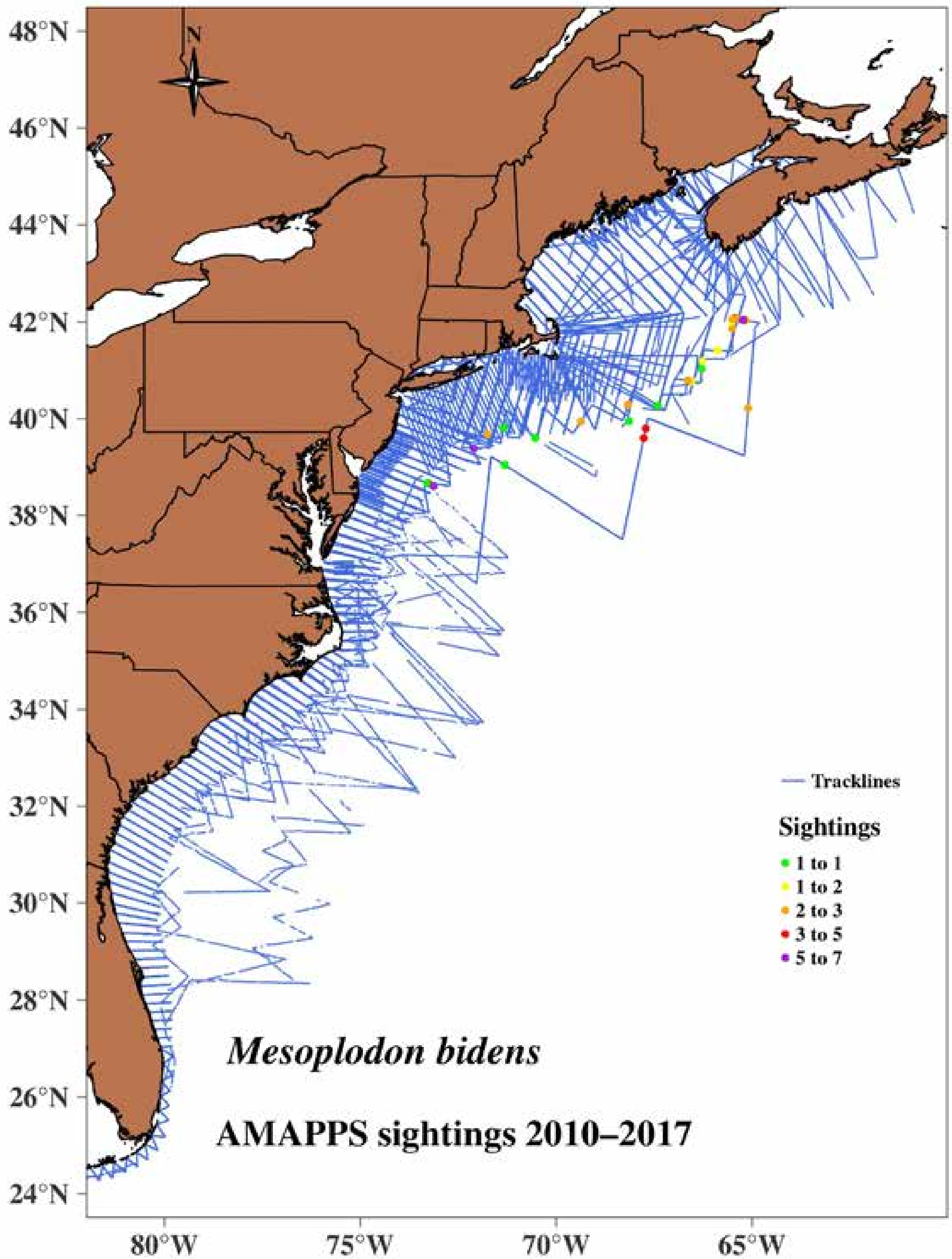

Figure 8-2 Distribution of track lines and Sowerby's beaked whale sightings 2010 to 2017

Table 8-1 AMAPPS research effort 2010 to 2017 and Sowerby's beaked whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	28	29
NE Shipboard	Fall	1,065	0	0
NE Aerial	Spring	13,314	0	0
NE Aerial	Summer	25,867	0	0
NE Aerial	Fall	37,850	0	0
NE Aerial	Winter	12,179	0	0
SE Shipboard	Spring	8,853	0	0
SE Shipboard	Summer	12,968	1	1
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	0	0
SE Aerial	Summer	28,236	1	1
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

8.2 Mark-Recapture Distance Sampling Analysis

Table 8-2 Intermediate parameters in Sowerby's beaked whale mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 4	distance * observer + sea state + glare	300	distance	LT43- 300	HR	0.86	0.18	0.98	0.96	0.95
NE–shipboard group 6	distance * observer + group size	3800	distance + sea state + swell + time of day	3800	HR	0.42	0.13	0.22	0.31	0.88
SE–shipboard group 4	distance + group size	2800	distance	2800	HR	0.32	0.40	0.52	0.99	1.00

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

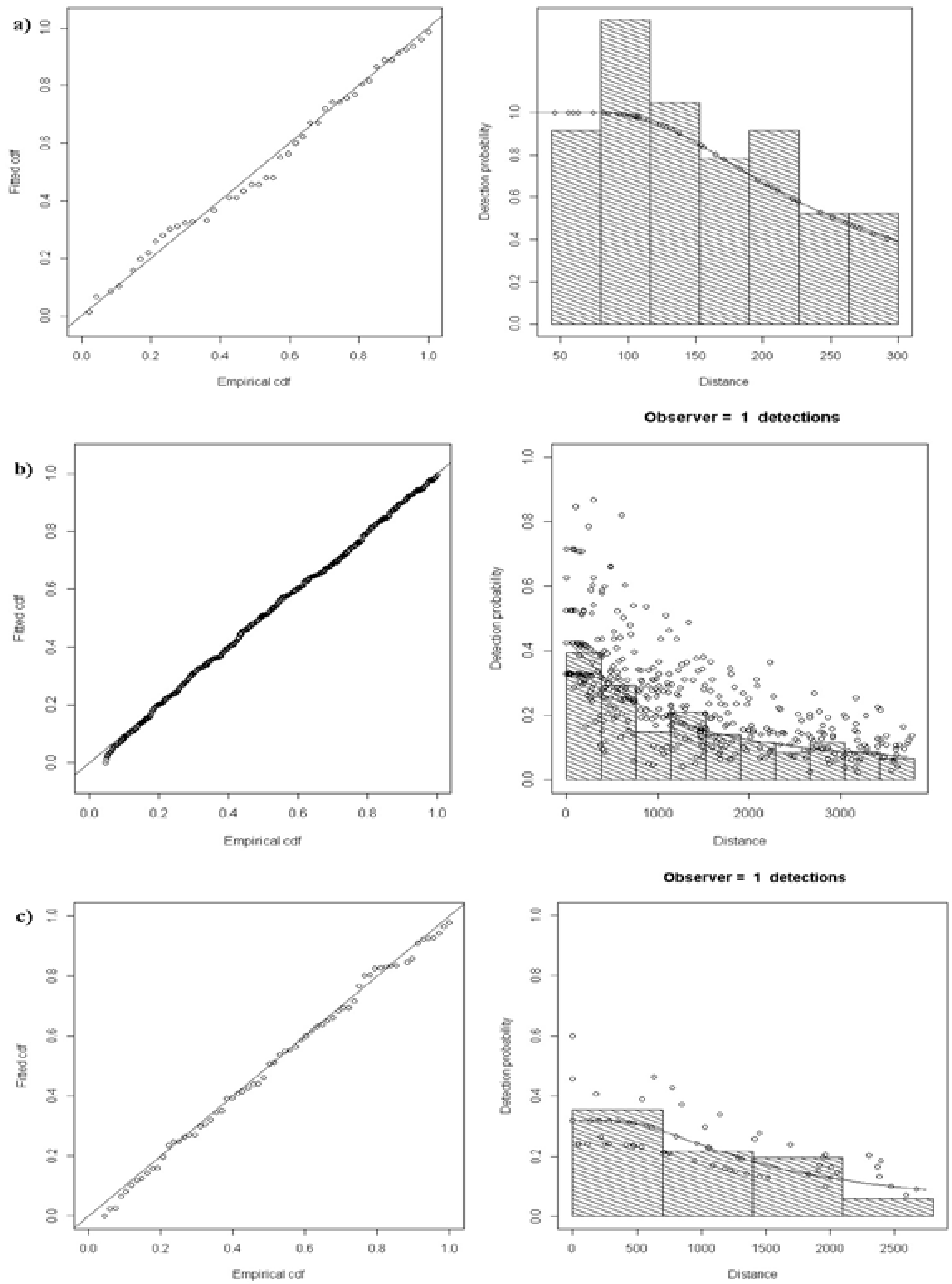

Figure 8-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 4; b) NE-shipboard analysis set 6; c) SE-shipboard analysis set 4.

8.3 Generalized Additive Model Analysis

Table 8-3 2010 to 2017 density-habitat model output for Sowerby's beaked whales

Covariates					
s(sla)	0.80	4	0.92	1.94	0.0292
s(sstfmt)	0.86	4	1.10	3.72	0.0220
s(btemp)	0.93	4	2.50	7.83	0.0009
s(dist1000)	1.01	4	3.47	11.41	0.0001
s(lat)	0.99	4	3.51	16.31	0.0001

Adjusted R^2 = 0.042. Deviance explained = 41.2%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

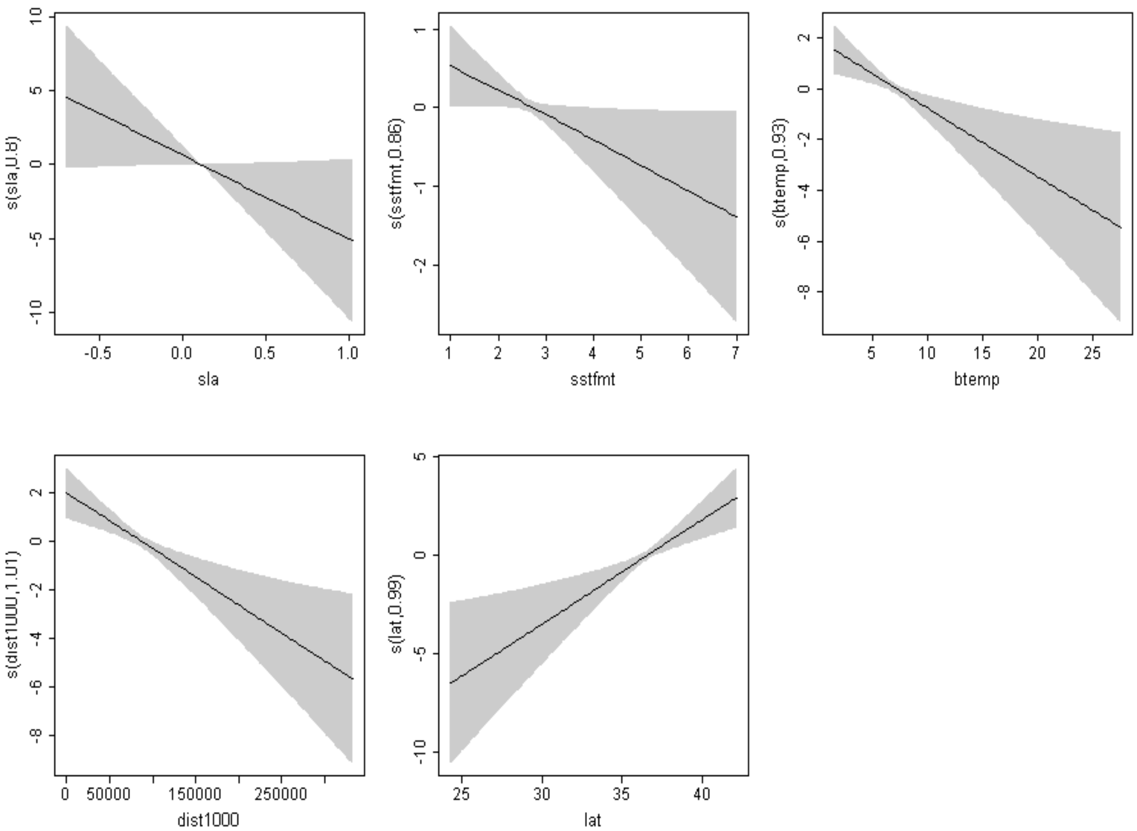

Figure 8-4 Sowerby's beaked whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

8.4 Model Cross-Validation

Table 8-4 Diagnostic statistics from the Sowerby's beaked whale density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.185	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	91.290	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.142	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.006	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

8.5 Abundance Estimates for AMAPPS Study Area

Table 8-5 Sowerby's beaked whale average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Summer (June–August)	1,001	0.49	403–2,485
Summer 2011 U.S. surveys[1]	3,653	0.69	
Summer 2016 U.S. surveys[2]	209	0.56	

[1]Palka 2012; [2]Palka 2020

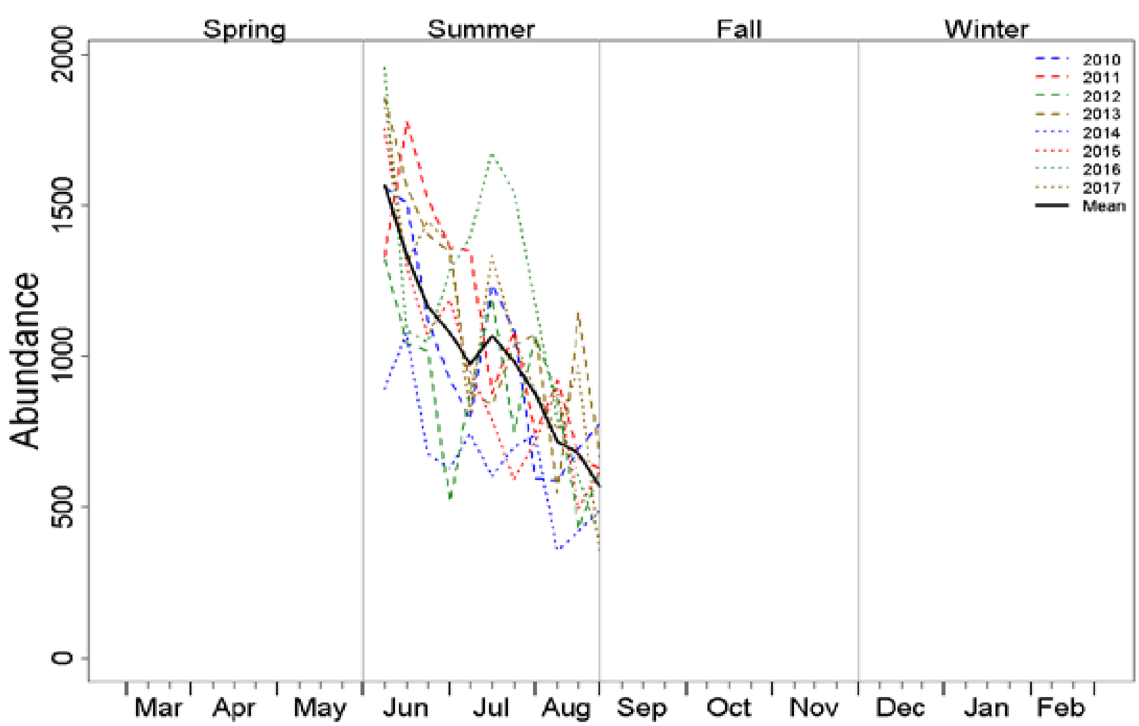

Figure 8-5 Annual abundance trends for Sowerby's beaked whales in the AMAPPS study area

8.6 Seasonal Prediction Maps

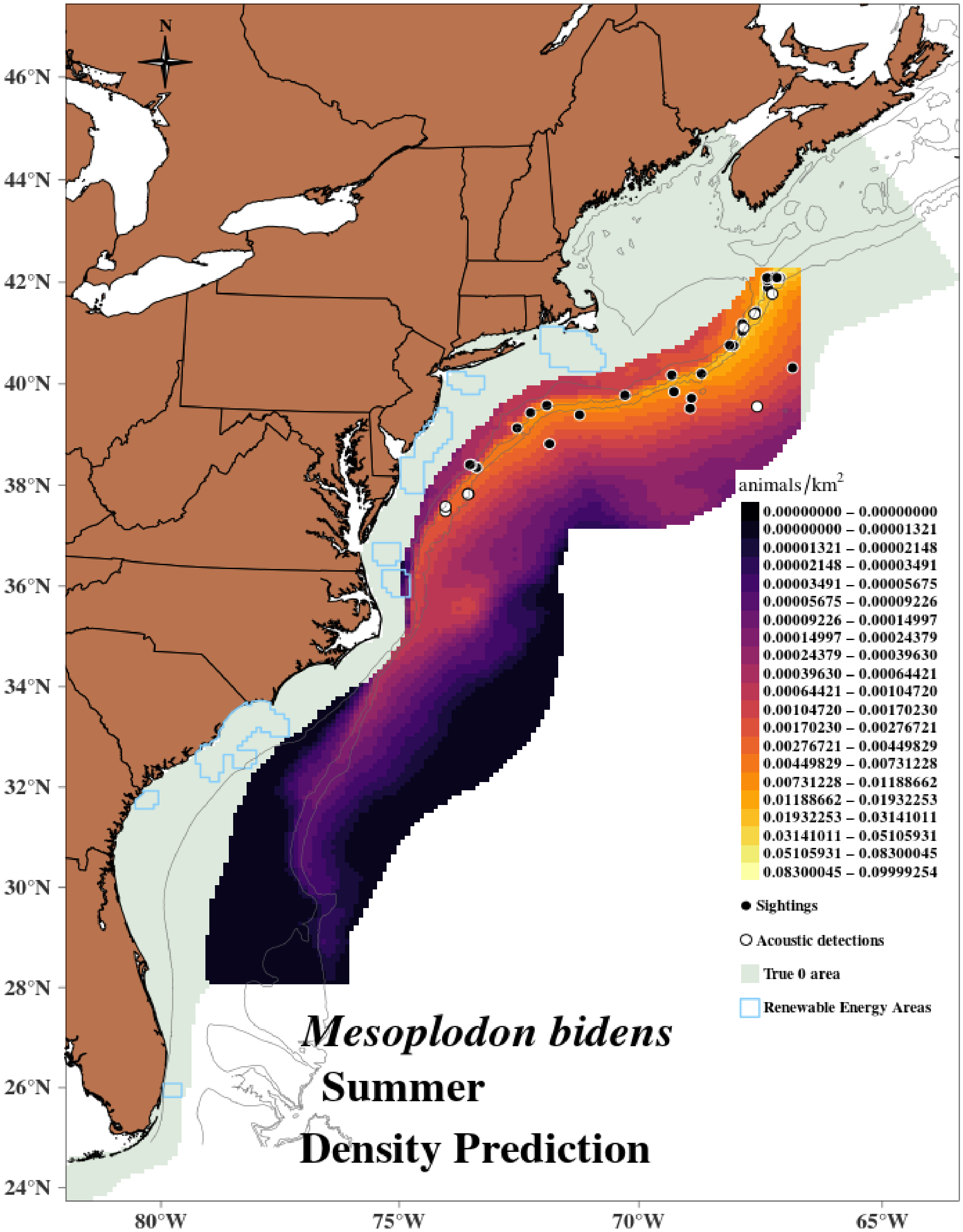

Figure 8-6 Sowerby's beaked whale summer average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Black circles indicate locations of animal sightings. White circles indicate locations of passive acoustic detections of Sowerby's beaked whales from the NEFSC and SEFSC 2013 and 2016 towed hydrophone arrays. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

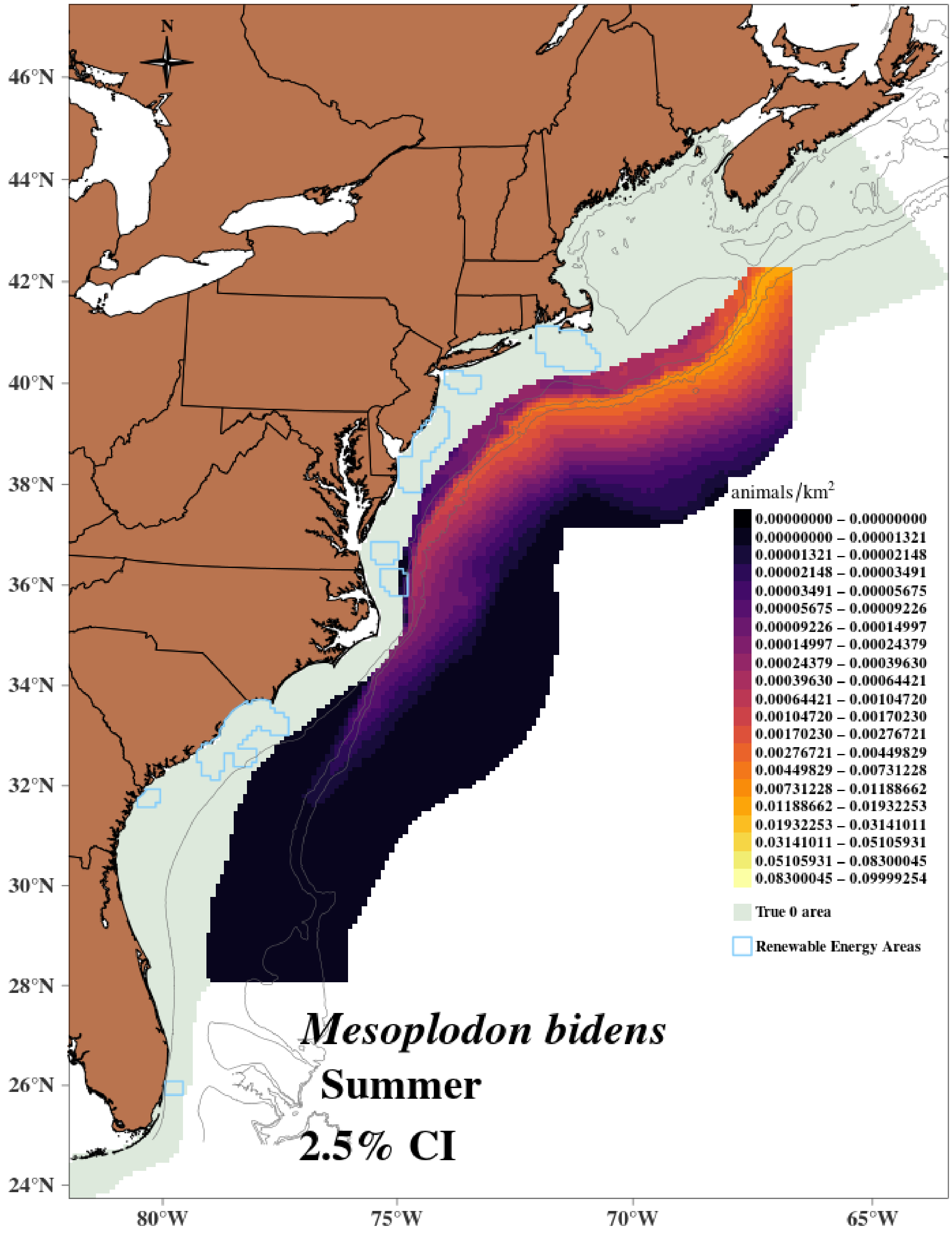

Figure 8-7 Lower 2.5% confidence interval of the summer Sowerby's beaked whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

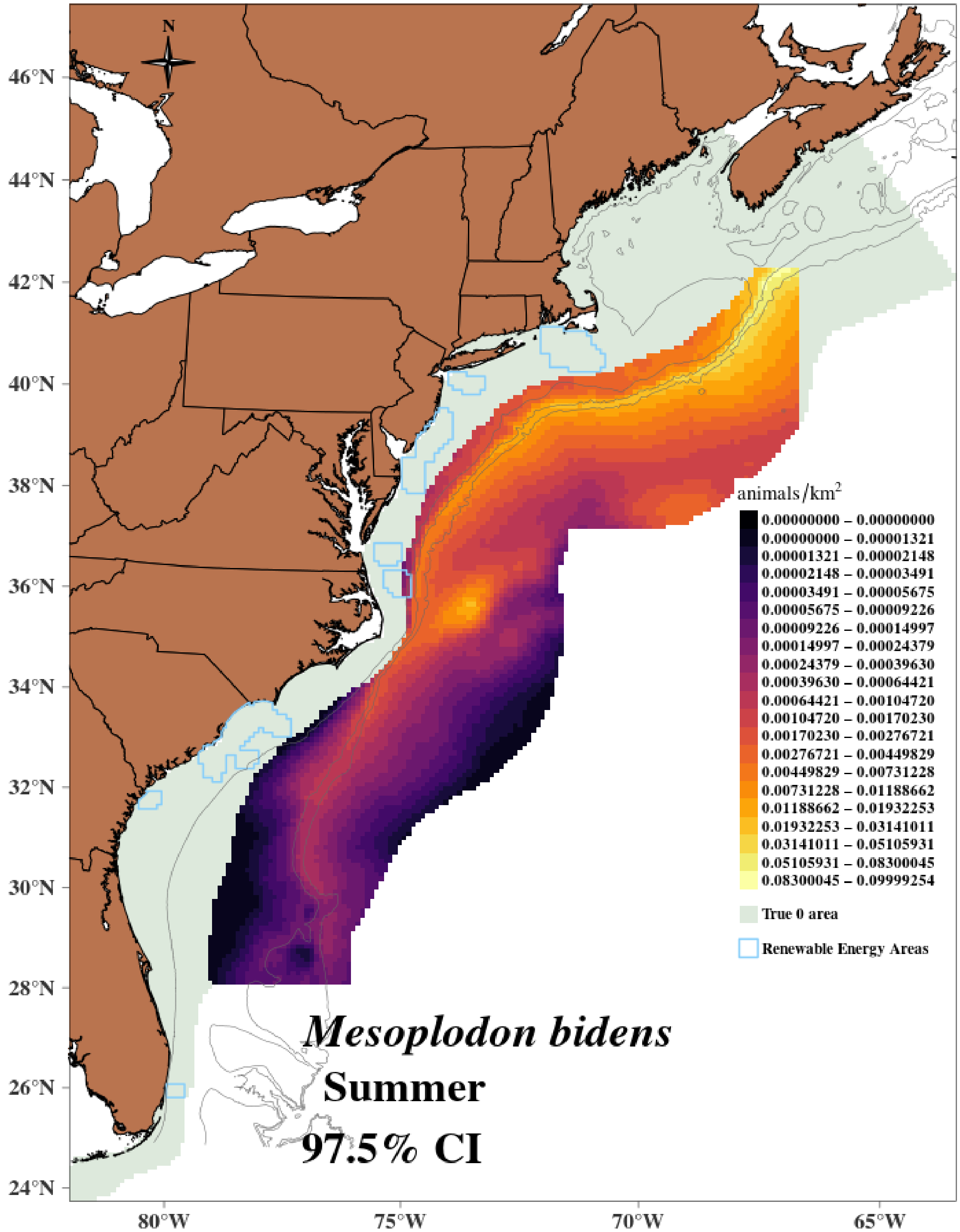

Figure 8-8 Upper 97.5% confidence interval of the summer Sowerby's beaked whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

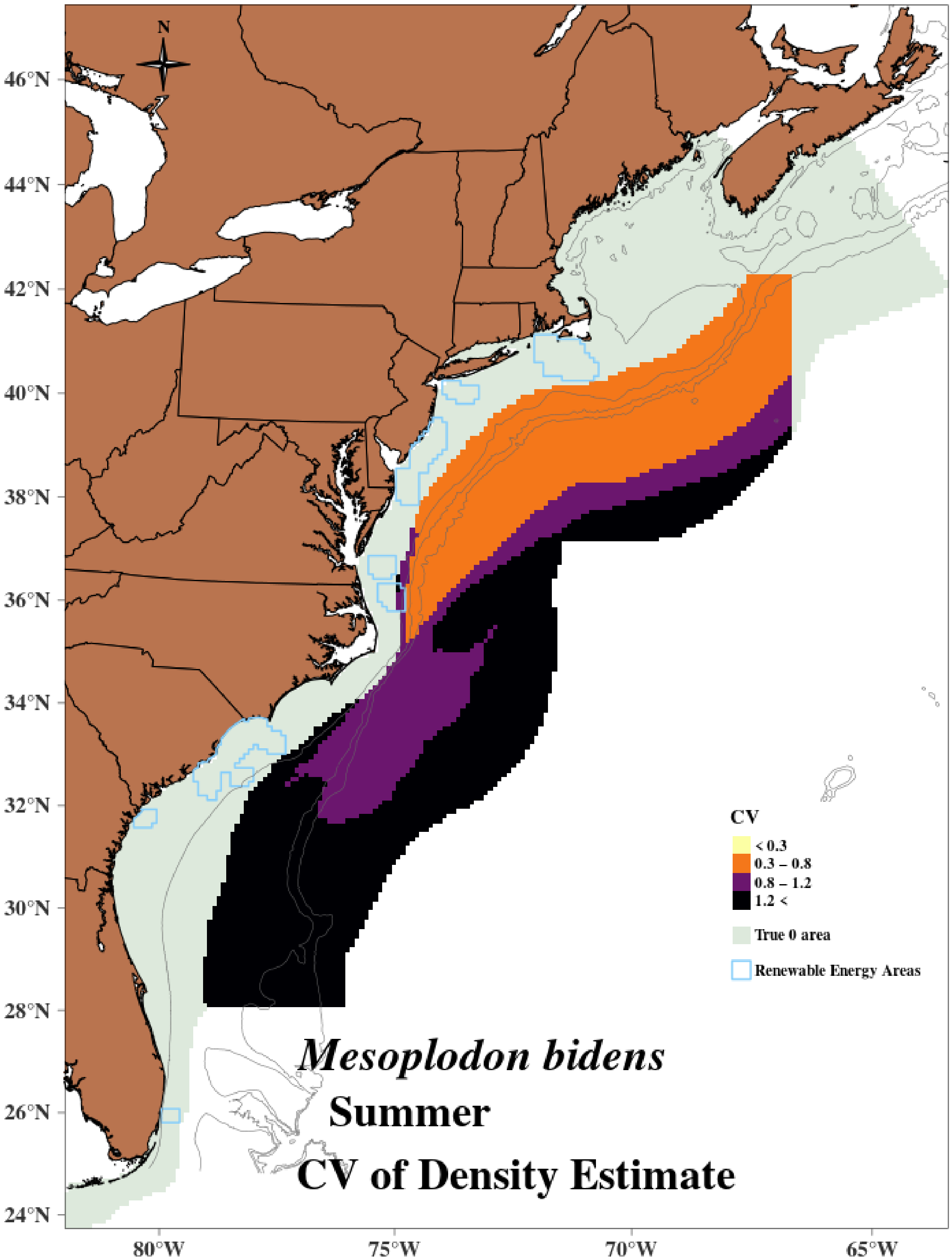

Figure 8-9 CV of summer Sowerby's beaked whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

8.7 Offshore Energy Development Areas

Table 8-6 Sowerby's beaked whale abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Summer (Jun–Aug)	NC	0.1	0.93	0.0–0.4

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

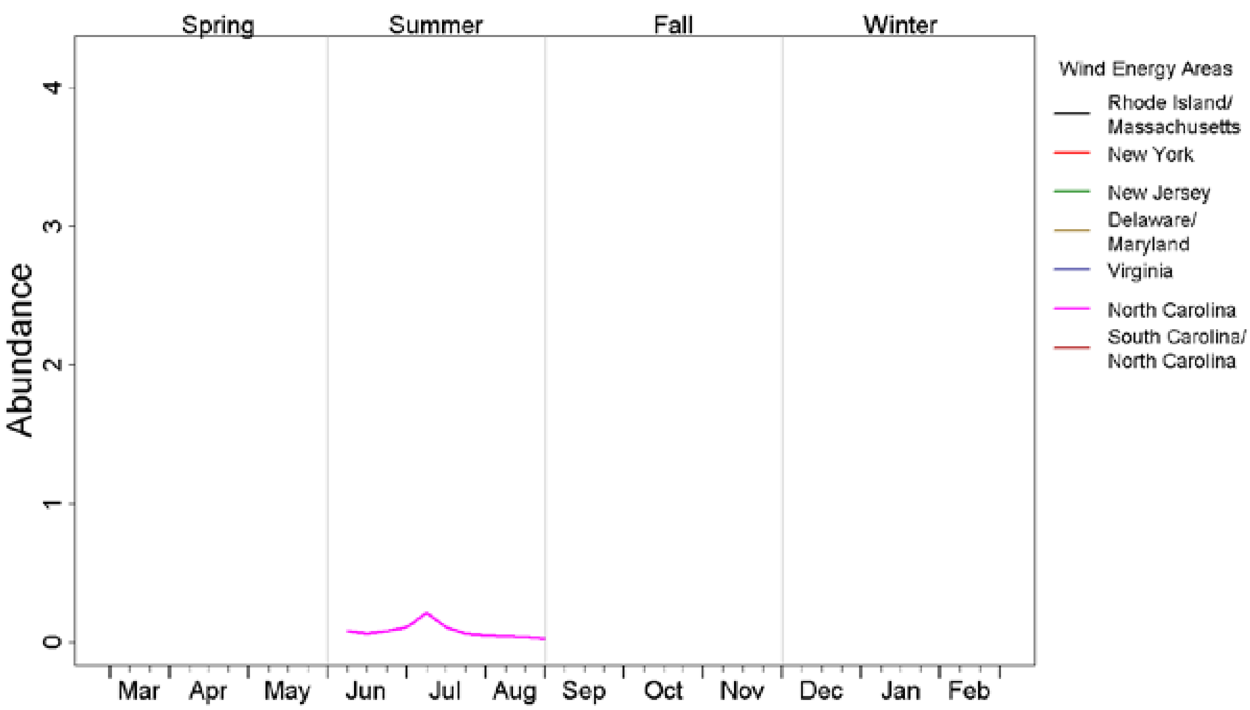

Figure 8-10 Average seasonal abundance of Sowerby's beaked whales in the wind-energy study areas

9 Unidentified Beaked Whales

Figure 9-1 Unidentified beaked whales
Image collected under MMPA Research permit #775-1875. Credit: NOAA/NEFSC/Robert DiGiovanni

9.1 Data Collection

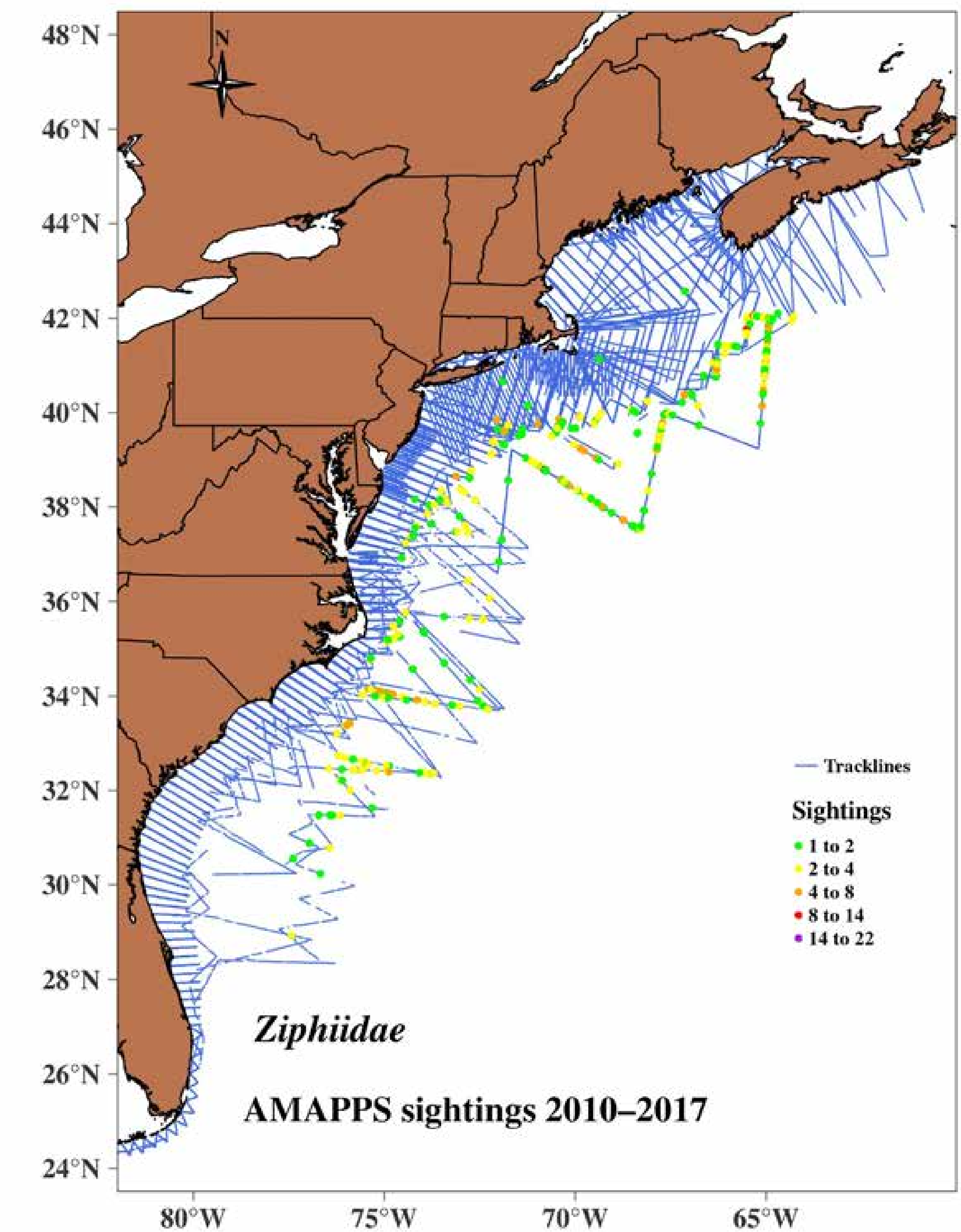

Figure 9-2 Distribution of track lines and unidentified beaked whale sightings 2010 to 2017

Table 9-1 AMAPPS research effort 2010 to 2017 and unidentified beaked whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	194	493
NE Shipboard	Fall	1,065	3	8
NE Aerial	Spring	13,314	4	8
NE Aerial	Summer	25,867	5	14
NE Aerial	Fall	37,850	4	7
NE Aerial	Winter	12,179	1	3
SE Shipboard	Spring	8,853	15	15
SE Shipboard	Summer	12,968	54	112
SE Shipboard	Fall	3,012	9	16
SE Aerial	Spring	41,293	0	0
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	2	2

9.2 Mark-Recapture Distance Sampling Analysis

Table 9-2 Intermediate parameters in unidentified beaked whale mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 4	distance * observer + sea state + glare	300	distance	LT43- 300	0.86	0.18	0.98	0.97	0.95
NE–aerial group 2	distance * observer + group size + sea state + quality	600	distance + sea state	L35-600	0.62	0.19	0.86	0.89	0.91
NE–shipboard group 6	distance * observer + group size	3800	distance + sea state + swell + time of day	3800	0.42	0.13	0.22	0.31	0.88
SE–shipboard group 4	distance + group size	2800	distance	2800	0.32	0.40	0.52	0.99	1.00

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

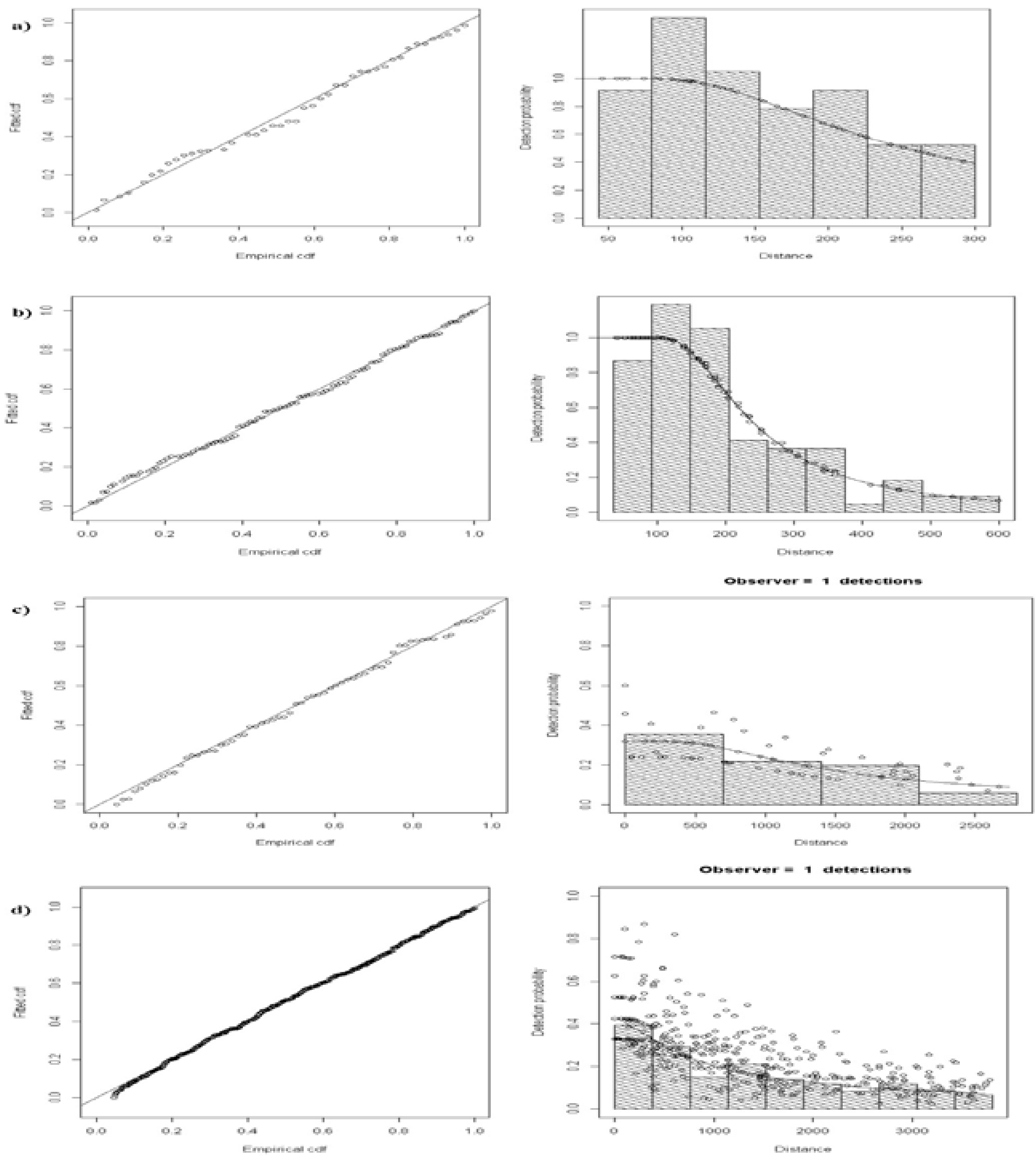

Figure 9-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 4; b) NE-aerial analysis set 2; c) SE-shipboard analysis set 4; d) NE-shipboard analysis set 6.

9.3 Generalized Additive Model Analysis

Table 9-3 2010 to 2017 density-habitat model output for unidentified beaked whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(sstfmt)	1.03	4	4.36	3.63	<0.0001
s(btemp)	1.08	4	16.25	13.27	<0.0001
s(dist1000)	1.71	4	5.10	2.58	<0.0001
s(lat)	1.04	4	6.76	4.76	<0.0001

Adjusted R^2 = 0.0156 .Deviance explained = 24.2%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

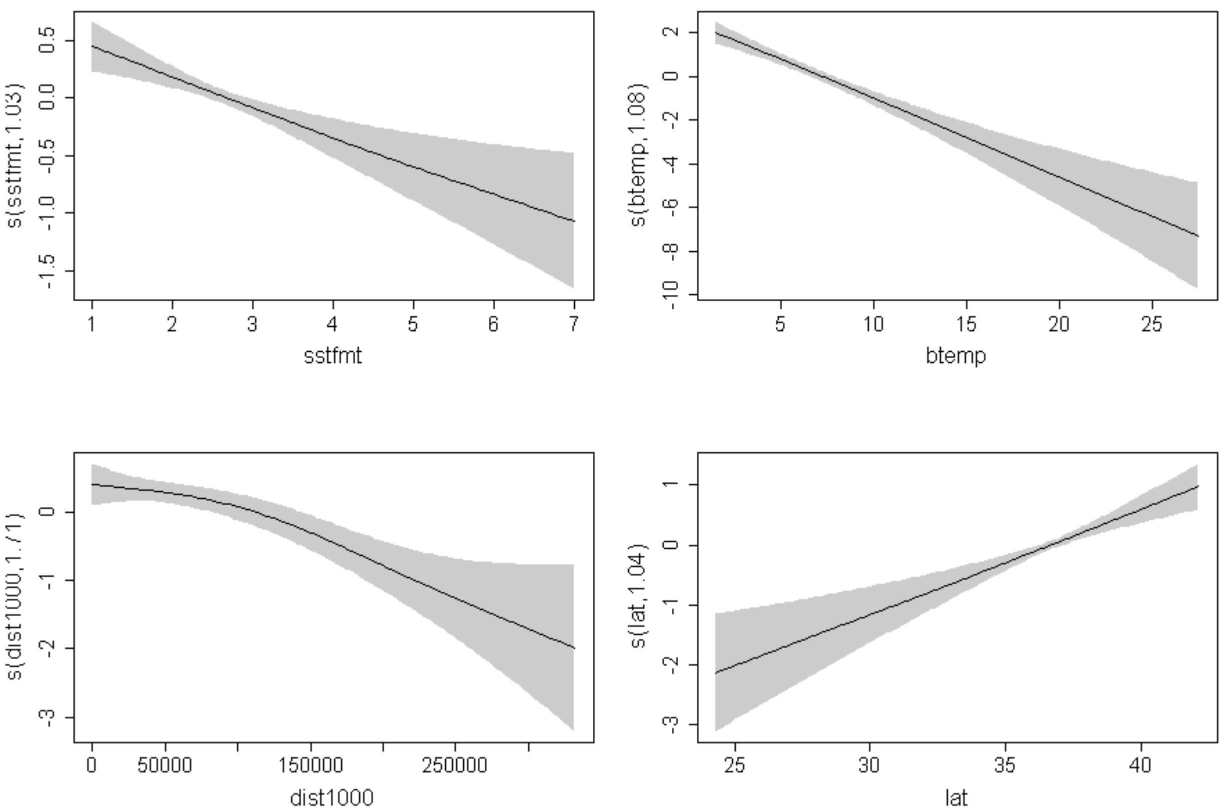

Figure 9-4 Unidentified beaked whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

9.4 Model Cross-Validation

Table 9-4 Diagnostic statistics from the unidentified beaked whale density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.140	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	80.328	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.210	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.025	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

9.5 Abundance Estimates for AMAPPS Study Area

Table 9-5 Unidentified beaked whale average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Summer (June–August)	9,592	0.2	6,506 14,141
Summer 2011 U.S. surveys[1]	7,092	0.54	
Summer 2016 U.S. surveys[1]	10,107	0.27	

[1]Hayes et al. 2020

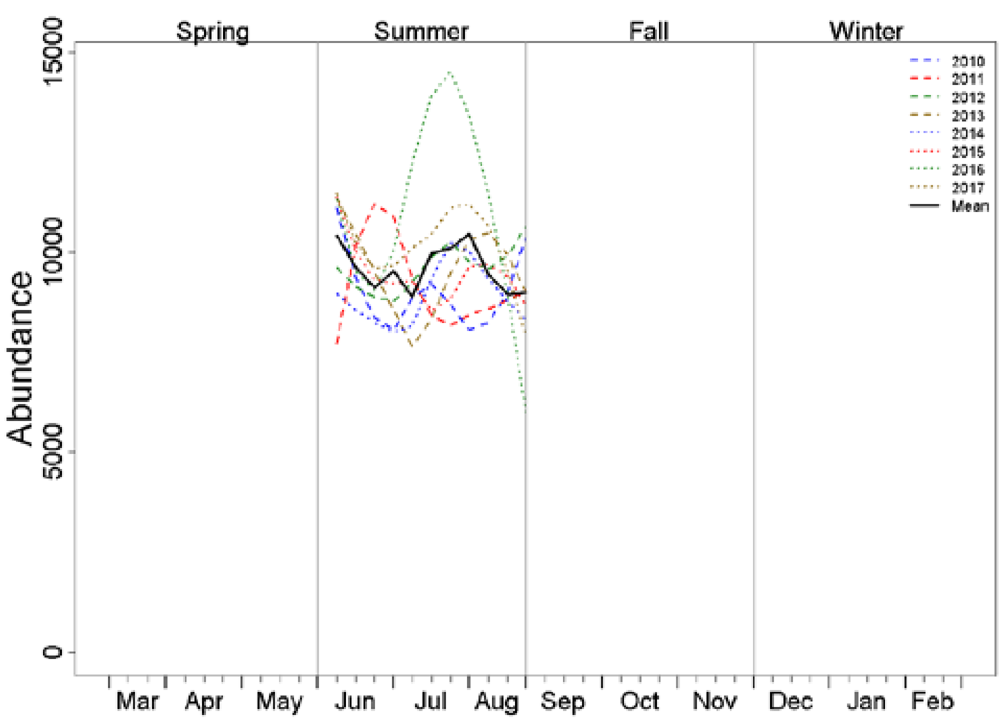

Figure 9-5 Annual abundance trends for unidentified beaked whales in the AMAPPS study area

9.6 Seasonal Prediction Maps

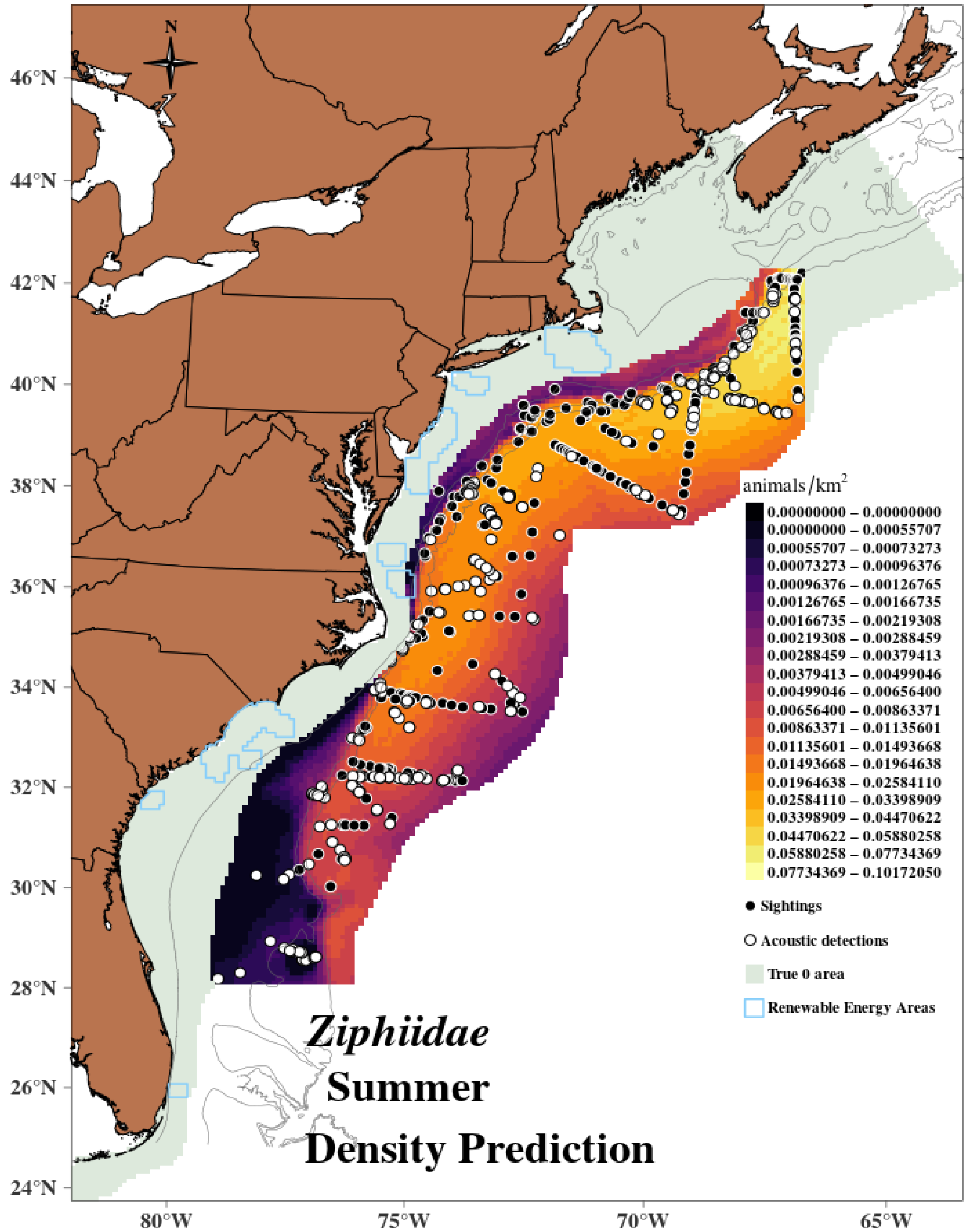

Figure 9-6 Unidentified beaked whale summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Black circles indicate locations of animal sightings. White circles indicate locations of passive acoustic detections of unidentified beaked whales and whales identified as Blainsville's, Gervais' or True's beaked whales from the NEFSC and SEFSC 2013 and 2016 towed hydrophone arrays. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

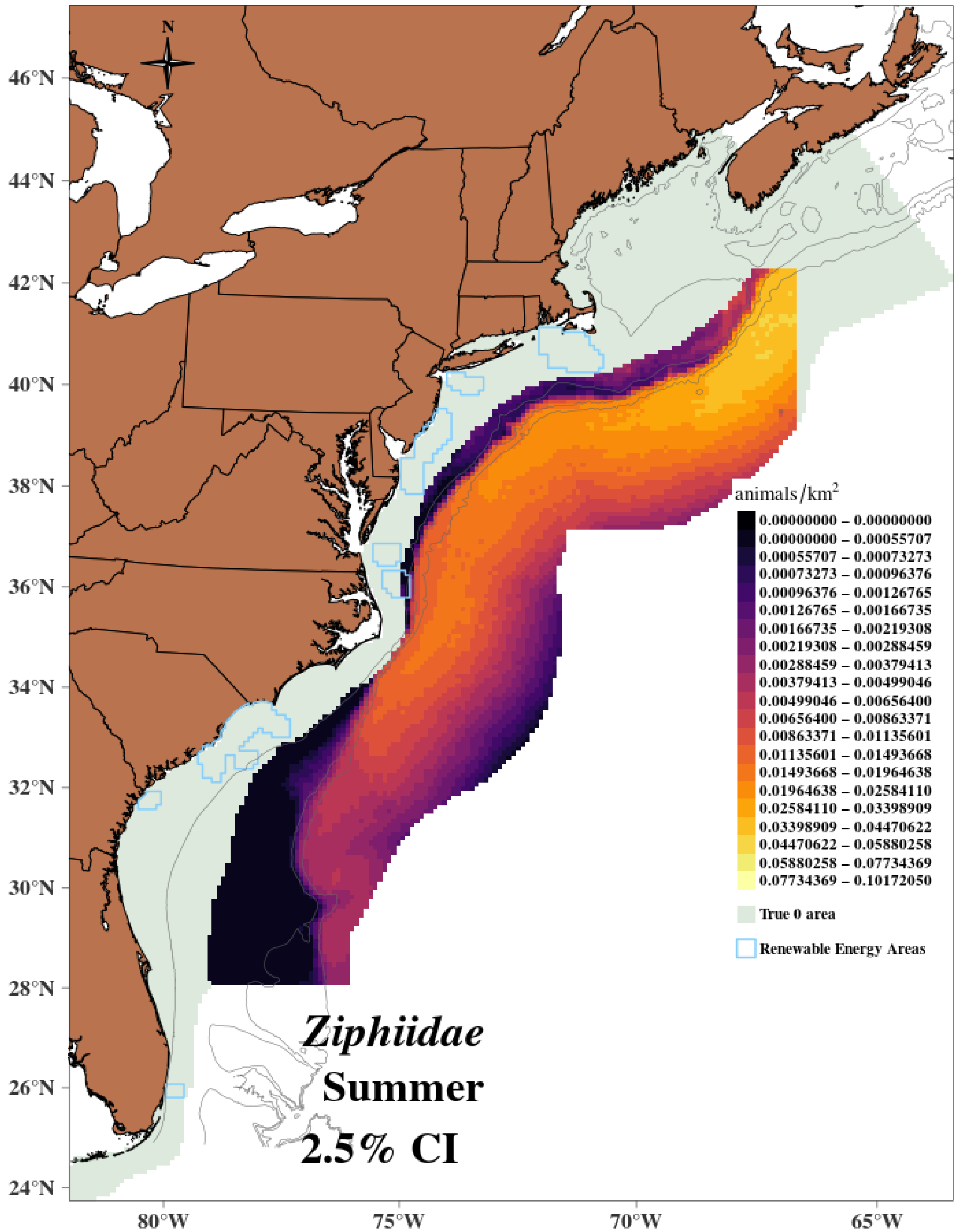

Figure 9-7 Lower 2.5% confidence interval of the summer unidentified beaked whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

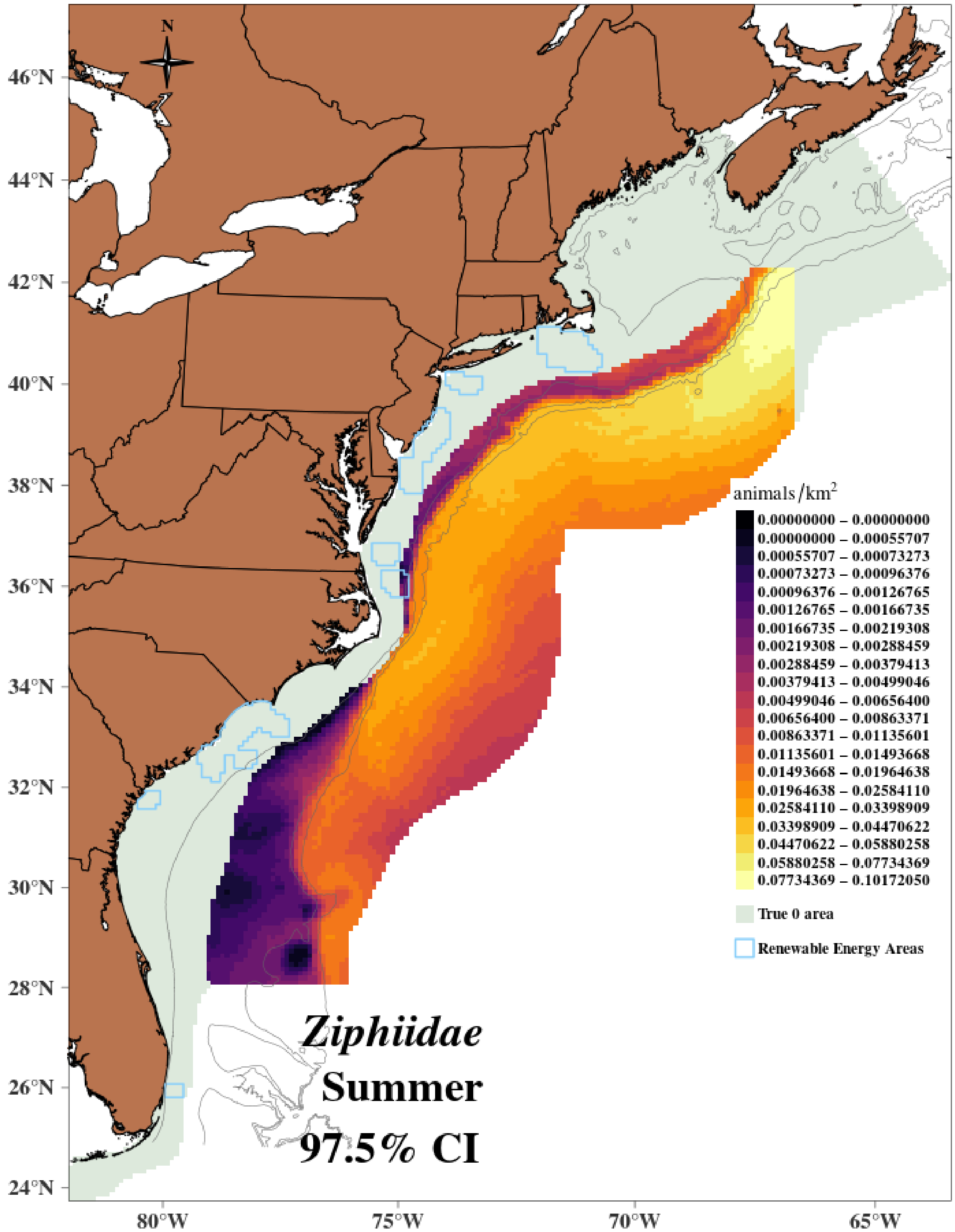

Figure 9-8 Upper 97.5% confidence interval of the summer unidentified beaked whale density estimates

CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

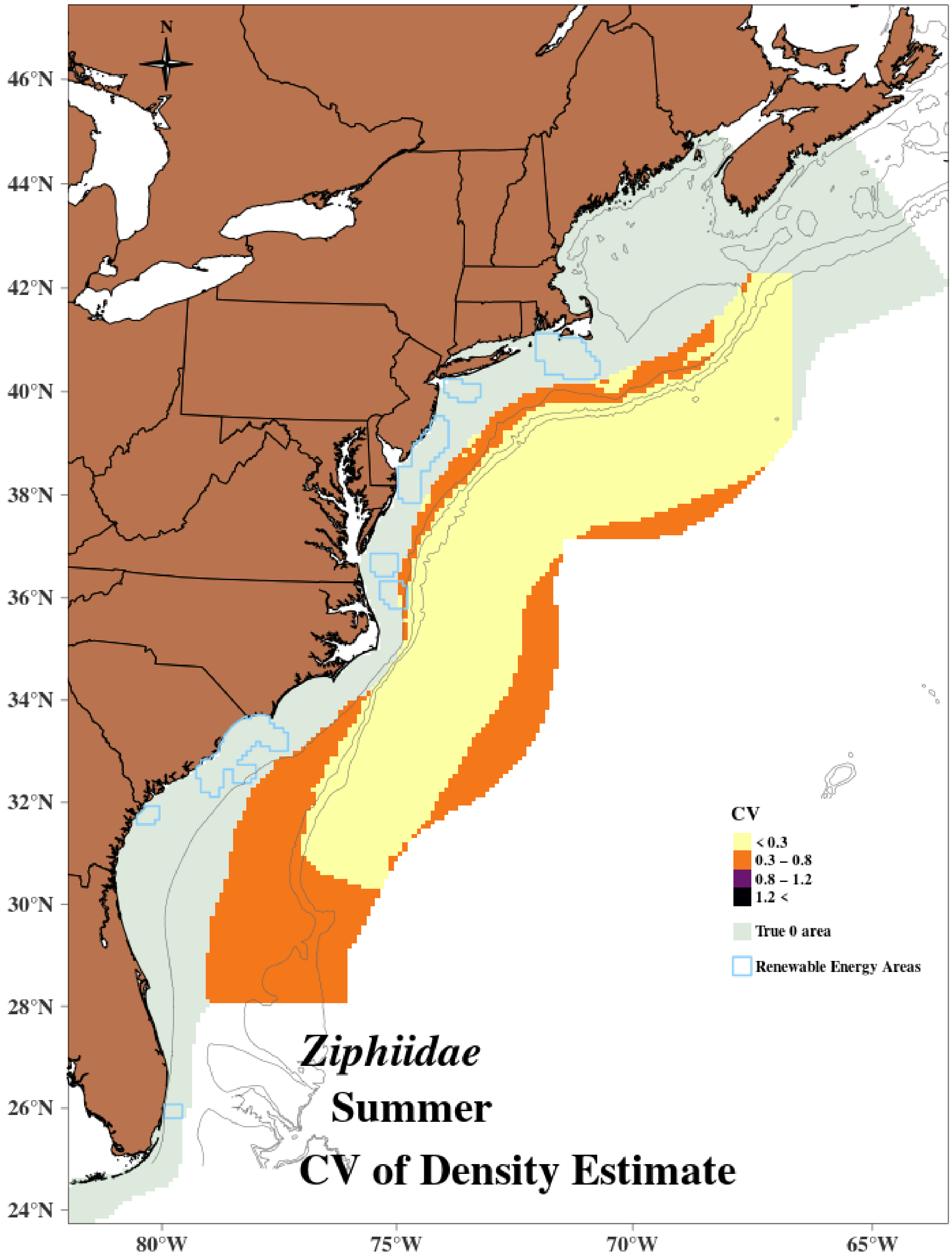

Figure 9-9 CV of summer unidentified beaked whale density estimates
100, 1,000 and 2,000 m depth contours shown.

9.7 Offshore Energy Development Areas

Table 9-6 Unidentified beaked whale abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Summer (Jun–Aug)	NC	0.9	0.29	0.5–1.6

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

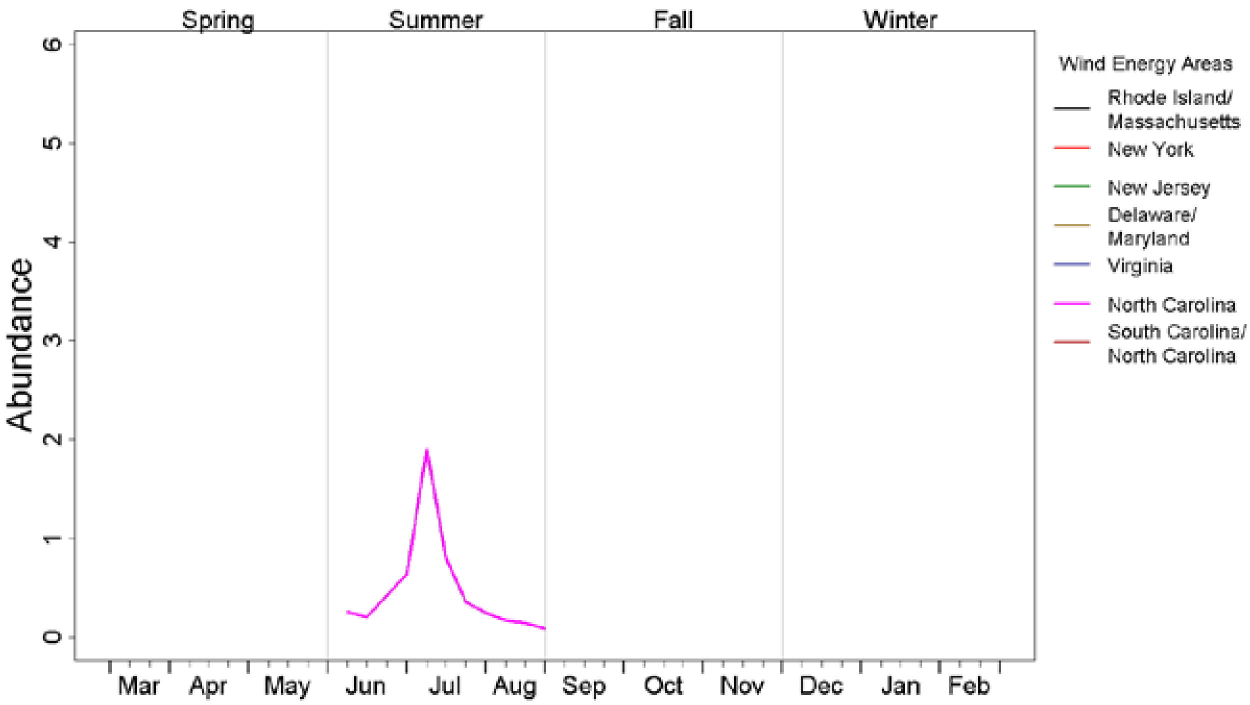

Figure 9-10 Average seasonal abundance of unidentified beaked whales in the wind-energy study areas

10 Pygmy Sperm Whale or Dwarf Sperm Whale (*Kogia* spp.)

Figure 10-1 Pygmy sperm whale or dwarf sperm whale
Image collected under MMPA research permit #779-1638. Credit: NOAA/SEFSC.

10.1 Data Collection

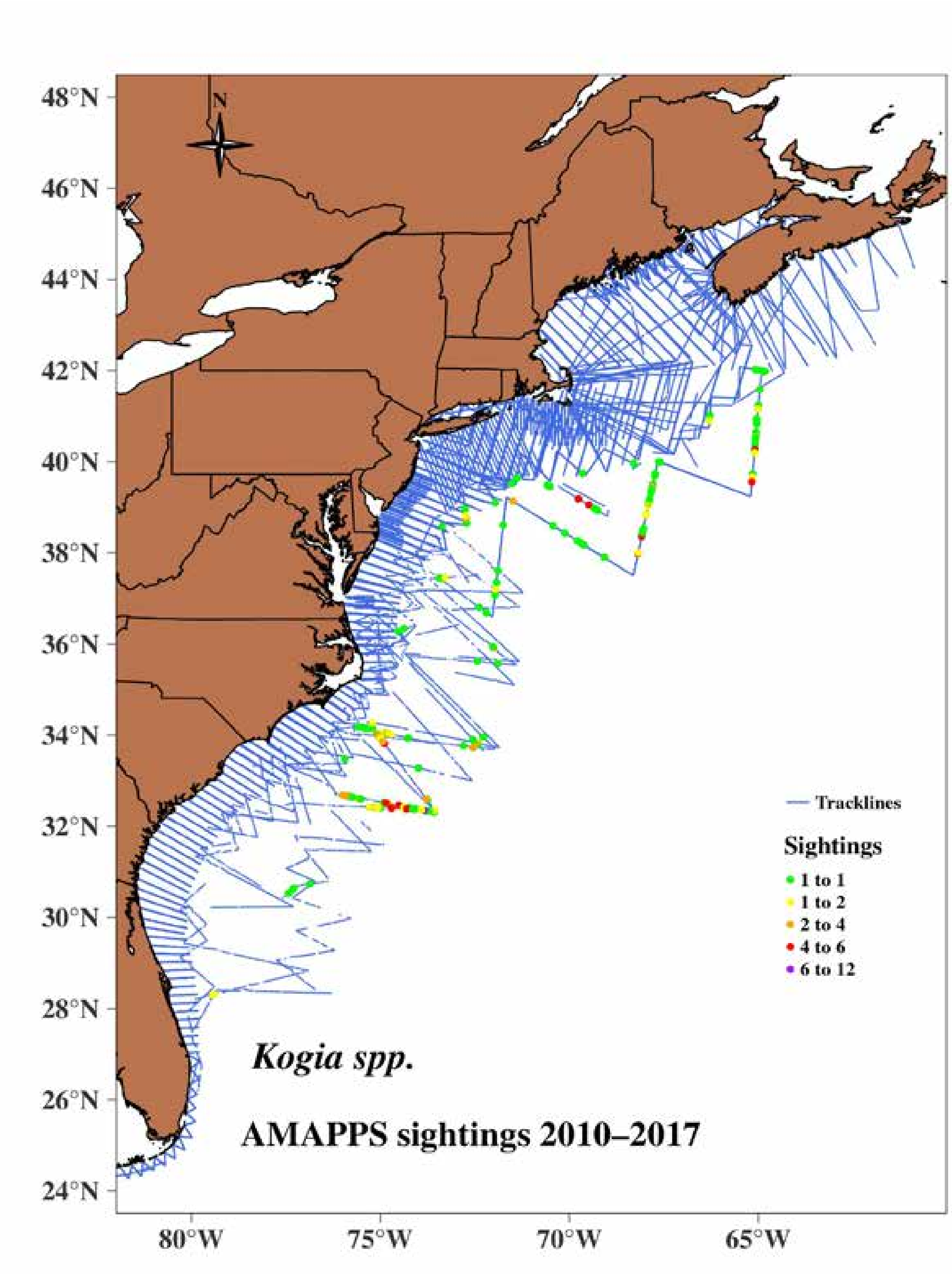

Figure 10-2 Distribution of track lines and *Kogia* spp. sightings 2010 to 2017

Table 10-1 AMAPPS research effort 2010 to 2017 and *Kogia* spp. sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	100	155
NE Shipboard	Fall	1,065	3	4
NE Aerial	Spring	13,314	0	0
NE Aerial	Summer	25,867	0	0
NE Aerial	Fall	37,850	0	0
NE Aerial	Winter	12,179	0	0
SE Shipboard	Spring	8,853	0	0
SE Shipboard	Summer	12,968	81	151
SE Shipboard	Fall	3,012	16	30
SE Aerial	Spring	41,293	0	0
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

10.2 Mark-Recapture Distance Sampling Analysis

Table 10-2 Intermediate parameters in *Kogia* spp. mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
NE–shipboard group 6	distance * observer + group size	3800	distance + sea state + swell + time of day	3800	HR	0.42	0.13	0.22	0.31	0.88
SE–shipboard group 6	distance	2800	distance + sea	2800	HR	0.48	0.26	0.74	0.99	0.99

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

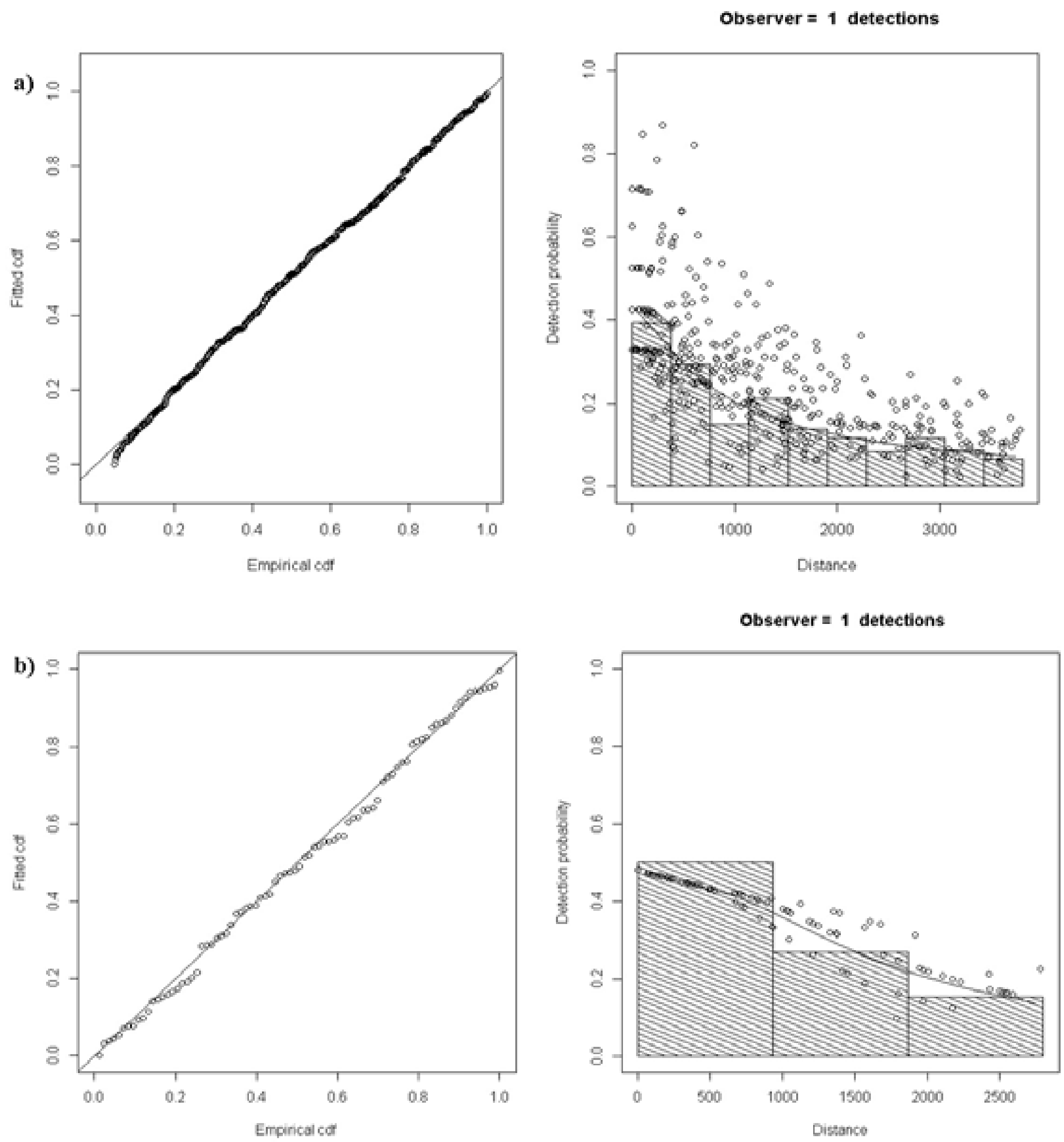

Figure 10-3 Q-Q plots and detection functions from the MRDS analyses
a) NE-shipboard analysis set 6; b) SE-shipboard analysis set 6.

10.3 Generalized Additive Model Analysis

Table 10-3 2010 to 2017 density-habitat model output for *Kogia* spp.

Covariates	Edf	Ref.df	F	C.dev	p-value
s(btemp)	1.84	4	13.27	20.95	<0.0001
s(mlp)	0.89	4	1.66	1.85	0.0050
s(pocma)	0.88	4	1.76	1.62	0.0037
s(dist2GSSw)	1.99	4	5.13	3.21	<0.0001

Adjusted R^2 = 0.0376. Deviance explained = 27.6%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

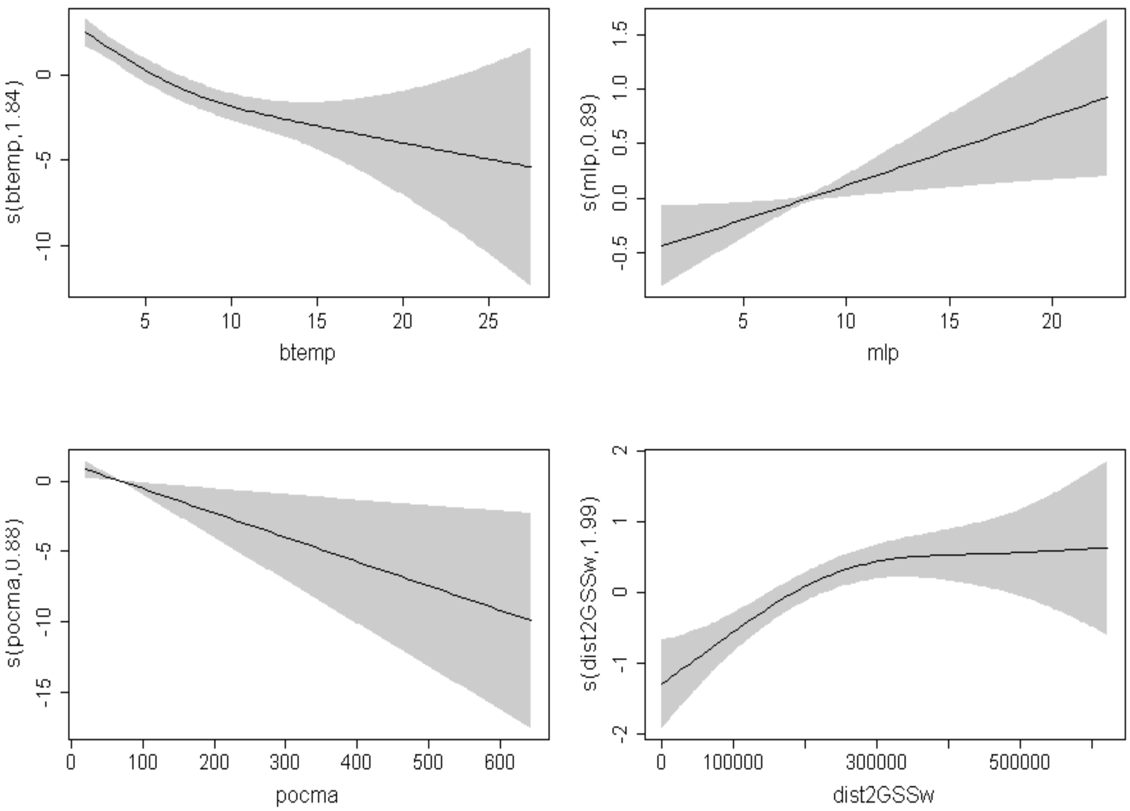

Figure 10-4 *Kogia* spp. density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

10.4 Model Cross-Validation

Table 10-4 Diagnostic statistics from the *Kogia* spp. density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.336	Excellent
MAPE	Mean absolute percentage error	Non-zero density	88.450	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.152	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.0143	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

10.5 Abundance Estimates for AMAPPS Study Area

Table 10-5 *Kogia* spp. average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Summer (June–August)	8,132	0.24	5,114 12,931
Summer 2011 U.S. surveys[1]	3,785	0.47	
Summer 2016 U.S. surveys[1]	7,750	0.38	

[1]Hayes et al. 2020

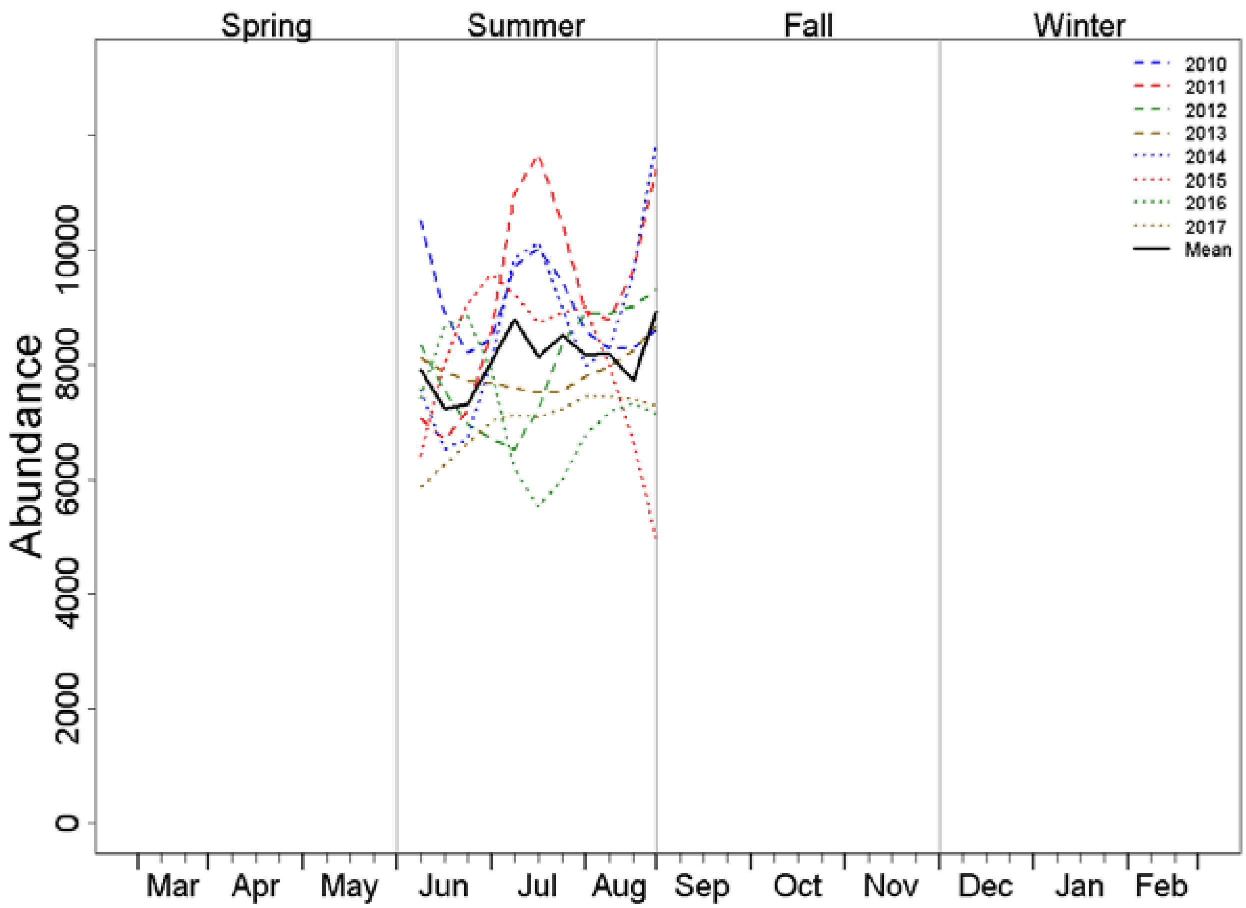

Figure 10-5 Annual abundance trends for *Kogia* spp. in the AMAPPS study area

10.6 Seasonal Prediction Maps

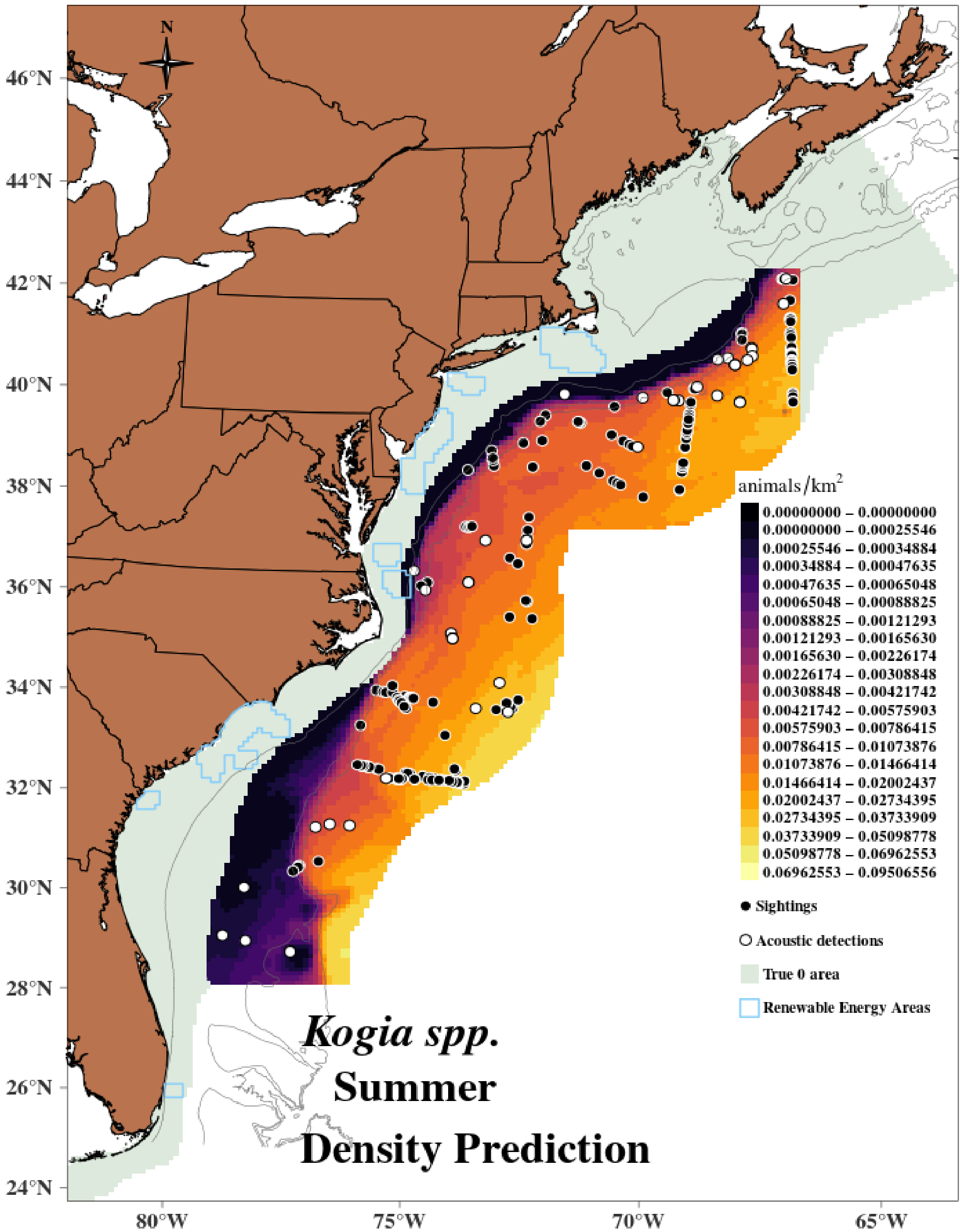

Figure 10-6 *Kogia* spp. summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Black circles indicate locations of animal sightings. White circles indicate locations of passive acoustic detections of *Kogia* spp. from the NEFSC and SEFSC 2016 and 2018 towed hydrophone arrays. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

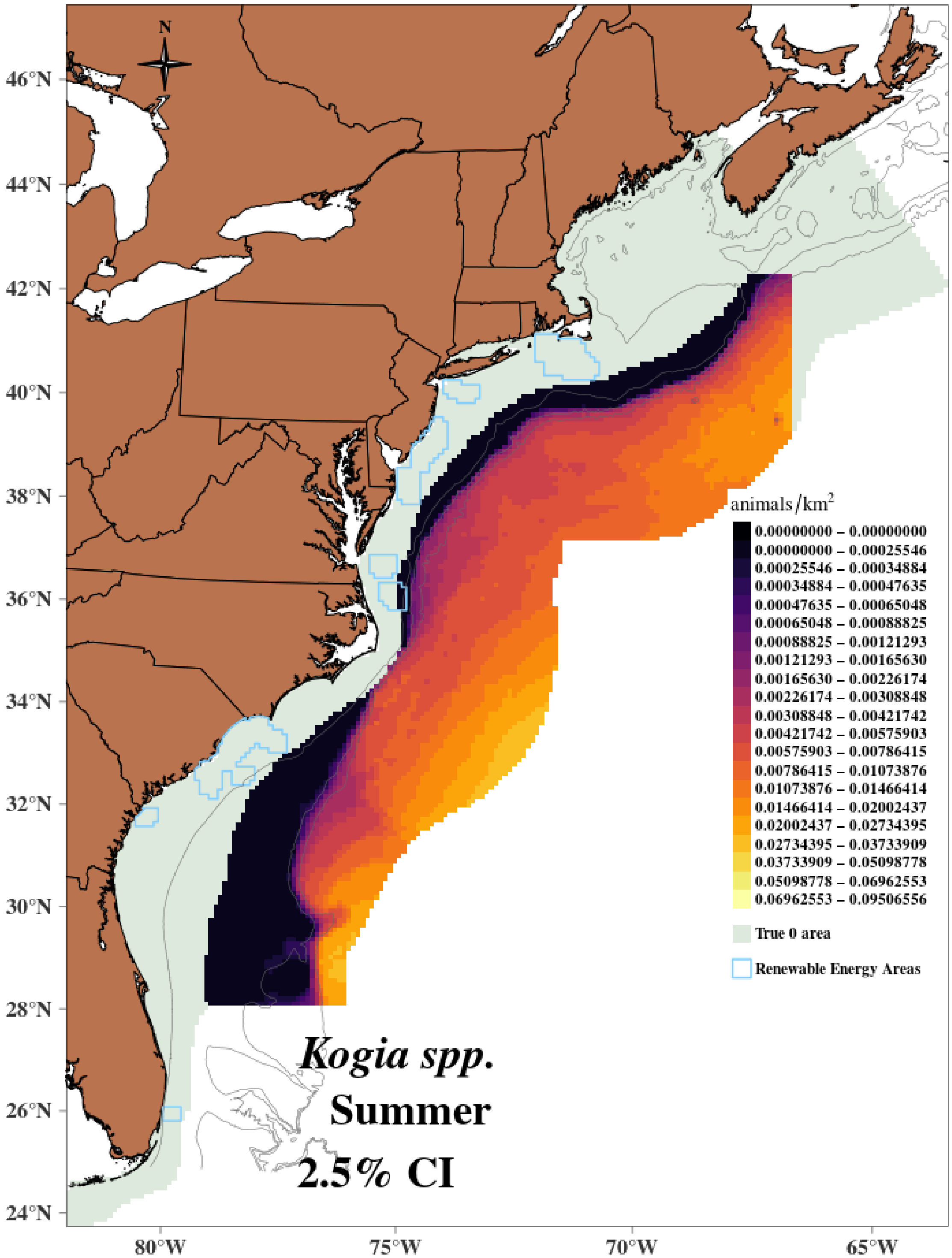

Figure 10-7 Lower 2.5% confidence interval of the summer *Kogia* spp. density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

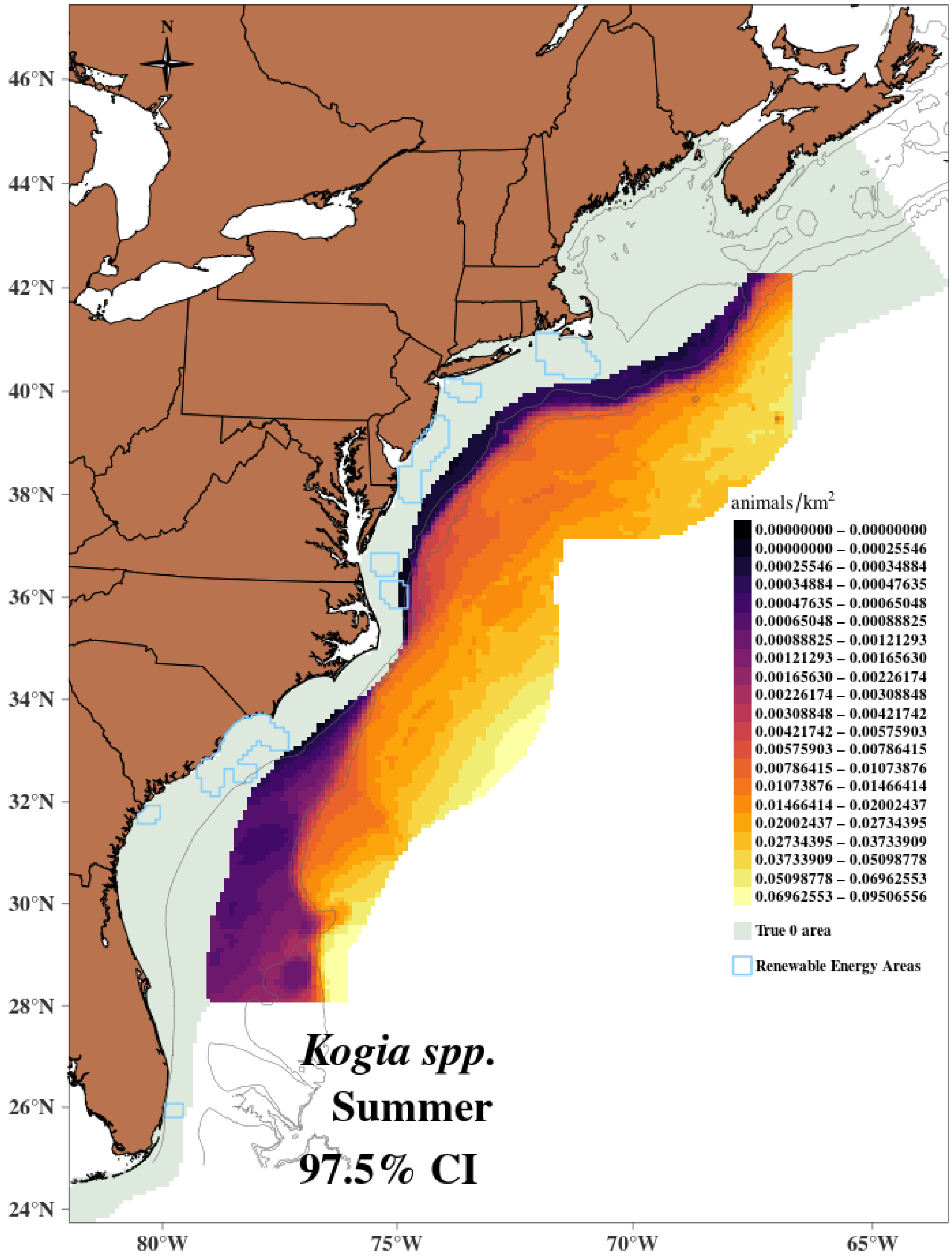

Figure 10-8 Upper 97.5% confidence interval of the summer *Kogia* spp. density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

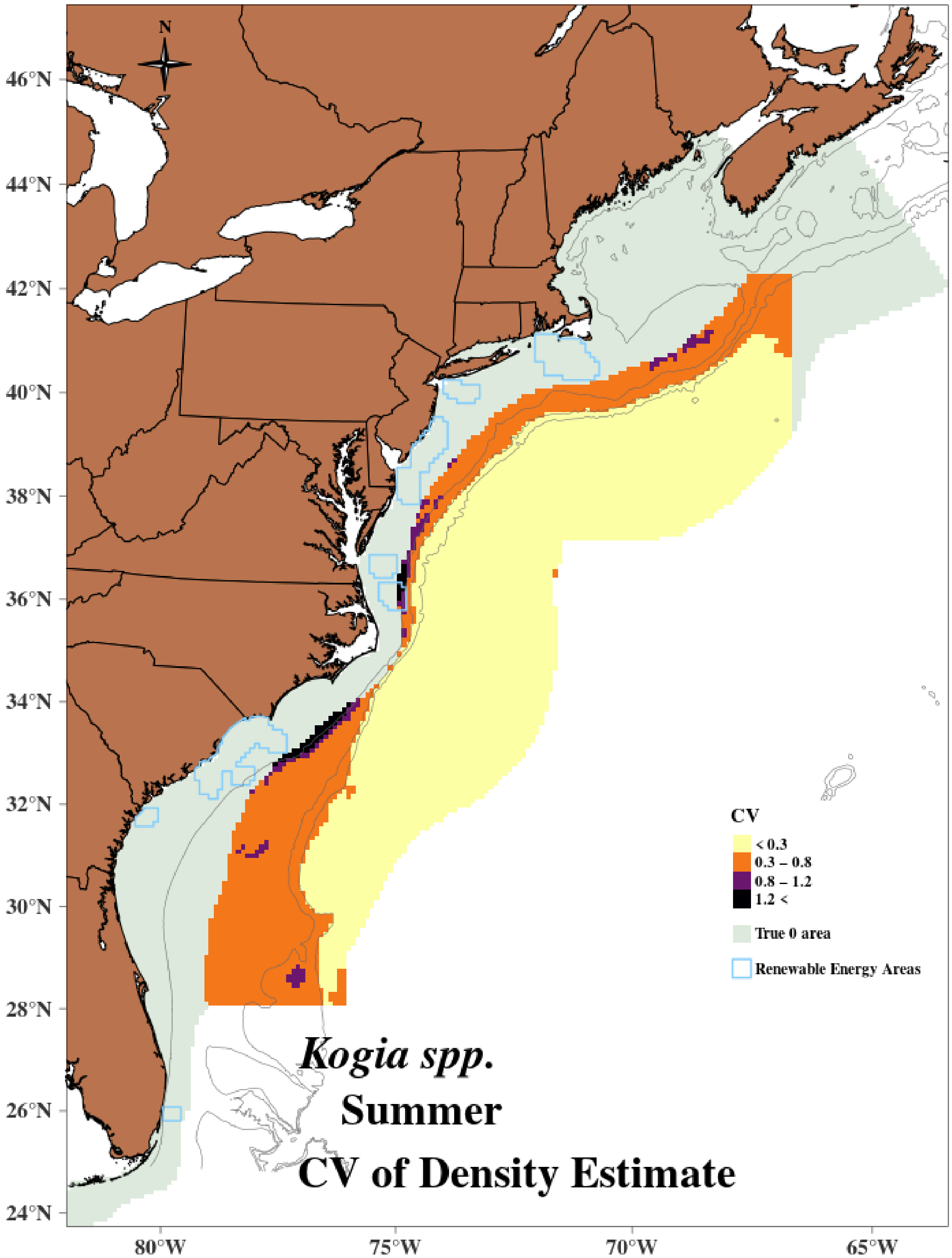

Figure 10-9 CV of summer *Kogia* spp. density estimates
CVs are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

10.7 Offshore Energy Development Areas

Table 10-6 *Kogia* spp. abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Summer (Jun – Aug)	NC	0.0	1.06	0.0–0.2

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

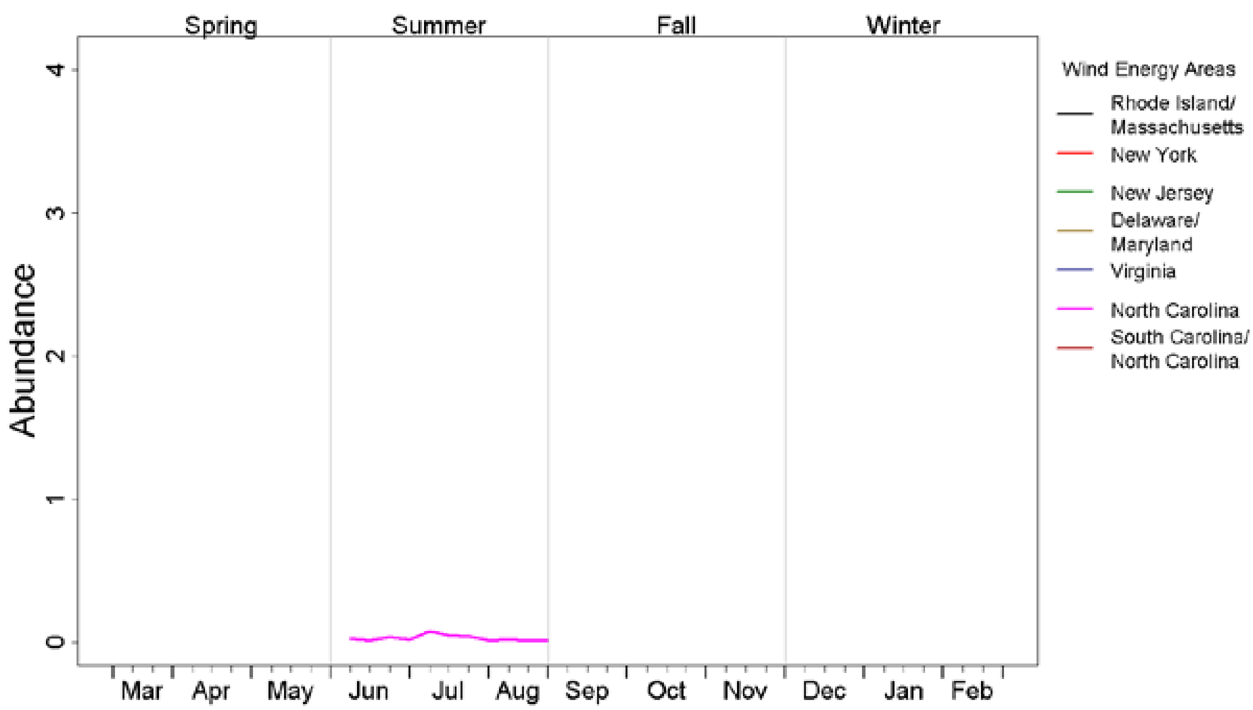

Figure 10-10 Average seasonal abundance of *Kogia* spp. in the wind-energy study areas

11 Short-finned Pilot Whale (*Globicephala macrorhynchus*)

Figure 11-1 Short-finned pilot whales
Image collected under MMPA research permit #779-1633. Credit: NOAA/SEFSC

11.1 Data Collection

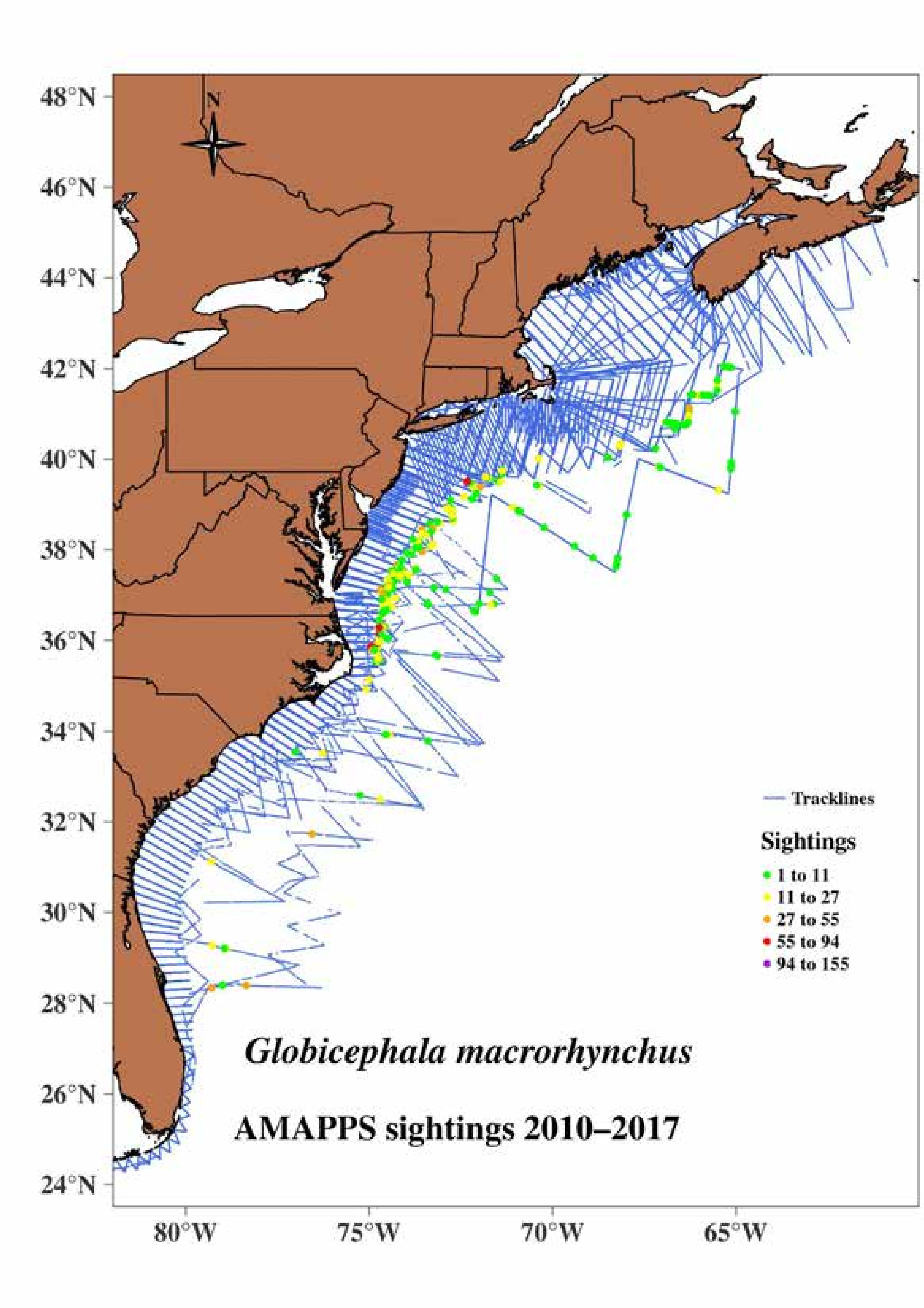

Figure 11-2 Distribution of track lines and short-finned pilot whale sightings 2010 to 2017

Table 11-1 AMAPPS research effort 2010 to 2017 and short-finned pilot whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	230	2,050
NE Shipboard	Fall	1,065	2	32
NE Aerial	Spring	13,314	0	0
NE Aerial	Summer	25,867	21	156
NE Aerial	Fall	37,850	15	82
NE Aerial	Winter	12,179	0	0
SE Shipboard	Spring	8,853	4	32
SE Shipboard	Summer	12,968	85	1,461
SE Shipboard	Fall	3,012	18	495
SE Aerial	Spring	41,293	10	269
SE Aerial	Summer	28,236	26	712
SE Aerial	Fall	18,974	31	485
SE Aerial	Winter	8,950	4	25

11.2 Mark-Recapture Distance Sampling Analysis

Table 11-2 Intermediate parameters in short-finned pilot whale mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 5	distance * observer + glare	320	distance + sea state + group size	LT50-360	HR	0.74	0.15	0.23	0.99	0.98
NE–aerial group 7	distance * observer	400	distance	400	HN	0.54	0.30	0.77	1.00	1.00
NE–shipboard group 7	distance * observer + group size + glare	3500	distance + glare + swell + time of day	3500	HR	0.66	0.10	0.09	0.86	0.91
SE–shipboard group 3	distance * observer + group size	2700	distance	2700	HR	0.71	0.08	0.37	0.91	0.81

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

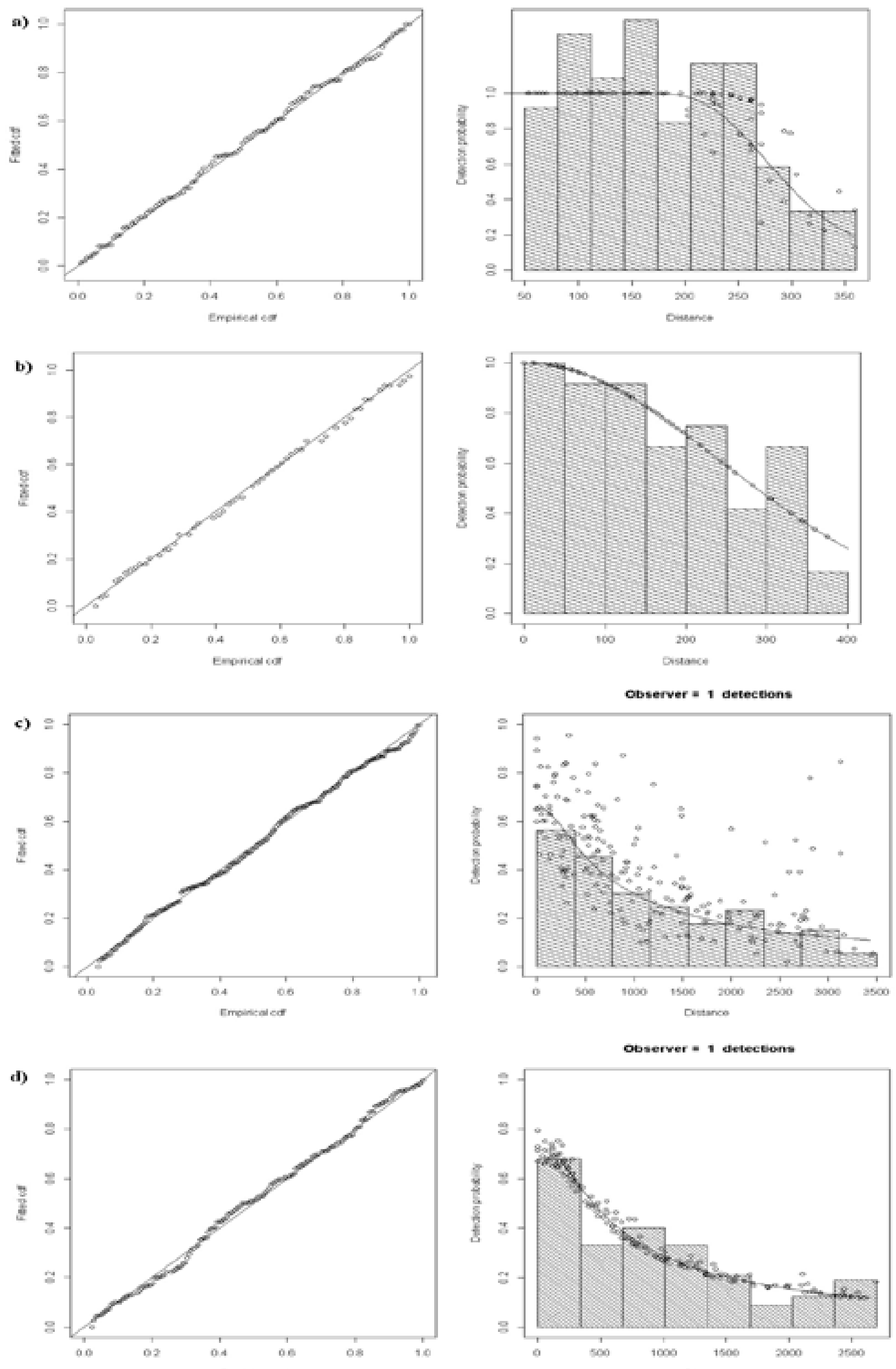

Figure 11-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 5; b) NE-aerial analysis set 7; c) NE-shipboard analysis set 7; d) SE-shipboard analysis set 3.

11.3 Generalized Additive Model Analysis

Table 11-3 2010 to 2017 density-habitat model output for short-finned pilot whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(chla)	0.97	4	8.90	6.12	<0.0001
s(salinity)	1.00	4	3.36	5.26	0.0001
s(btemp)	3.34	4	19.55	15.15	<0.0001
s(mlp)	0.99	4	7.07	5.33	<0.0001
s(dist2GSNw)	2.18	4	18.70	17.68	<0.0001
s(depth)	1.06	4	4.52	1.65	<0.0001
s(dist1000)	3.31	4	23.38	14.60	<0.0001

Adjusted $R^2 = 0.0358$. Deviance explained = 58.3%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

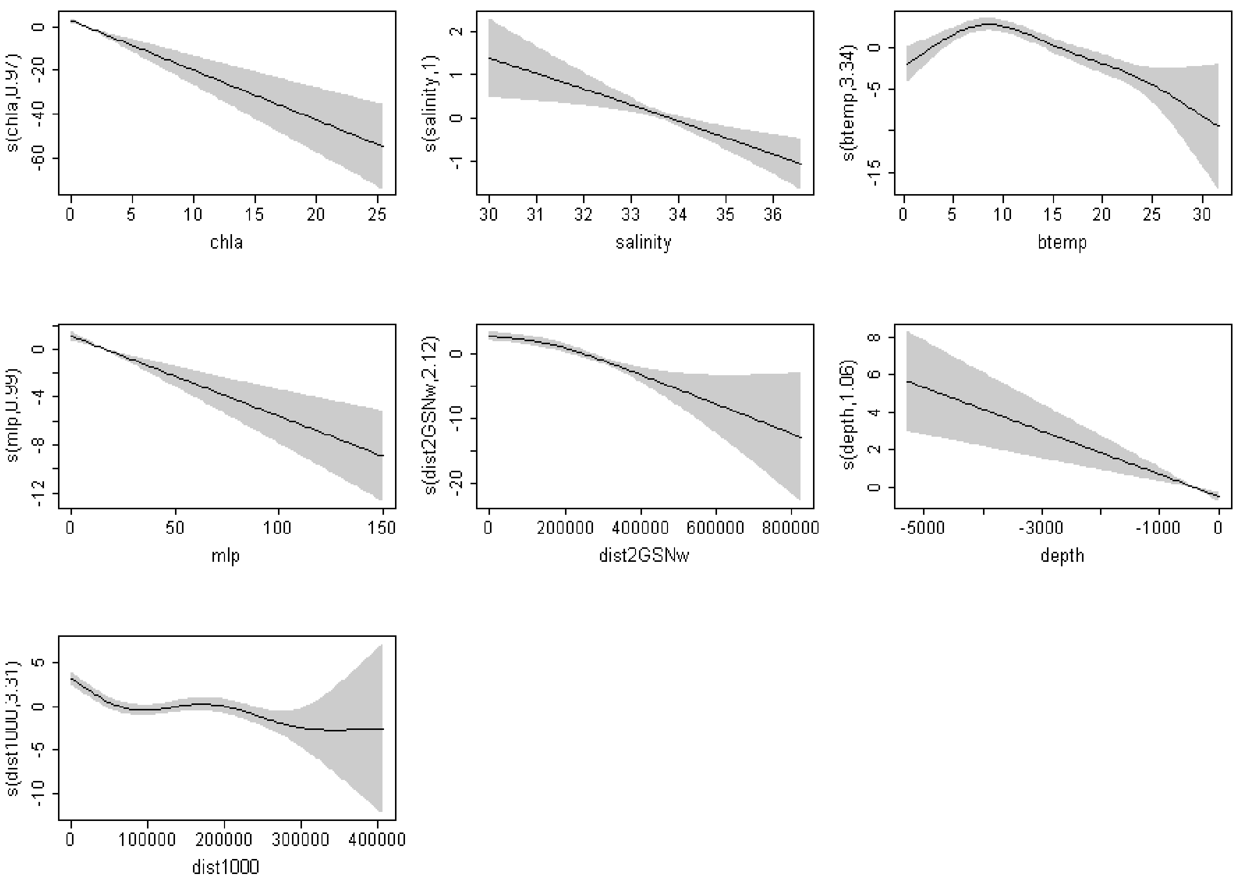

Figure 11-4 Short-finned pilot whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

11.4 Model Cross-Validation

Table 11-4 Diagnostic statistics from the short-finned pilot whale density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.284	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	85.550	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.136	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.018	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

11.5 Abundance Estimates for AMAPPS Study Area

Table 11-5 Short-finned pilot whale average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	8,497	0.34	4,444 16,248
Summer (June–August)	29,091	0.31	16,066 52,675
Fall (September–November)	11,654	0.32	6,320 21,491
Winter (December–February)	1,961	0.44	860 4,473
Summer 2011 U.S. surveys[1]	21,515	0.37	
Summer 2016 U.S. surveys[1]	28,924	0.24	

[1]Hayes et al. 2020

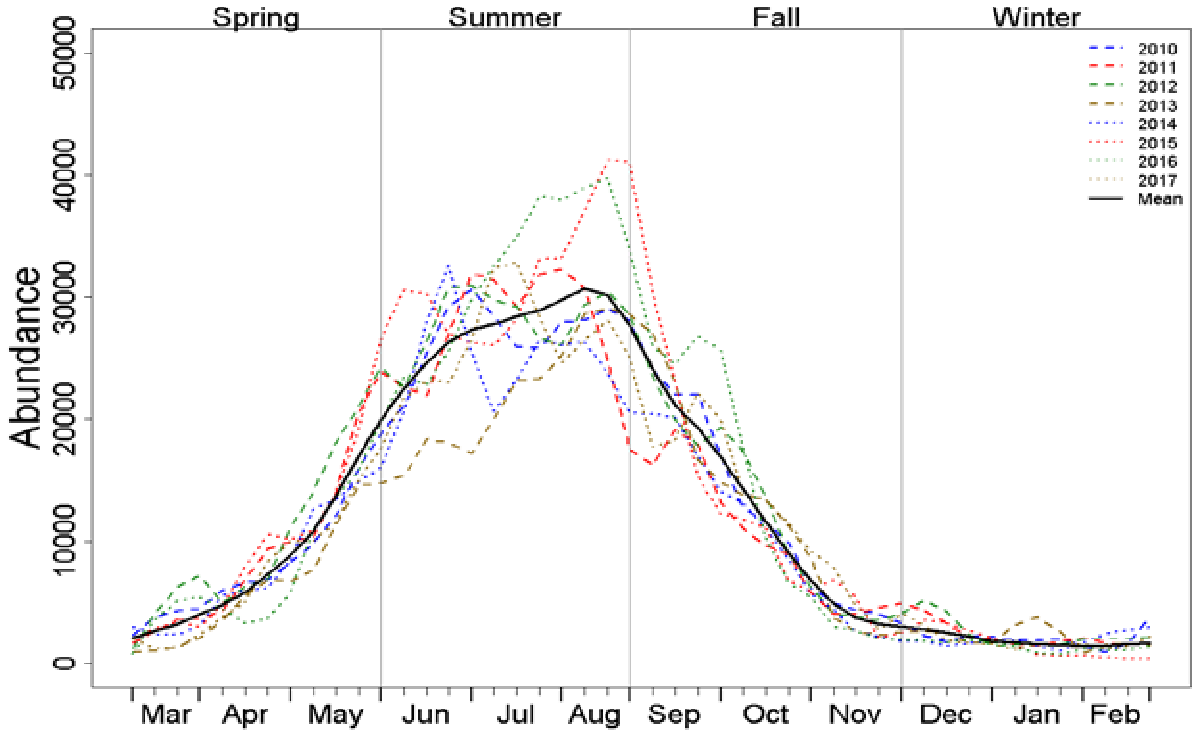

Figure 11-5 Annual abundance trends for short-finned pilot whales in the AMAPPS study area

11.6 Seasonal Prediction Maps

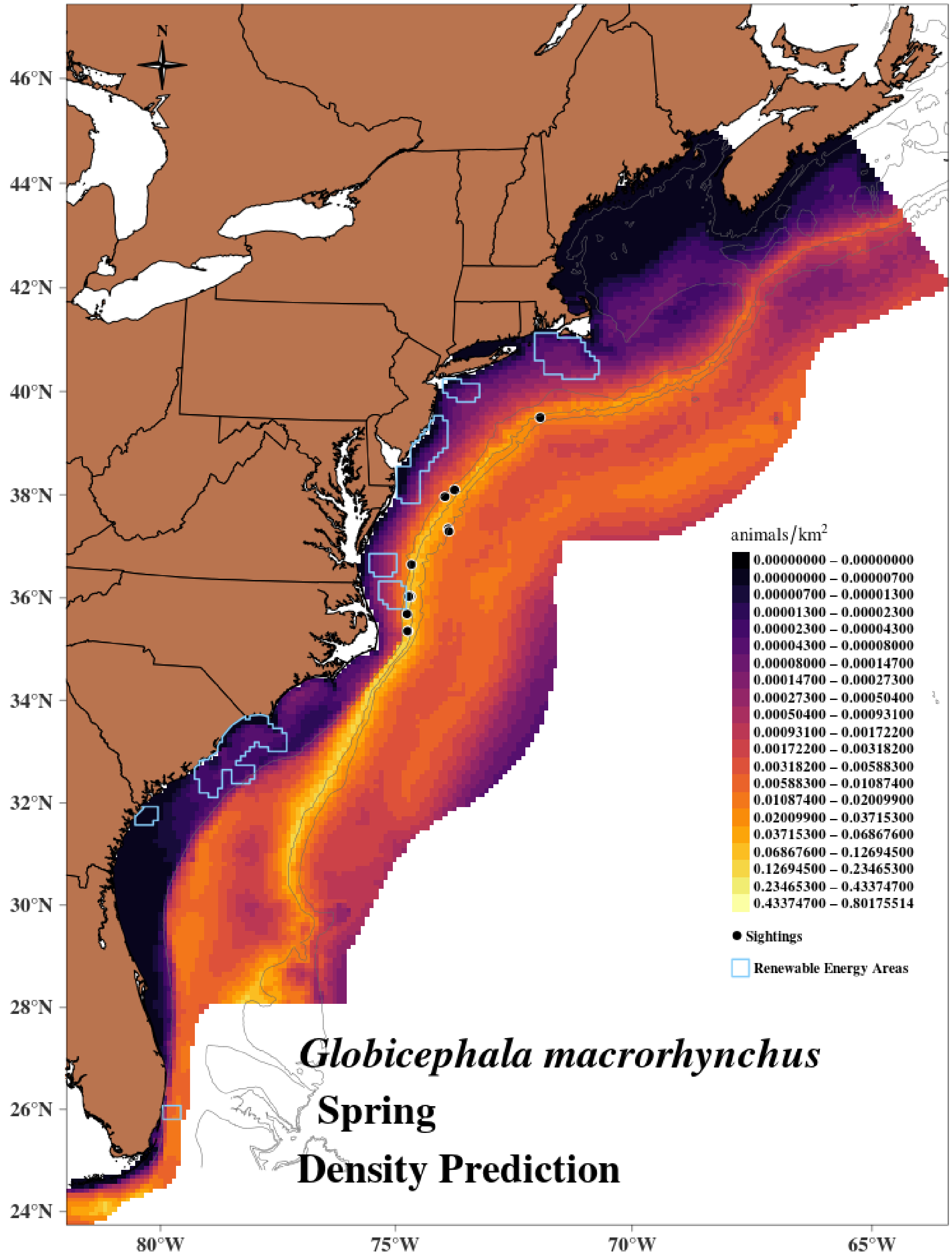

Figure 11-6 Long-finned pilot whale spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

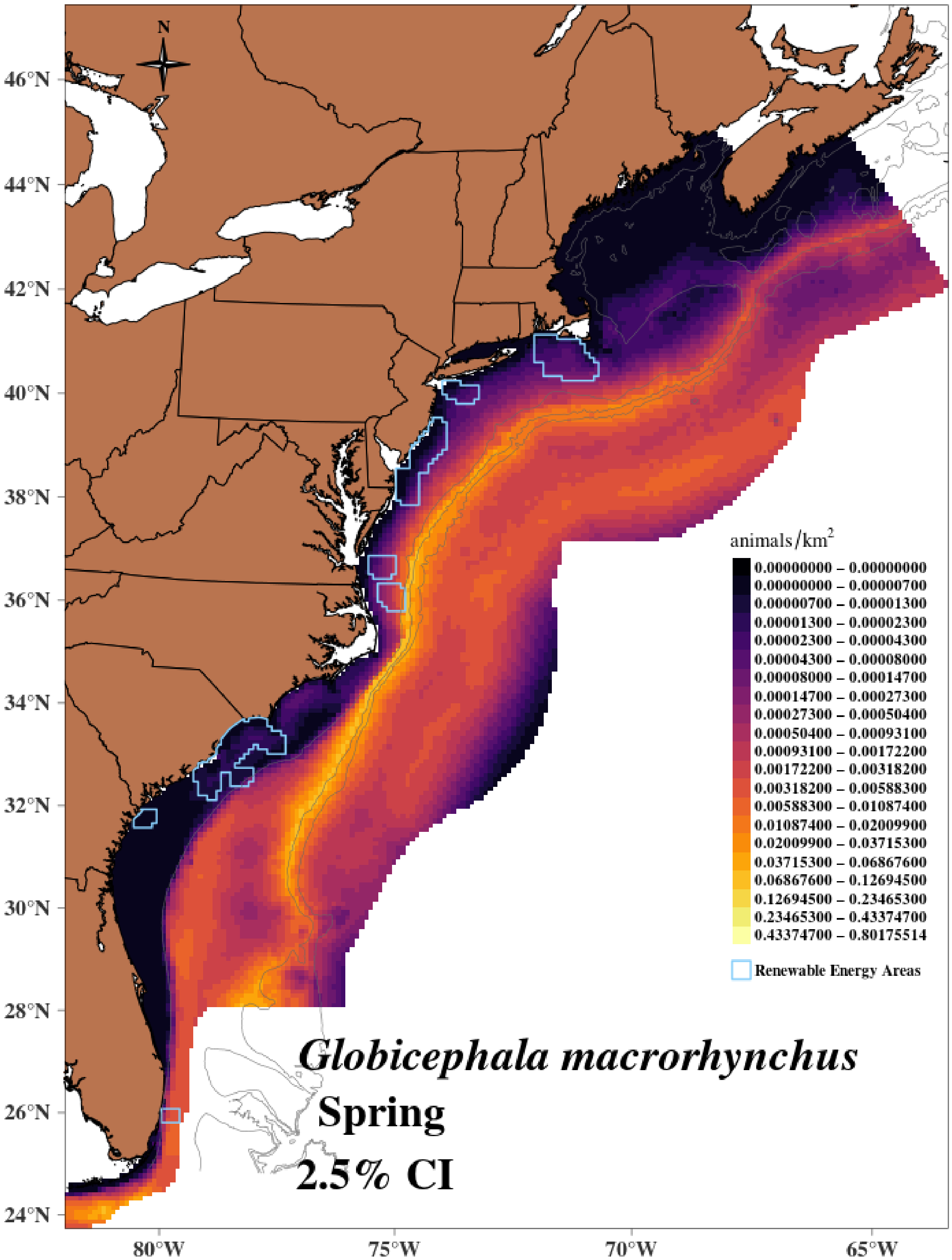

Figure 11-7 Lower 2.5% confidence interval of the spring short-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

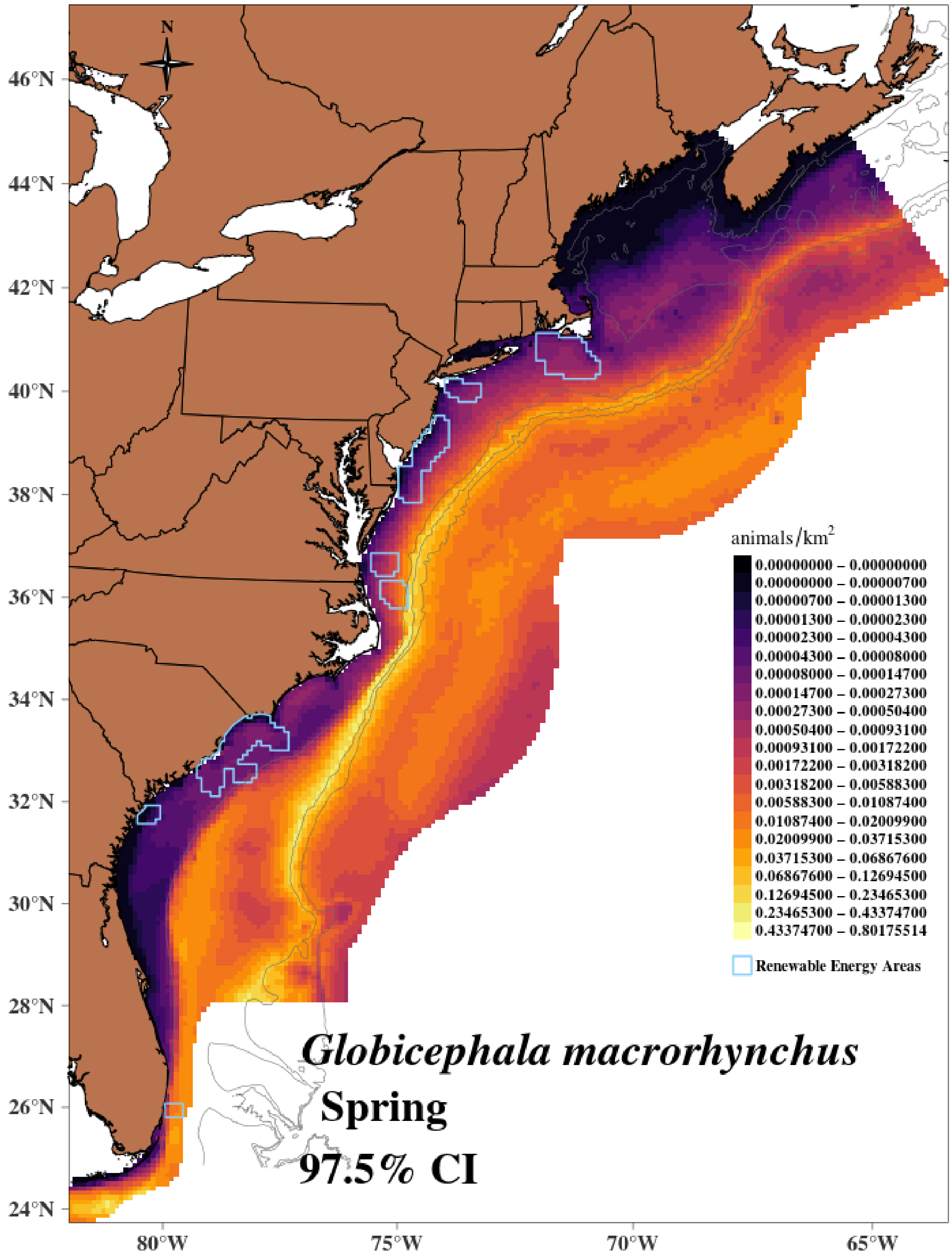

Figure 11-8 Upper 97.5% confidence interval of the spring short-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

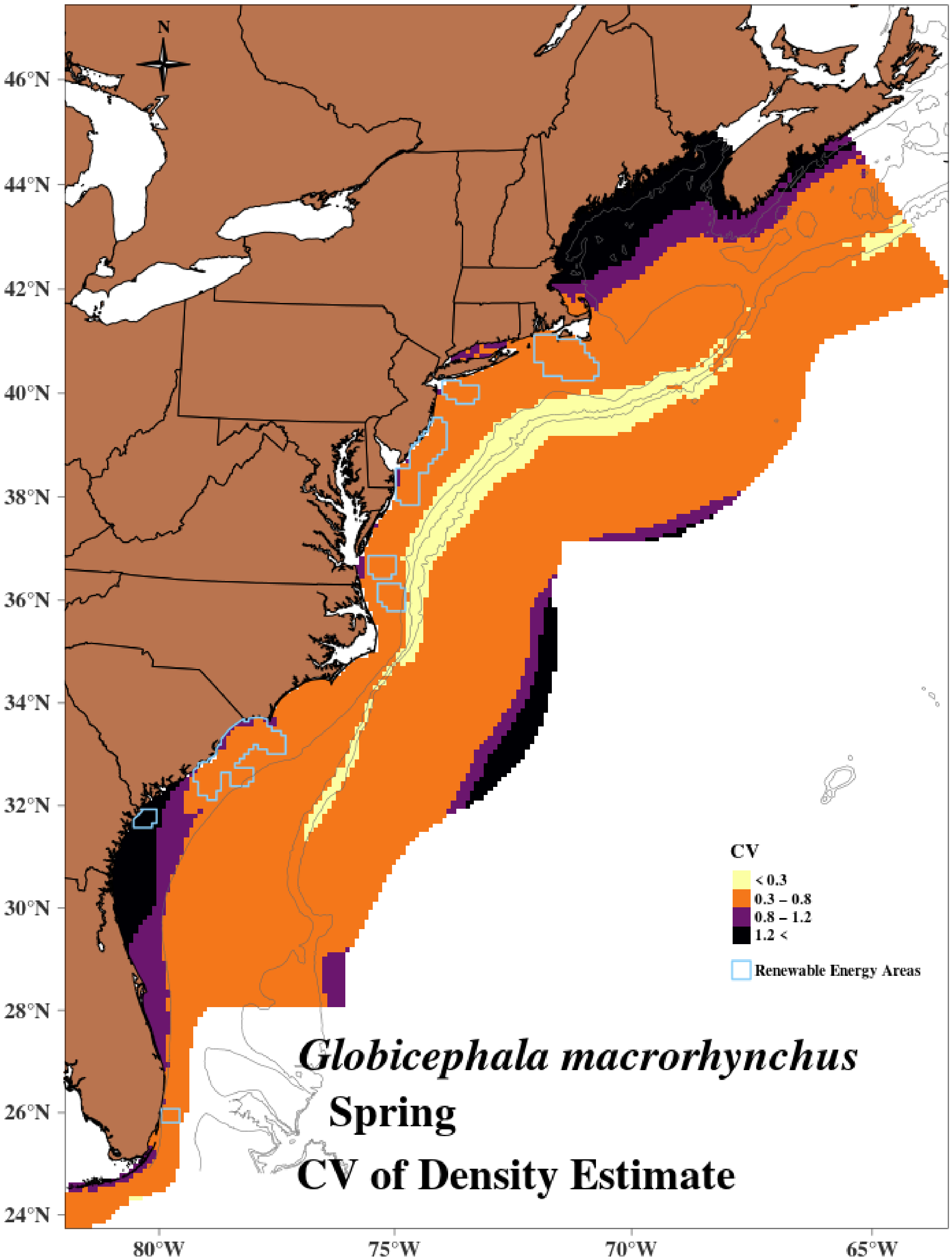

Figure 11-9 CV of spring short-finned pilot whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

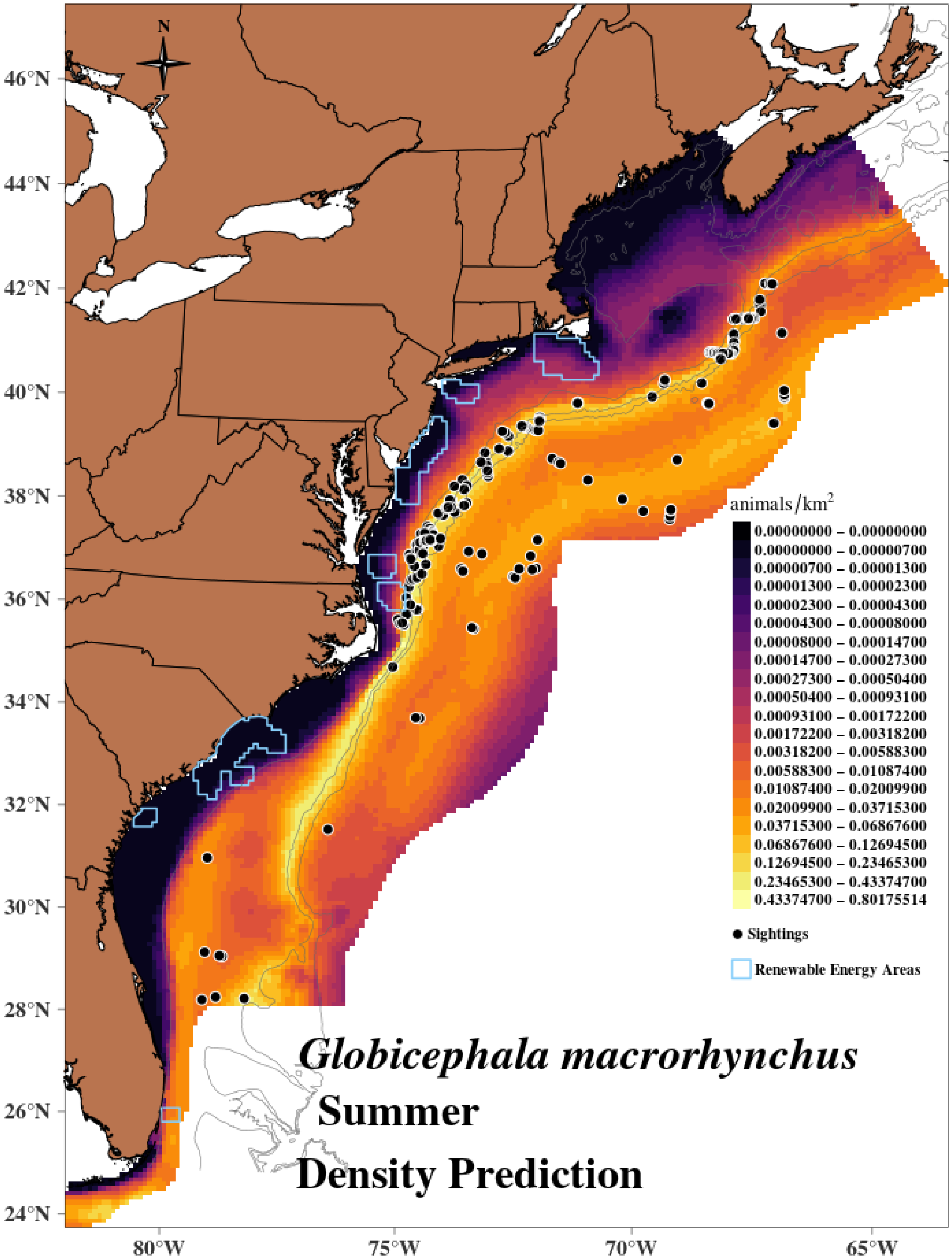

Figure 11-10 Short-finned pilot whale summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

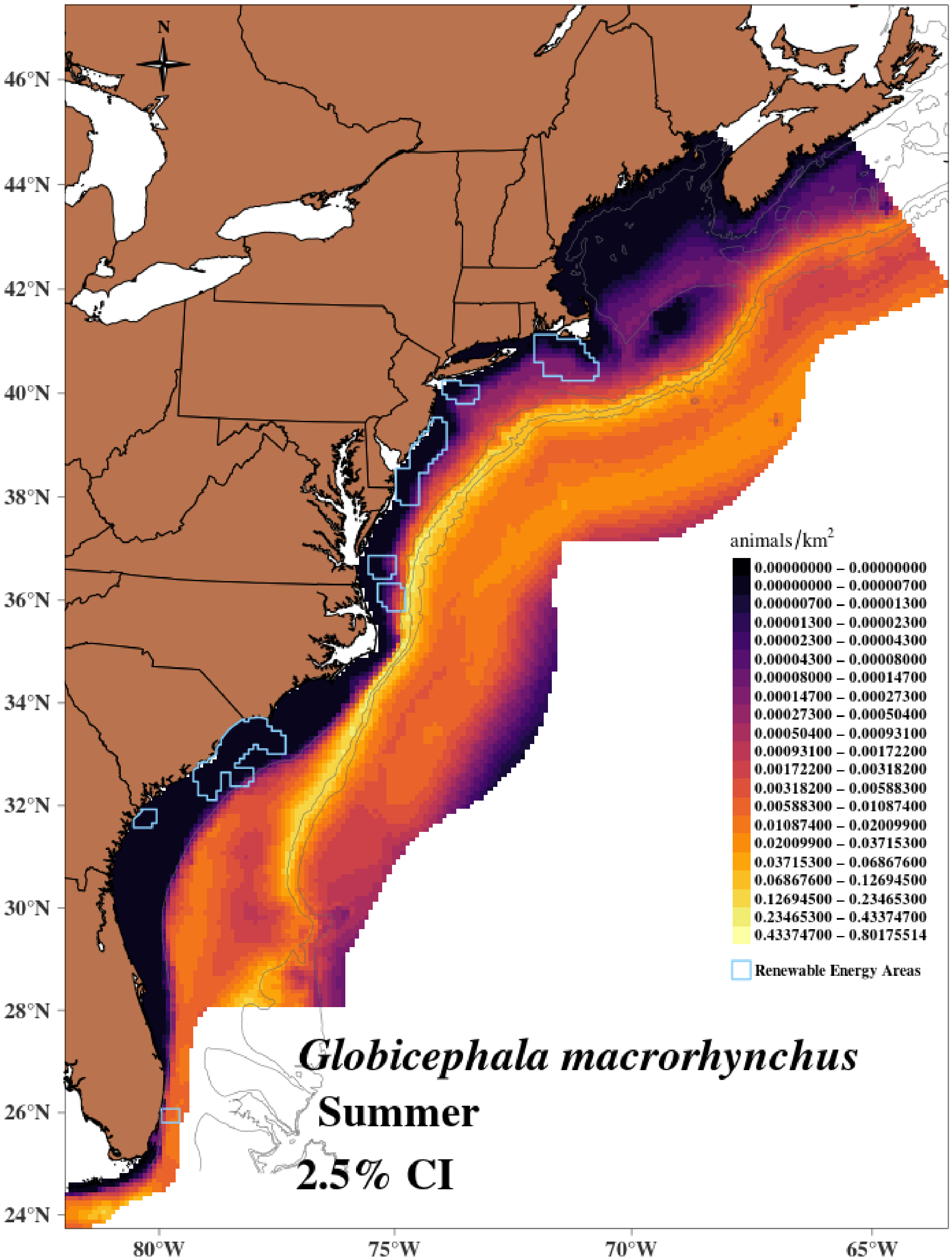

Figure 11-11 Lower 2.5% confidence interval of the summer short-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

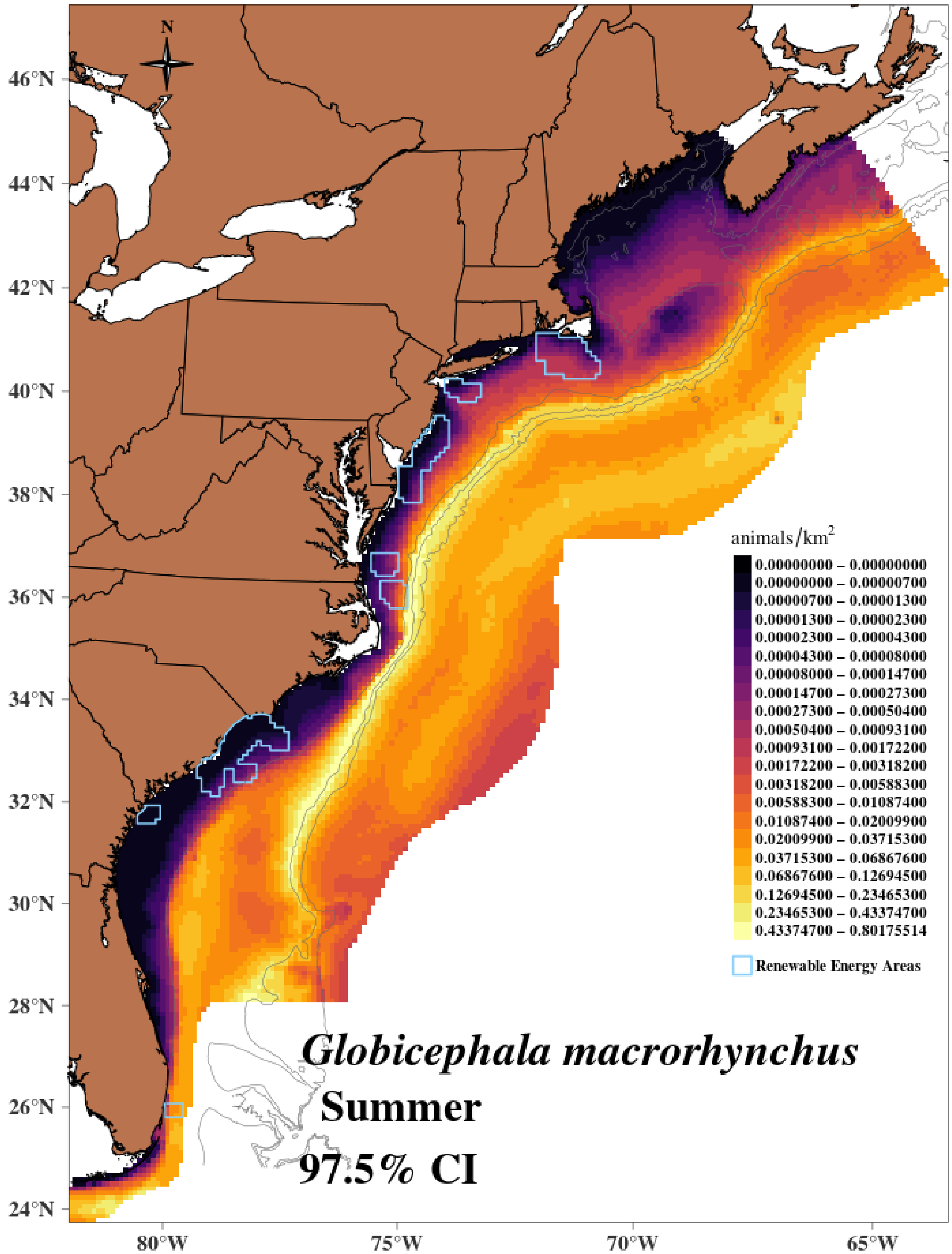

Figure 11-12 Upper 97.5% confidence interval of the summer short-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

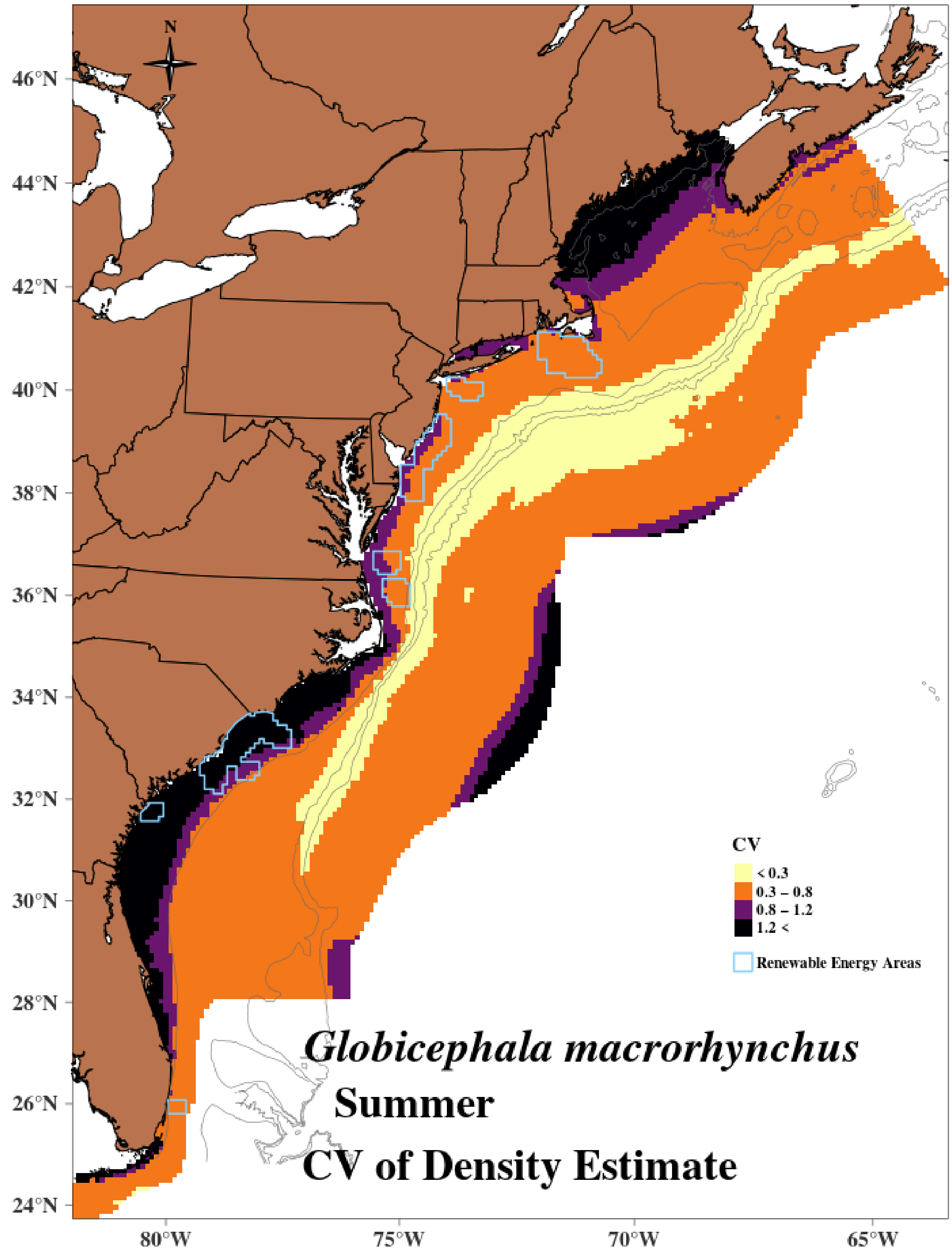

Figure 11-13 CV of summer short-finned pilot whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

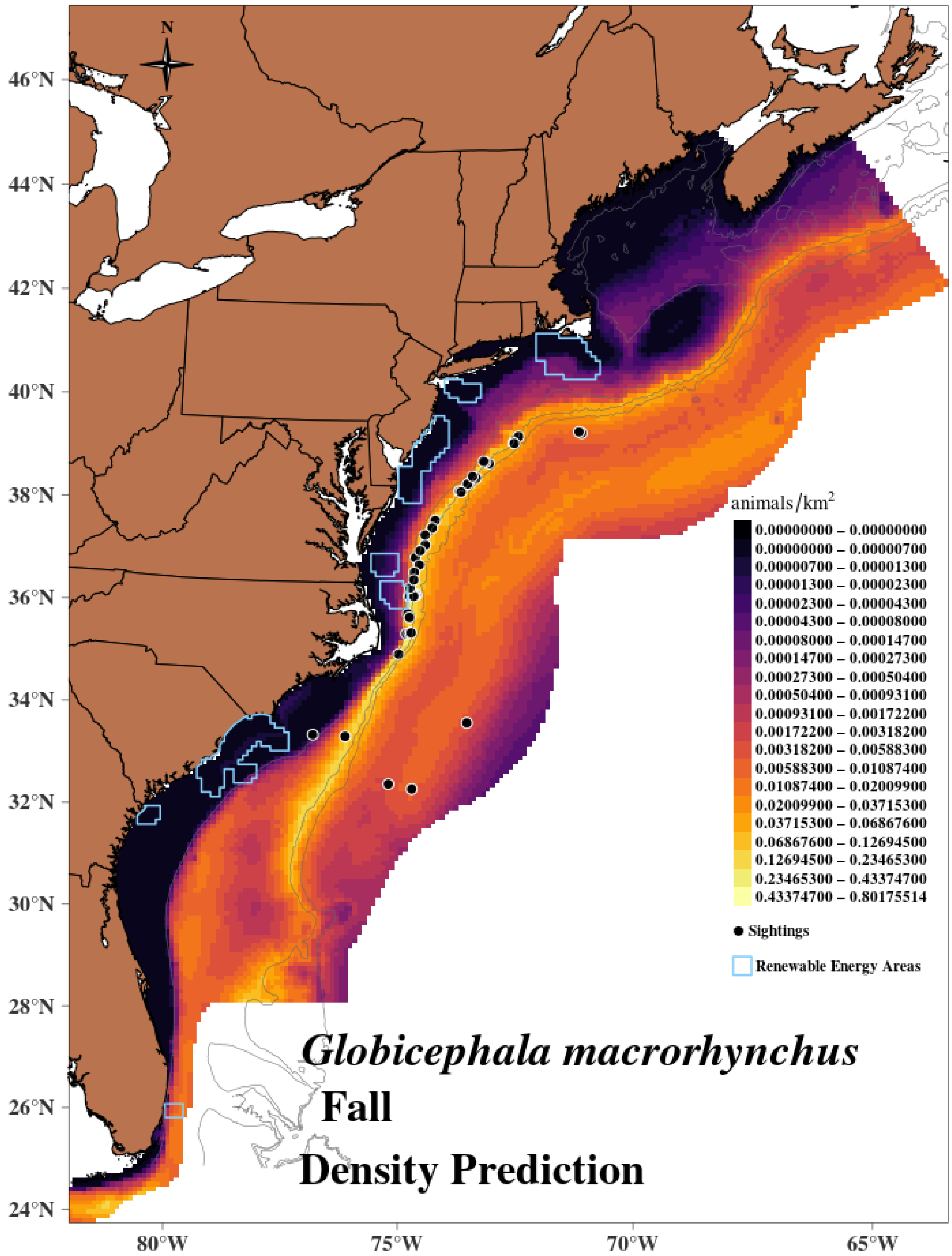

Figure 11-14 Short-finned pilot whale fall average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

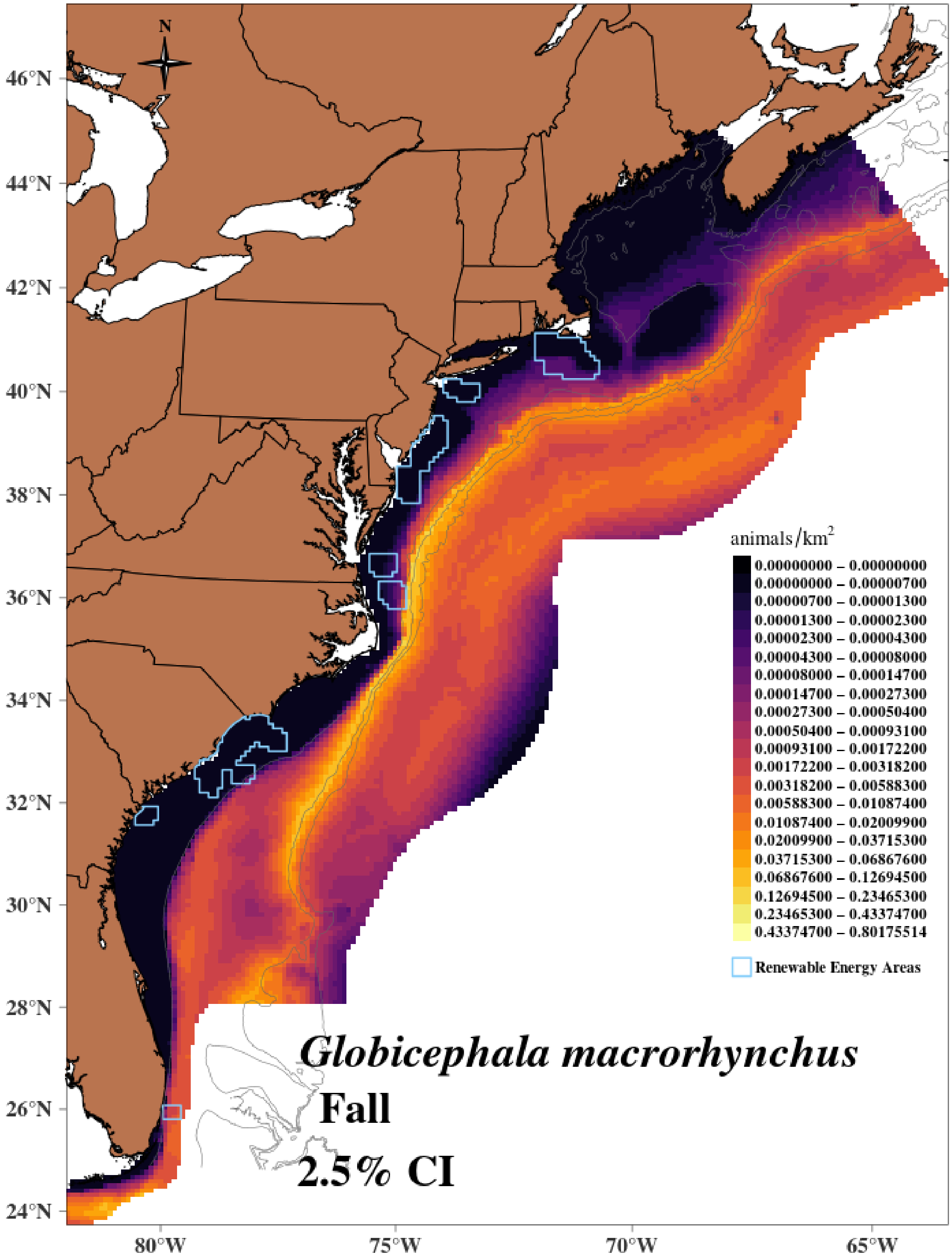

Figure 11-15 Lower 2.5% confidence interval of the fall short-finned pilot whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

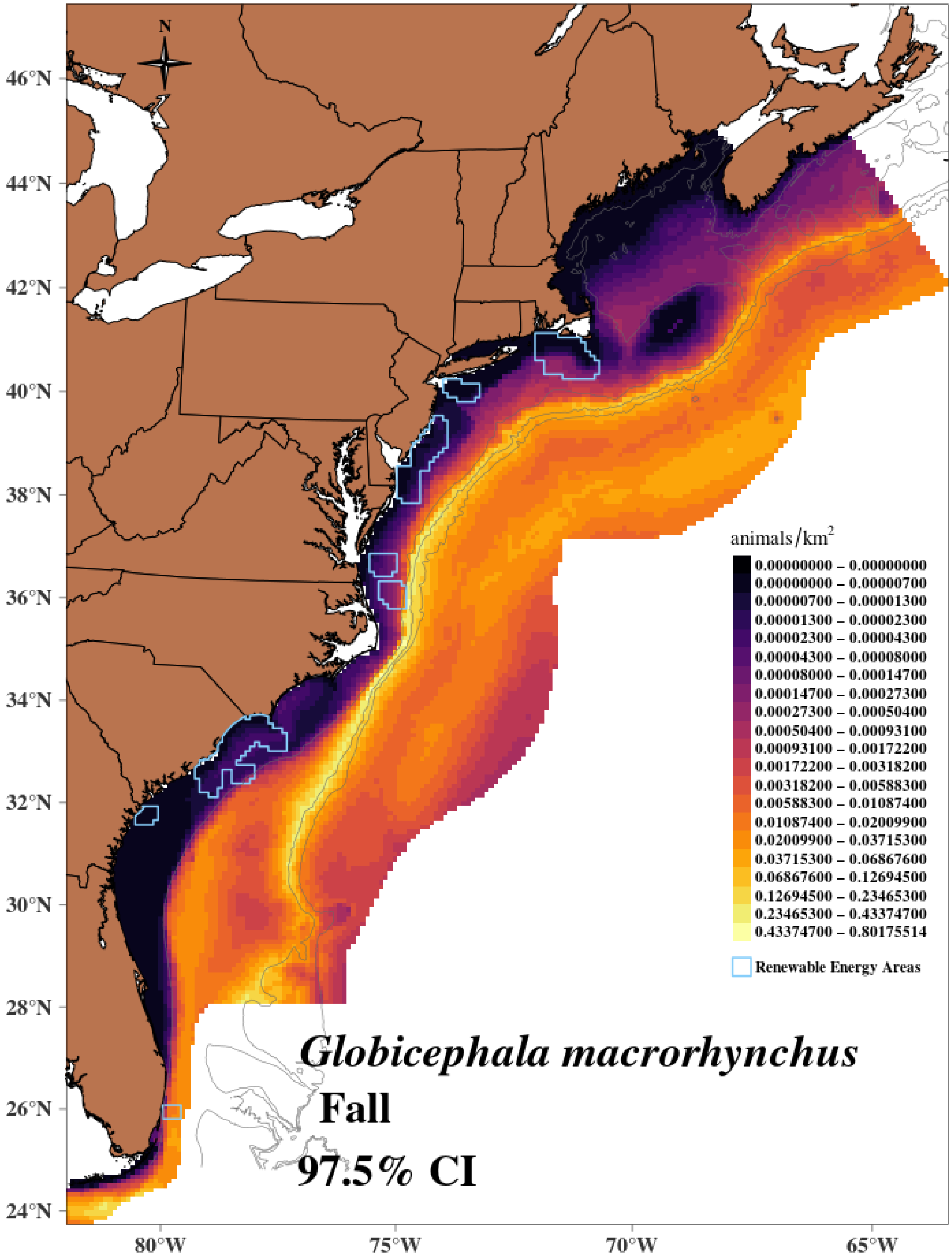

Figure 11-16 Upper 97.5% confidence interval of the fall short-finned pilot whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

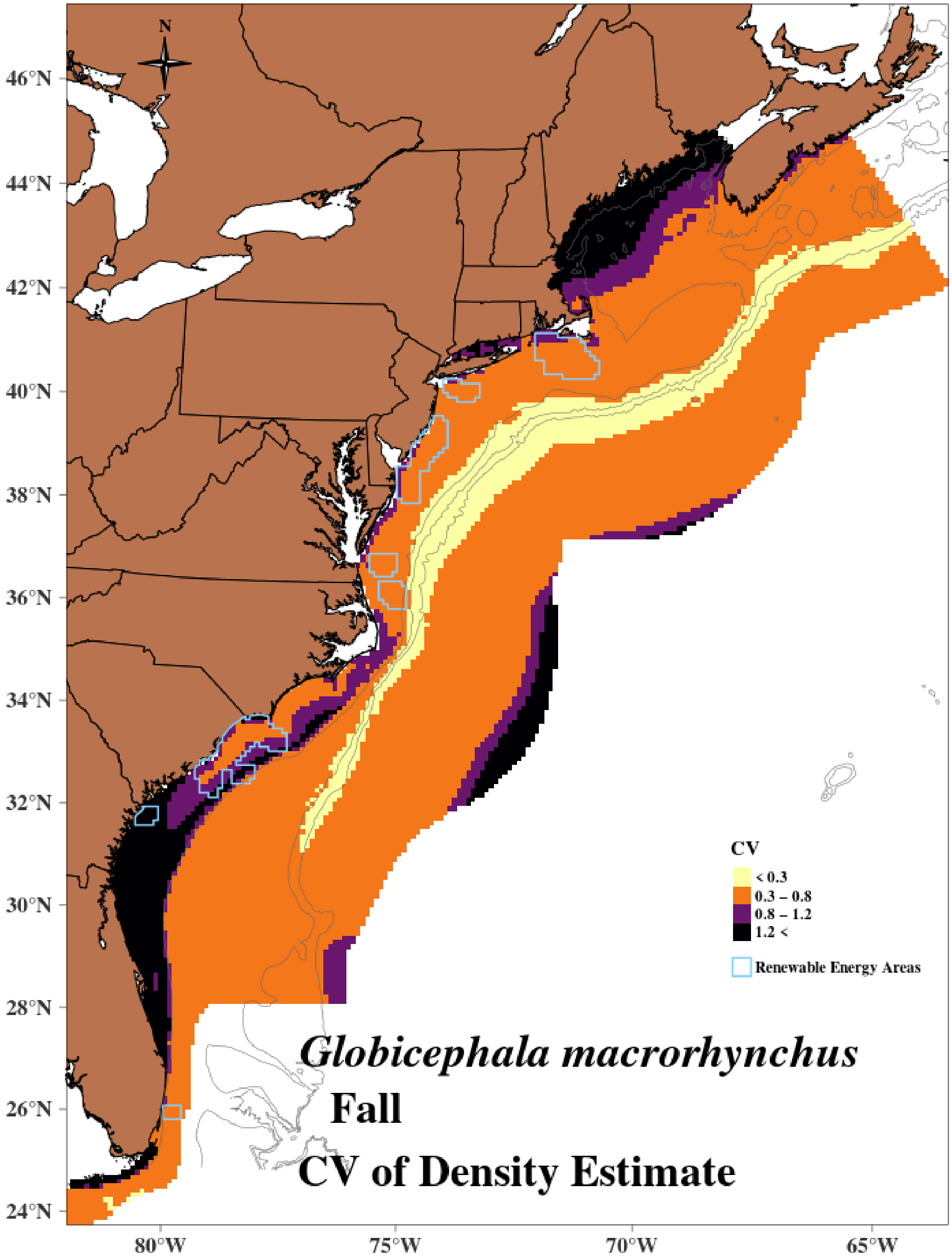

Figure 11-17 CV of fall short-finned pilot whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

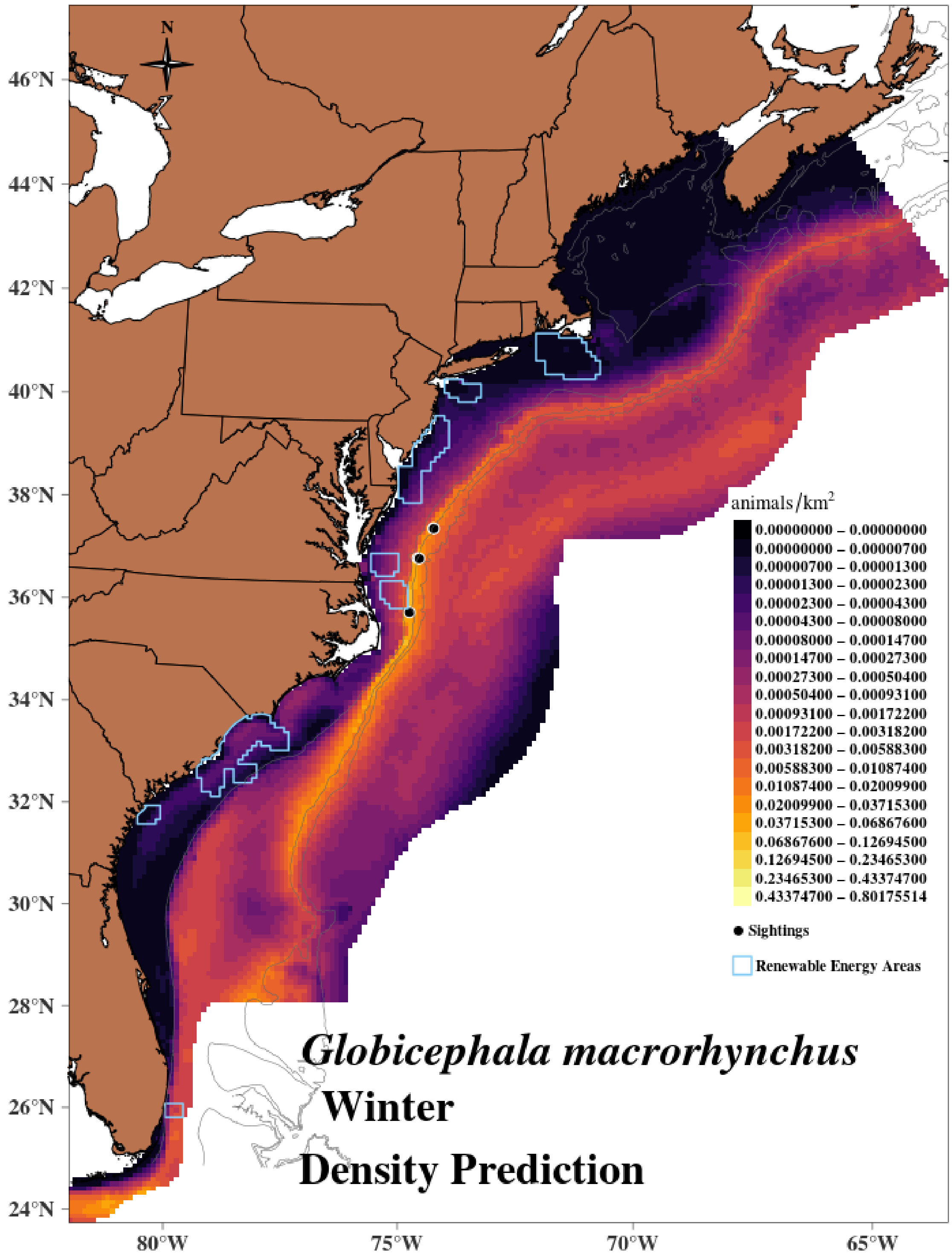

Figure 11-18 Short-finned pilot whale winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

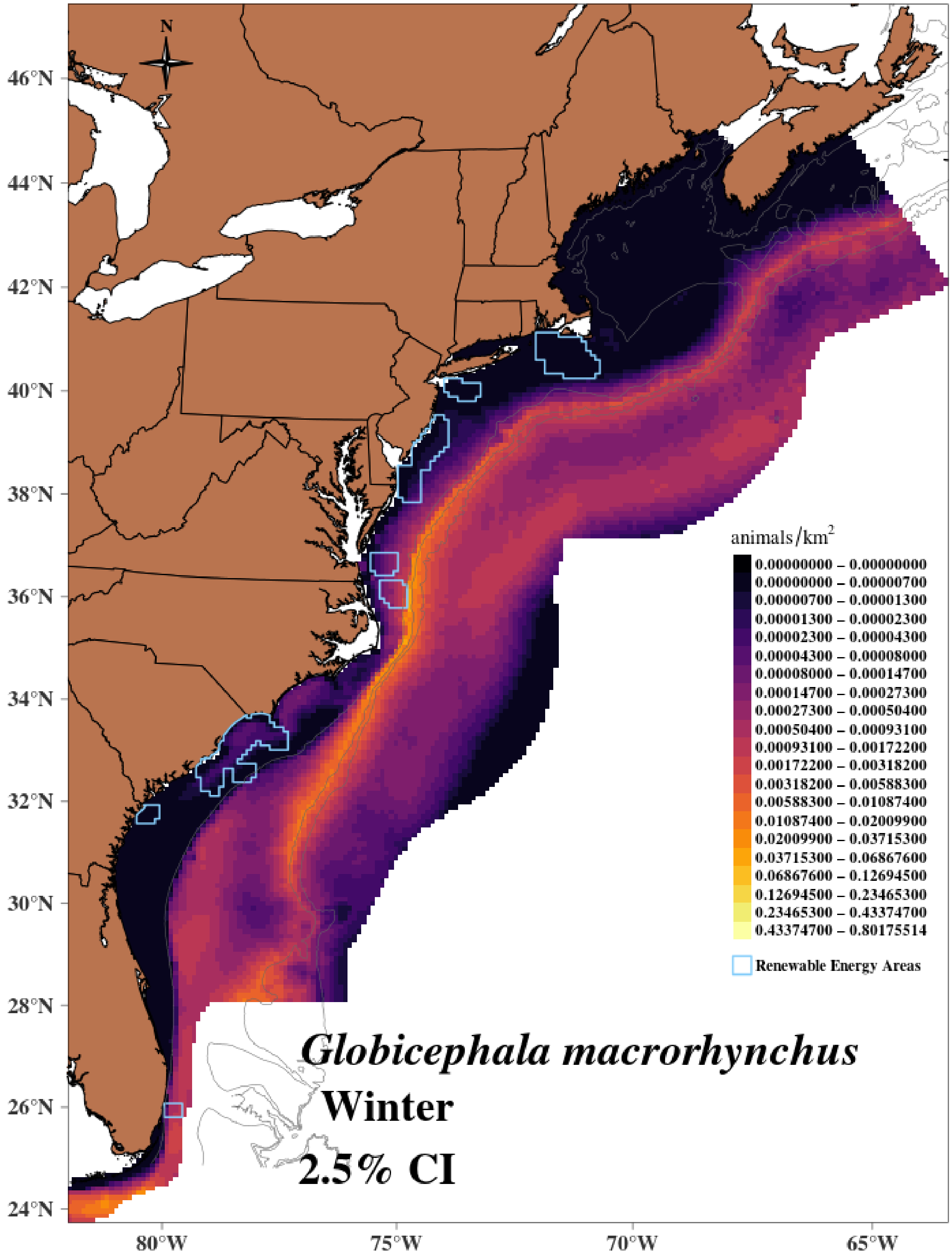

Figure 11-19 Lower 2.5% confidence interval of the winter short-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

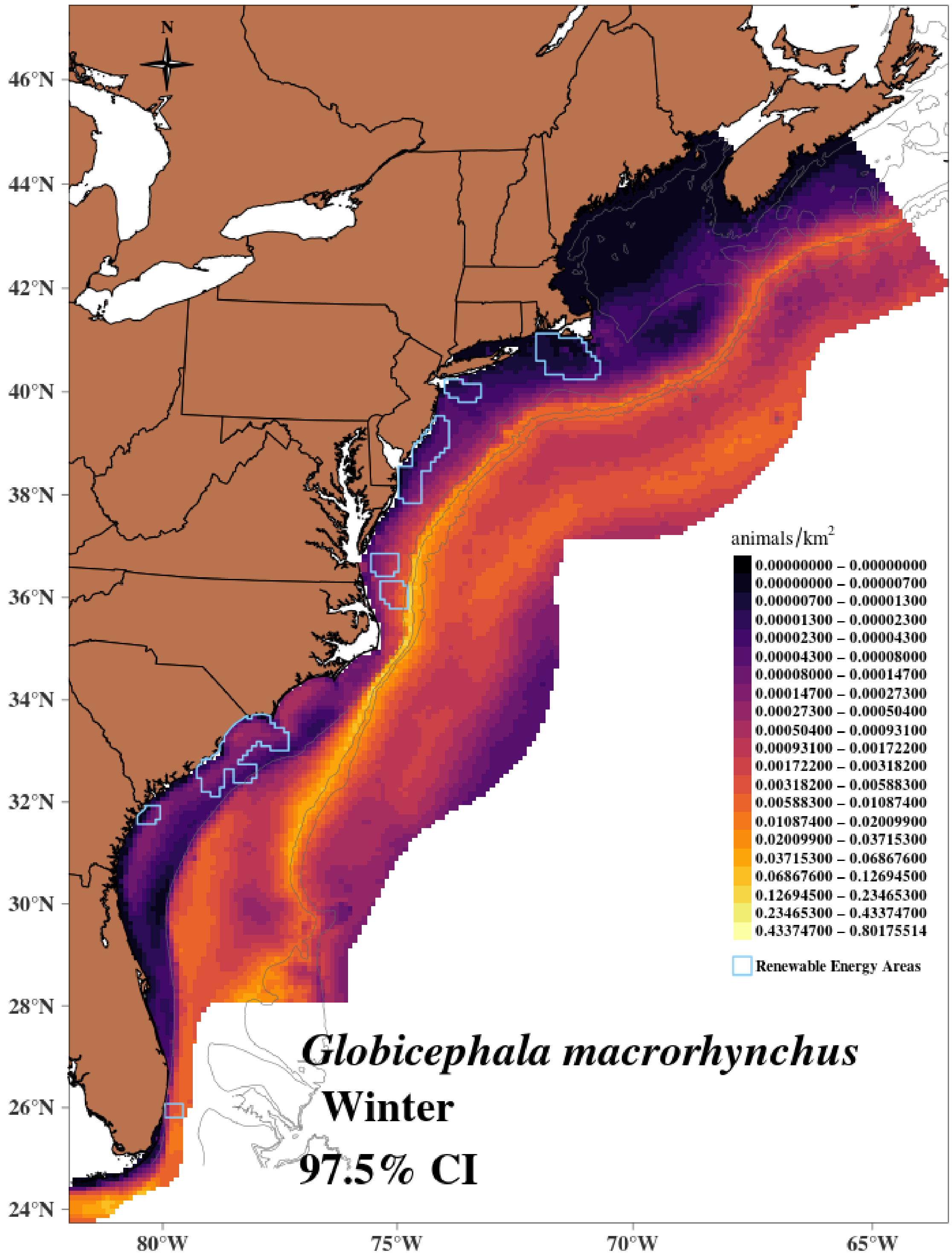

Figure 11-20 Upper 97.5% confidence interval of the winter short-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

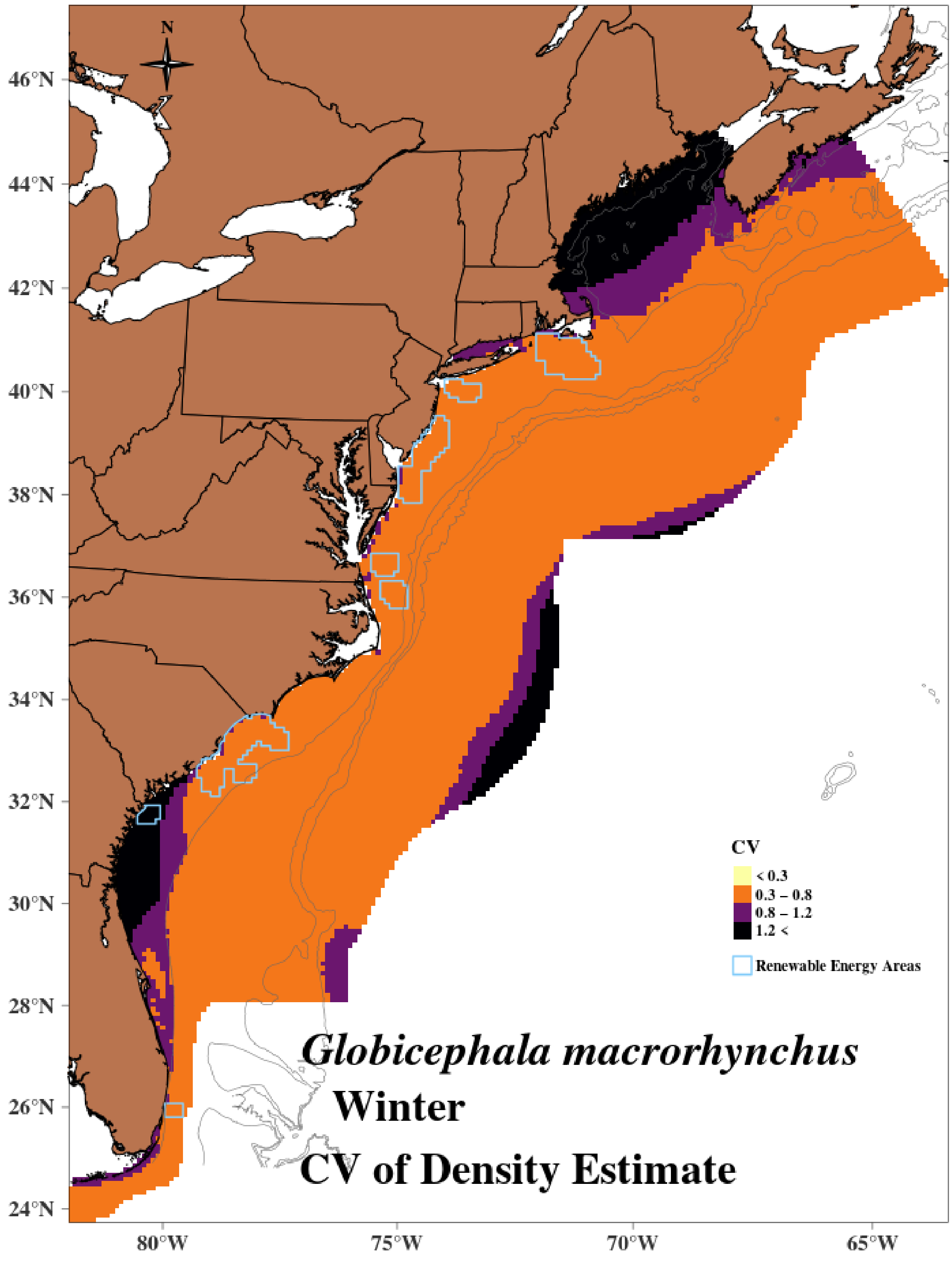

Figure 11-21 CV of winter short-finned pilot whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

11.7 Offshore Energy Development Areas

Table 11-6 Short-finned pilot whale abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval
Spring (Mar–May)	RI/MA	1.7	0.47	
	NY	0.2	0.49	
	NJ	0.3	0.47	
	DE/MD	0.4	0.43	
	VA	1.7	0.41	
	NC	18.6	0.33	
	NC/SC	0.6	0.61	
Summer (Jun–Aug)	RI/MA	3.2	0.43	
	NY	0.3	0.45	
	NJ	0.0	0.58	0.0 0.1
	DE/MD	0.2	0.44	
	VA	0.4	0.45	
	NC	24.1	0.34	
	NC/SC	0.2	0.62	
Fall (Sep–Nov)	RI/MA	0.6	0.42	
	NY	0.0	0.61	0.0 0.0
	NJ	0.0	0.58	0.0 0.1
	DE/MD	0.0	0.59	0.0 0.1
	VA	0.1	0.60	0.0 0.2
	NC	5.3	0.40	
	NC/SC	0.1	0.69	0.0 0.4
Winter (Dec–Feb)	RI/MA	0.1	0.63	0.0 0.2
	NY	0.0	0.62	0.0 0.1
	NJ	0.1	0.52	0.0 0.3
	DE/MD	0.1	0.50	
	VA	0.7	0.47	
	NC	6.5	0.40	
	NC/SC	0.9	0.58	

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

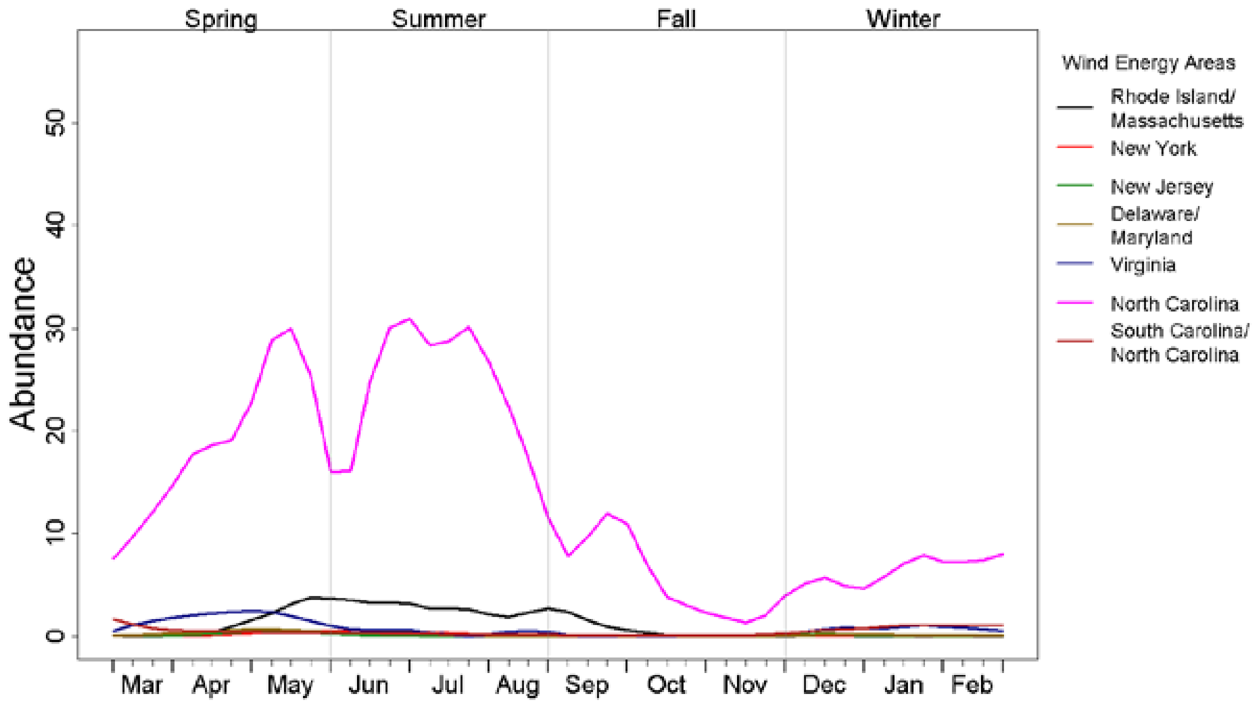

Figure 11-22 Average seasonal abundance of short-finned pilot whales in the wind-energy study areas

12 Long-finned Pilot Whale (*Globicephala melas*)

Figure 12-1 Long-finned pilot whales
Image collected under MMPA Research permit #21371. Credit: NOAA/NEFSC/Jennifer Gatzke

12.1 Data Collection

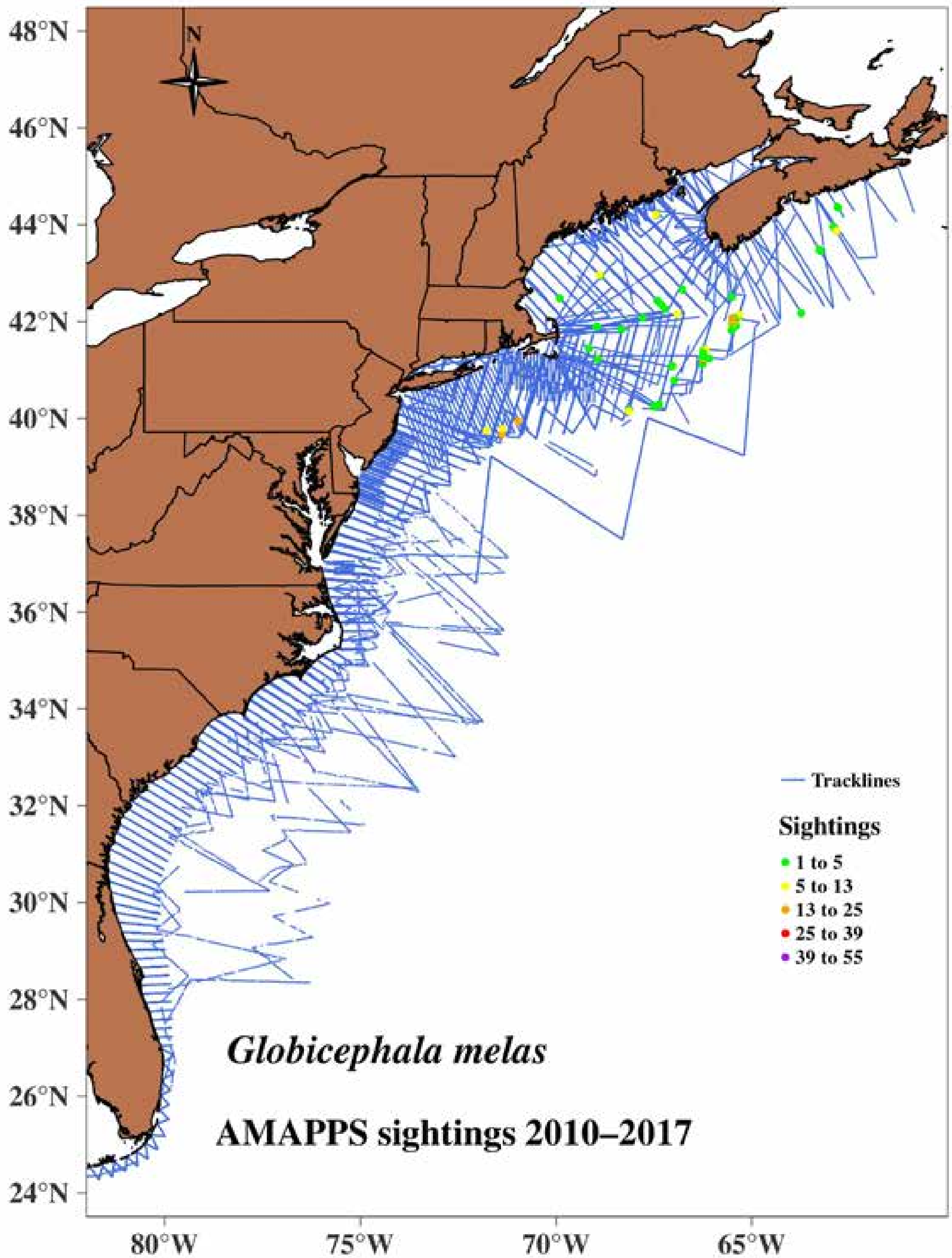

Figure 12-2 Distribution of track lines and long-finned pilot whale sightings 2010 to 2017

Table 12-1 AMAPPS research effort 2010 to 2017 and long-finned pilot whale sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	41	666
NE Shipboard	Fall	1,065	0	0
NE Aerial	Spring	13,314	6	7
NE Aerial	Summer	25,867	18	86
NE Aerial	Fall	37,850	19	78
NE Aerial	Winter	12,179	2	3
SE Shipboard	Spring	8,853	44	312
SE Shipboard	Summer	12,968	0	0
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	0	0
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

12.2 Mark-Recapture Distance Sampling Analysis

Table 12-2 Intermediate parameters in long-finned pilot whale mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 5	distance * observer + glare	320	distance + sea state + group size	LT50-360	HR	0.74	0.15	0.23	0.99	0.98
NE–aerial group 7	distance * observer	400	distance	400	HN	0.54	0.30	0.77	1.00	1.00
NE–shipboard group 7	distance * observer + group size + glare	3500	distance + glare + swell + time of day	3500	HR	0.66	0.10	0.09	0.86	0.91
SE–shipboard group 3	distance * observer + group size	2700	distance	2700	HR	0.71	0.08	0.37	0.91	0.81

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

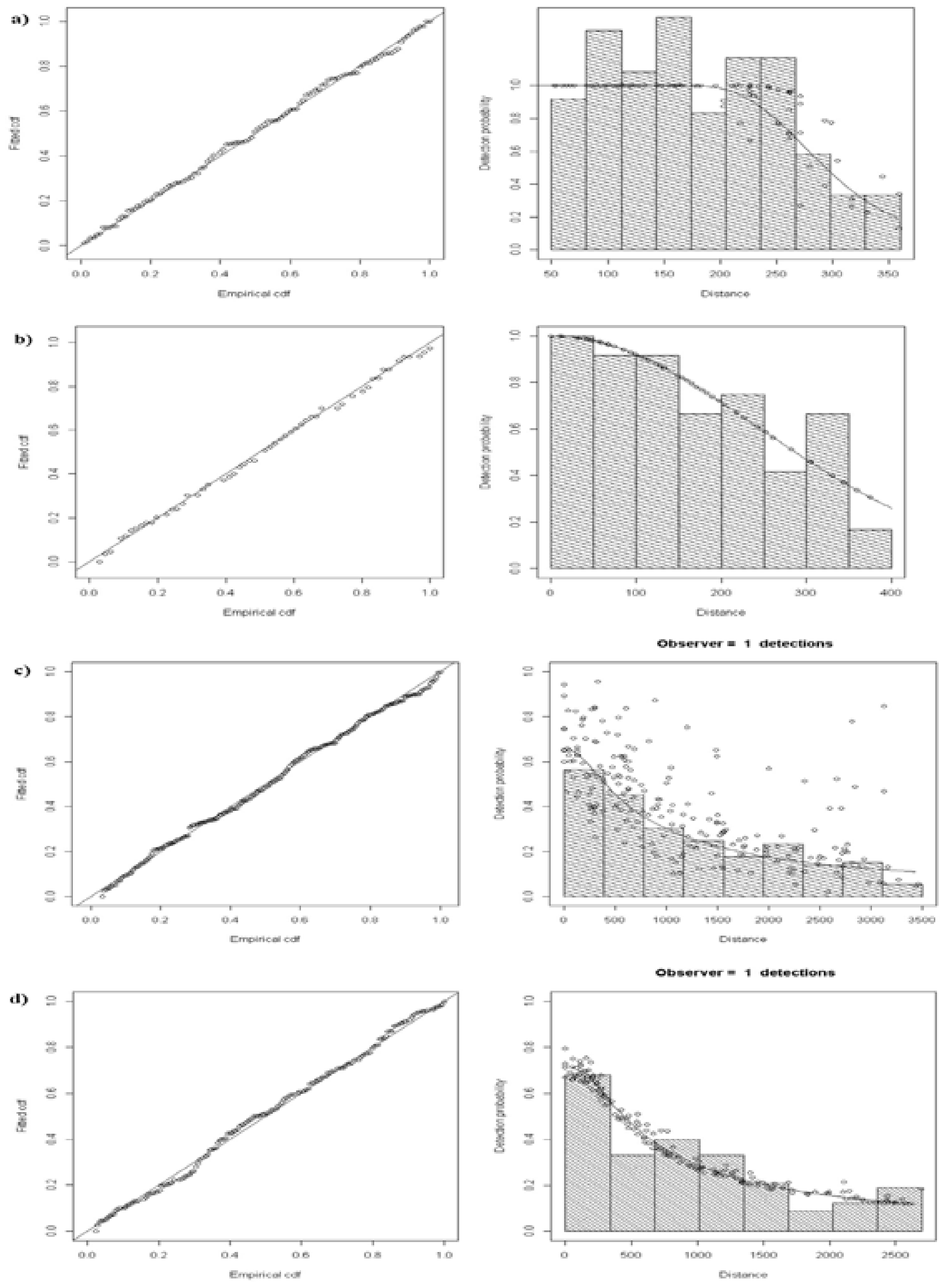

Figure 12-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 5; b) NE-aerial analysis set 7; c) NE-shipboard analysis set 7; d) SE-shipboard analysis set 3.

12.3 Generalized Additive Model Analysis

Table 12-3 2015–2017 density-habitat model output for long-finned pilot whales

Covariates	Edf	Ref.df	F	C.dev	p-value
s(sstfma)	0.86	4	1.03	0.49	0.0257
s(picma)	0.89	4	1.63	1.42	0.0065
s(dist2GSNw)	1.56	4	3.81	5.95	<0.0001
s(dist1000)	3.17	4	7.81	11.32	<0.0001
s(lat)	1.90	4	19.59	44.31	<0.0001

Adjusted R^2 = 0.0542. Deviance explained = 63.5%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

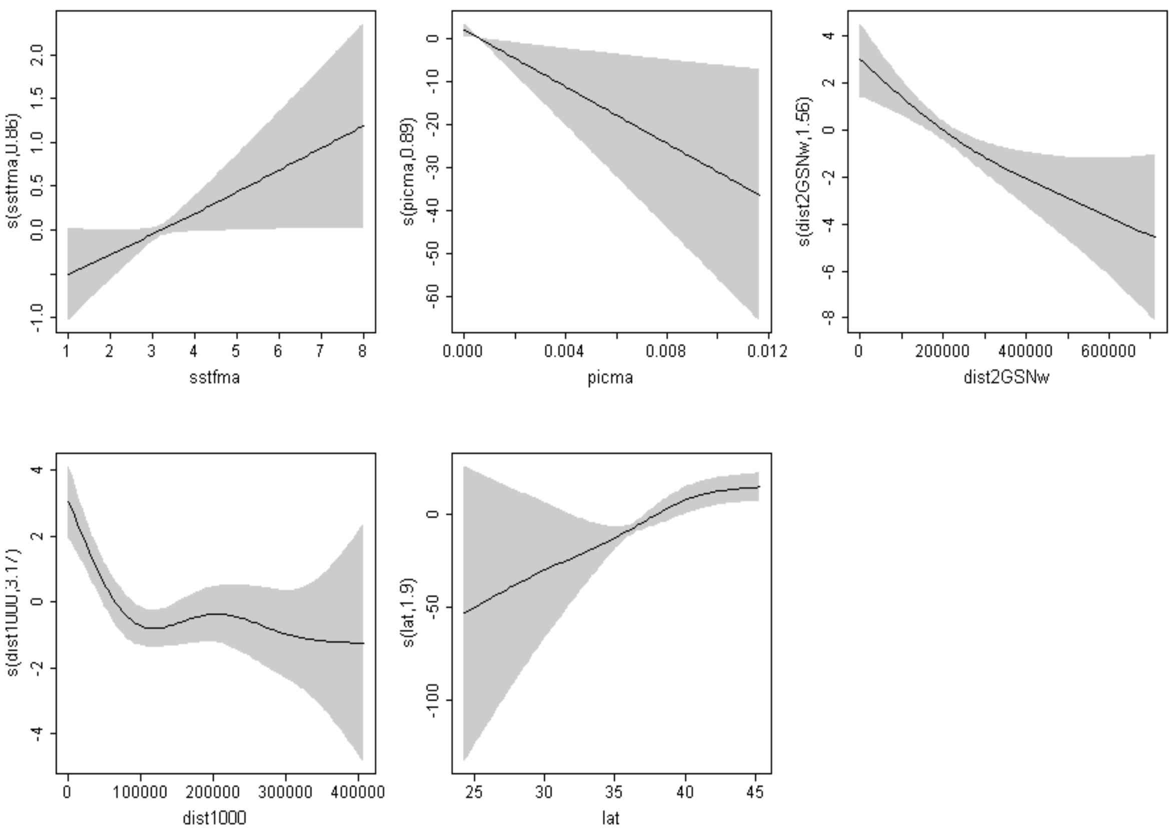

Figure 12-4 Long-finned pilot whale density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2. Data from 2015 to 2017.

12.4 Model Cross-Validation

Table 12-4 Diagnostic statistics from the long-finned pilot whale density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.374	Excellent
MAPE	Mean absolute percentage error	Non-zero density	87.760	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.189	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.005	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

12.5 Abundance Estimates for AMAPPS Study Area

Table 12-5 Long-finned pilot whale average abundance estimates for the AMAPPS study area
Abundance estimates averaged over 2015 to 2017.

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	6,765	0.56	2,431–18,829
Summer (June–August)	9,901	0.59	3,392–28,900
Fall (September–November)	12,888	0.58	4,485–37,031
Winter (December–February)	4,909	0.56	1,764–13,664
Summer 2011 U.S. surveys[1]	5,636	0.63	
Summer 2016 U.S. surveys[1]	9,972	0.55	

[1]Hayes et al. 2020

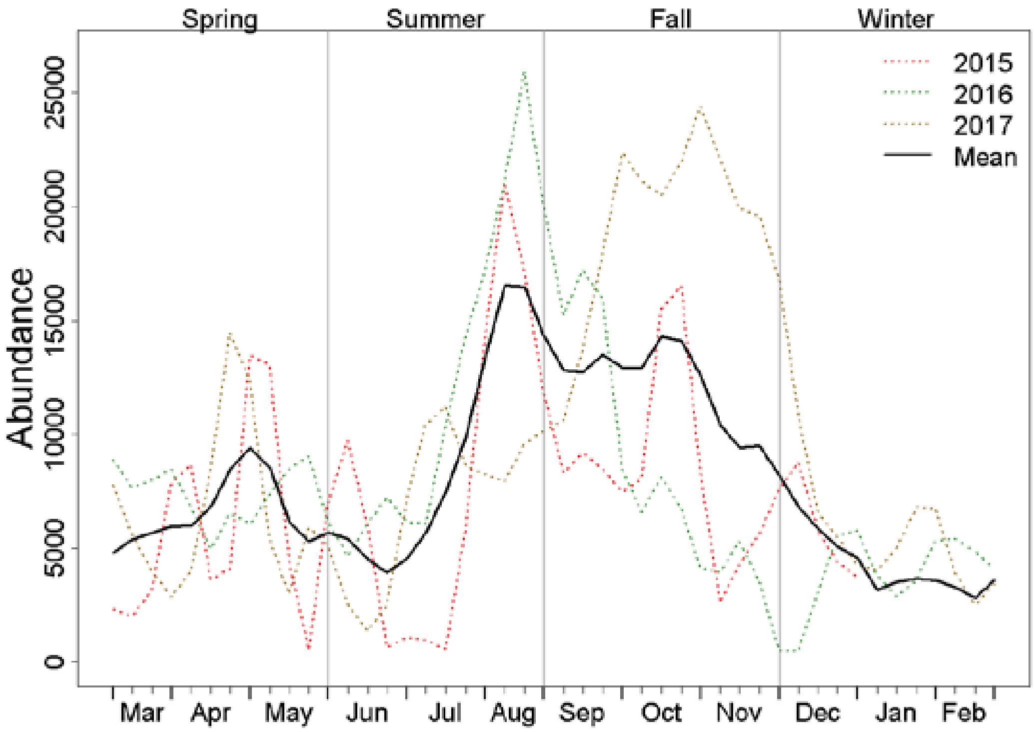

Figure 12-5 Annual abundance trends for long-finned pilot whales in the AMAPPS study area
Abundance trends from only 2015 to 2017.

12.6 Seasonal Prediction Maps

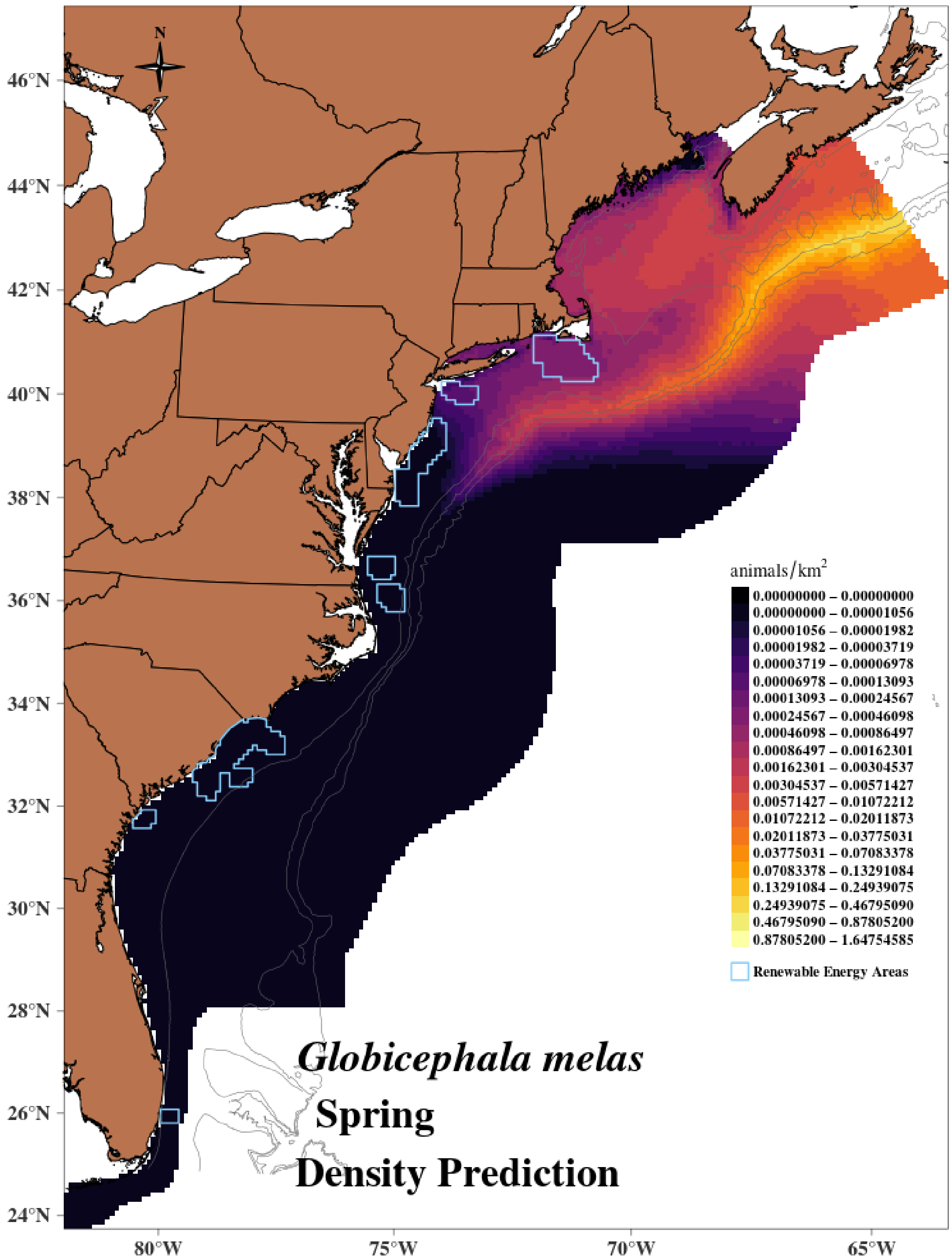

Figure 12-6 Long-finned pilot whale spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

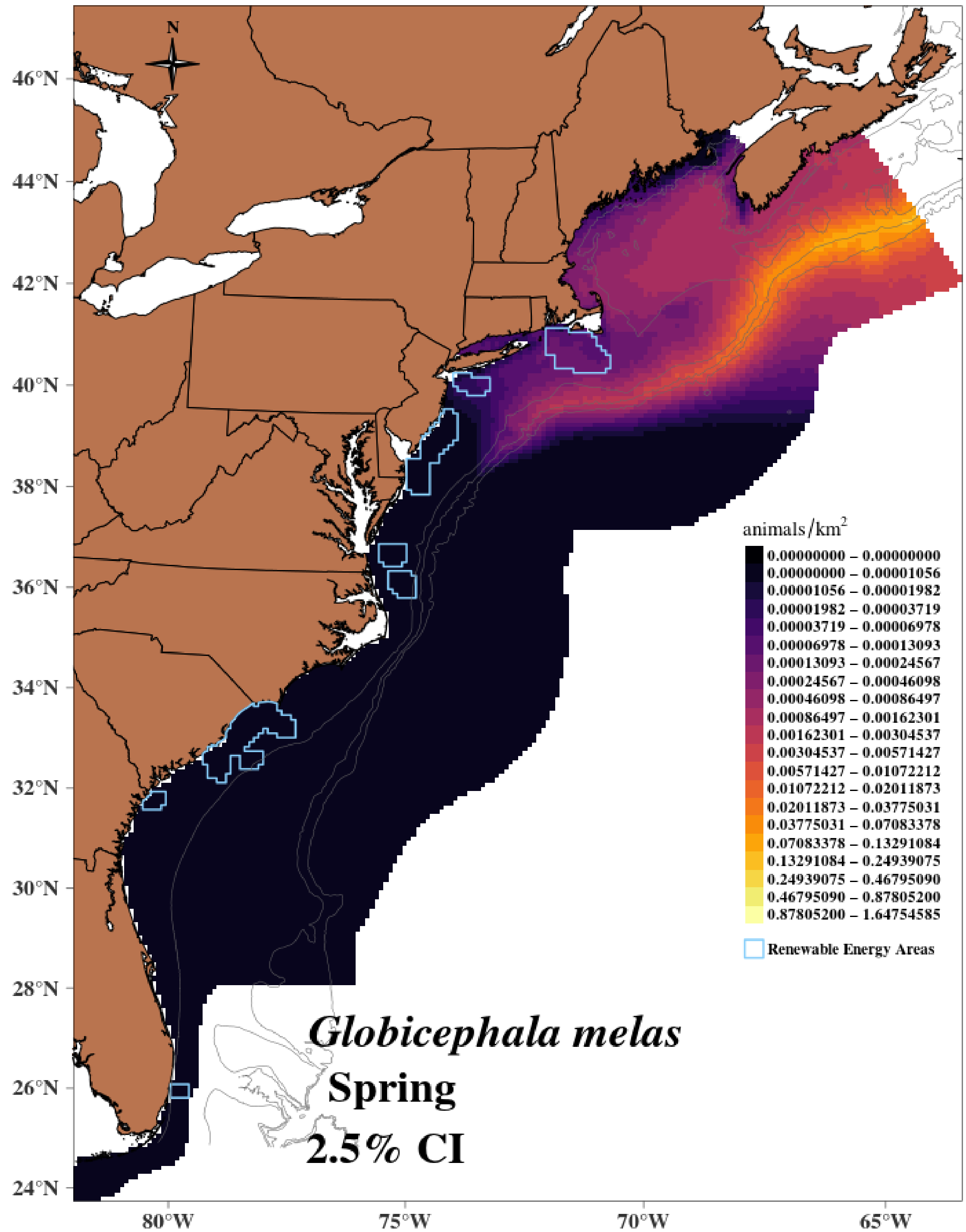

Figure 12-7 Lower 2.5% confidence interval of the spring long-finned pilot whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

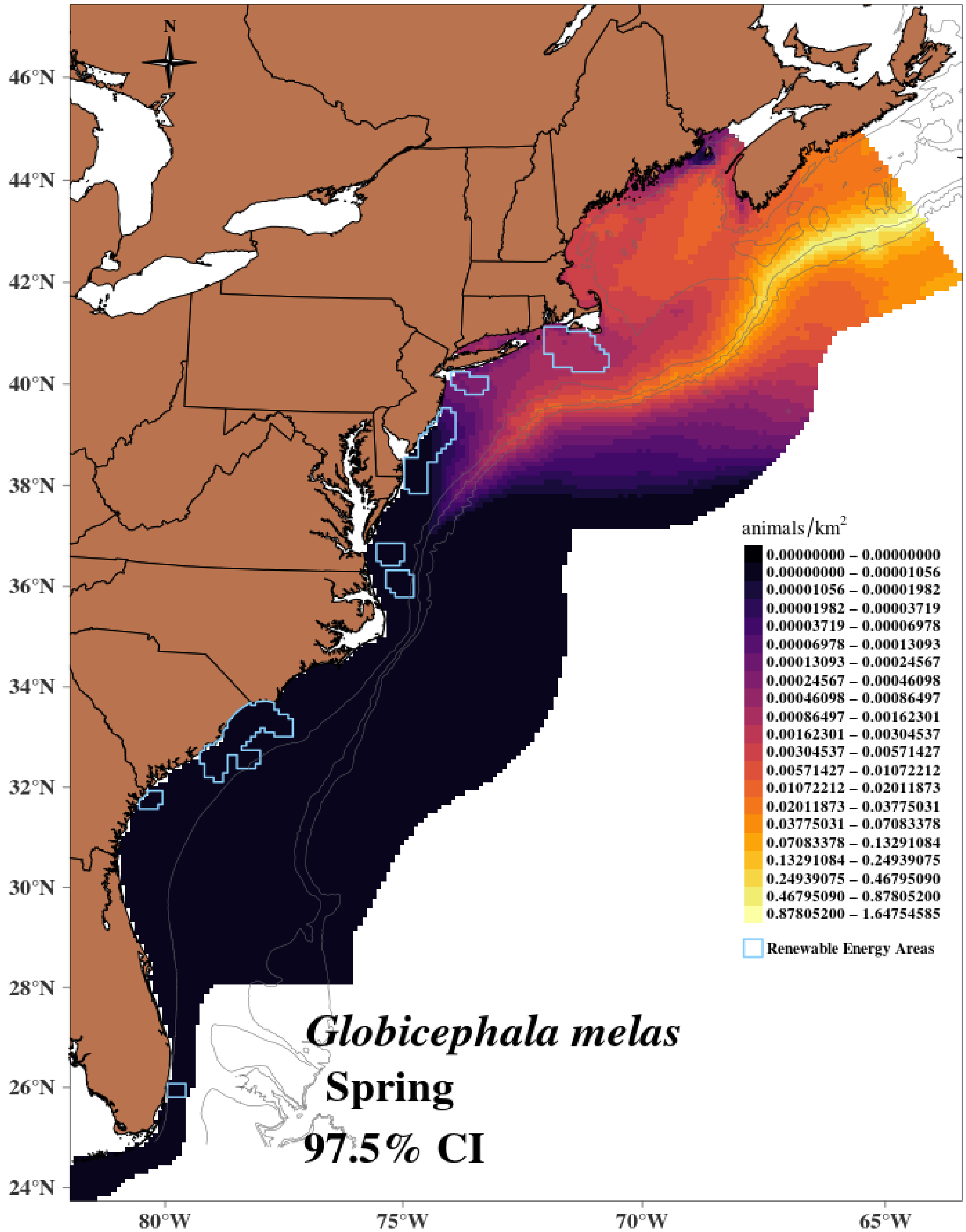

Figure 12-8 Upper 97.5% confidence interval of the spring long-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

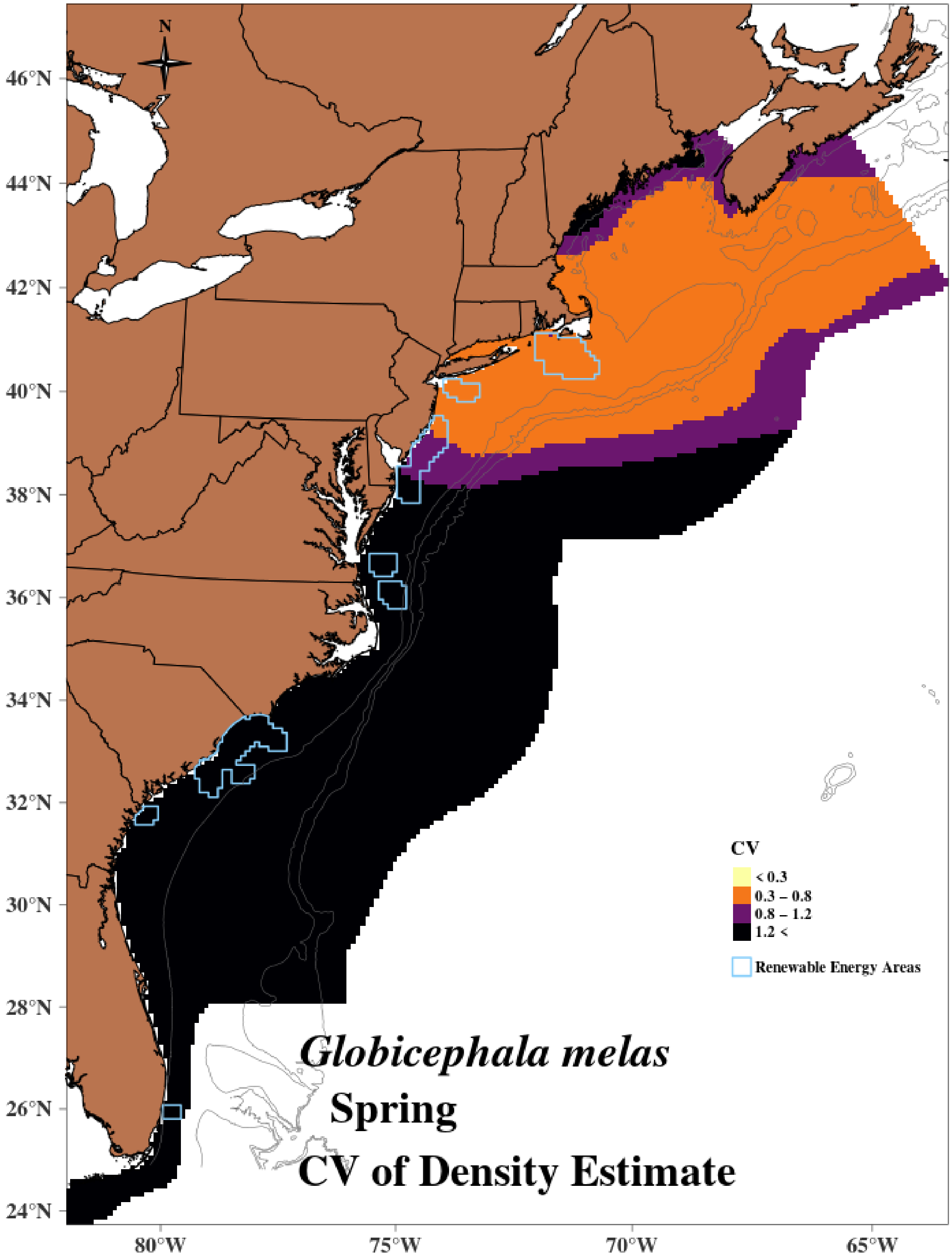

Figure 12-9 CV of spring long-finned pilot whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

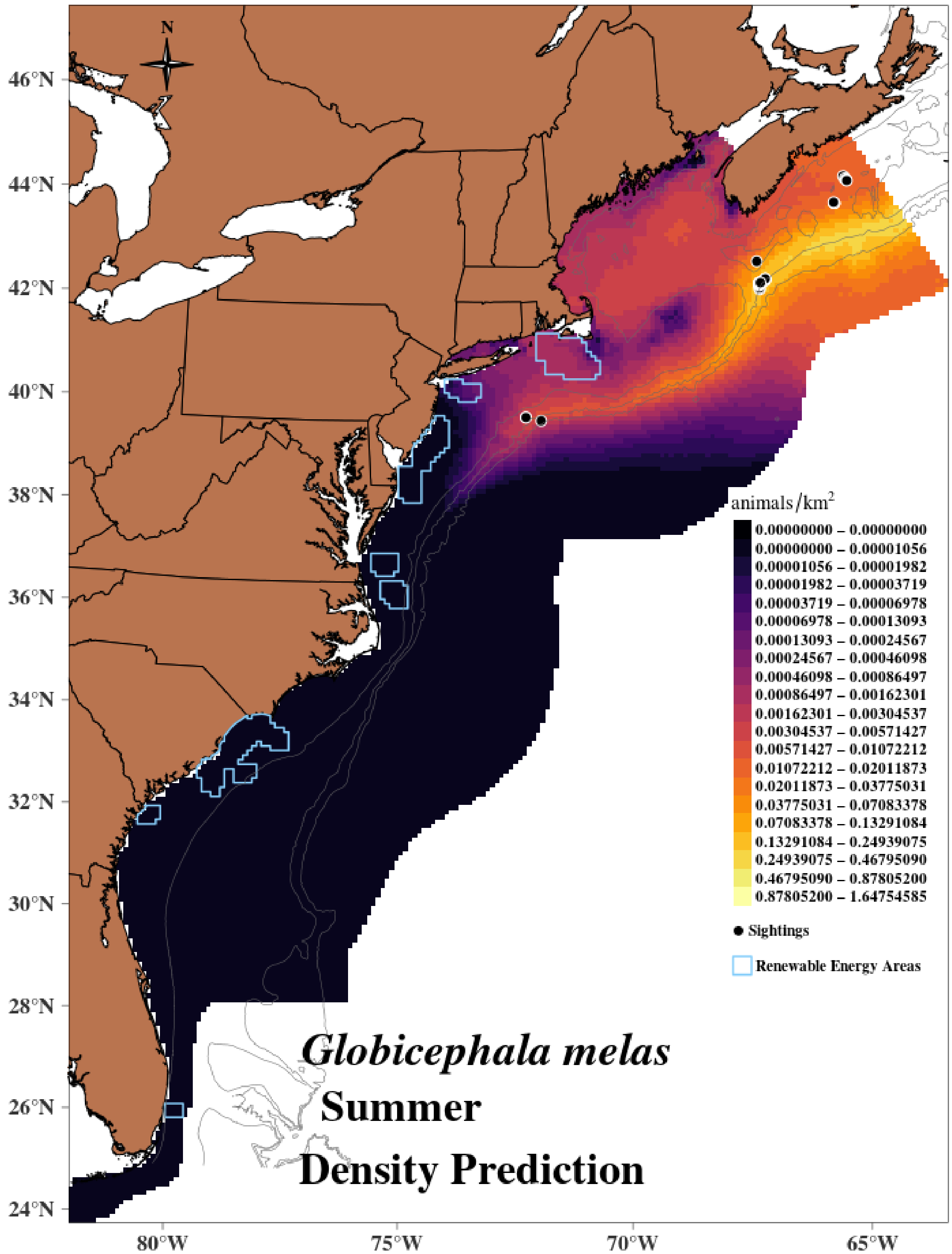

Figure 12-10 Long-finned pilot whale summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

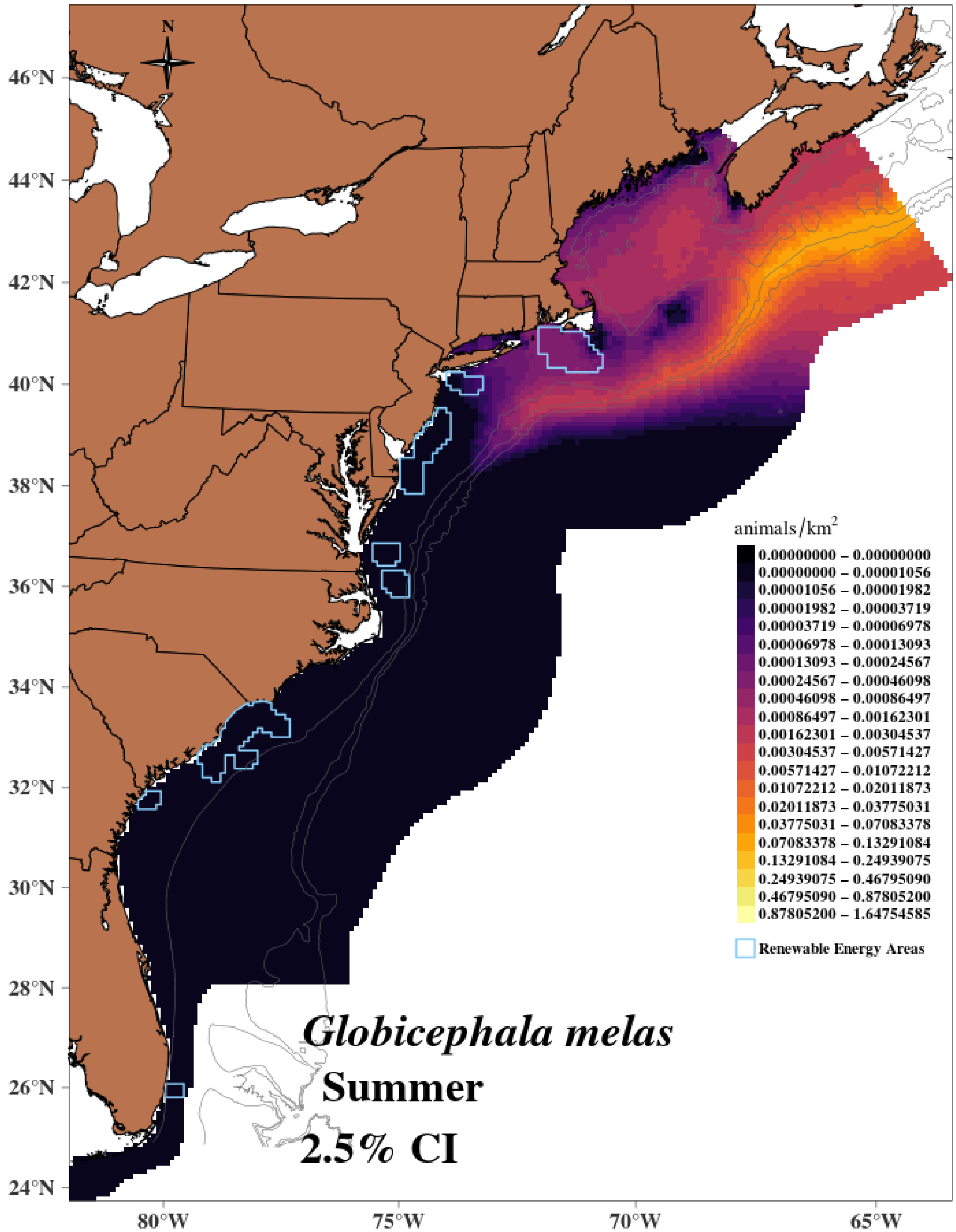

Figure 12-11 Lower 2.5% confidence interval of the summer long-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

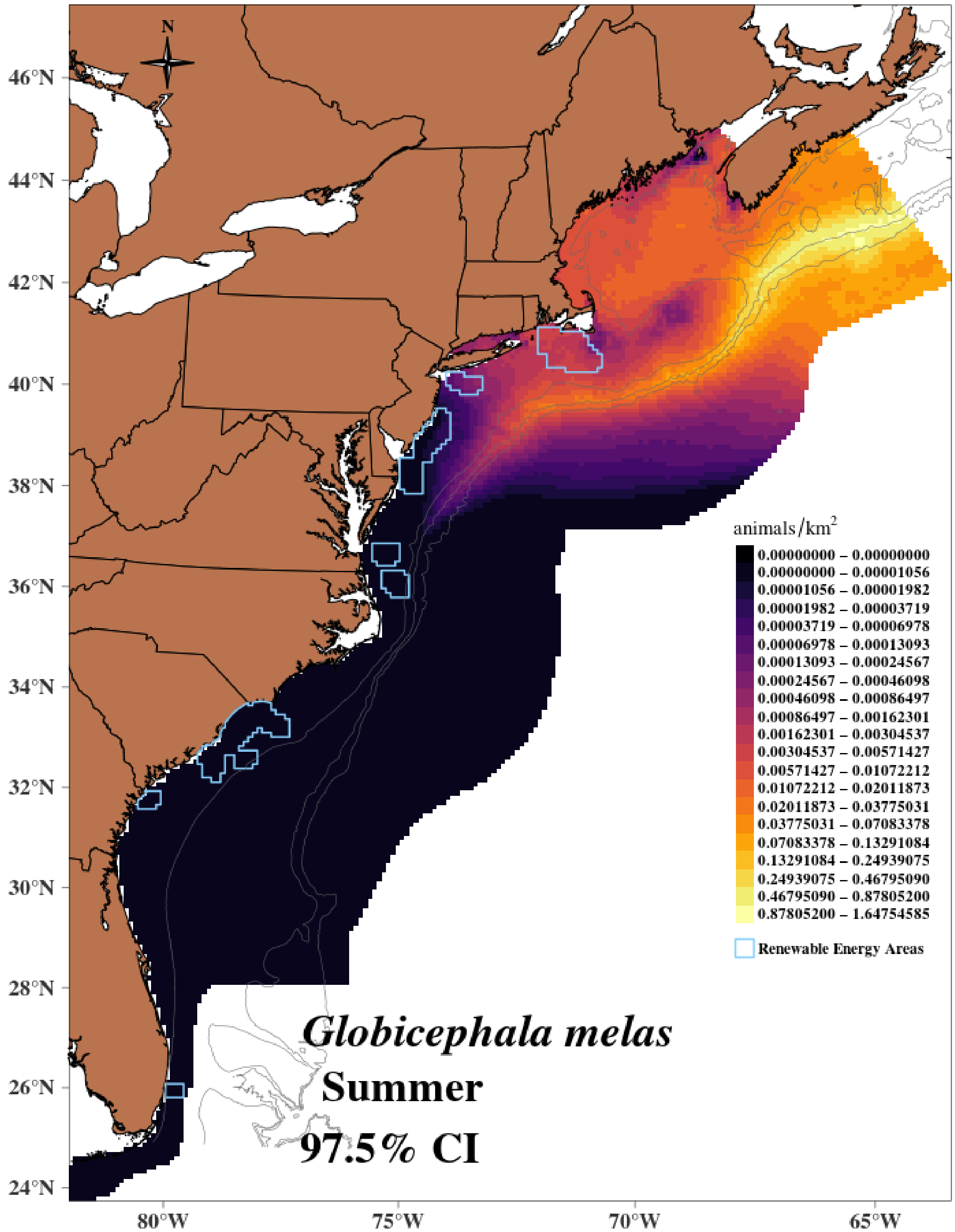

Figure 12-12 Upper 97.5% confidence interval of the summer long-finned pilot whale density estimates

CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

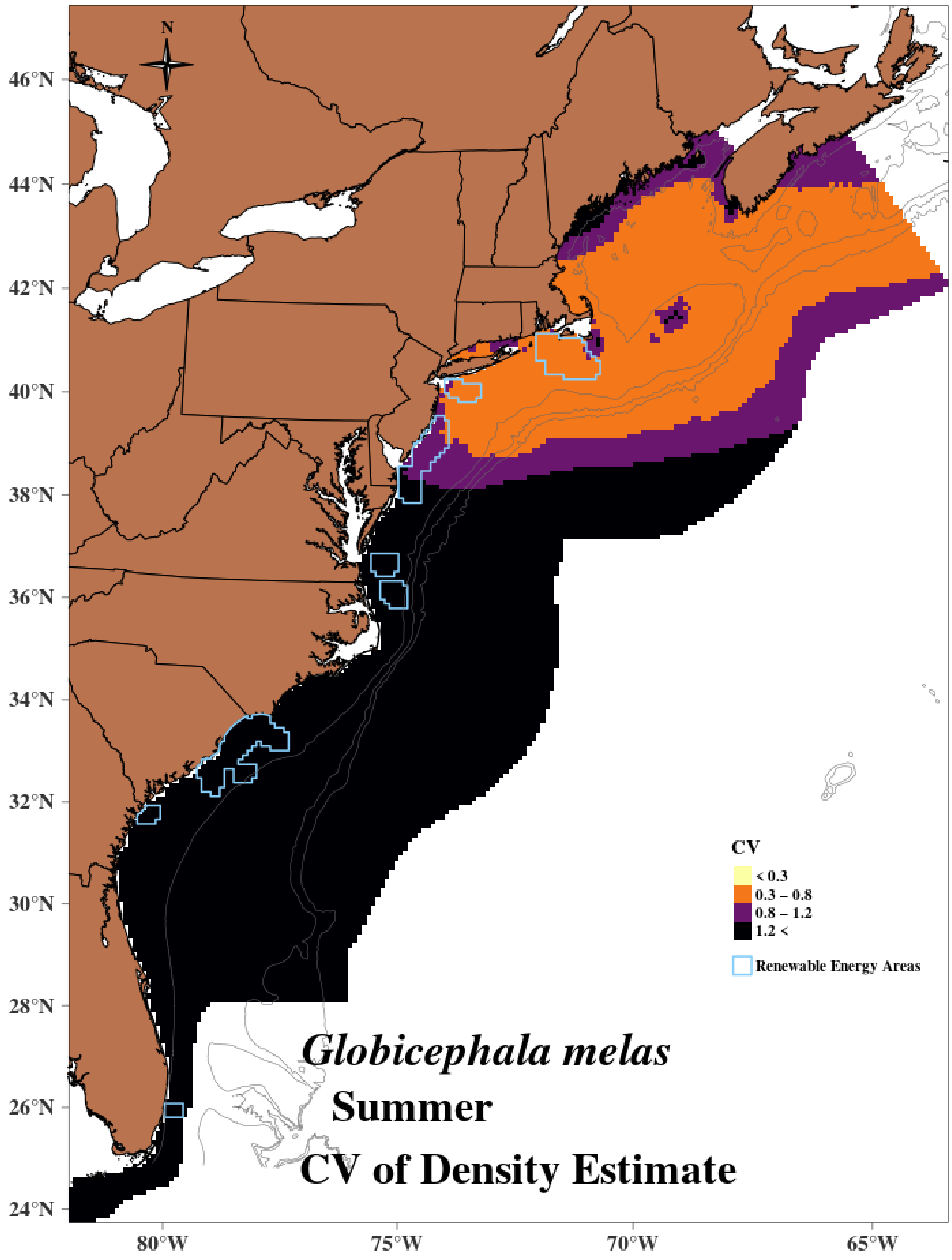

Figure 12-13 CV of summer long-finned pilot whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

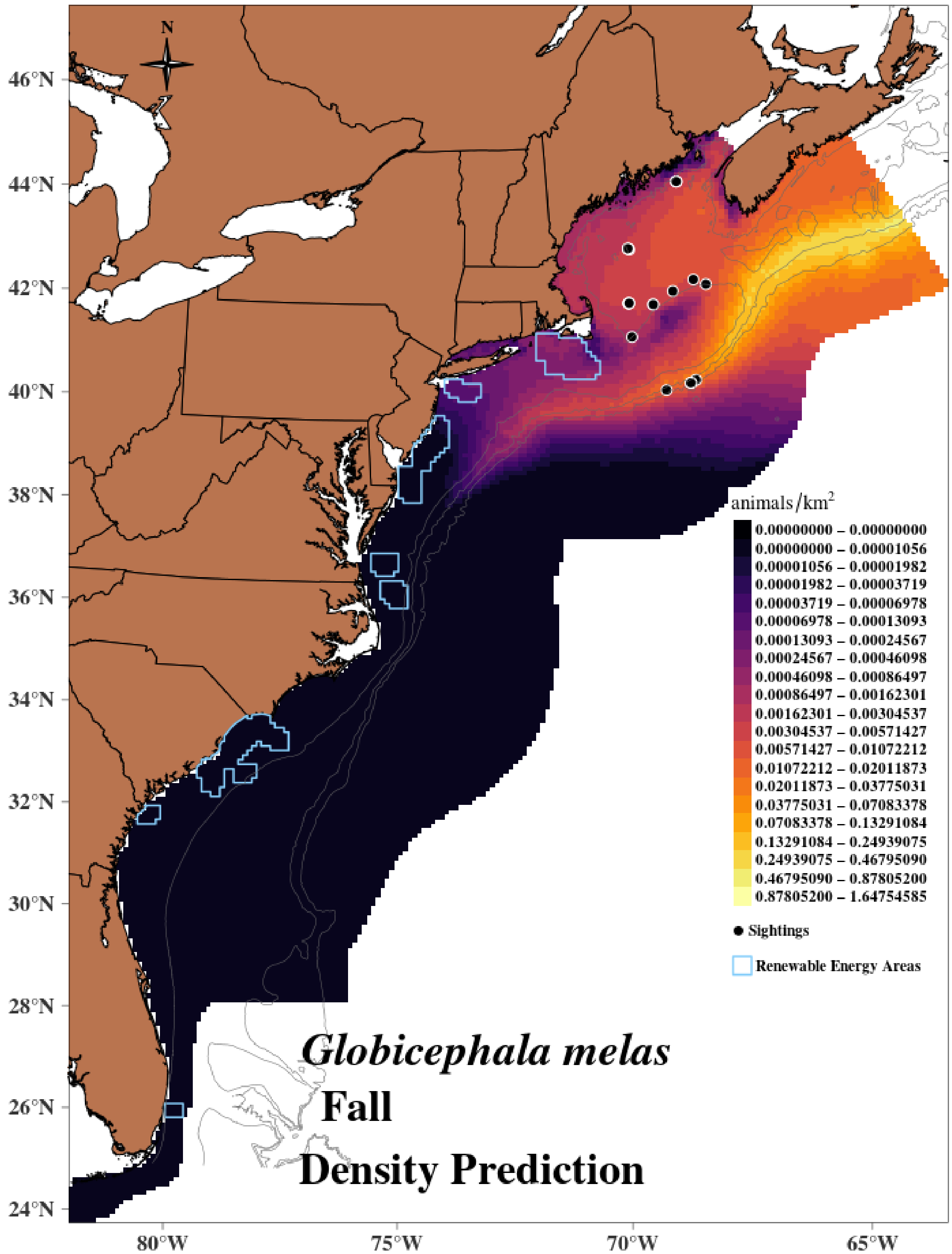

Figure 12-14 Long-finned pilot whale fall average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

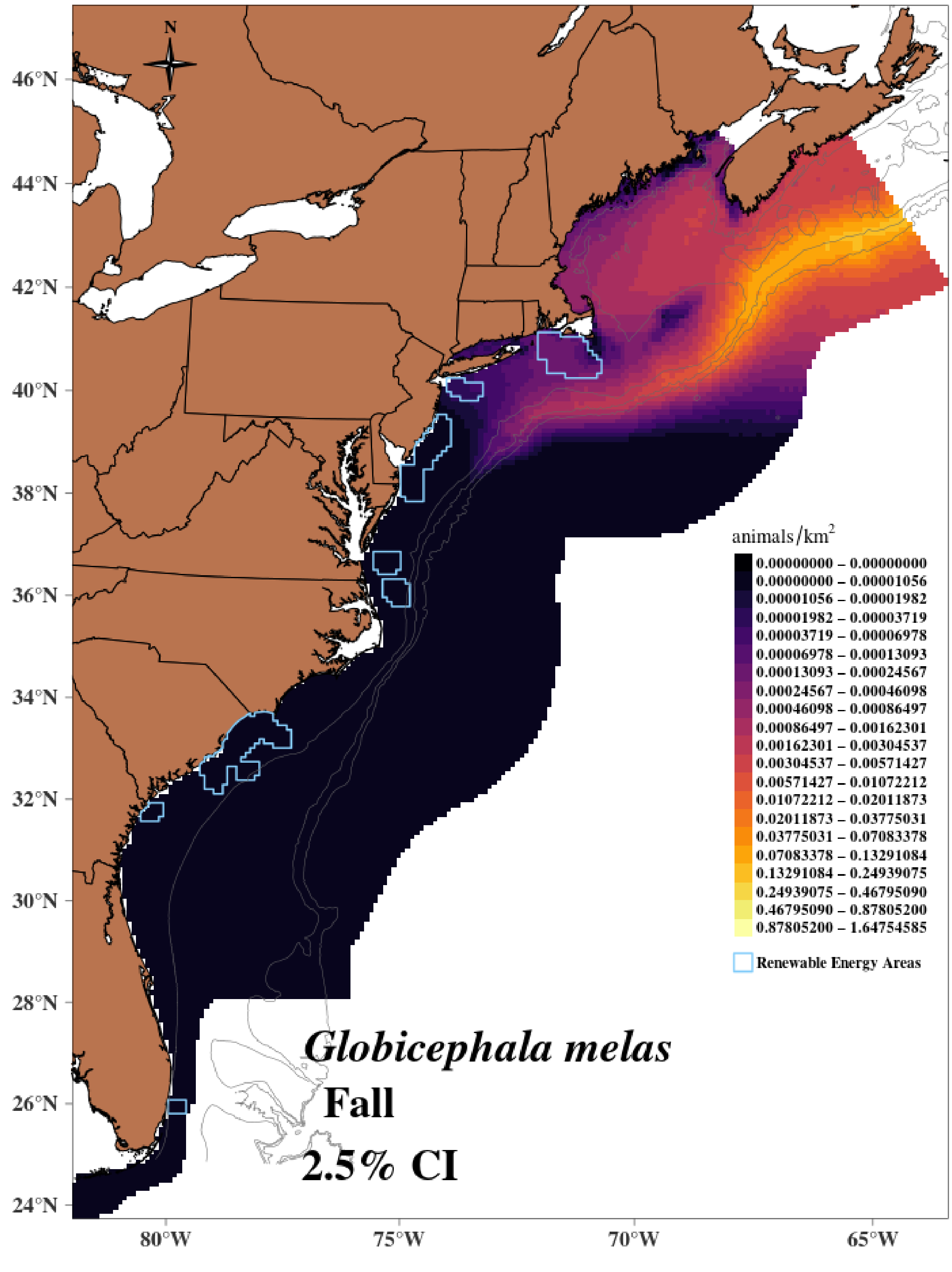

Figure 12-15 Lower 2.5% confidence interval of the fall long-finned pilot whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

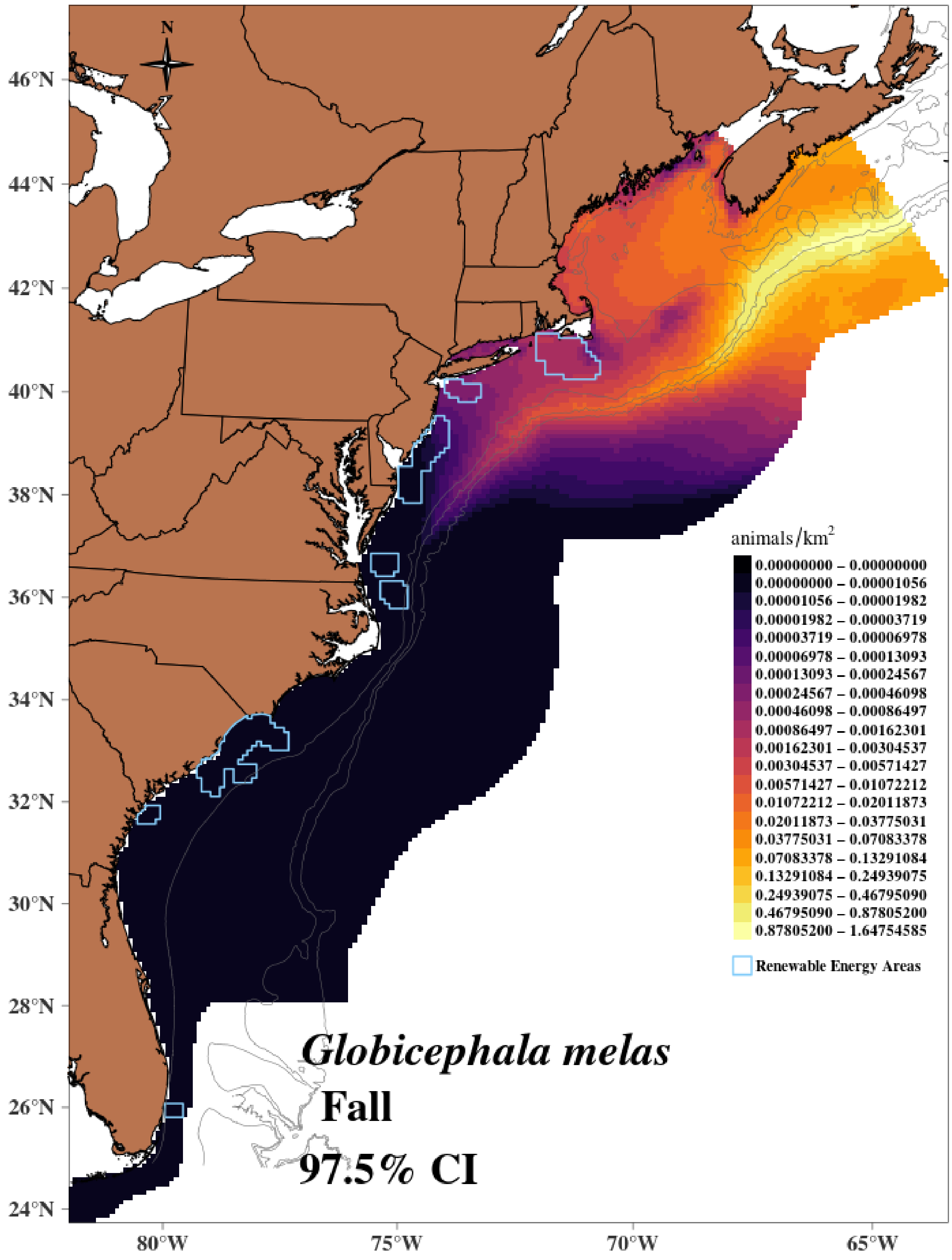

Figure 12-16 Upper 97.5% confidence interval of the fall long-finned pilot whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

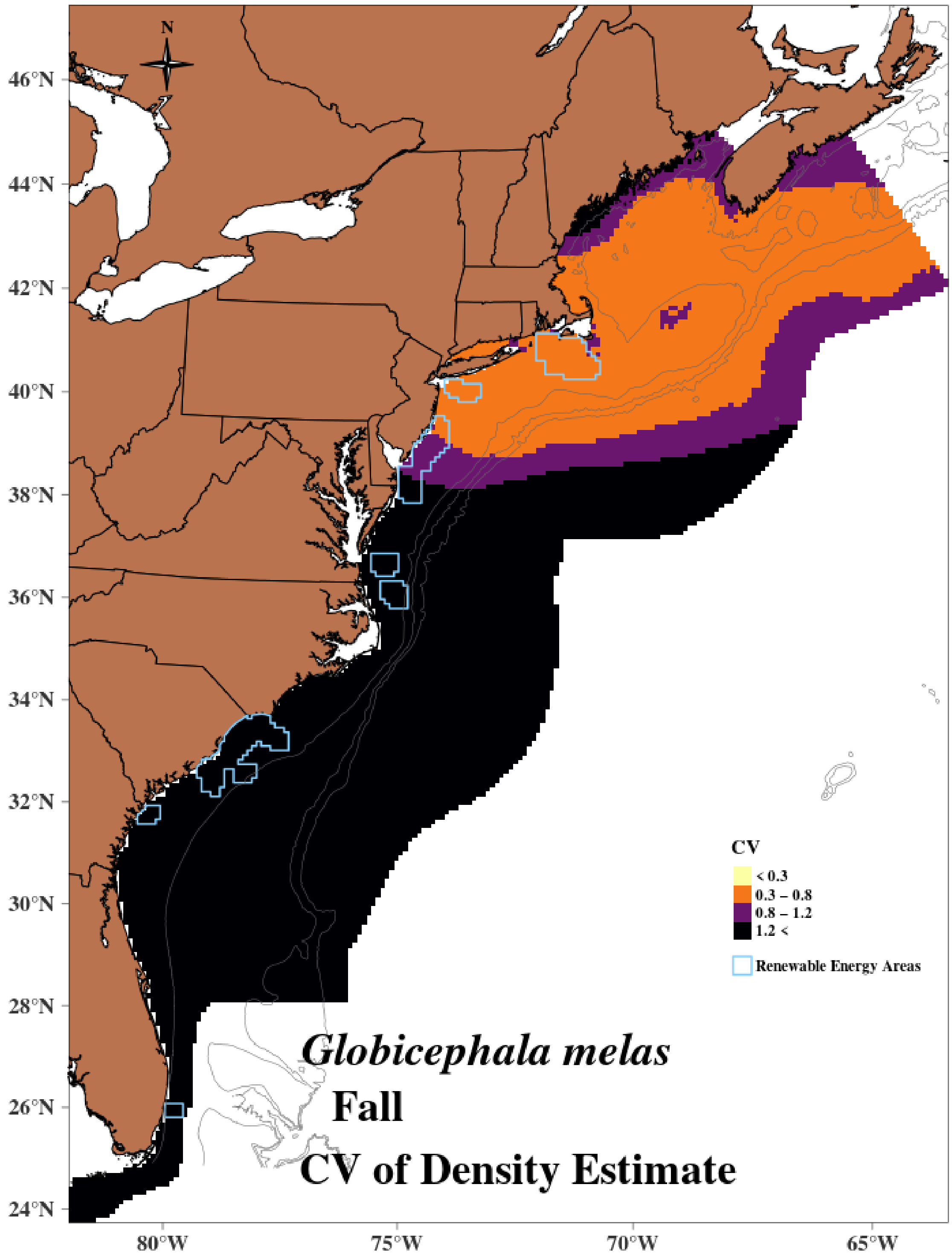

Figure 12-17 CV of fall long-finned pilot whale density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

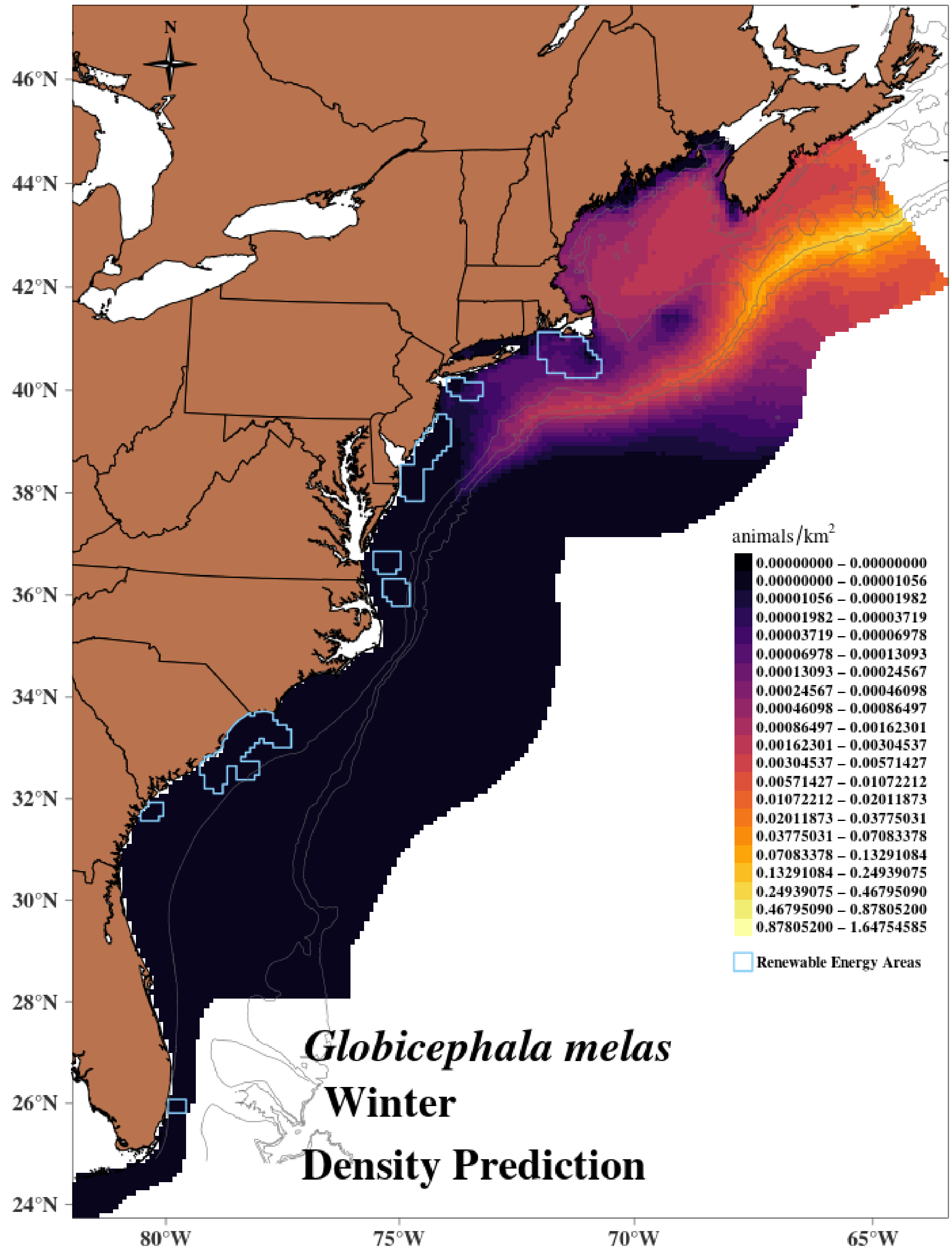

Figure 12-18 Long-finned pilot whale winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

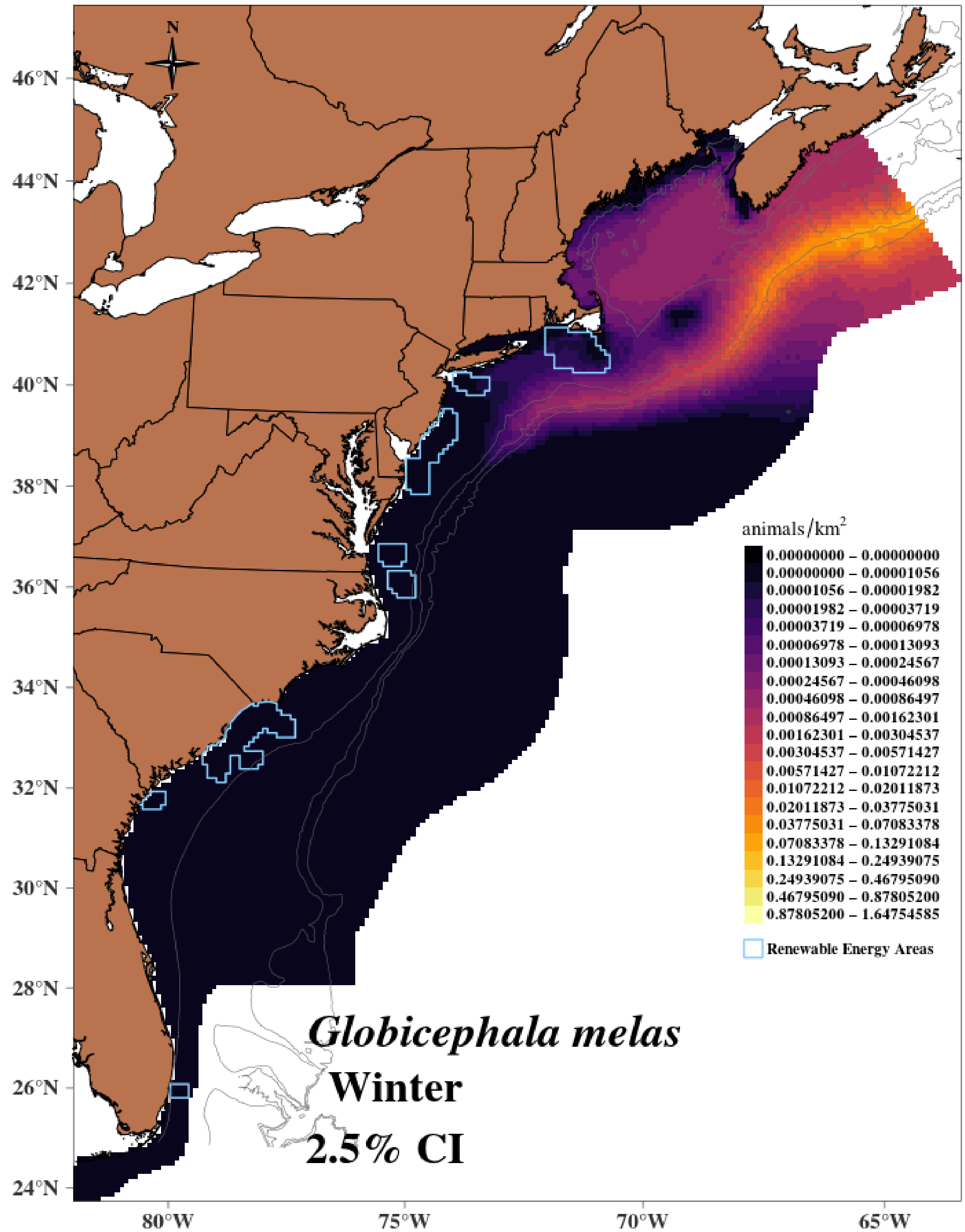

Figure 12-19 Lower 2.5% confidence interval of the winter long-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

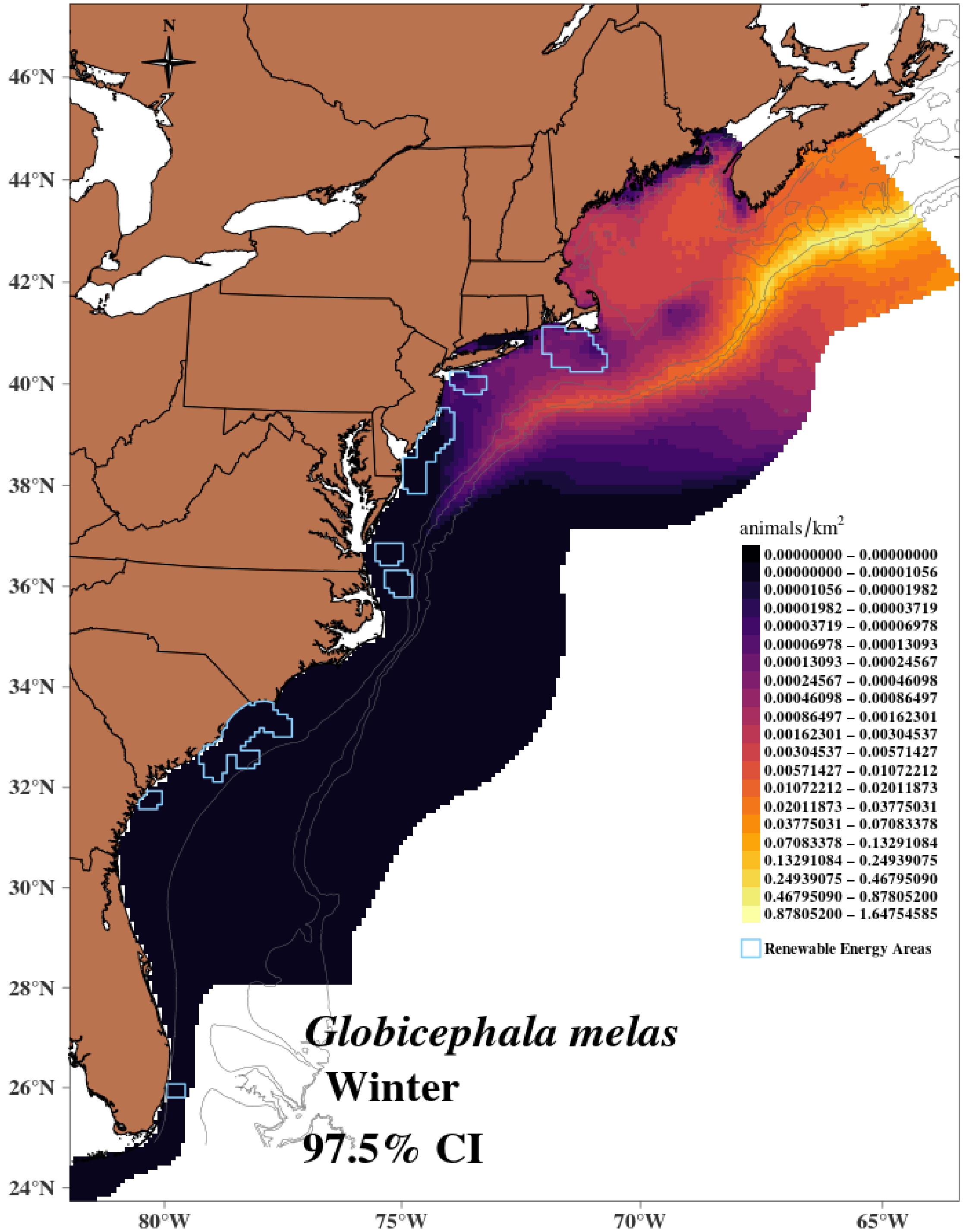

Figure 12-20 Upper 97.5% confidence interval of the winter long-finned pilot whale density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

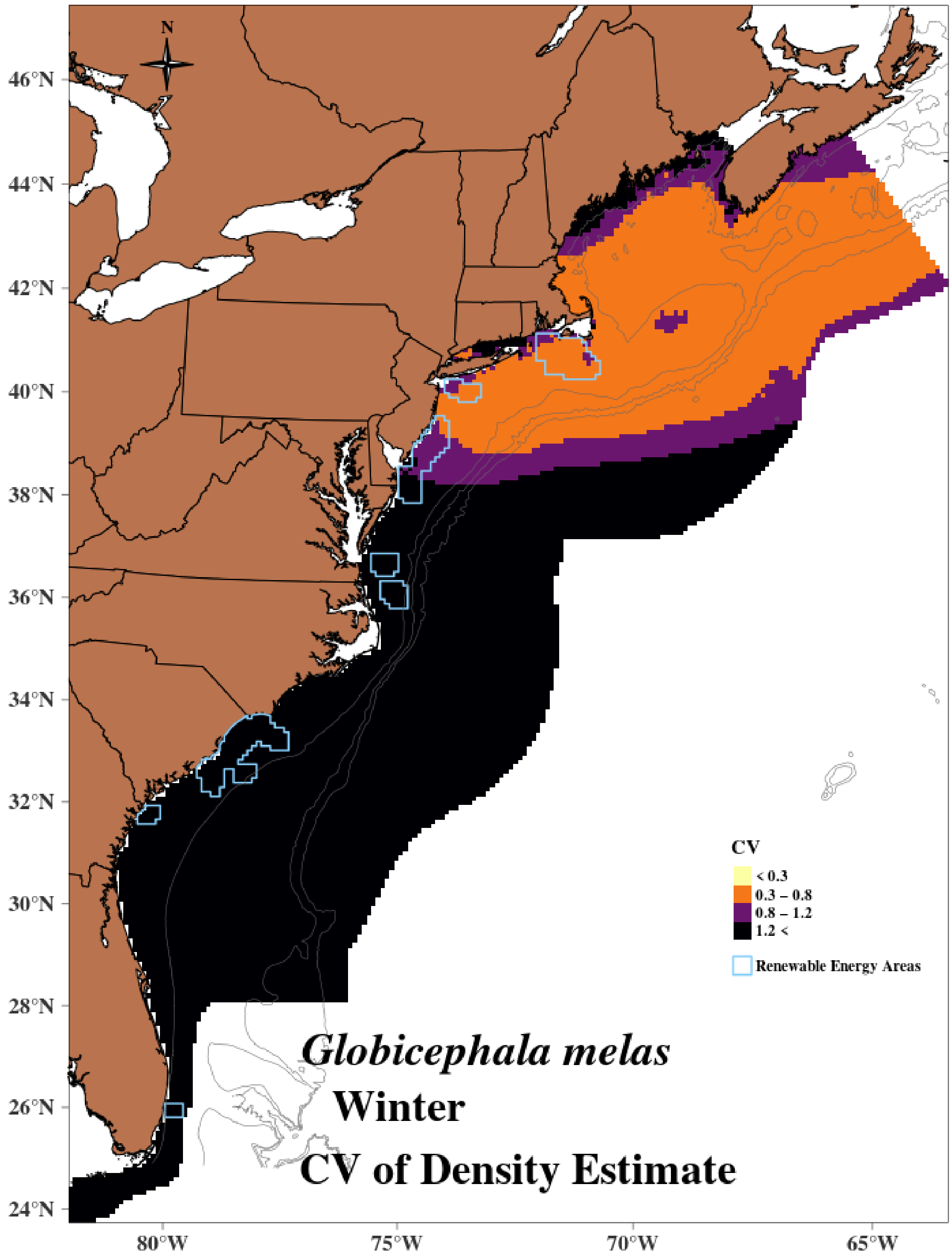

Figure 12-21 CV of winter long-finned pilot whale density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Data are from 2015 to 2017 only.

12.7 Offshore Energy Development Areas

Table 12-6 Long-finned pilot whale abundance estimates for wind-energy study areas
Abundance estimates averaged over 2015 to 2017.

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval
Spring (Mar–May)	RI/MA	4.7	0.58	1.7–13.5
	NY	0.3	0.62	0.1–0.9
	NJ	0.0	0.81	0.0–0.1
	DE/MD	0.0	1.26	0.0–0.0
	VA	0.0	2.84	0.0–0.0
	NC	0.0	3.76	0.0–0.0
	NC/SC	0.0	10.74	0.0–0.0
Summer (Jun–Aug)	RI/MA	11.1	0.63	3.6–34.6
	NY	0.2	0.66	0.1–0.8
	NJ	0.0	0.89	0.0–0.1
	DE/MD	0.0	1.24	0.0–0.0
	VA	0.0	2.84	0.0–0.0
	NC	0.0	3.75	0.0–0.0
	NC/SC	0.0	10.85	0.0–0.0
Fall (Sep–Nov)	RI/MA	5.3	0.59	1.8–15.2
	NY	0.3	0.65	0.1–0.9
	NJ	0.0	0.81	0.0–0.2
	DE/MD	0.0	1.24	0.0–0.0
	VA	0.0	2.83	0.0–0.0
	NC	0.0	3.74	0.0–0.0
	NC/SC	0.0	10.73	0.0–0.0
Winter (Dec–Feb)	RI/MA	0.8	0.67	0.2–2.6
	NY	0.1	0.68	0.0–0.2
	NJ	0.0	0.84	0.0–0.1
	DE/MD	0.0	1.28	0.0–0.0
	VA	0.0	2.83	0.0–0.0
	NC	0.0	3.76	0.0–0.0
	NC/SC	0.0	10.88	0.0–0.0

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

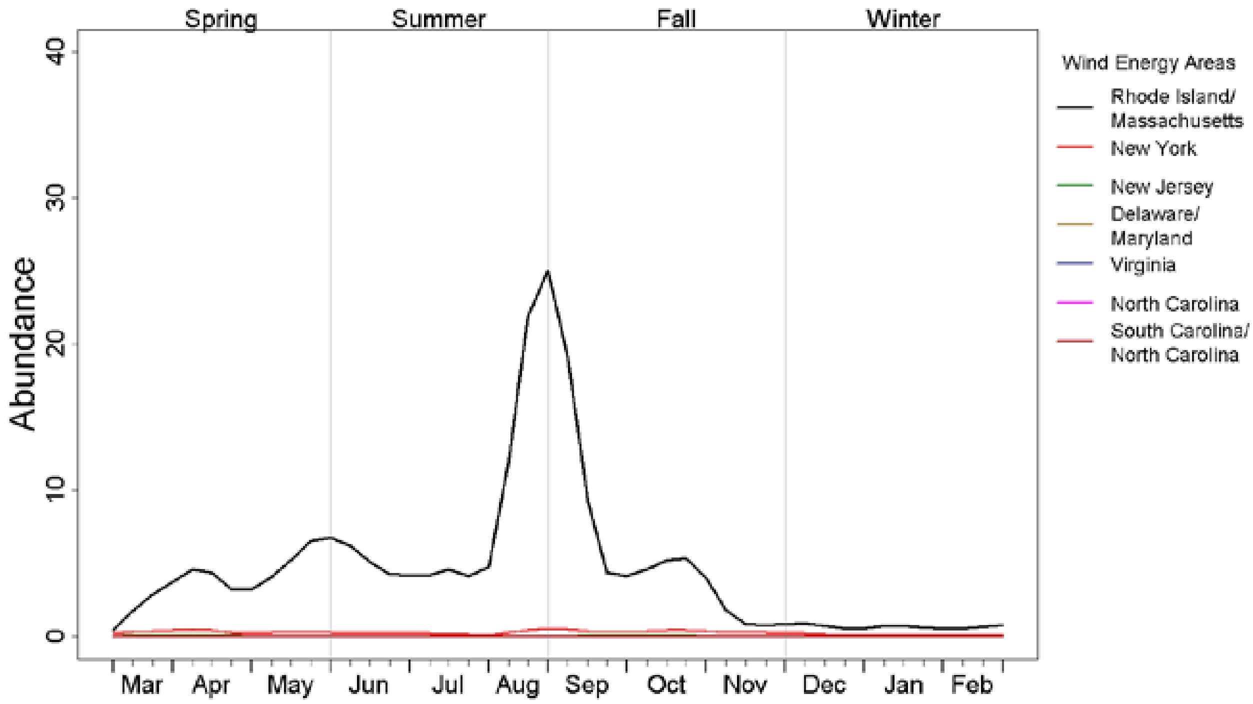

Figure 12-22 Average seasonal abundance of long-finned pilot whales in wind-energy study areas
Data from 2015 to 2017 only.

13 Risso’s Dolphin (*Grampus griseus*)

Figure 13-1 Risso's dolphin
Image collected under MMPA Research permit #132-1362. Credit: NOAA/NEFSC/Peter Duley

13.1 Data Collection

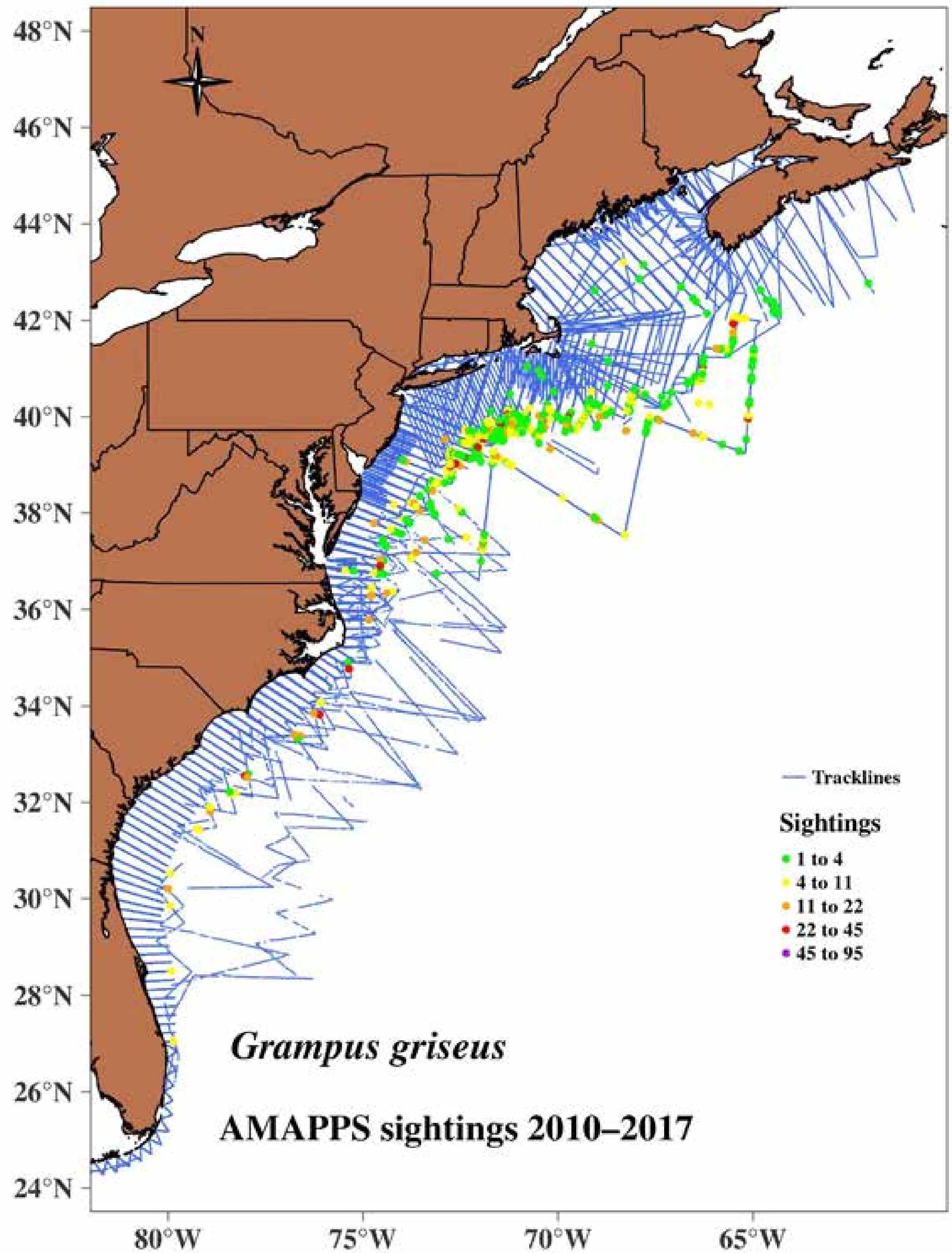

Figure 13-2 Distribution of track lines and Risso's dolphin sightings 2010 to 2017

Table 13-1 AMAPPS research effort 2010 to 2017 and Risso's dolphin sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	486	3,131
NE Shipboard	Fall	1,065	23	218
NE Aerial	Spring	13,314	14	34
NE Aerial	Summer	25,867	22	249
NE Aerial	Fall	37,850	55	481
NE Aerial	Winter	12,179	24	61
SE Shipboard	Spring	8,853	18	91
SE Shipboard	Summer	12,968	26	292
SE Shipboard	Fall	3,012	12	120
SE Aerial	Spring	41,293	36	207
SE Aerial	Summer	28,236	14	227
SE Aerial	Fall	18,974	2	10
SE Aerial	Winter	8,950	8	105

13.2 Mark-Recapture Distance Sampling Analysis

Table 13-2 Intermediate parameters in Risso's dolphin mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 5	distance * observer + glare	320	distance + sea state + group size	LT50-360	HR	0.74	0.15	0.23	0.99	0.98
NE–aerial group 6	distance * observer + group size	300	distance + time of day	300	HR	0.62	0.16	0.4	0.99	0.98
NE–shipboard group 4	sea state + group size	2200	distance + sea state + swell + group size	2200	HR	0.5	0.11	0.66	0.47	0.62
SE–shipboard group 3	distance * observer + group size	2700	distance	2700	HR	0.71	0.08	0.37	0.91	0.81

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

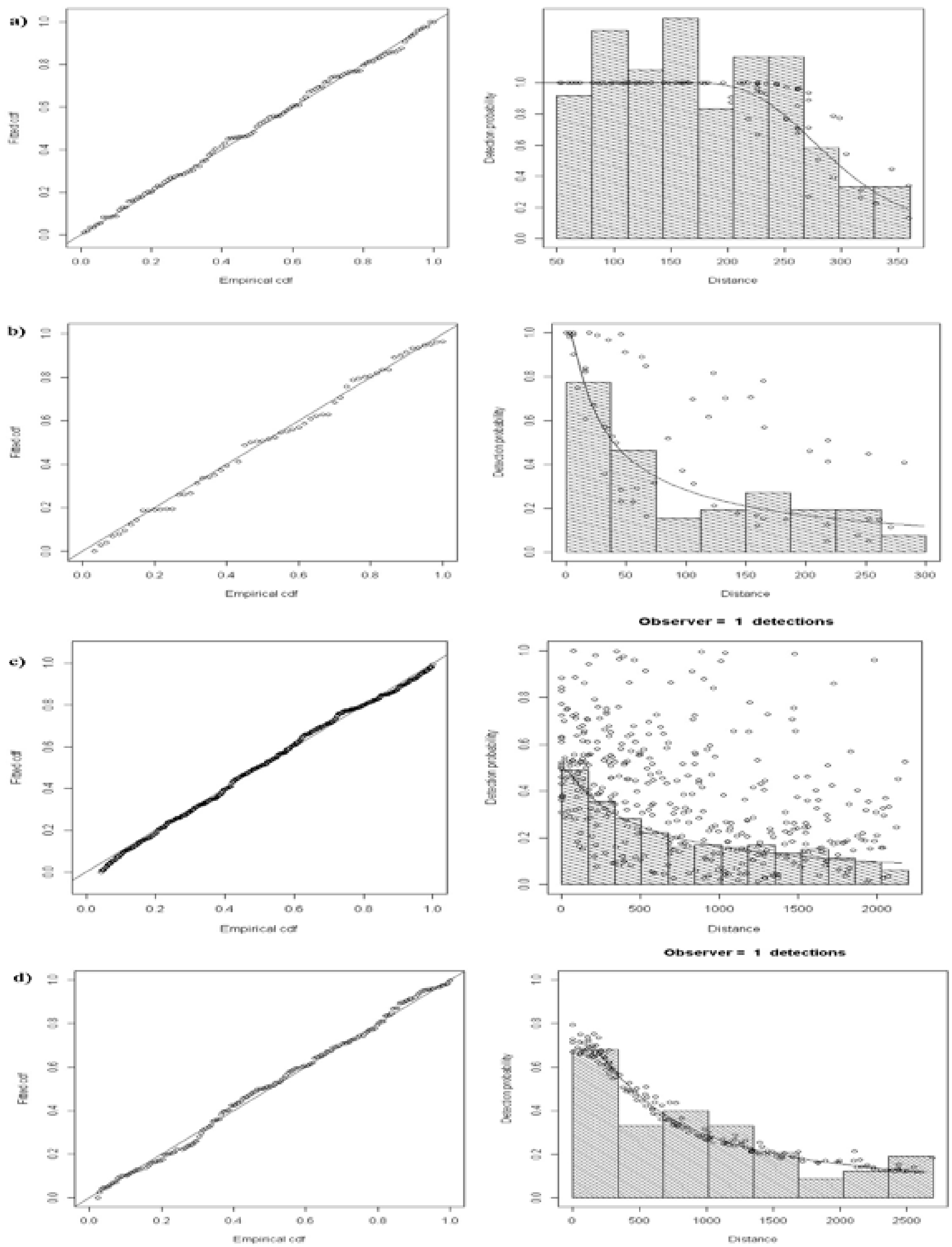

Figure 13-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 5; b) NE-aerial analysis set 6; c) NE-shipboard analysis set 4; d) SE-shipboard analysis set 3.

13.3 Generalized Additive Model Analysis

Table 13-3 2010 to 2017 density-habitat model output for Risso's dolphins

Covariates	Edf	Ref.df	F	C.dev	p-value
s(chla)	0.97	4	7.11	6.06	<0.0001
s(sstfmt)	0.99	4	3.53	4.64	0.0001
s(btemp)	3.22	4	16.34	7.95	<0.0001
s(mlp)	0.97	4	4.94	4.27	<0.0001
s(dist2GSSw)	2.86	4	12.77	5.58	<0.0001
s(depth)	3.78	4	12.39	4.96	<0.0001
s(dist2shore)	3.66	4	15.00	9.95	<0.0001
s(dist200)	1.10	4	13.36	8.10	<0.0001
s(lat)	0.99	4	3.35	0.74	0.0001

Adjusted R^2 = 0.0199. Deviance explained = 52.3%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

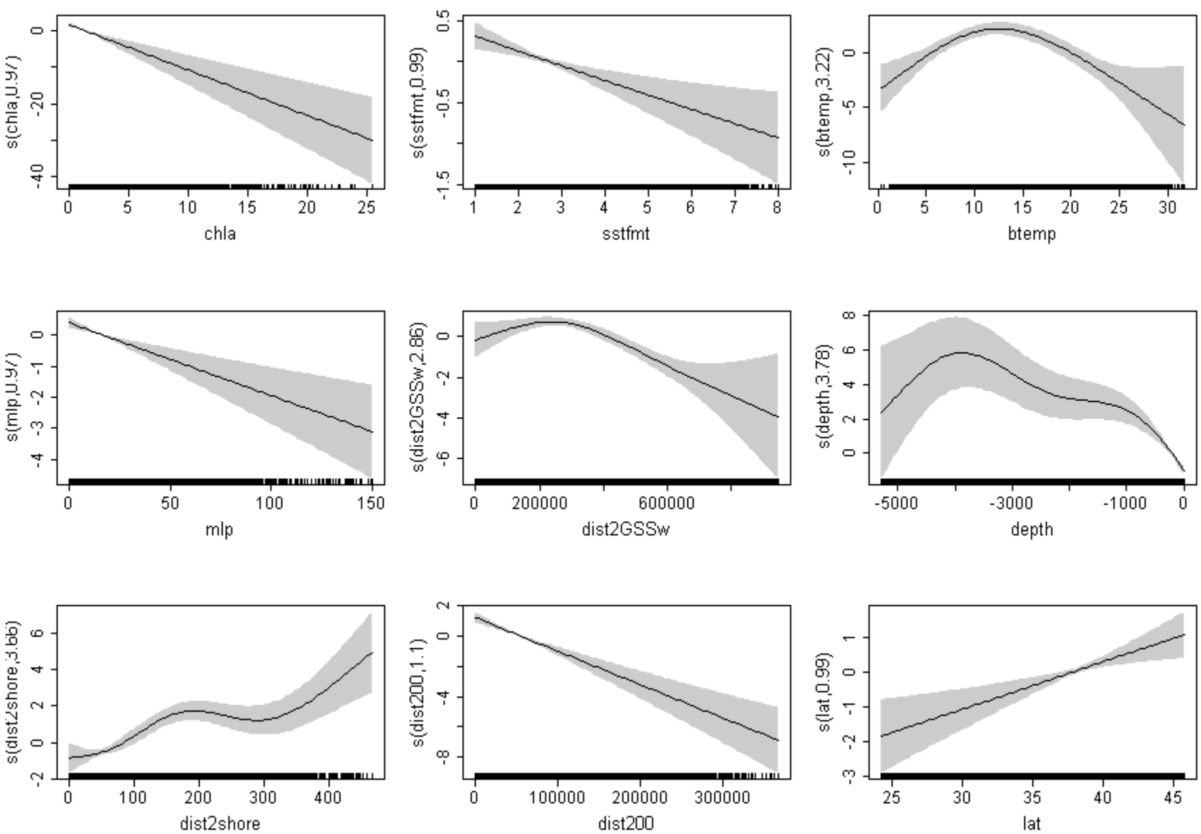

Figure 13-4 Annual abundance trends for Risso's dolphins in the AMAPPS study area
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

13.4 Model Cross-Validation

Table 13-4 Diagnostic statistics from the Risso's dolphin density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.251	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	84.200	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.165	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.023	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

13.5 Abundance Estimates for AMAPPS Study Area

Table 13-5 Risso's dolphin average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	11,221	0.34	5,868 – 21,457
Summer (June–August)	23,884	0.32	12,952 – 44,044
Fall (September–November)	17,939	0.32	9,728 – 33,081
Winter (December–February)	8,971	0.37	4,446 – 18,103
Summer 2011 U.S. surveys[1]	18,250	0.46	
Summer 2016 U.S. surveys[1]	29,142	0.20	

[1]Hayes et al. 2020

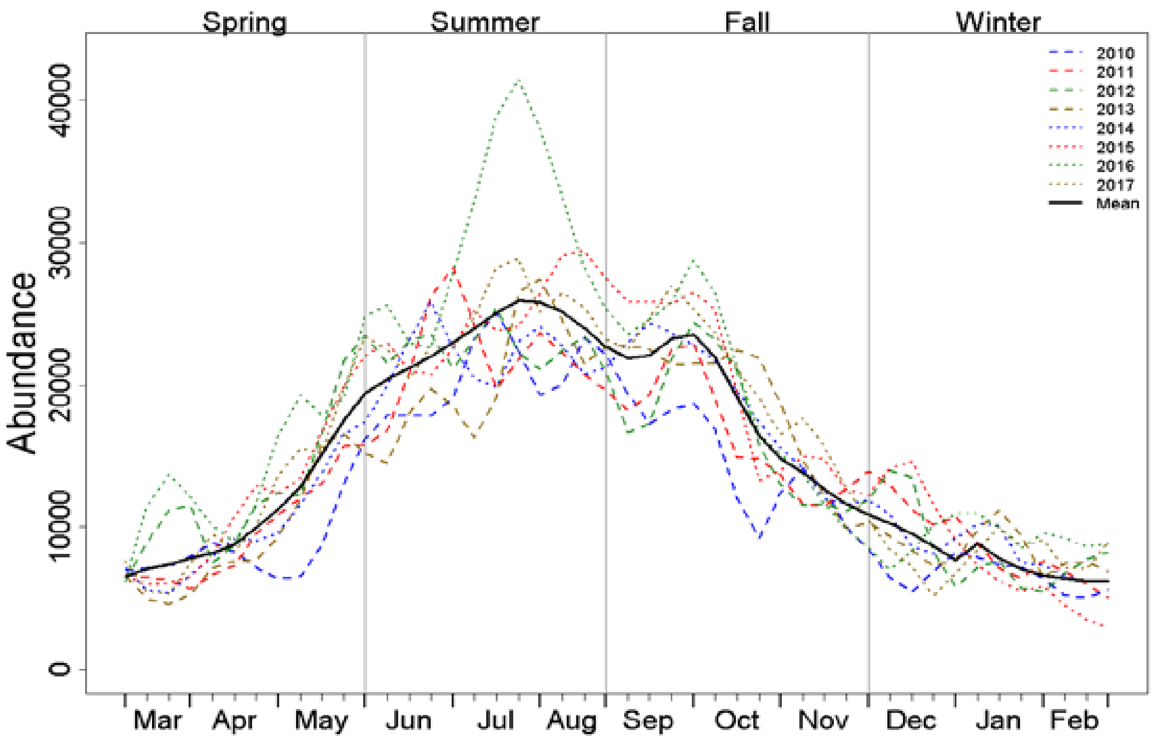

Figure 13-5 Annual abundance trends for Risso's dolphins in the AMAPPS study area

13.6 Seasonal Prediction Maps

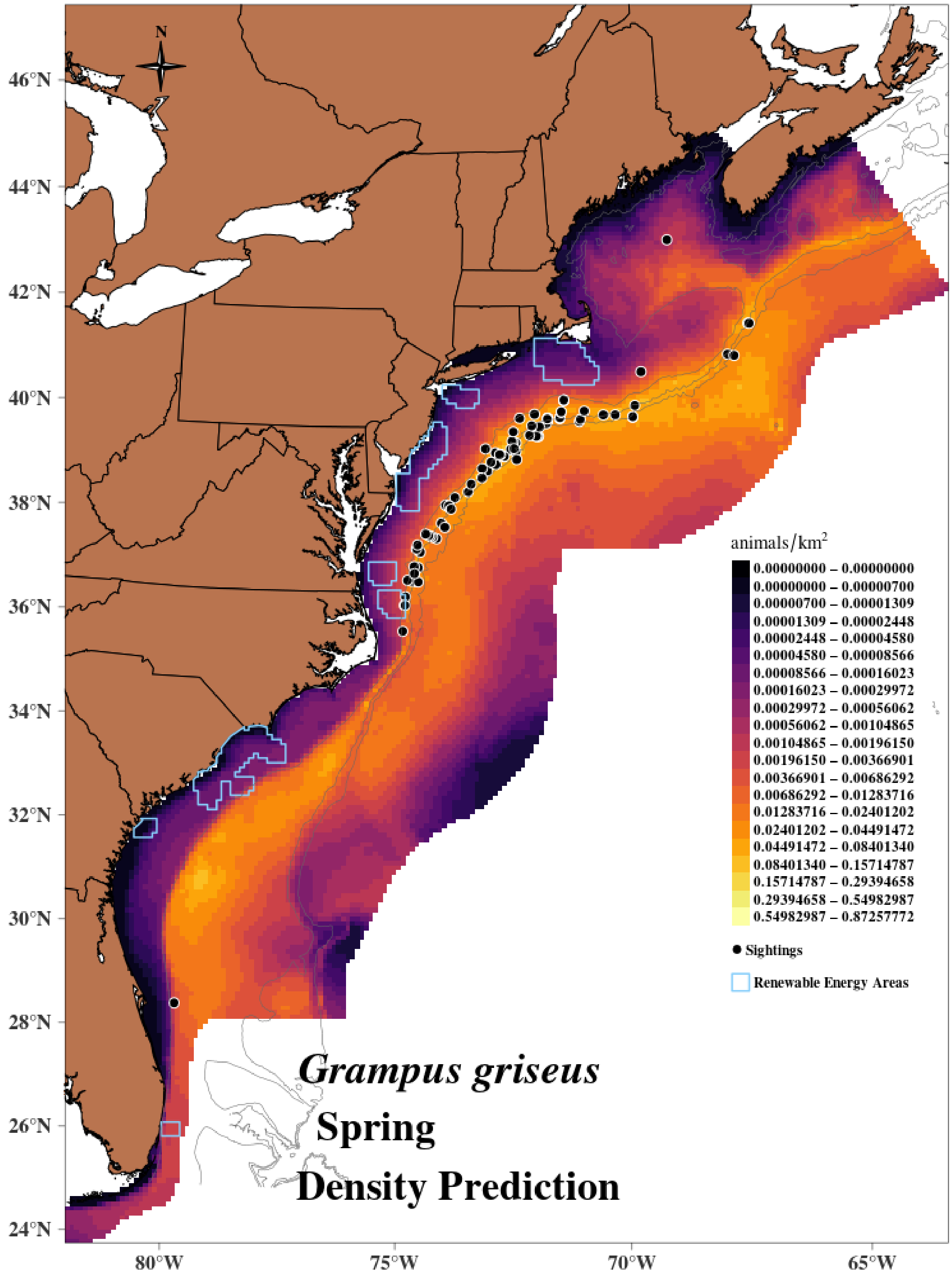

Figure 13-6 Risso's dolphin spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

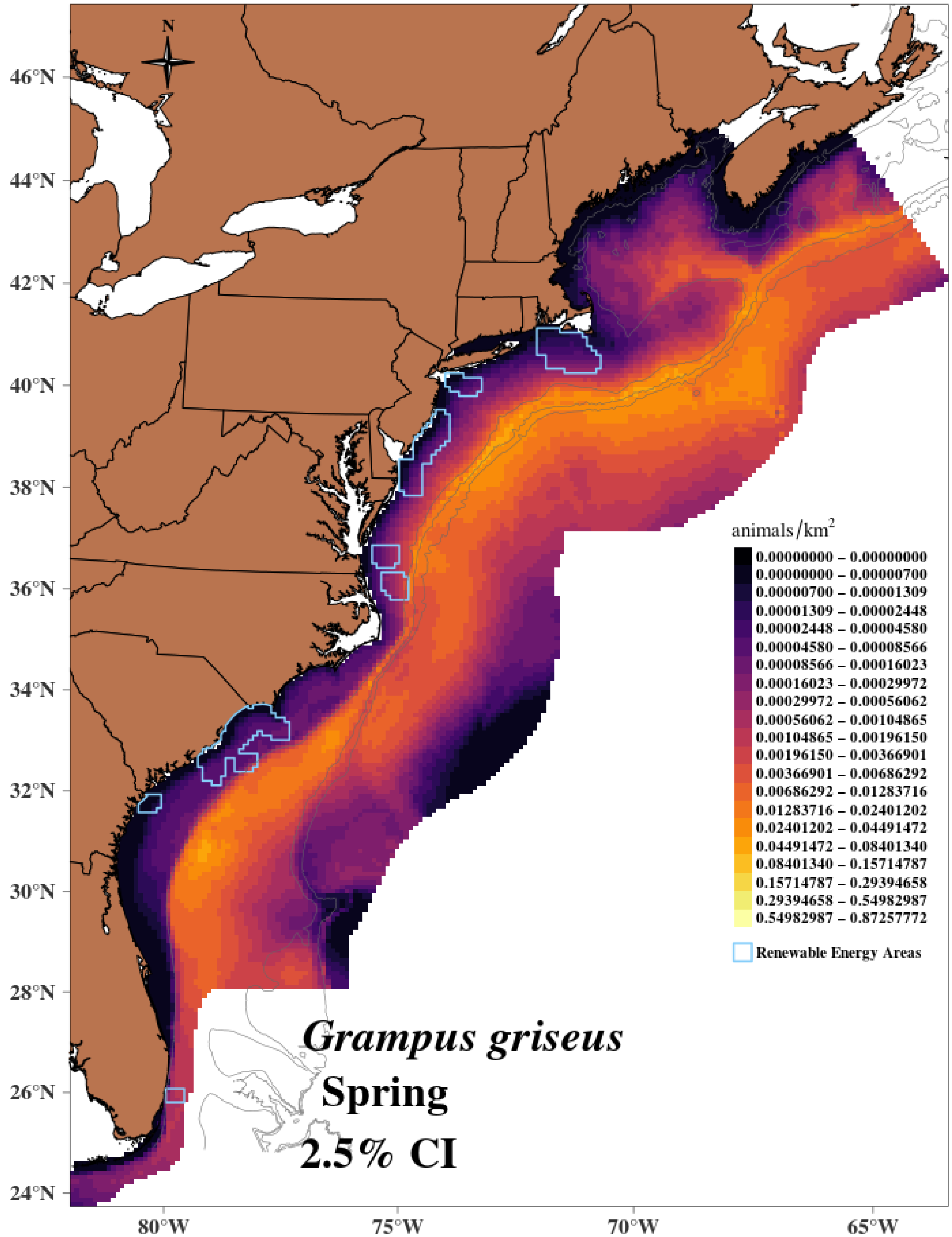

Figure 13-7 Lower 2.5% confidence interval of the spring Risso's dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

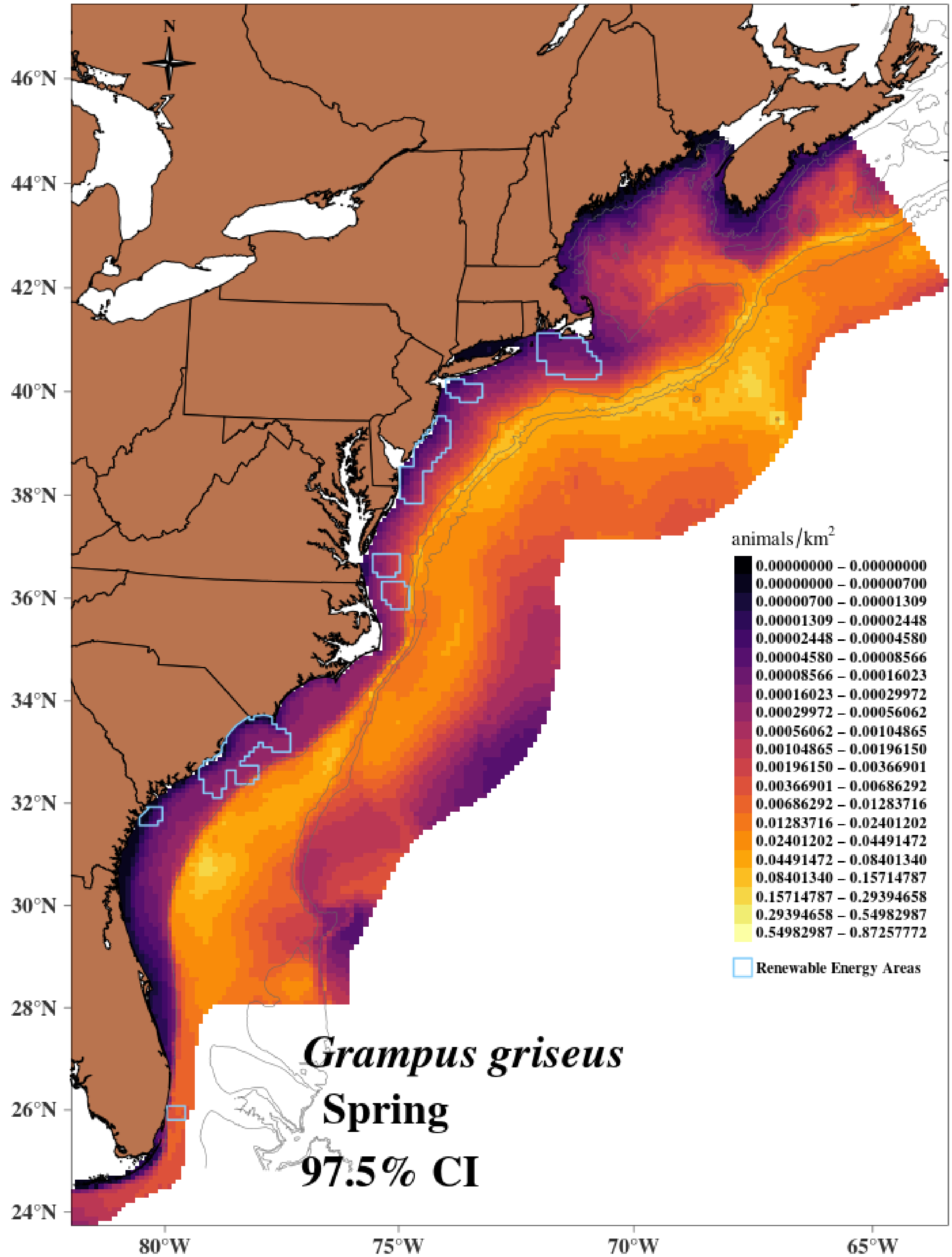

Figure 13-8 Upper 97.5% confidence interval of the spring Risso's dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

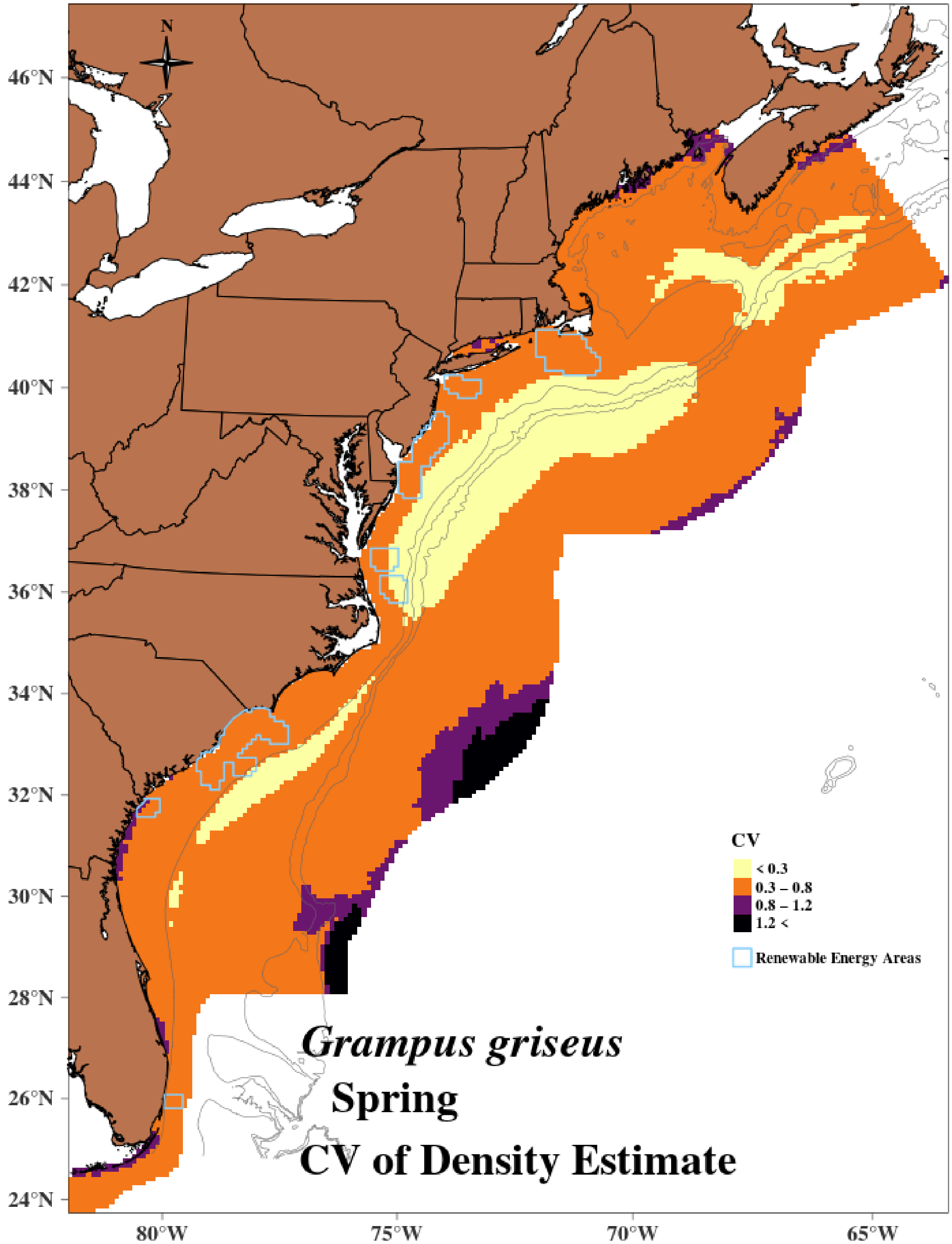

Figure 13-9 CV of spring Risso's dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

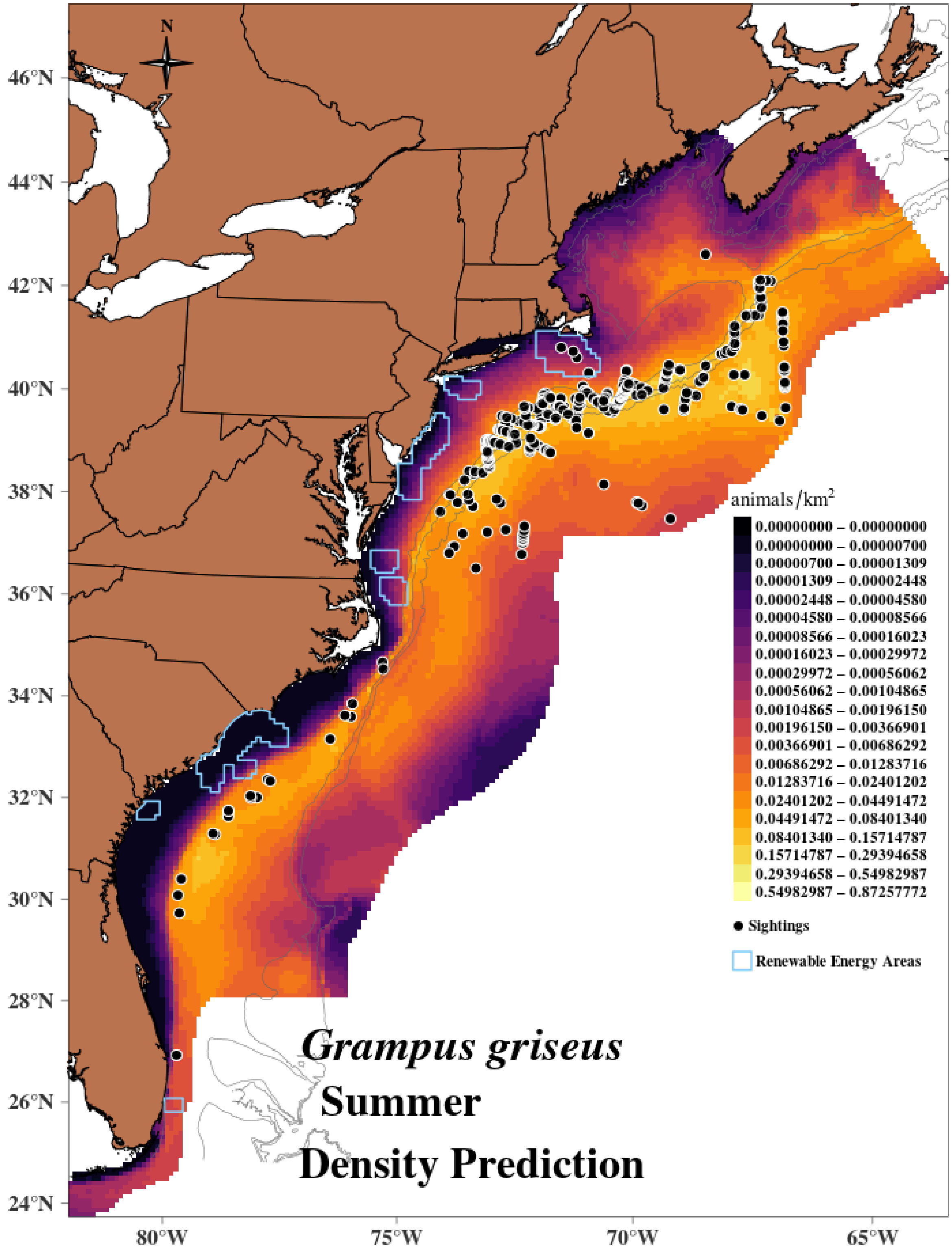

Figure 13-10 Risso's dolphin summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

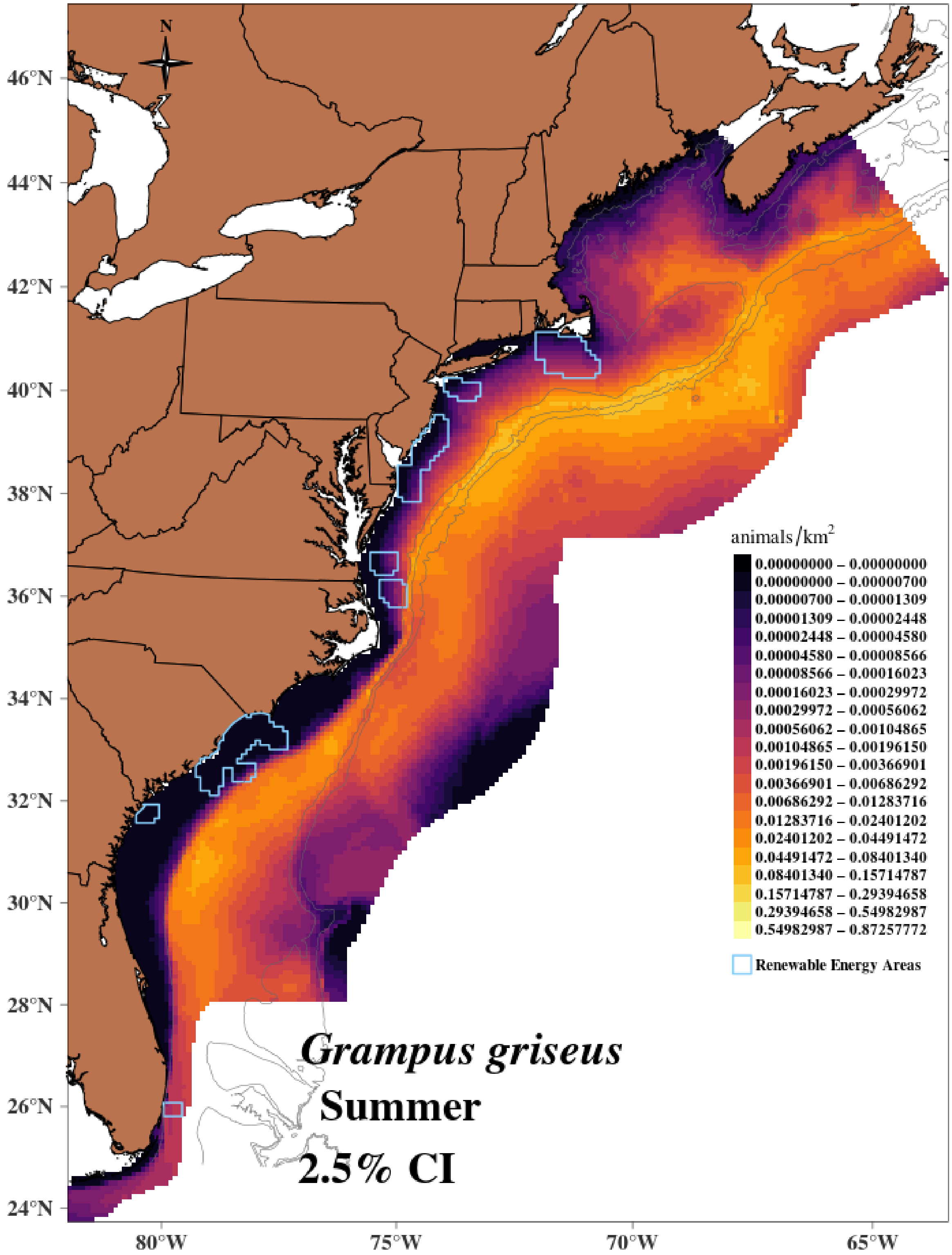

Figure 13-11 Lower 2.5% confidence interval of the summer Risso's dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

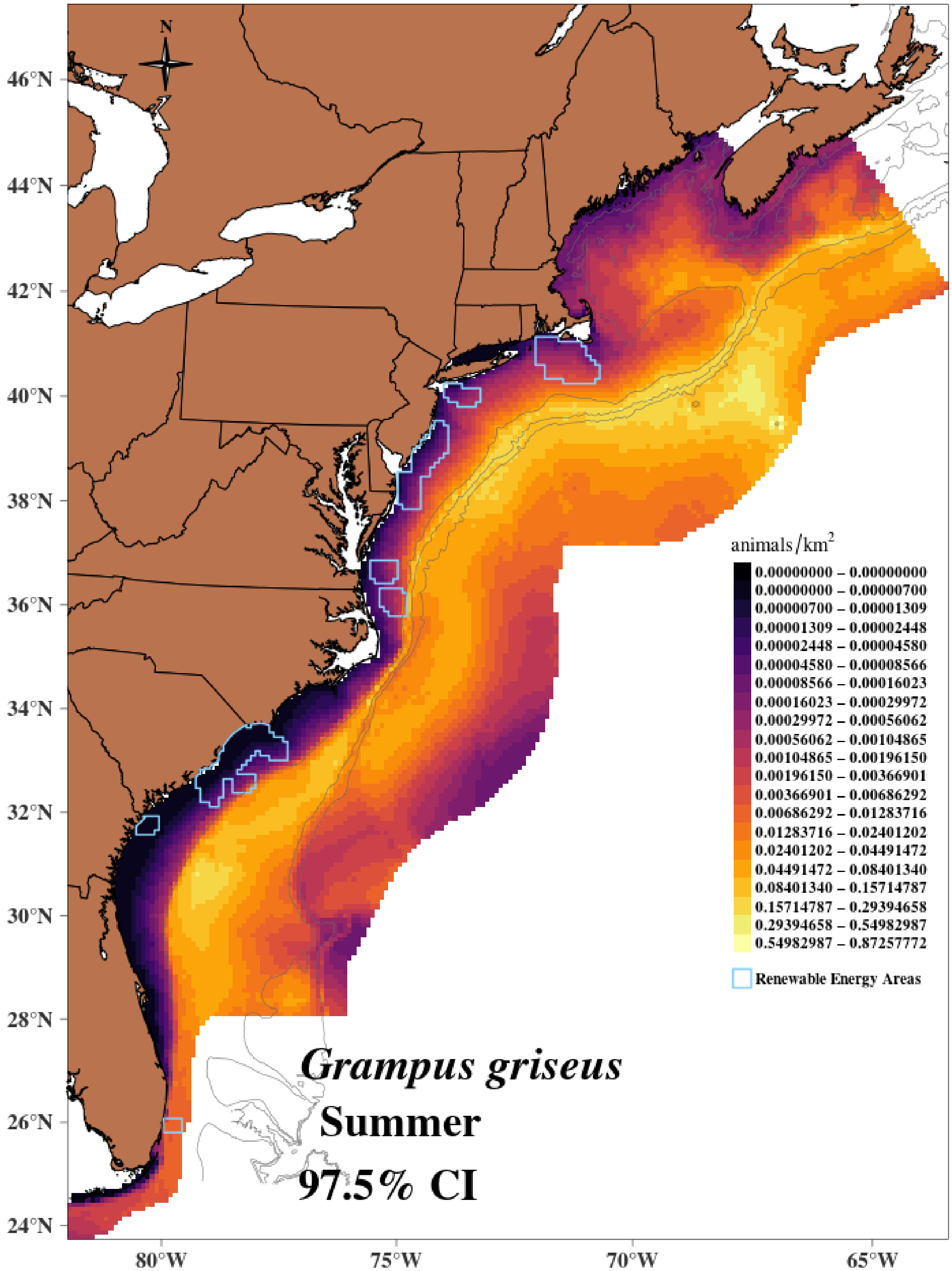

Figure 13-12 Upper 97.5% confidence interval of the summer Risso's dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

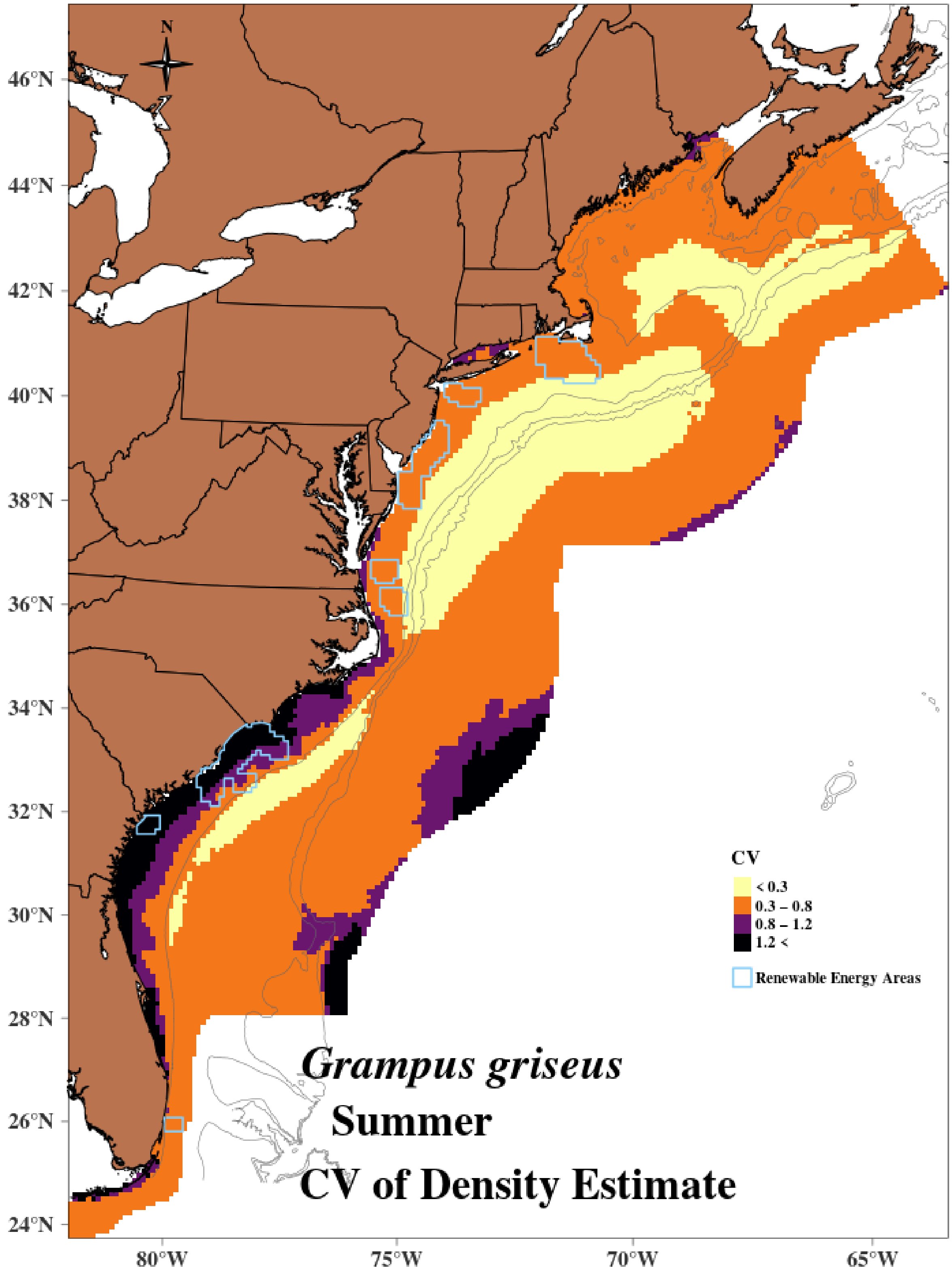

Figure 13-13 CV of summer Risso's dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

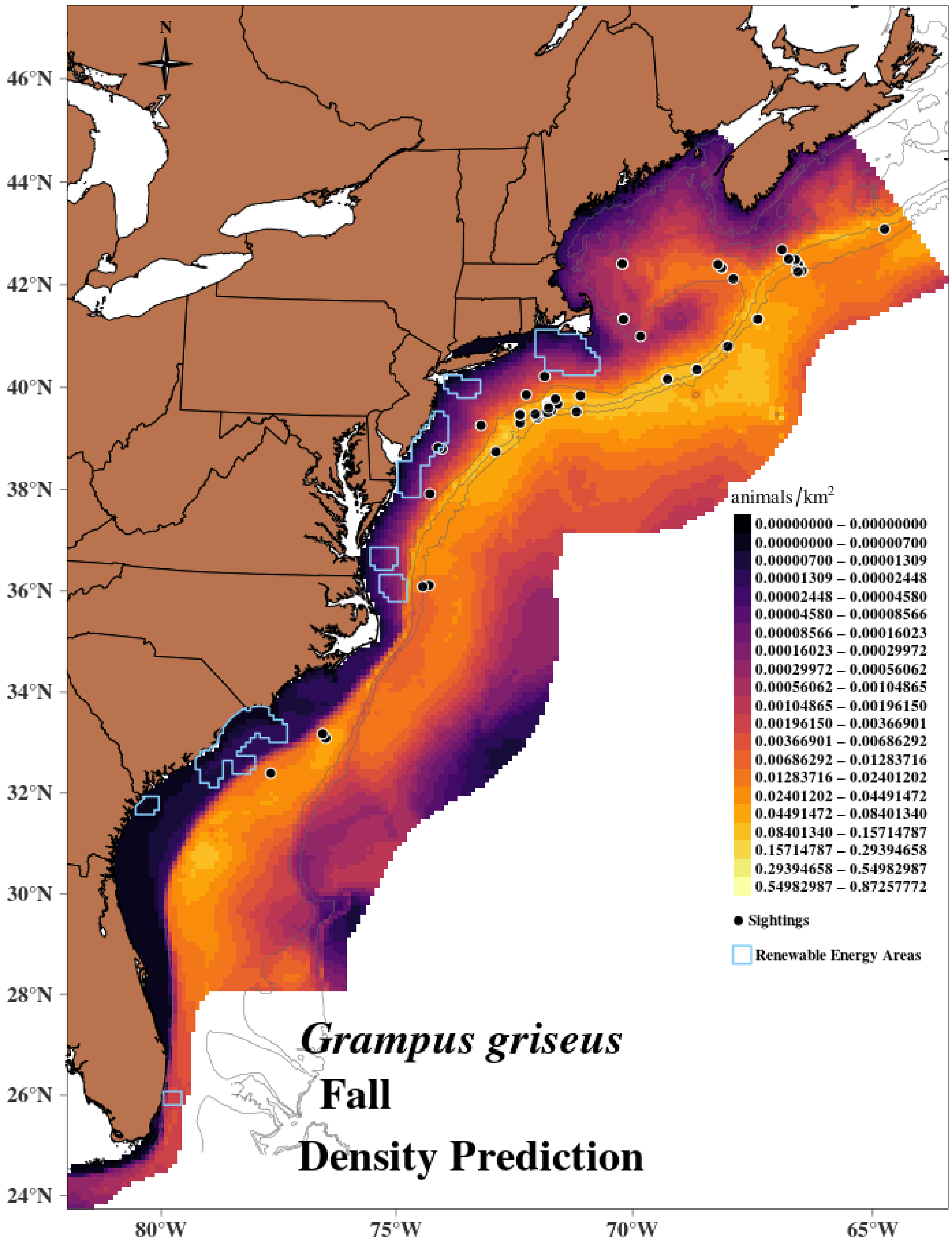

Figure 13-14 Risso's dolphin fall average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

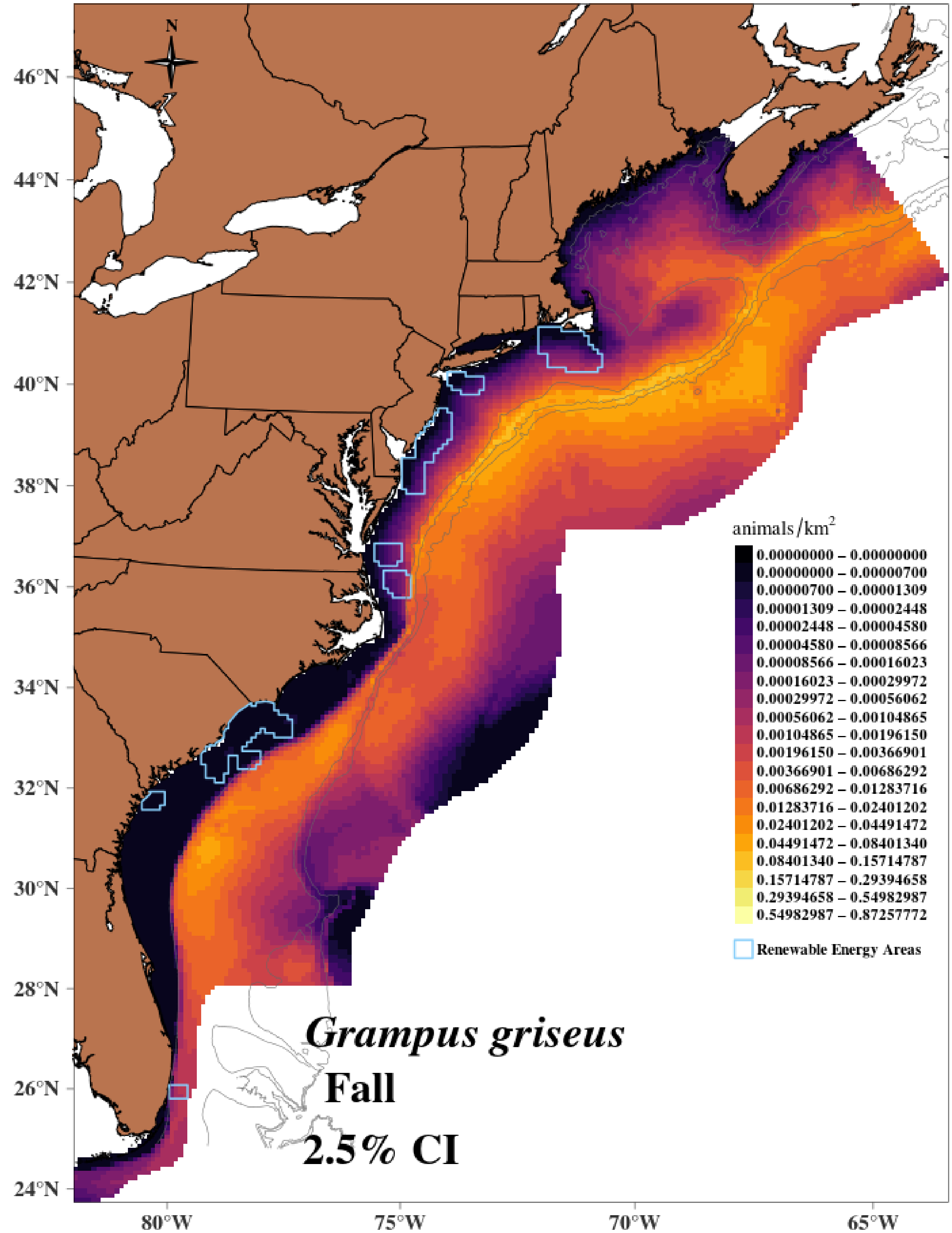

Figure 13-15 Lower 2.5% confidence interval of the fall Risso's dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

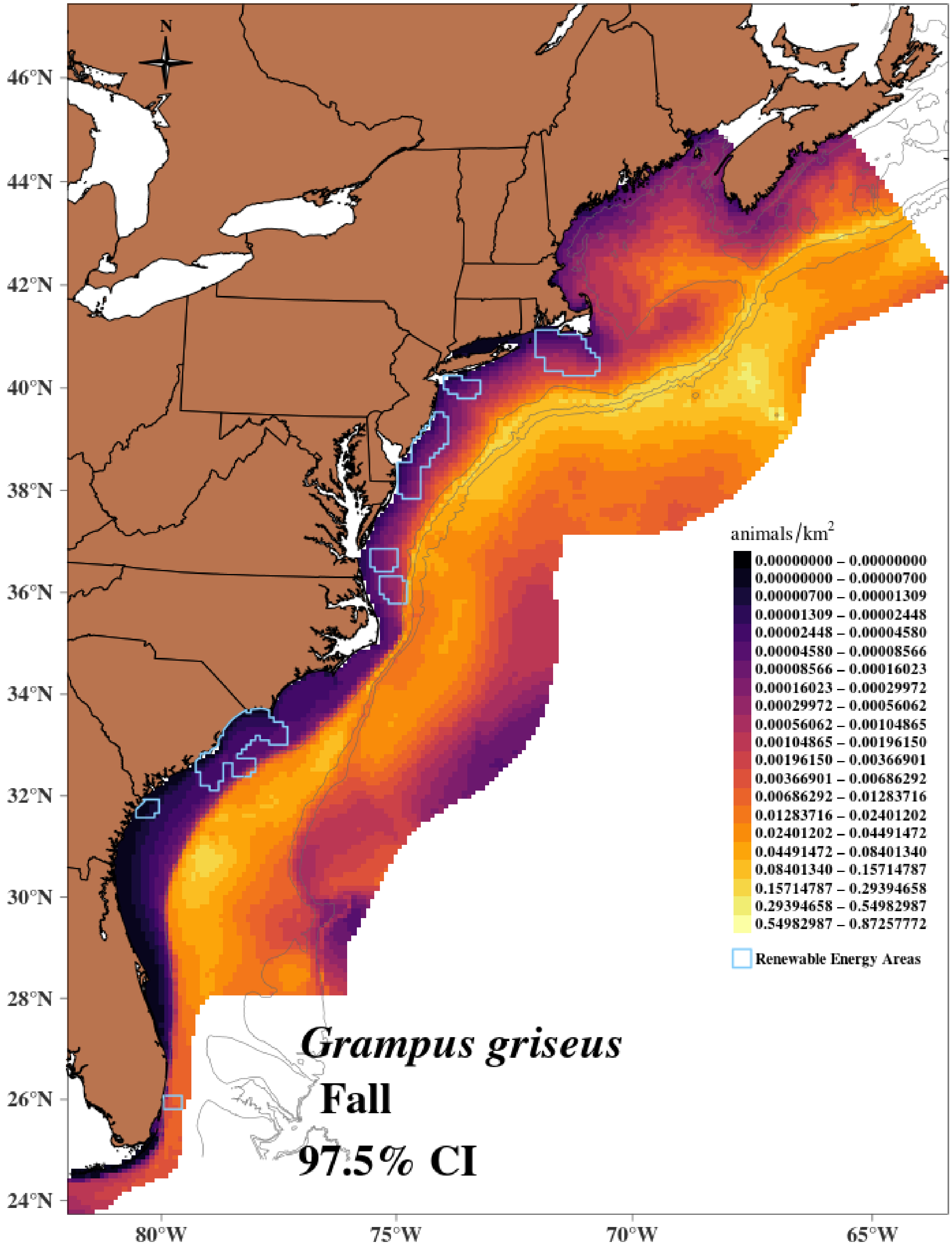

Figure 13-16 Upper 97.5% confidence interval of the fall Risso's dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

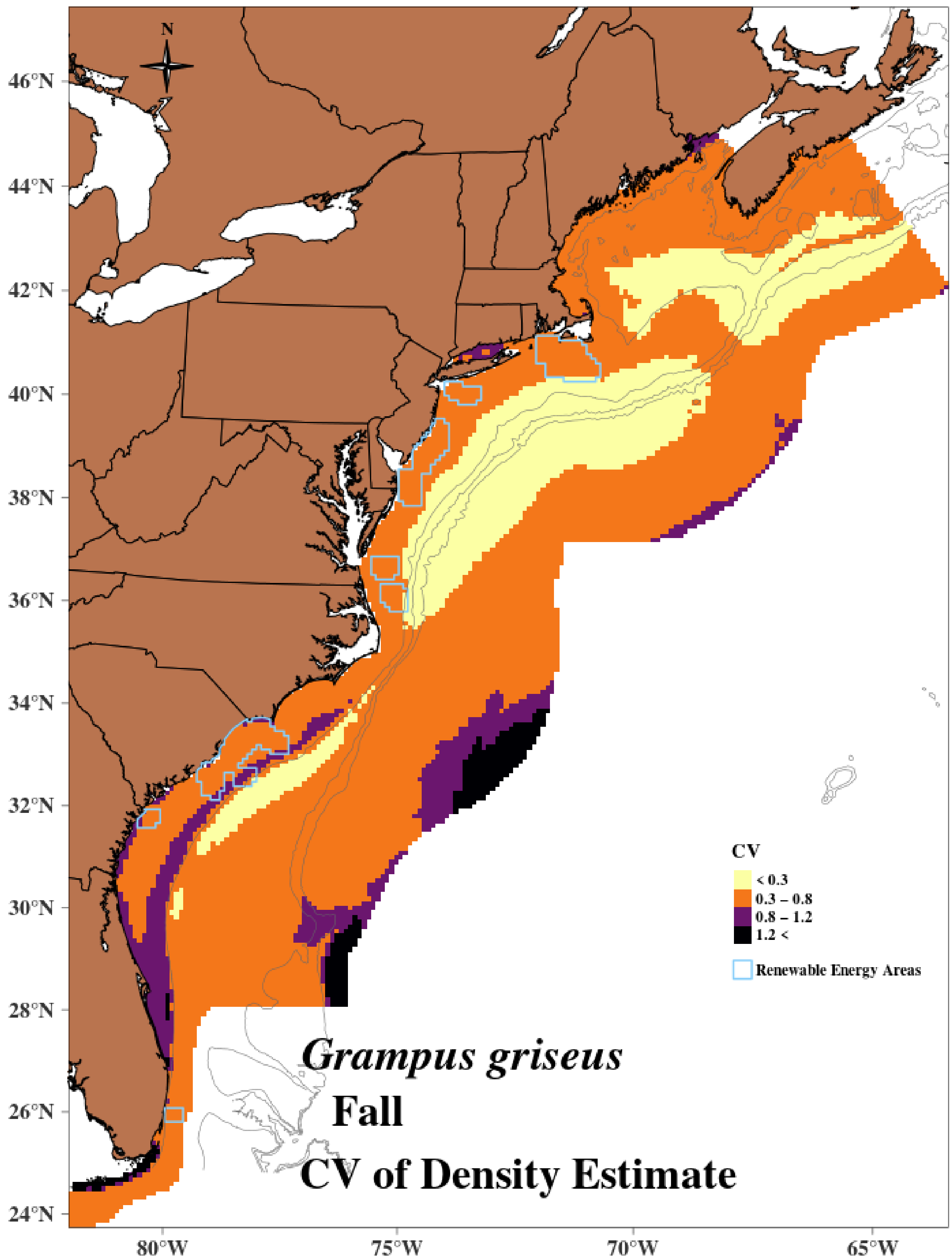

Figure 13-17 CV of fall Risso's dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

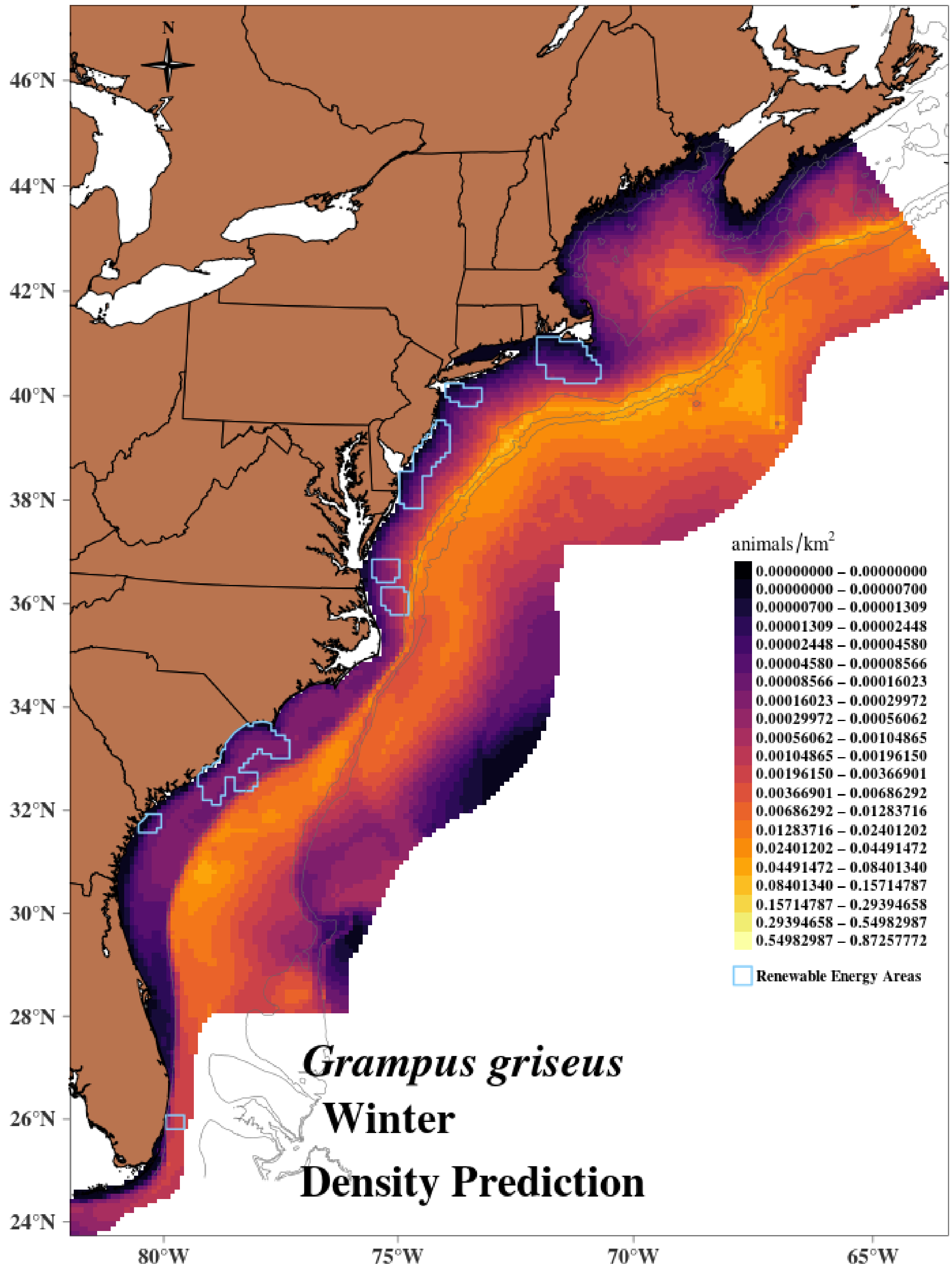

Figure 13-18 Risso's dolphin winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

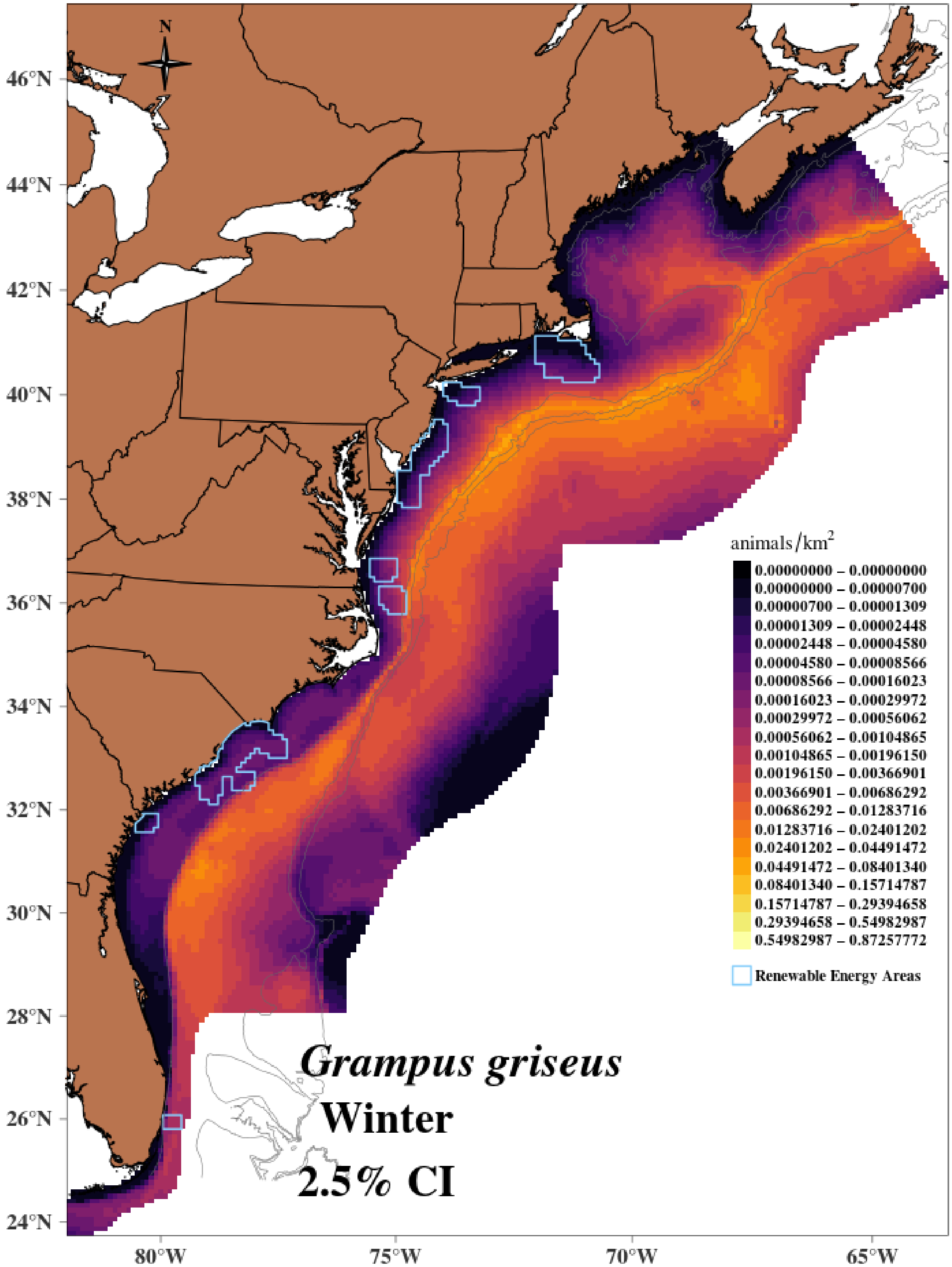

Figure 13-19 Lower 2.5% confidence interval of the winter Risso's dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

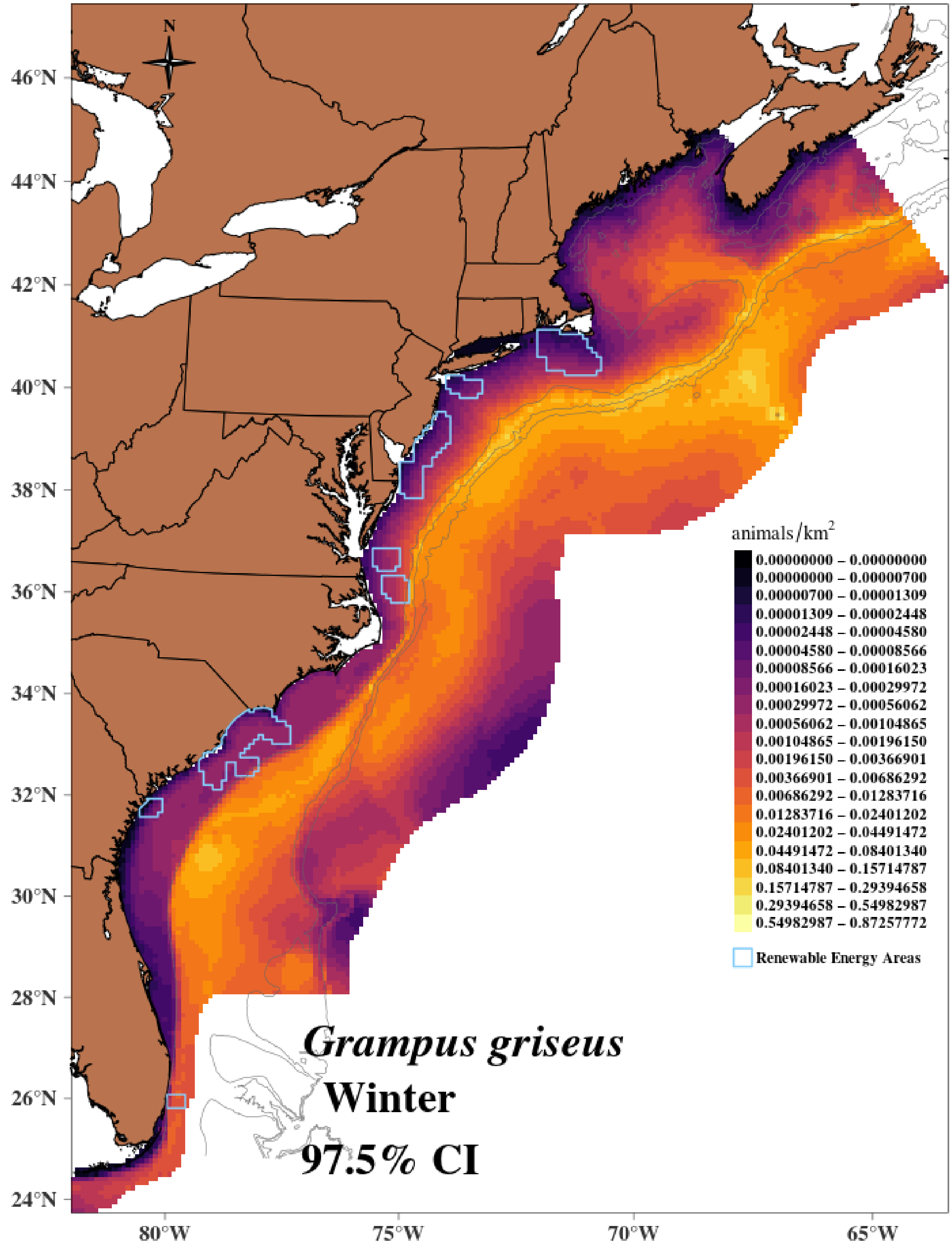

Figure 13-20 Upper 97.5% confidence interval of the winter Risso's dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

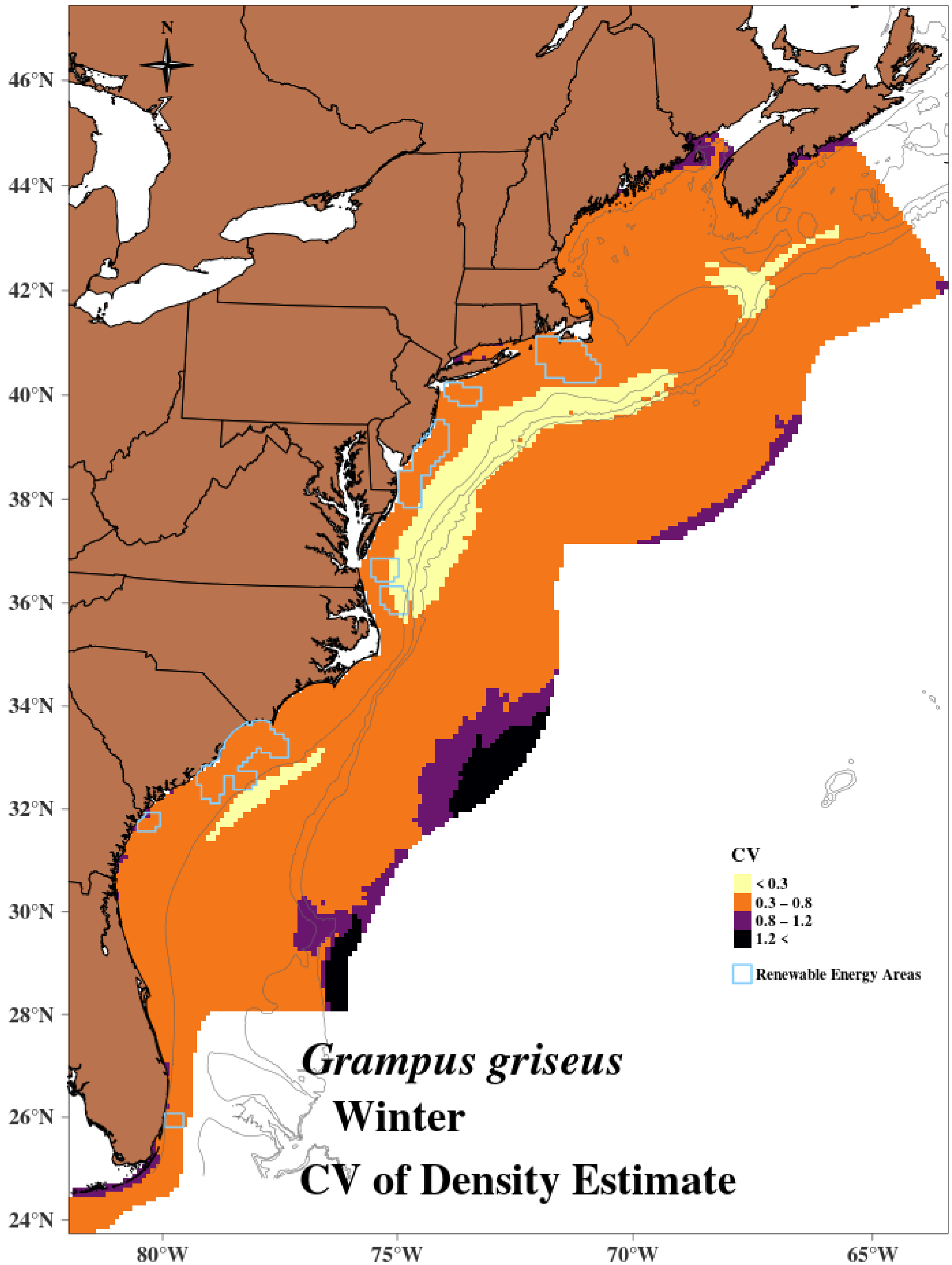

Figure 13-21 CV of winter Risso's dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

13.7 Offshore Energy Development Areas

Table 13-6 Risso's dolphin abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	2.1	0.37	1.0 4.2
	NY	0.3	0.41	
	NJ	0.6	0.40	
	DE/MD	0.7	0.36	
	VA	1.5	0.29	
	NC	5.9	0.26	
	NC/SC	2.5	0.35	
Summer (Jun–Aug)	RI/MA	9.2	0.33	
	NY	0.5	0.39	.0
	NJ	0.3	0.44	
	DE/MD	0.4	0.38	
	VA	0.5	0.36	.0
	NC	4.7	0.27	
	NC/SC	1.9	0.32	
Fall (Sep–Nov)	RI/MA	4.5	0.34	
	NY	0.2	0.42	
	NJ	0.3	0.45	
	DE/MD	0.3	0.41	
	VA	0.4	0.36	
	NC	2.5	0.29	
	NC/SC	1.0	0.36	.0
Winter (Dec–Feb)	RI/MA	1.2	0.37	
	NY	0.2	0.41	
	NJ	0.4	0.41	
	DE/MD	0.4	0.36	
	VA	1.0	0.30	
	NC	4.2	0.27	
	NC/SC	2.6	0.37	

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

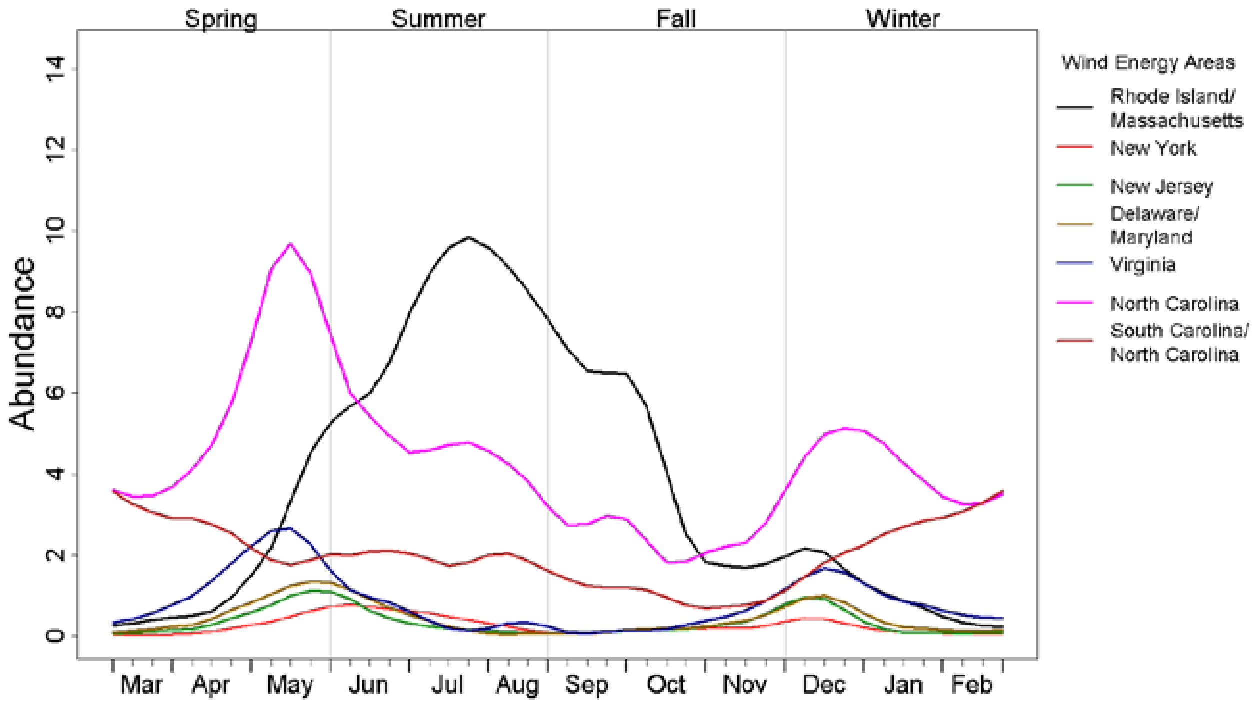

Figure 13-22 Average seasonal abundance of Risso's dolphins in the wind-energy study areas

14 Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)

Figure 14-1 White-sided dolphins
Image collected under MMPA Research permit #1355. Credit: NOAA/NEFSC/Peter Duley

14.1 Data Collection

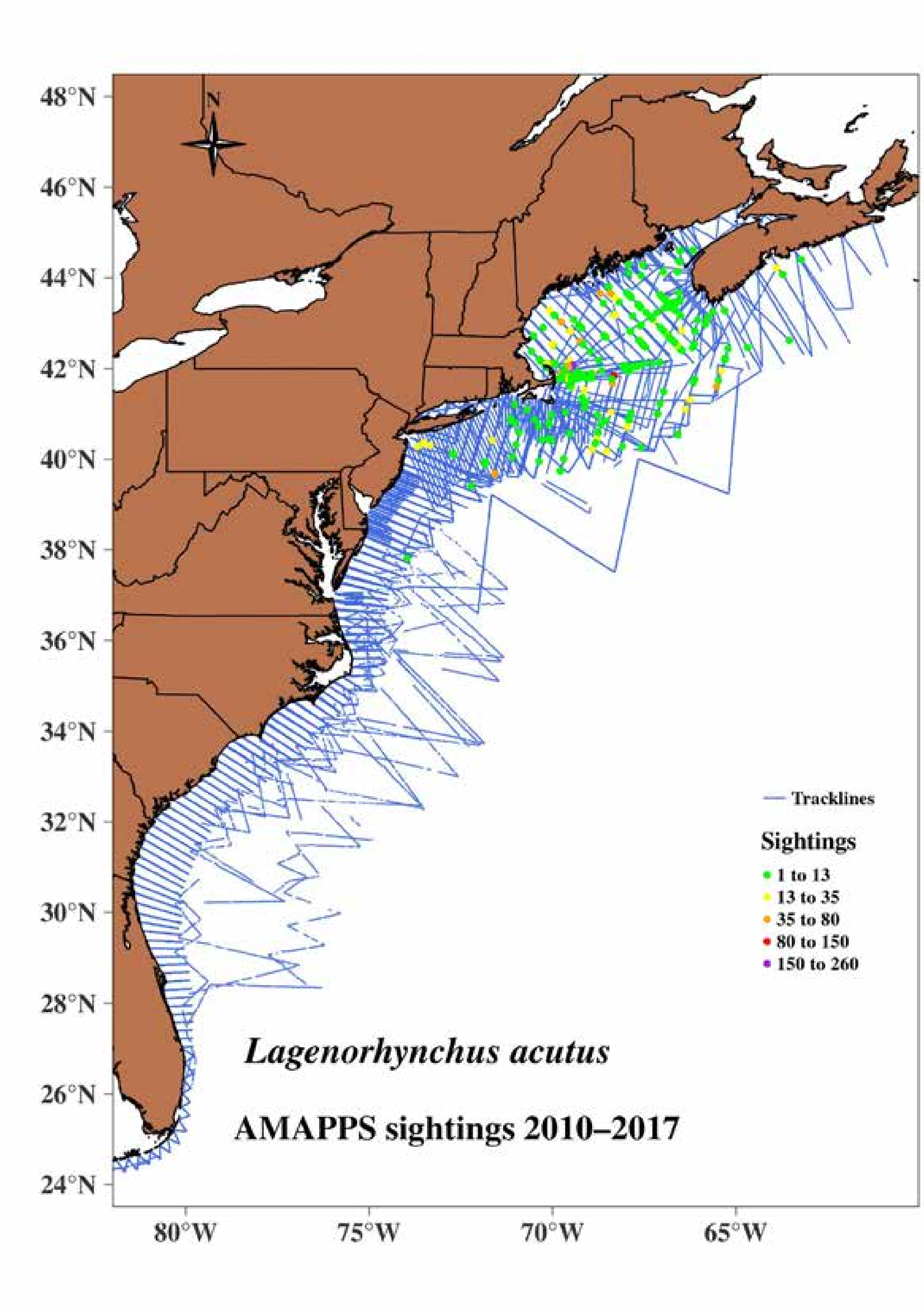

Figure 14-2 Distribution of track lines and white-sided dolphin sightings 2010 to 2017

Table 14-1 AMAPPS research effort 2010 to 2017 and Atlantic white-sided dolphin sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	3	61
NE Shipboard	Fall	1,065	0	0
NE Aerial	Spring	13,314	62	536
NE Aerial	Summer	25,867	82	929
NE Aerial	Fall	37,850	144	2,675
NE Aerial	Winter	12,179	25	208
SE Shipboard	Spring	8,853	27	261
SE Shipboard	Summer	12,968	0	0
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	0	0
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

14.2 Mark-Recapture Distance Sampling Analysis

Table 14-2 Intermediate parameters in Atlantic white-sided dolphin mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
NE–aerial group 8	distance * observer	400	distance + group size + sea state	400	HR	0.57	0.10	0.19	0.87	0.90
NE–shipboard group 5	distance * observer + group size	3800	distance + swell	3800	HR	0.52	0.08	0.22	0.71	0.78
SE–shipboard group 1	distance + group size	2700	distance + sea state + glare	2700	HR	0.62	0.09	0.23	0.98	0.98

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

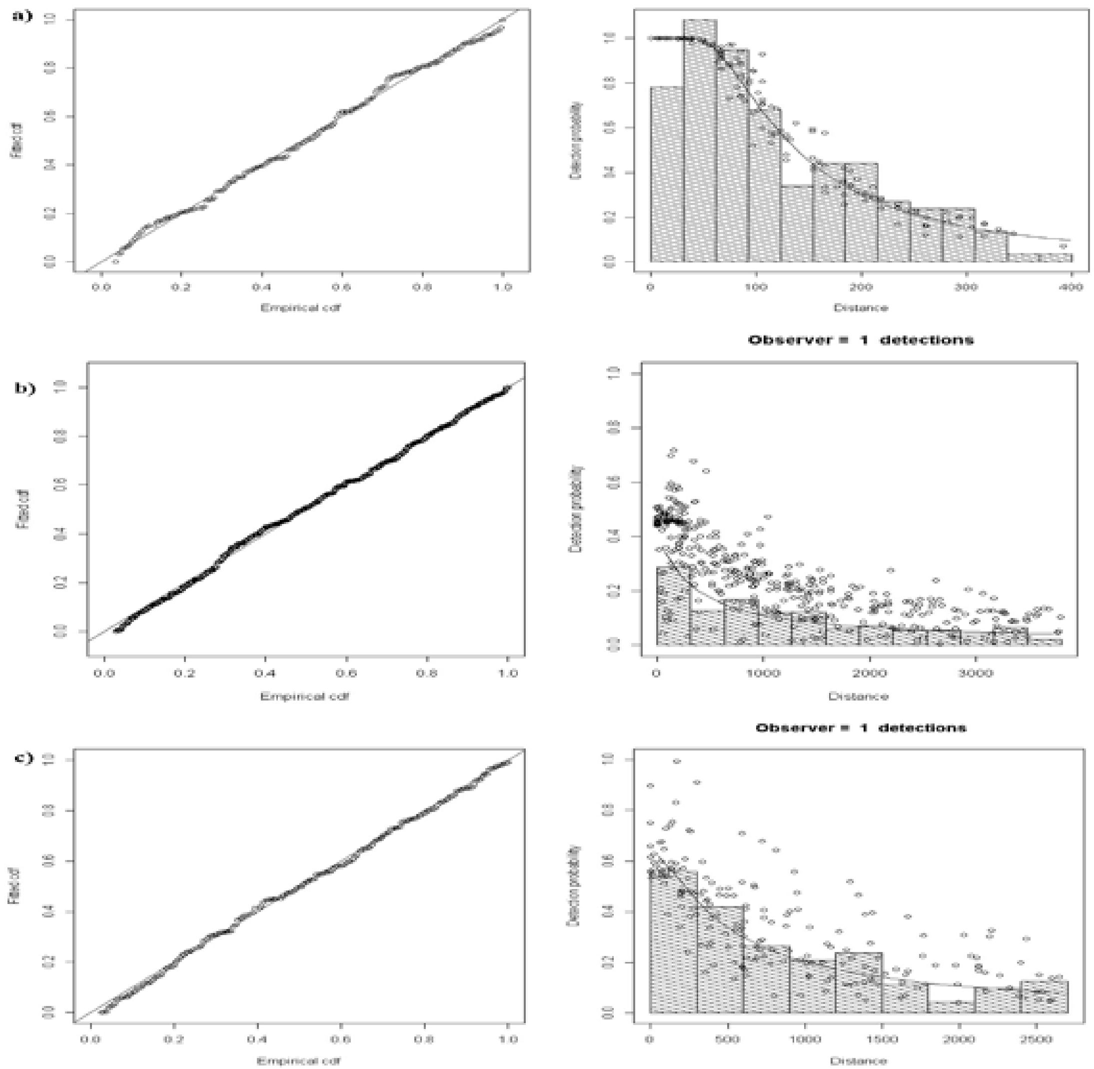

Figure 14-3 Q-Q plots and detection functions from the MRDS analyses
a) NE-aerial analysis set 8; b) NE-shipboard analysis set 5; c) SE-shipboard analysis set 1.

14.3 Generalized Additive Model Analysis

Table 14-3 2010 to 2017 density-habitat model output for Atlantic white-sided dolphins

Covariates	Edf	Ref.df	F	C.dev	p-value
s(sstmur)	2.01	4	6.88	6.73	<0.0001
s(picma)	0.95	4	4.71	6.56	<0.0001
s(dist200)	0.94	4	3.24	4.81	<0.0001
te(LY,dist2GSSw)	10.95	24	3.69	28.18	<0.0001

Adjusted R^2 = 0.0117. Deviance explained = 46.2%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

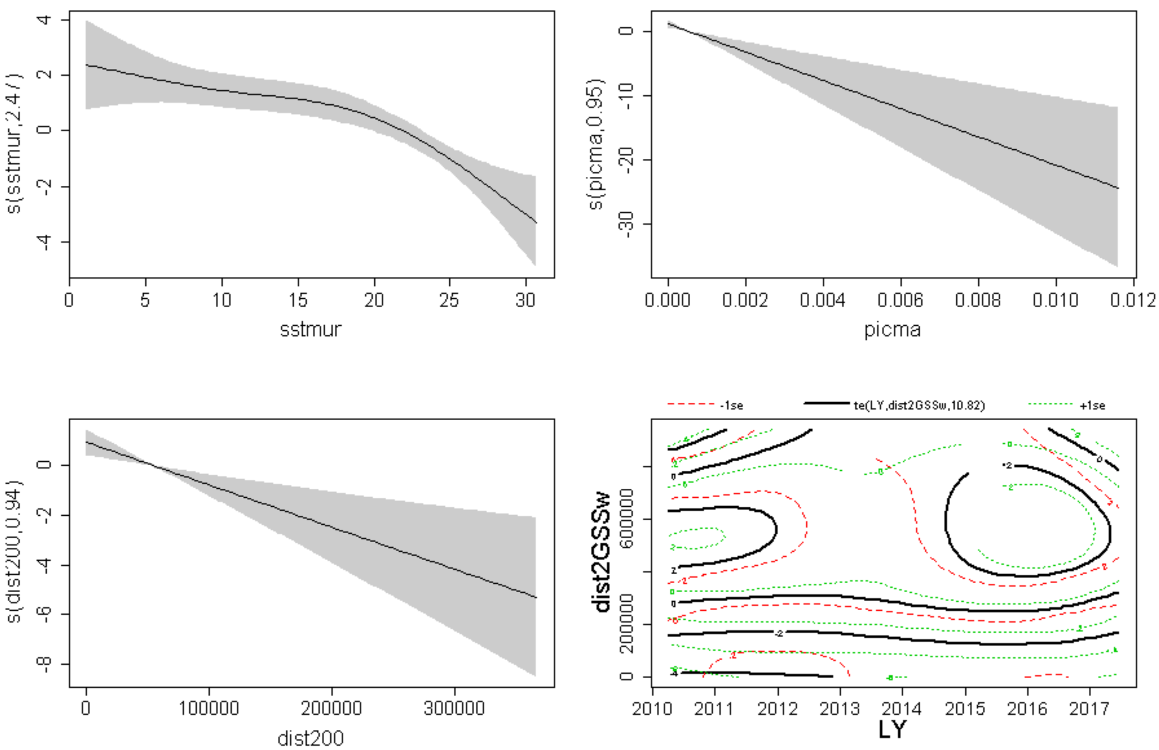

Figure 14-4 Atlantic white-sided dolphin density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

14.4 Model Cross-Validation

Table 14-4 Diagnostic statistics from the Atlantic white-sided dolphin density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.104	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	91.000	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.097	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.012	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

14.5 Abundance Estimates for AMAPPS Study Area

Table 14-5 Atlantic white-sided dolphin average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	8,002	0.59	2,741–23,357
Summer (June–August)	2,938	0.48	1,204–7,172
Fall (September–November)	3,794	0.46	1,608–8,954
Winter (December–February)	7,084	0.55	2,586–19,403
Summer 2011 U.S. surveys[1]	48,819	0.61	
Summer 2016 U.S. surveys[1]	31,912	0.61	

[1]Hayes et al. 2020

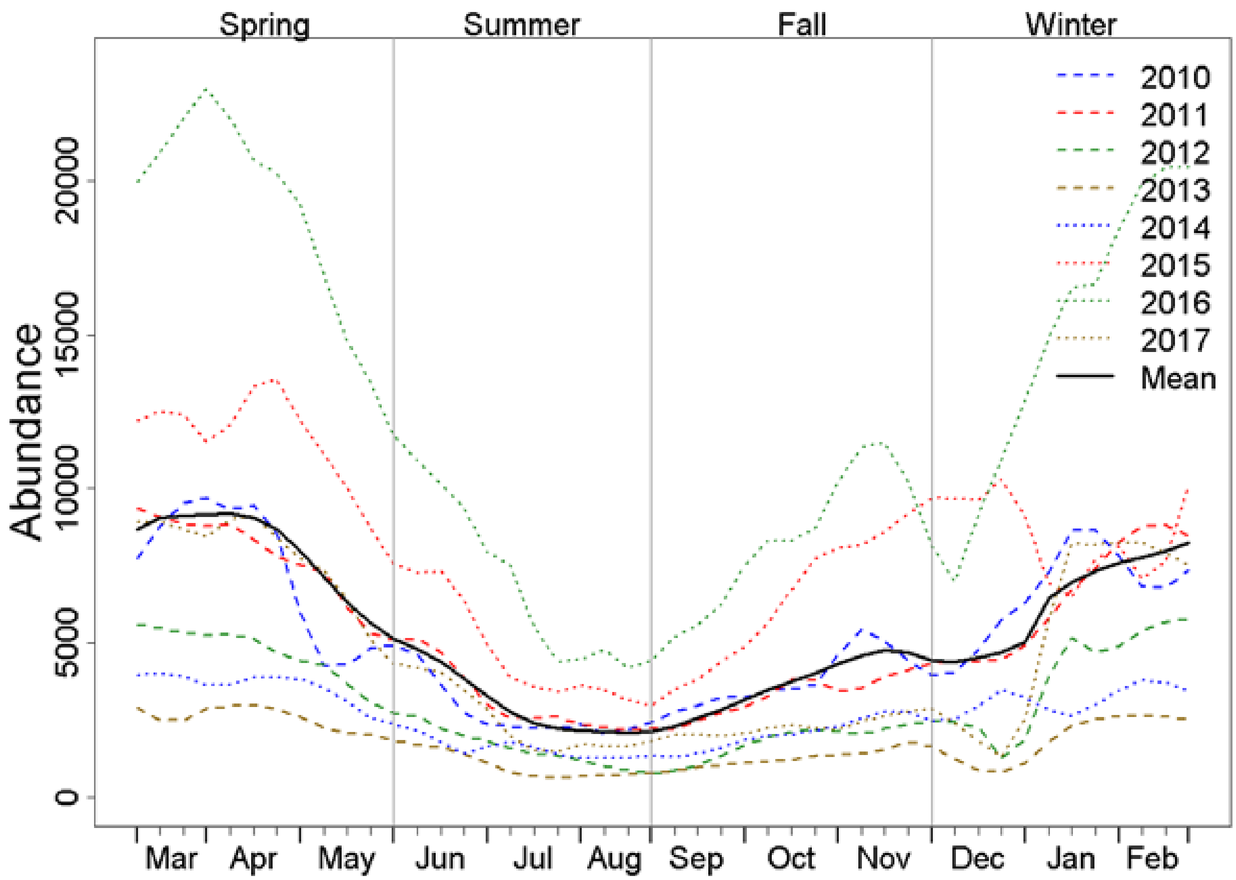

Figure 14-5 Annual abundance trends for Atlantic white-sided dolphins in the AMAPPS study area

14.6 Seasonal Prediction Maps

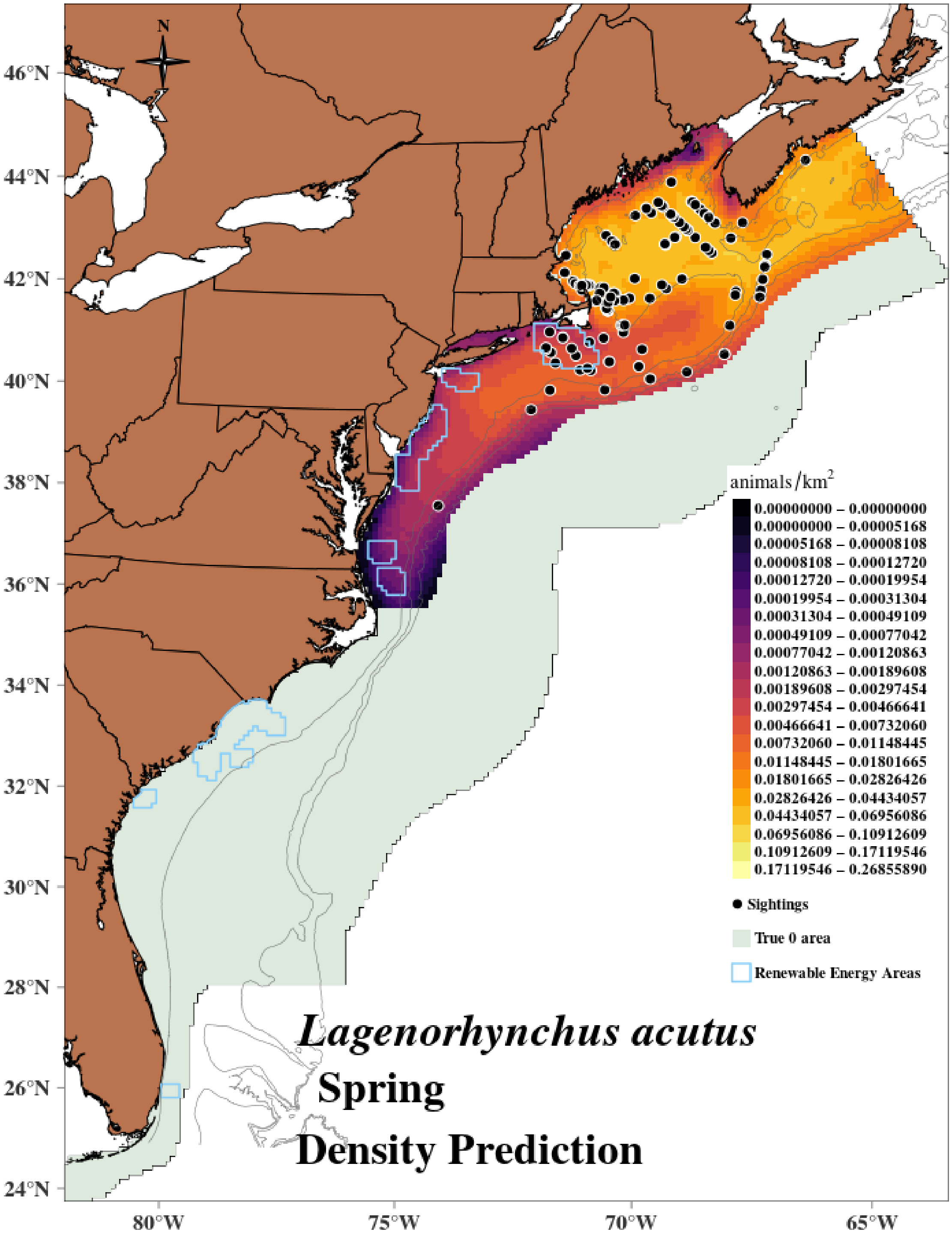

Figure 14-6 Atlantic white-sided dolphin spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

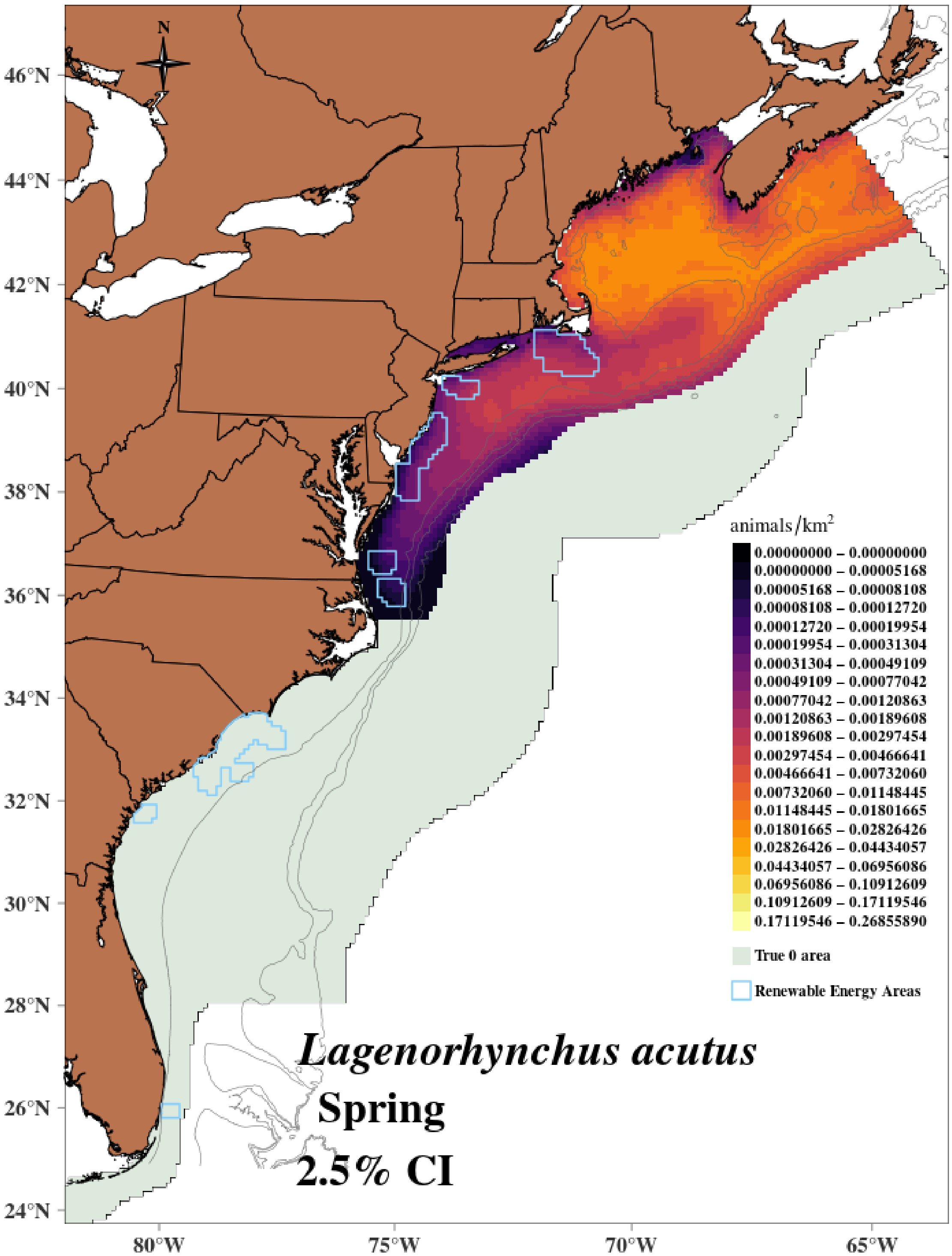

Figure 14-7 Lower 2.5% confidence interval of the spring white-sided dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

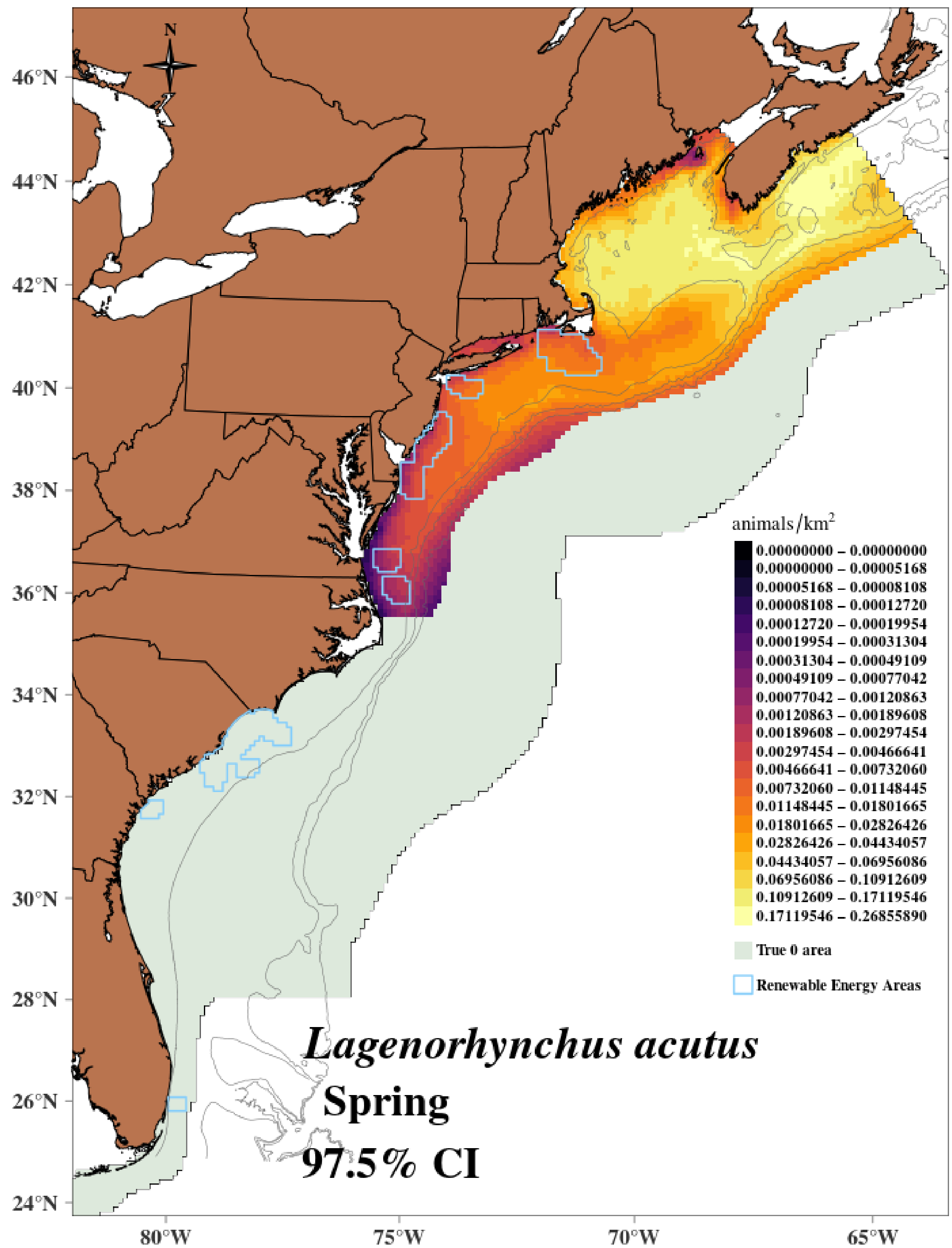

Figure 14-8 Upper 97.5% confidence interval of the spring white-sided dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

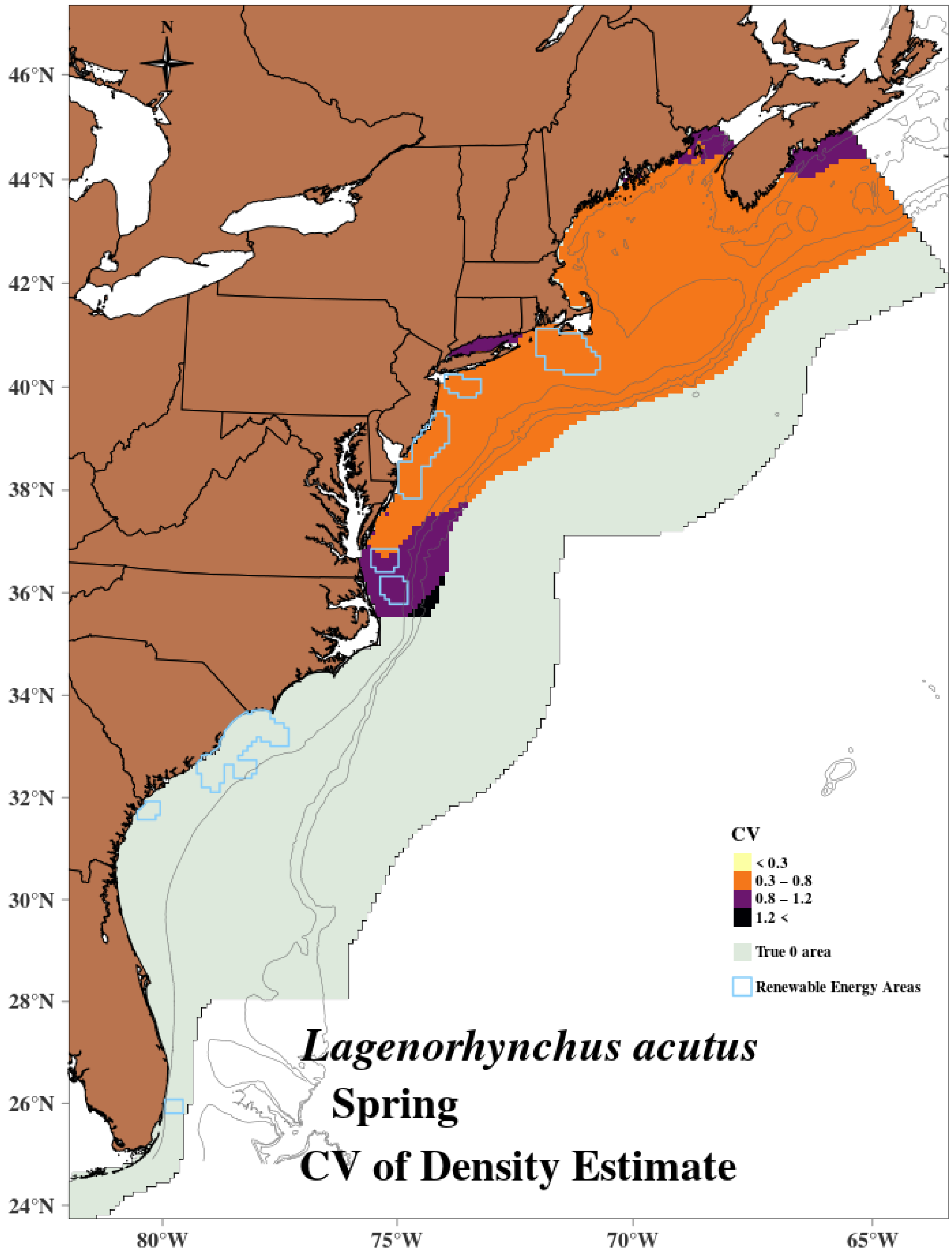

Figure 14-9 CV of spring Atlantic white-sided dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

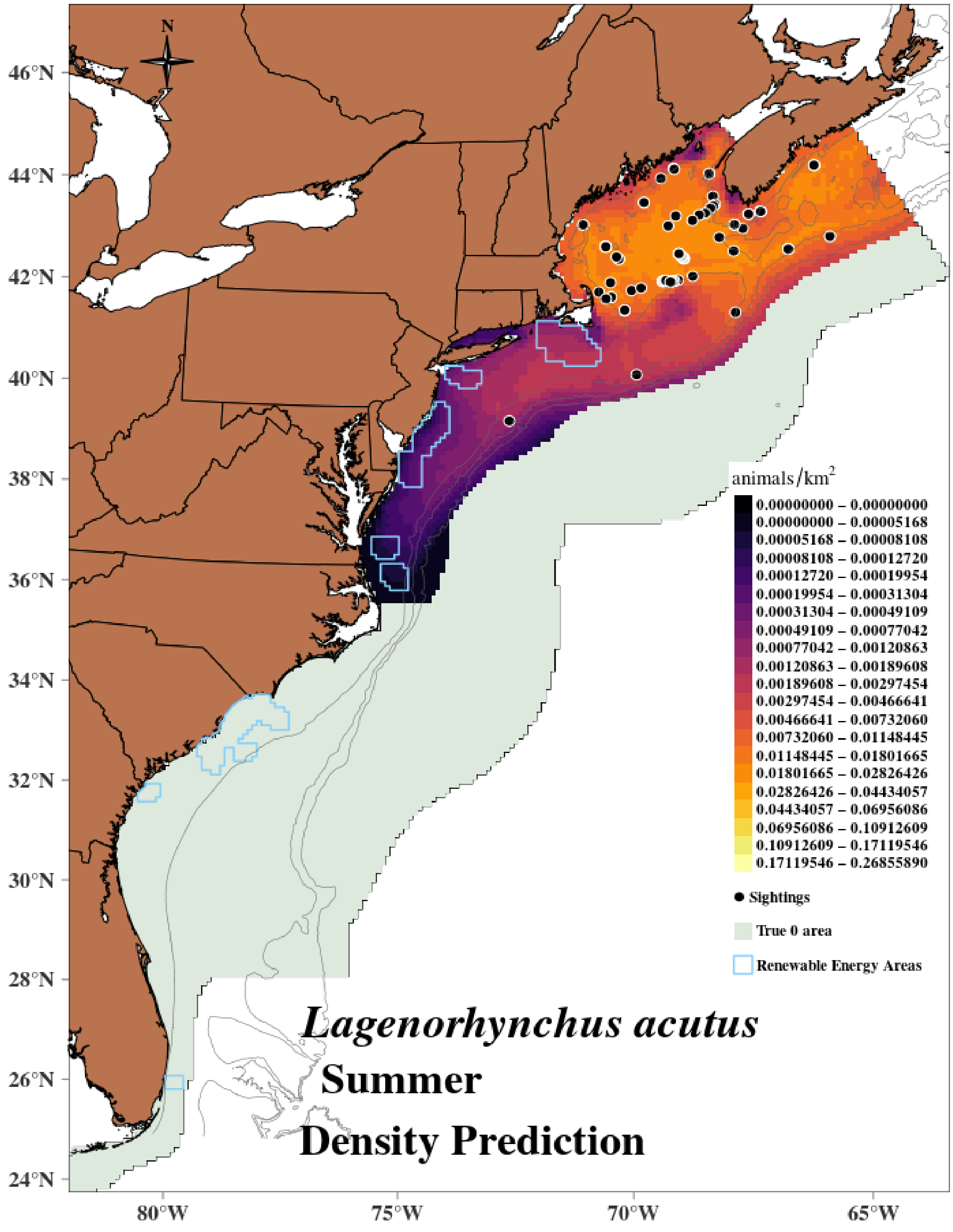

Figure 14-10 Atlantic white-sided dolphin summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

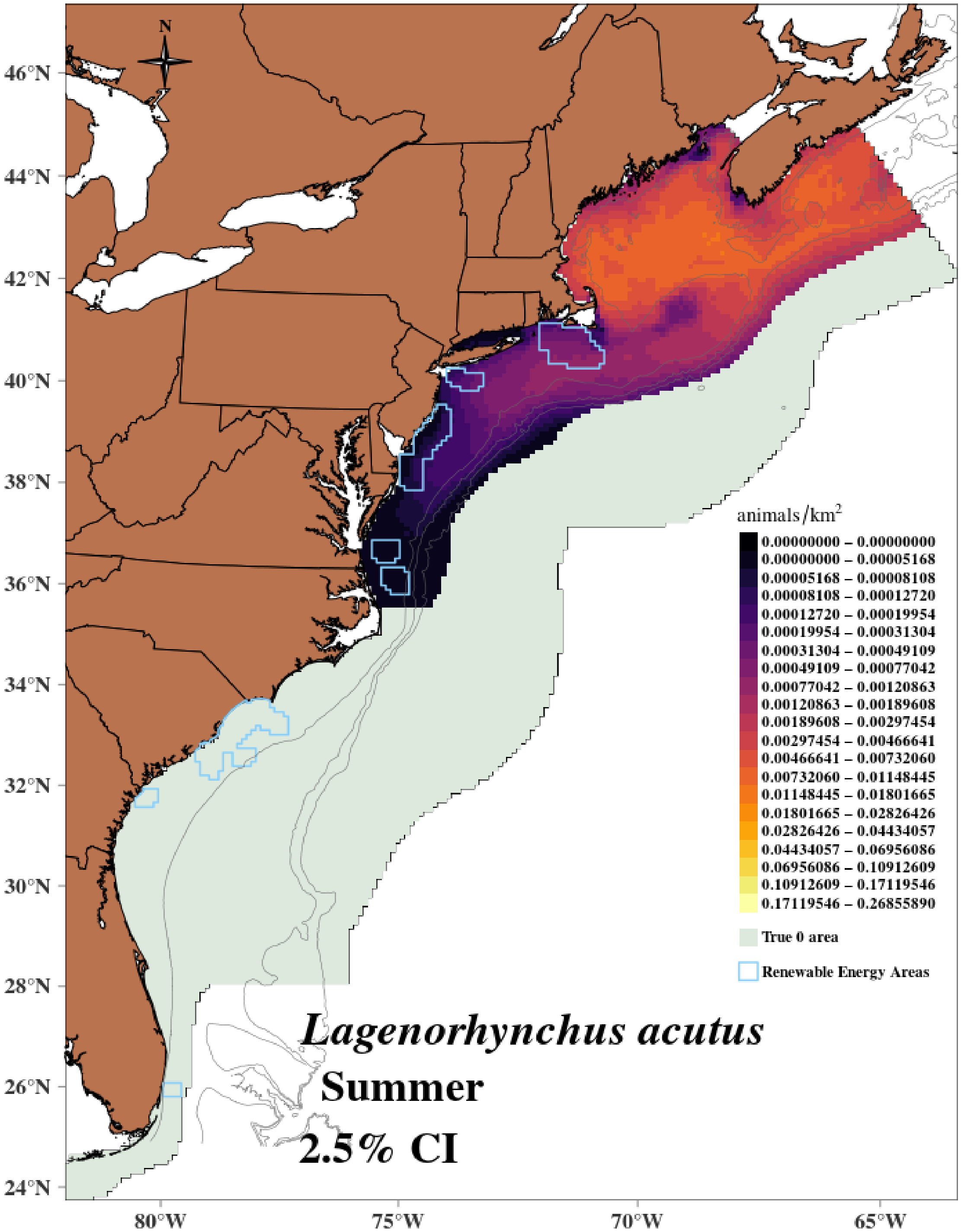

Figure 14-11 Lower 2.5% confidence interval of the summer white-sided dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

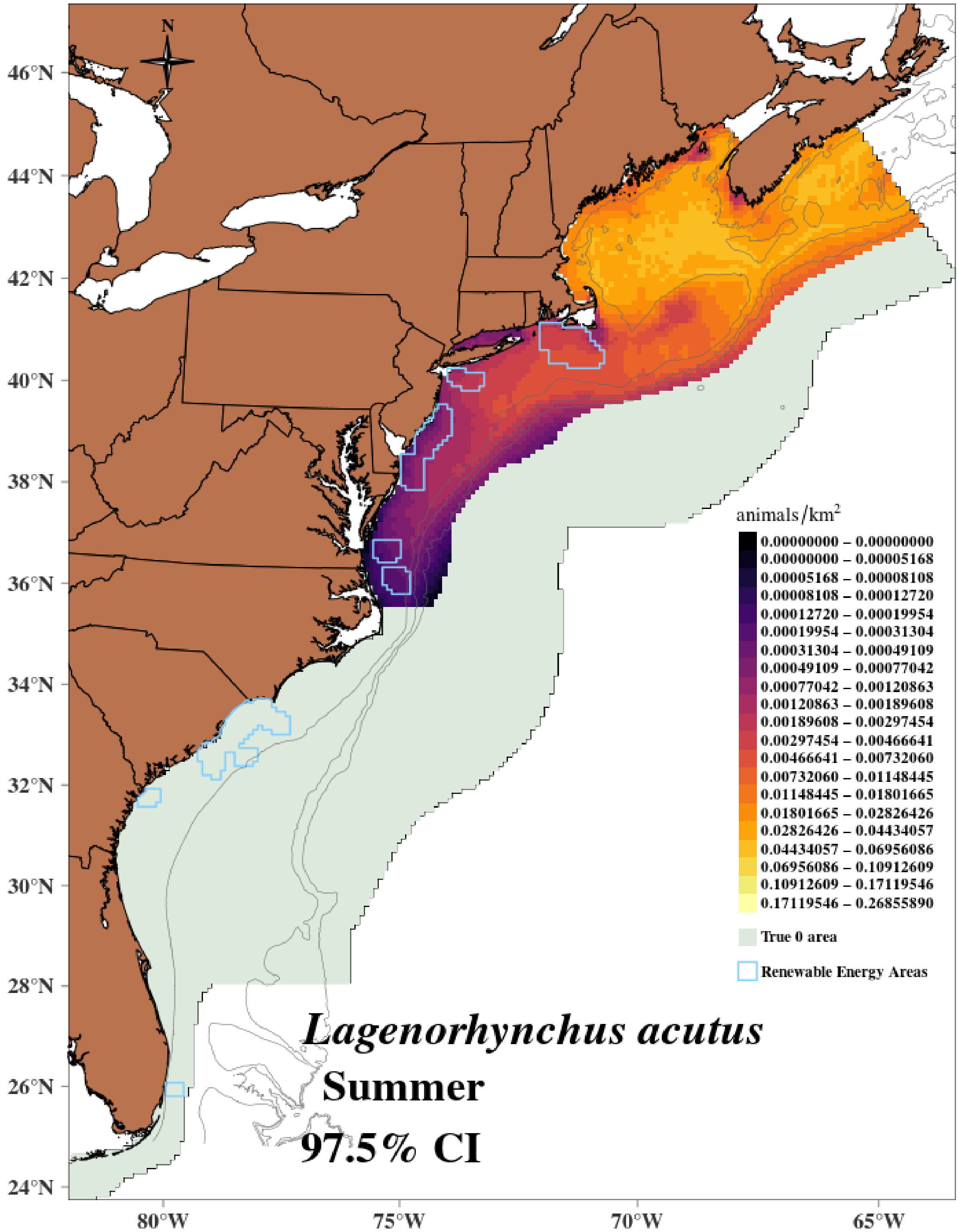

Figure 14-12 Upper 97.5% confidence interval of the summer white-sided dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

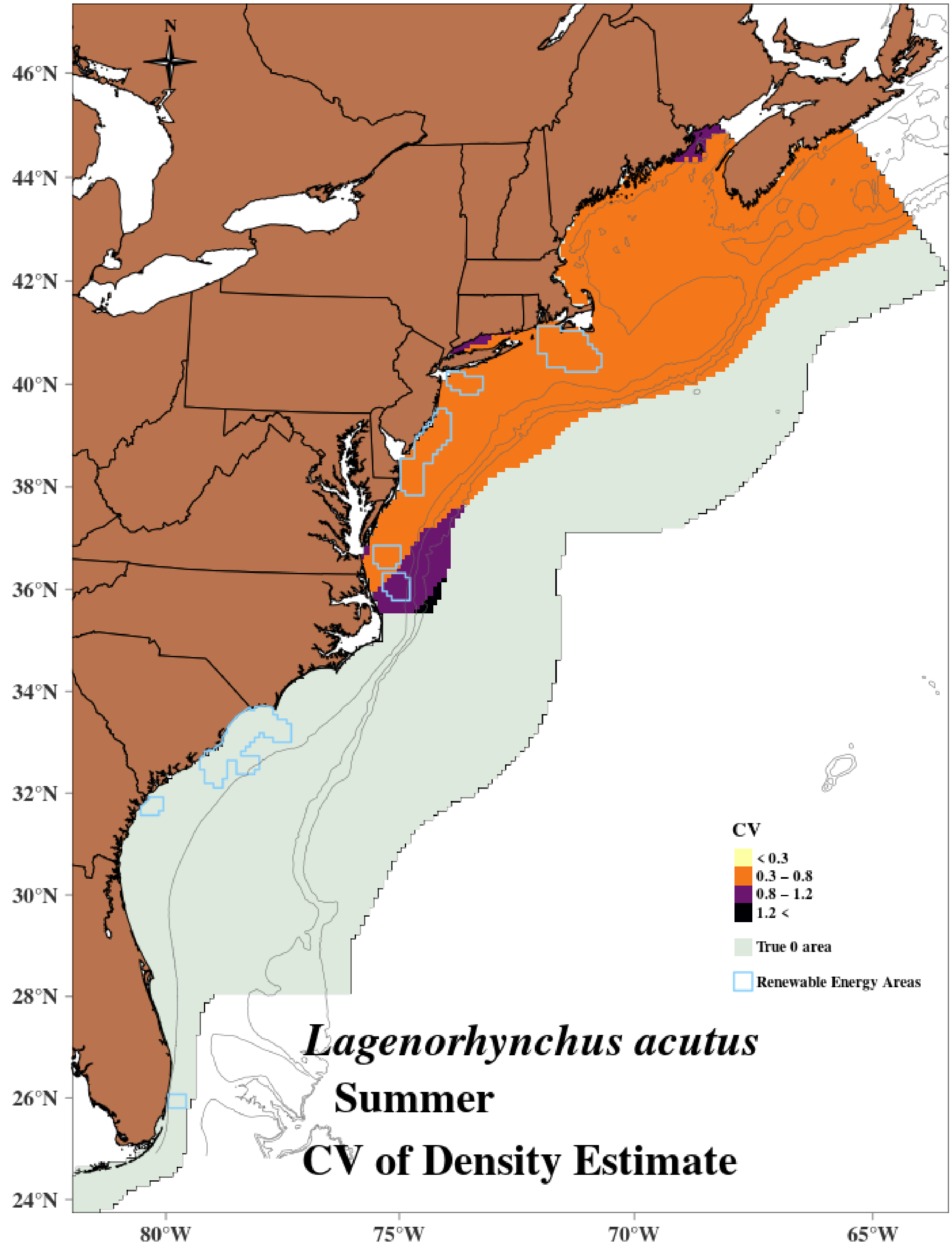

Figure 14-13 CV of summer Atlantic white-sided dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

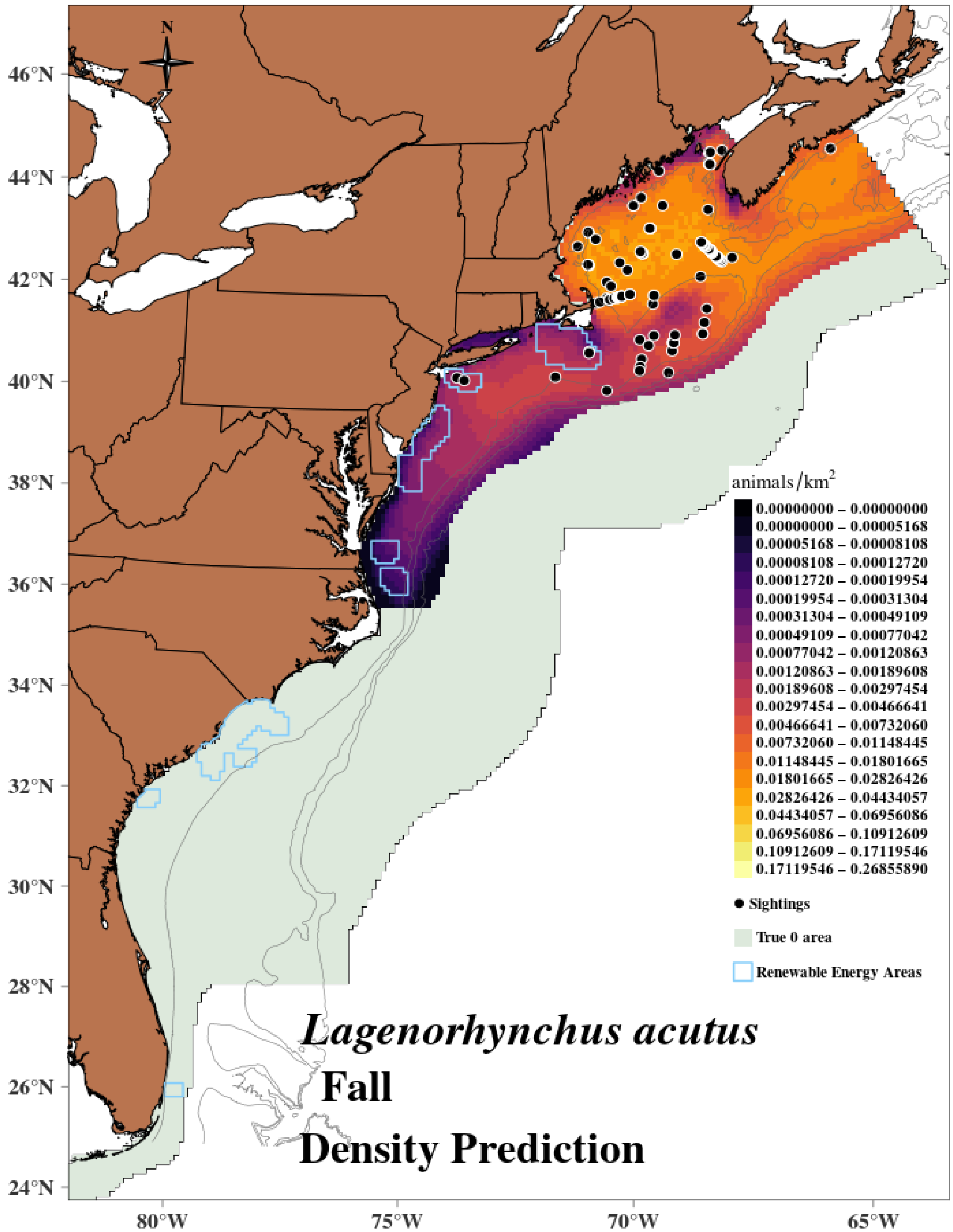

Figure 14-14 Atlantic white-sided dolphin fall average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

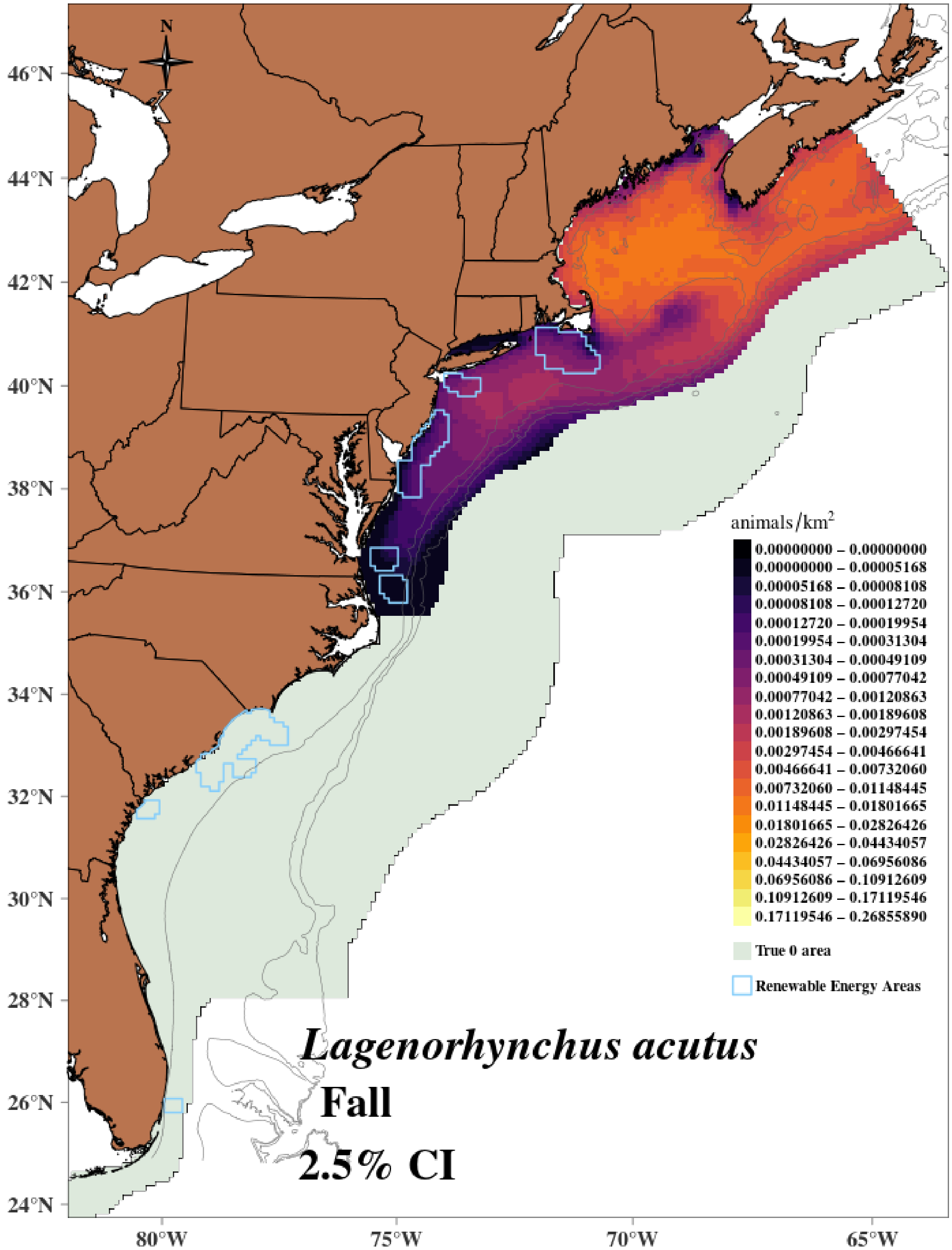

Figure 14-15 Lower 2.5% confidence interval of the fall white-sided dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

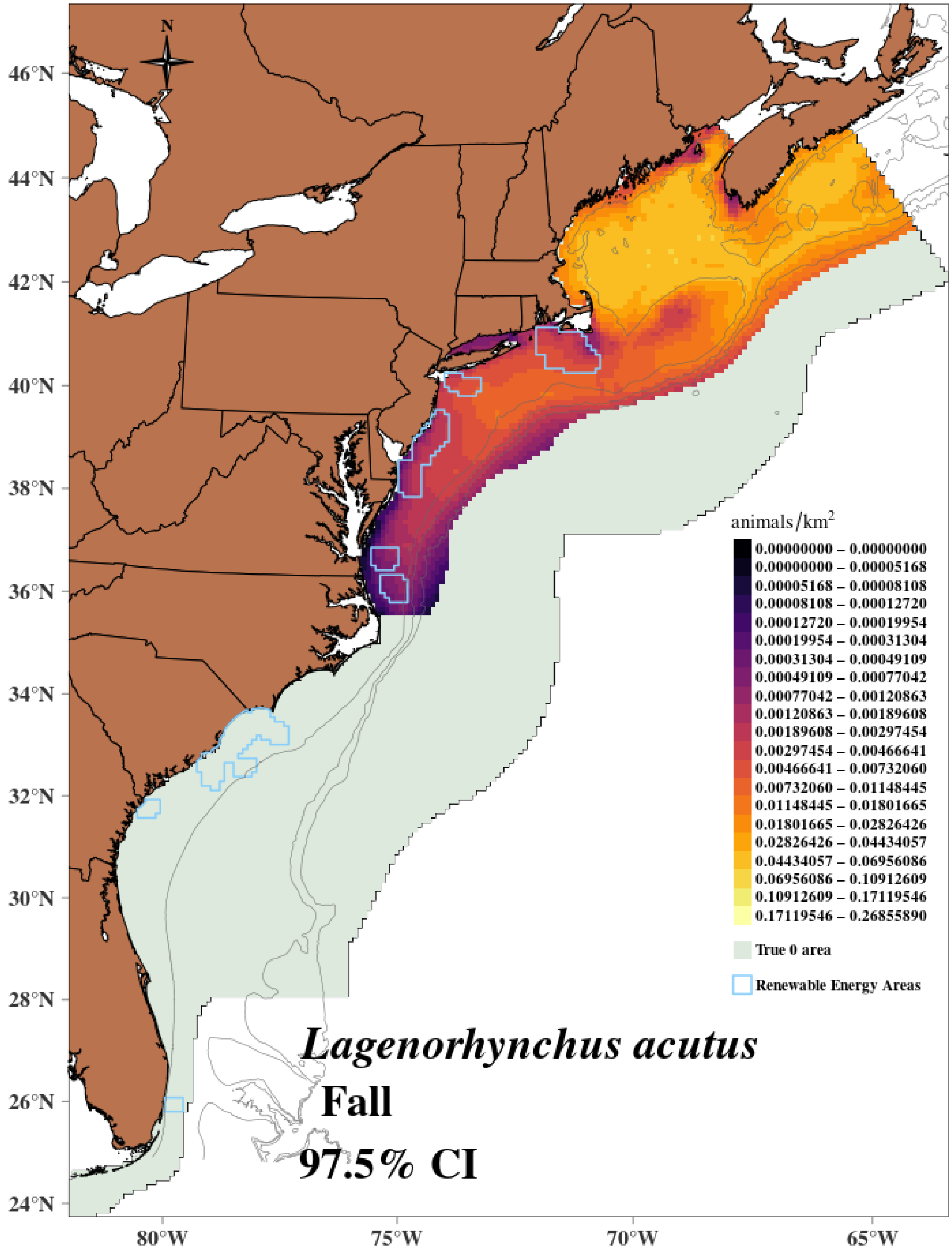

Figure 14-16 Upper 97.5% confidence interval of the fall white-sided dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

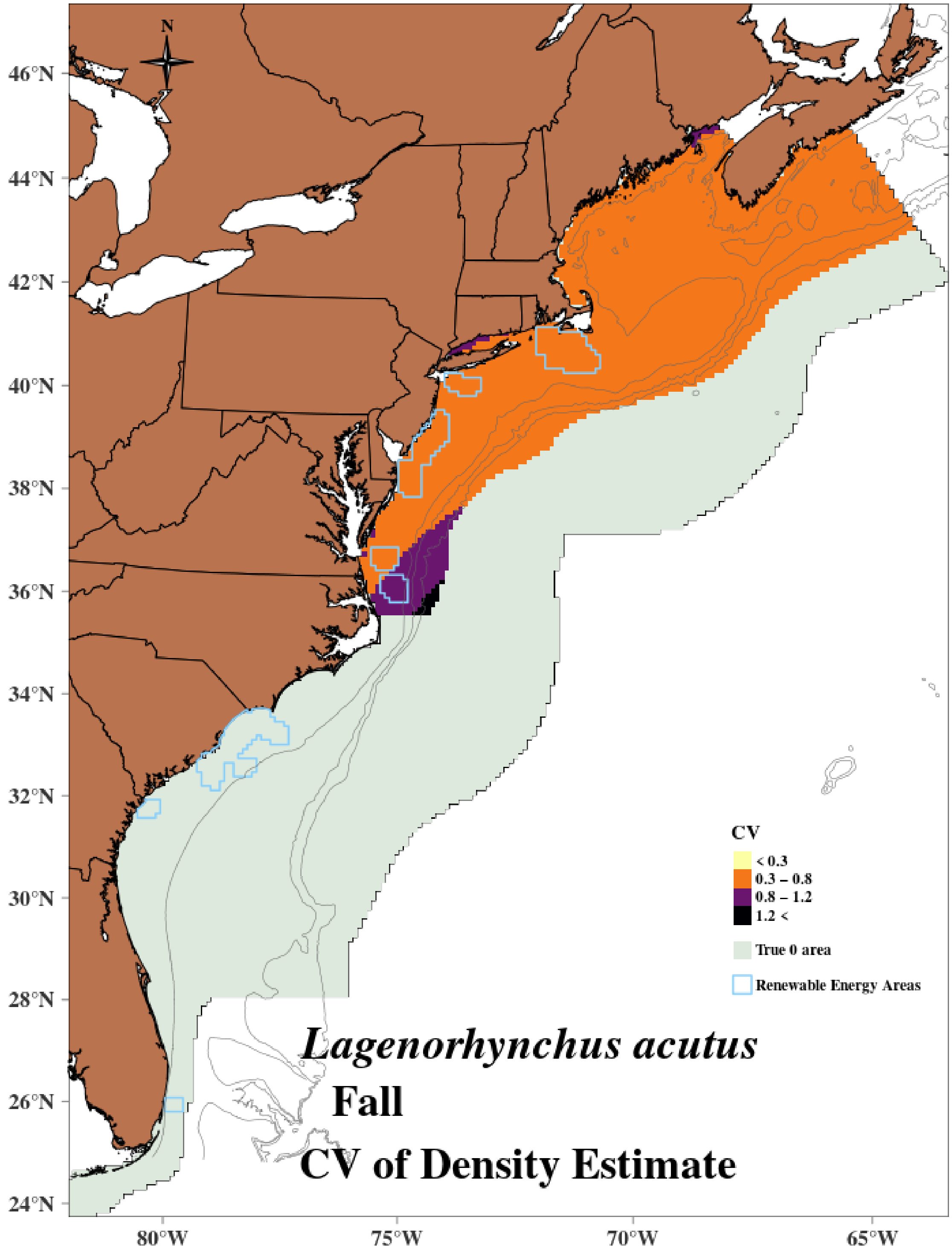

Figure 14-17 CV of fall Atlantic white-sided dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

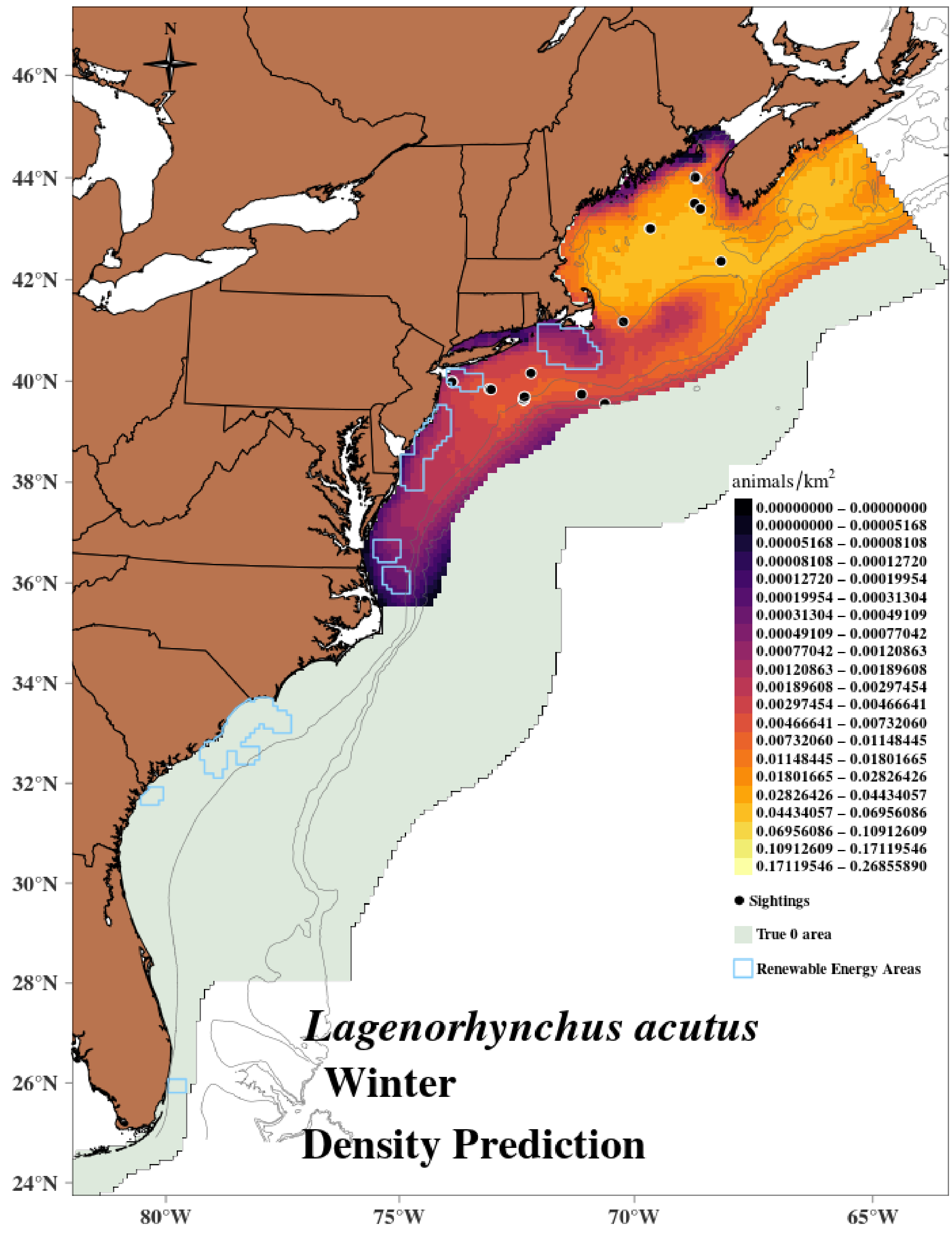

Figure 14-18 Atlantic white-sided dolphin winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

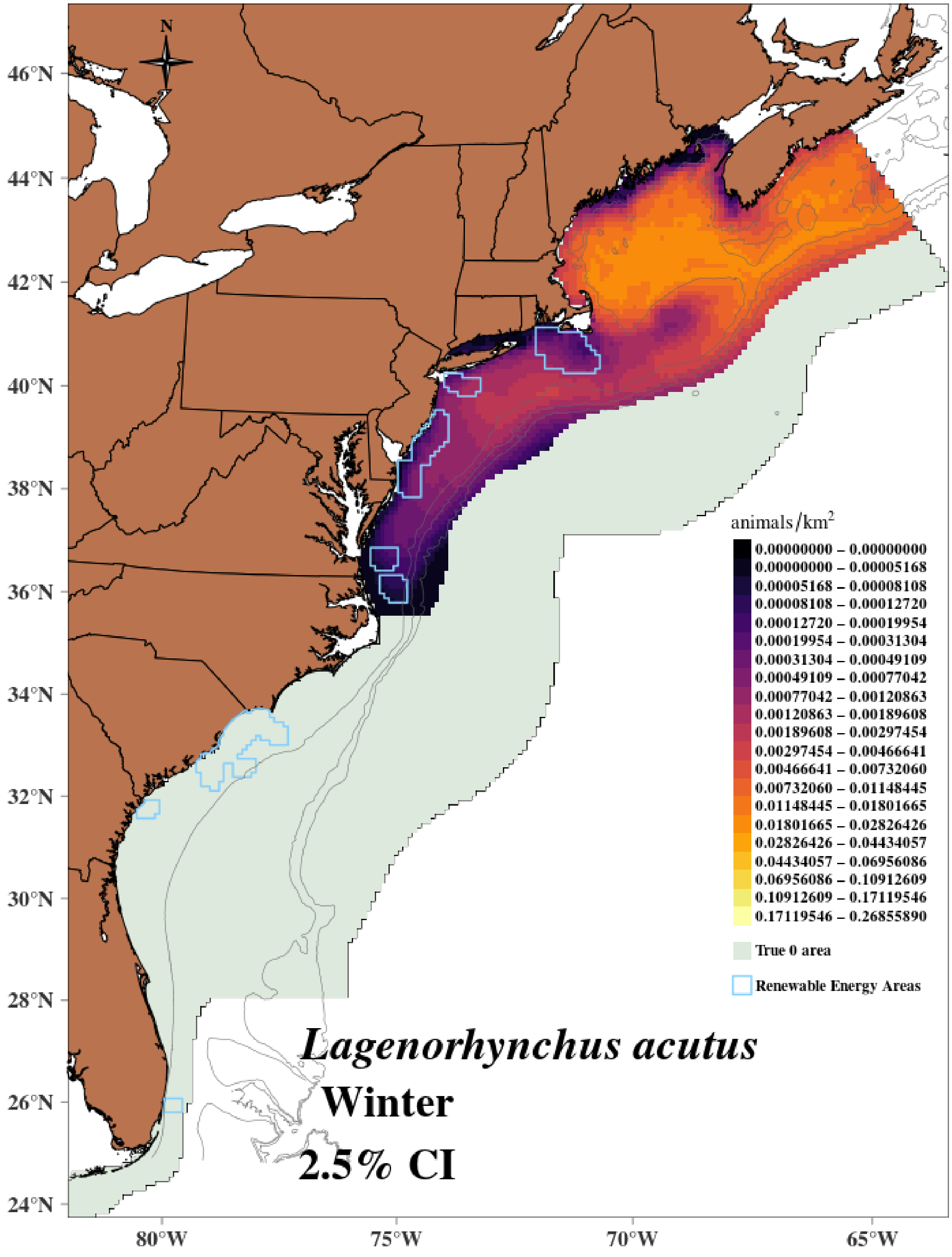

Figure 14-19 Lower 2.5% confidence interval of the winter white-sided dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

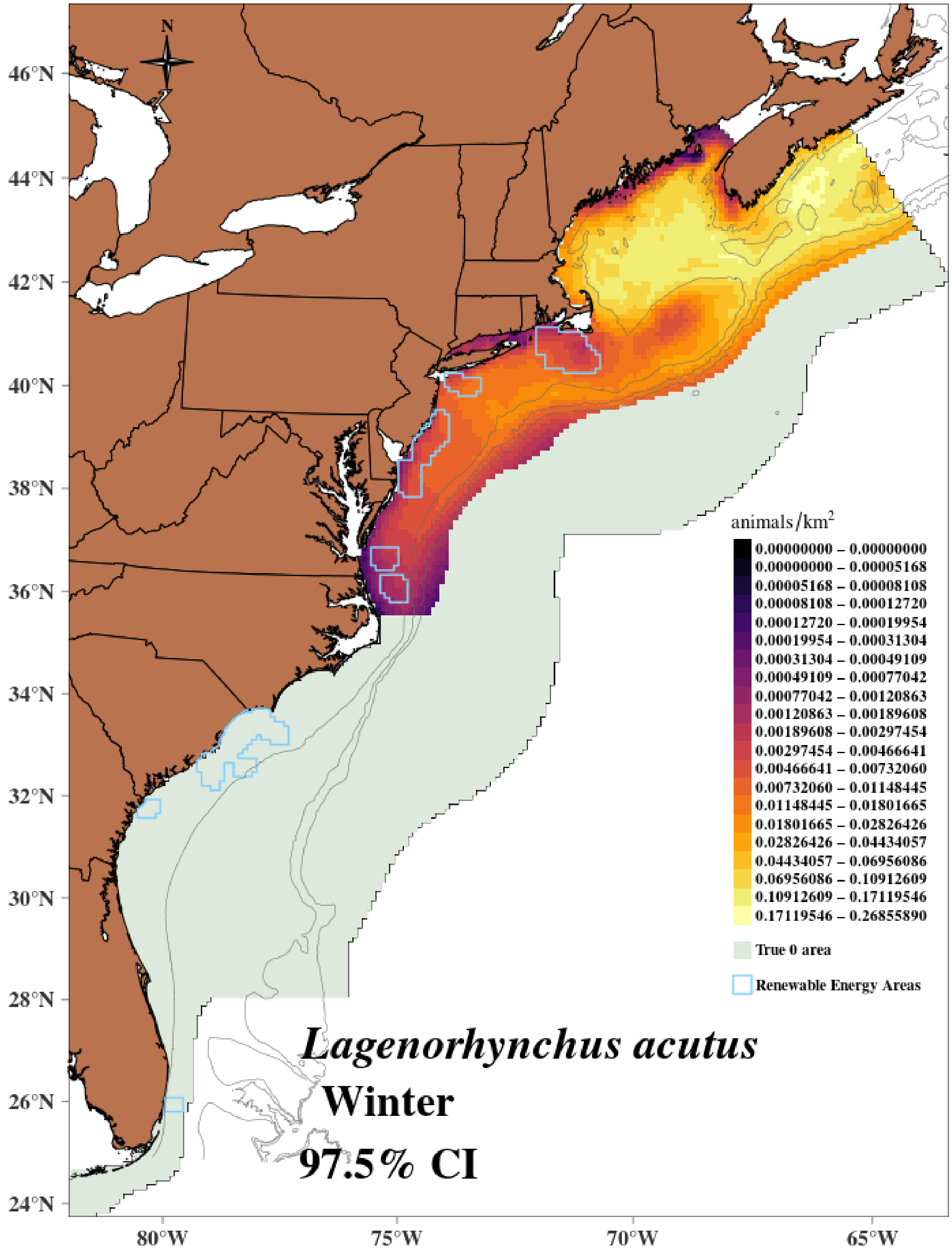

Figure 14-20 Upper 97.5% confidence interval of the winter white-sided dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

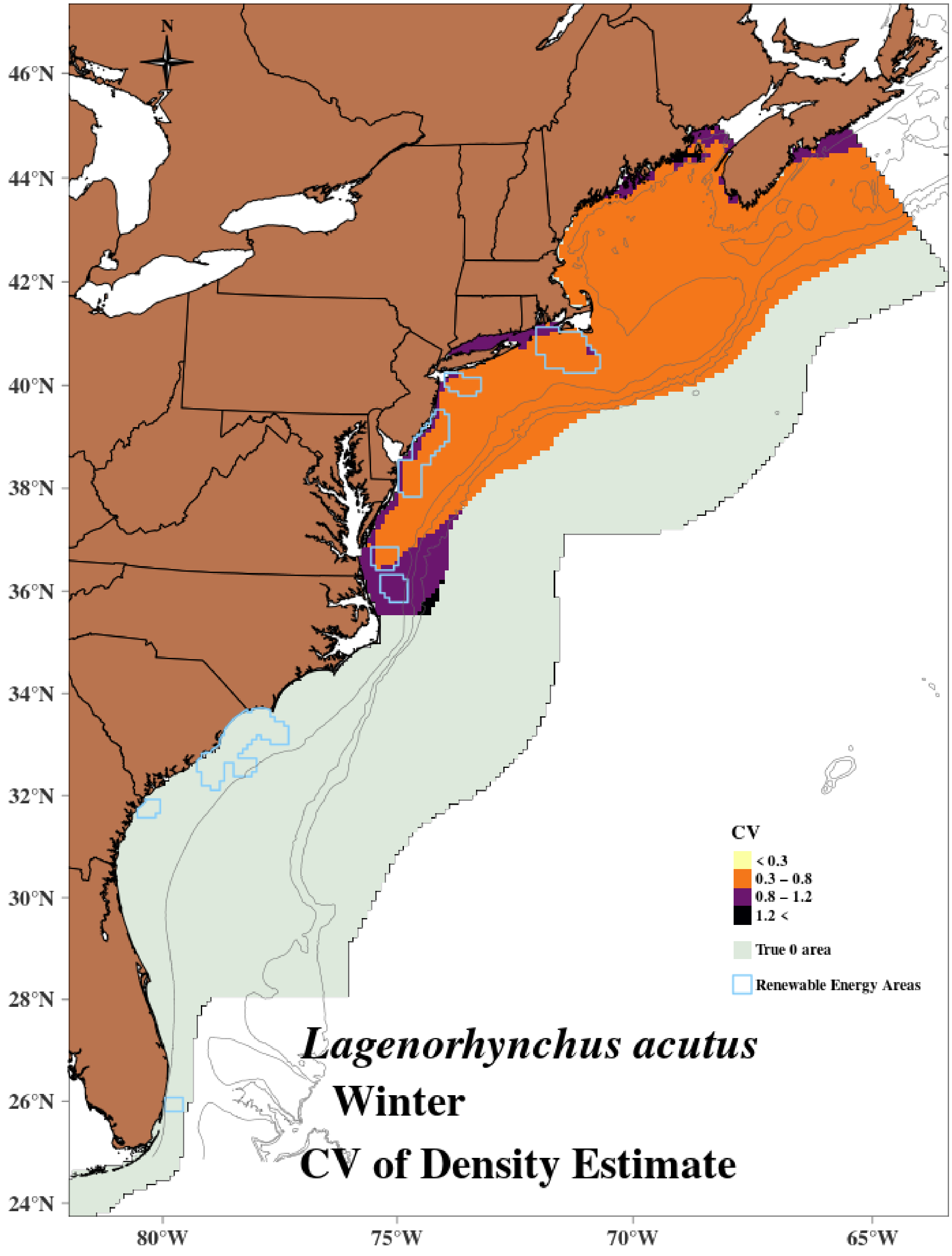

Figure 14-21 CV of winter Atlantic white-sided dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

14.7 Offshore Energy Development Areas

Table 14-6 Atlantic white-sided dolphin abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	53.5	0.61	
	NY	10.3	0.63	.0
	NJ	10.6	0.68	
	DE/MD	4.3	0.69	
	VA	1.2	0.81	
	NC	1.1	0.95	
Summer (Jun–Aug)	RI/MA	19.6	0.54	7.3 - 52.7
	NY	2.1	0.59	0.7 - 6.2
	NJ	1.6	0.66	0.5 – 5.0
	DE/MD	0.8	0.66	0.3 - 2.7
	VA	0.2	0.73	0.1 - 0.8
	NC	0.2	0.88	0.0 - 0.8
Fall (Sep–Nov)	RI/MA	17.9	0.56	6.5 - 49.7
	NY	5.5	0.56	2.0 - 15.4
	NJ	4.8	0.60	1.6 - 14.2
	DE/MD	1.9	0.61	0.6 - 5.7
	VA	0.5	0.74	0.1 – 2.0
	NC	0.5	0.90	0.1 - 2.1
Winter (Dec–Feb)	RI/MA	18.9	0.65	5.9 - 60.2
	NY	9.1	0.66	2.8 - 29.5
	NJ	11.0	0.73	3.1 - 39.5
	DE/MD	4.5	0.71	1.3 - 15.8
	VA	1.5	0.77	0.4 - 5.6
	NC	1.2	0.92	0.2 - 5.3

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

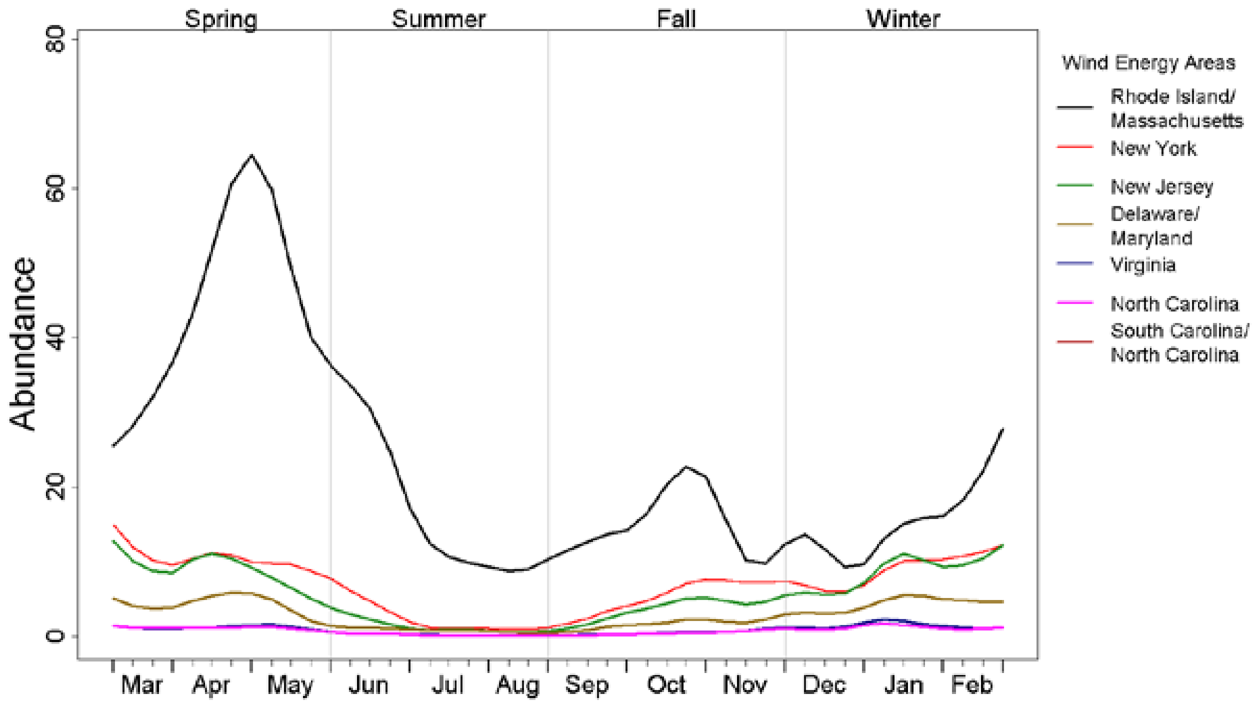

Figure 14-22 Average seasonal abundance of white-sided dolphins in the wind-energy study areas

15 Common dolphin (*Delphinus delphis*)

Figure 15-1 Common dolphin
Image collected under MMPA Research permit #775-1875. Credit: NOAA/NEFSC/Allison Henry.

15.1 Data Collection

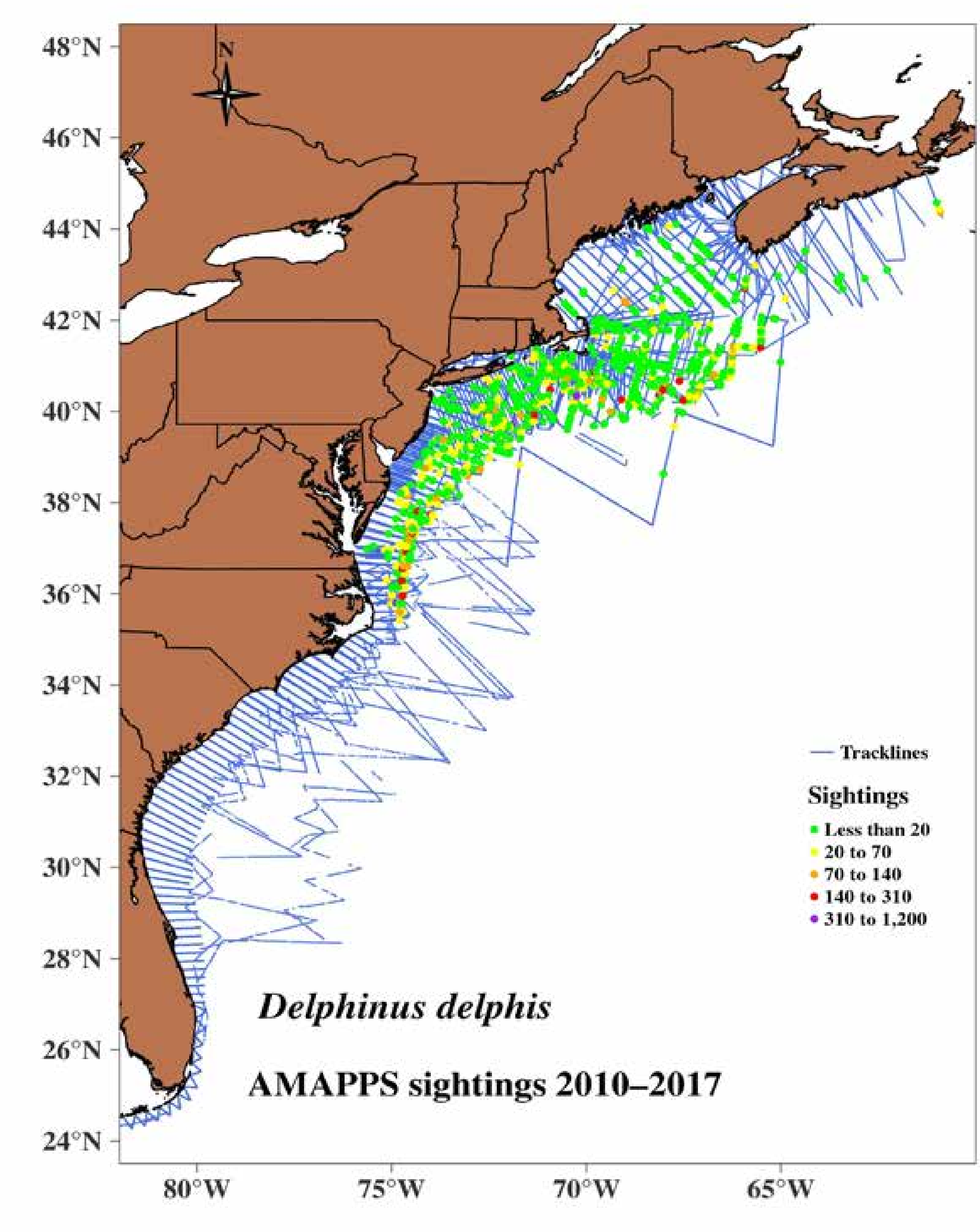

Figure 15-2 Distribution of track lines and common dolphin sightings 2010 to 2017

Table 15-1 AMAPPS research effort 2010 to 2017 and common dolphin sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	444	19,802
NE Shipboard	Fall	1,065	5	280
NE Aerial	Spring	13,314	8	215
NE Aerial	Summer	25,867	223	5,570
NE Aerial	Fall	37,850	223	5,823
NE Aerial	Winter	12,179	136	3,558
SE Shipboard	Spring	8,853	63	1,648
SE Shipboard	Summer	12,968	6	575
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	125	6,520
SE Aerial	Summer	28,236	11	784
SE Aerial	Fall	18,974	5	254
SE Aerial	Winter	8,950	36	1,625

15.2 Mark-Recapture Distance Sampling Analysis

Table 15-2 Intermediate parameters in common dolphin mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 3	distance + sea state + group size	300	distance + glare	LT20-300	HR	0.78	0.08	0.40	0.99	1.00
NE–aerial group 9	distance* observer + group size + sea state	300	distance + glare + size	300	HN	0.56	0.10	0.38	0.61	0.84
NE–shipboard group 5	distance * observer + group size	3800	distance + swell	3800	HR	0.52	0.08	0.22	0.71	0.78
SE–shipboard group 1	distance + group size	2700	distance + sea state + glare	2700	HR	0.62	0.09	0.23	0.98	0.98

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

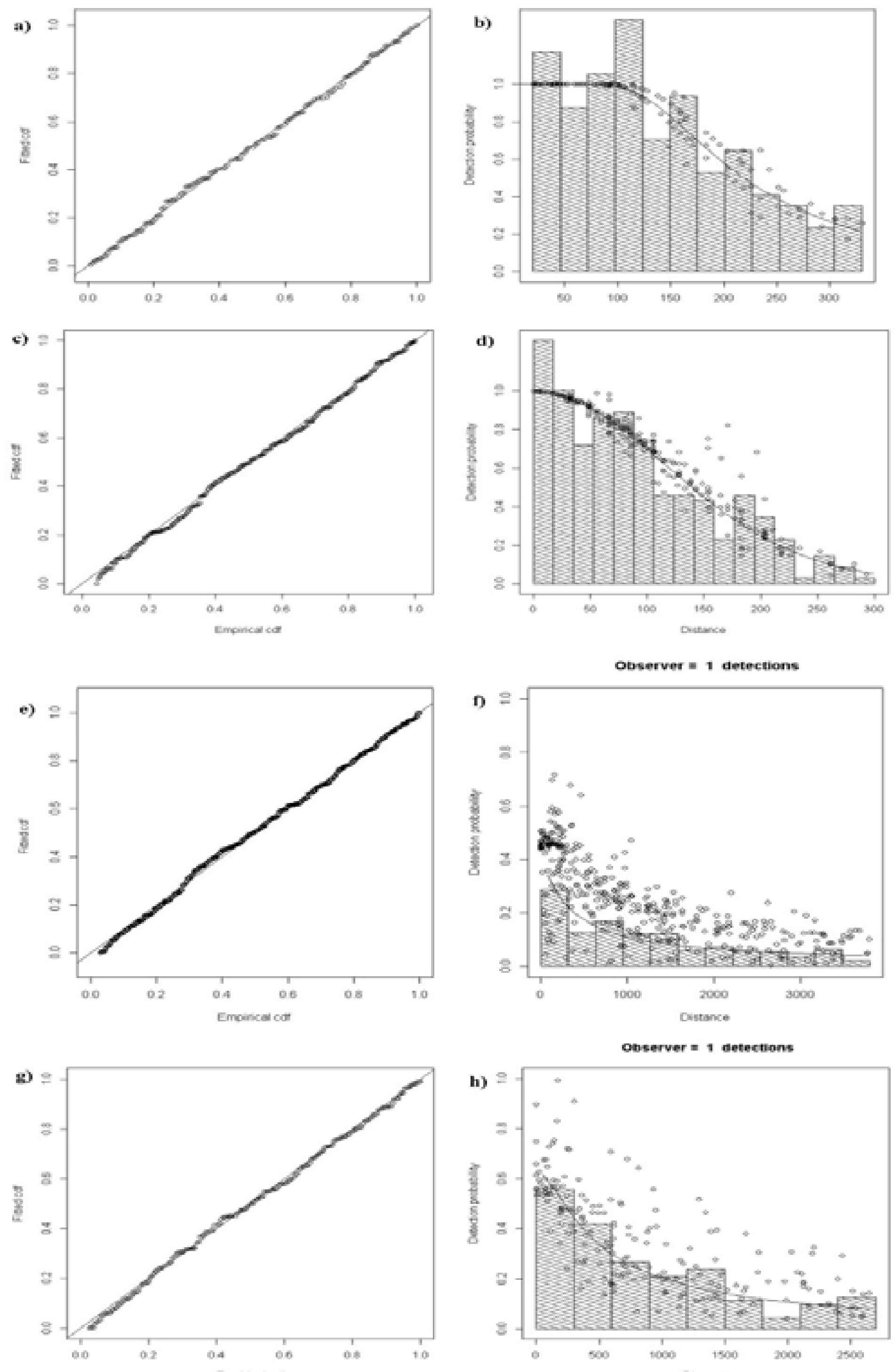

Figure 15-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 3; b) NE-aerial analysis set 9; c) NE-shipboard analysis set 5; d) SE-shipboard analysis set 1.

15.3 Generalized Additive Model Analysis

Table 15-3 2010 to 2017 density-habitat model output for common dolphins

Covariates	Edf	Ref.df	F	C. dev	p-value
s(sstmur)	4.12	5	13.23	11.80	<0.0001
s(btemp)	3.87	5	32.83	19.25	<0.0001
s(dist2GSNw)	3.82	5	7.19	4.42	<0.0001
s(dist2shore)	4.36	5	12.51	3.88	<0.0001
s(slope)	1.95	5	8.58	3.88	<0.0001
s(lat)	3.88	5	7.35	1.72	<0.0001
te(LY,lat)	5.70	23	0.88	5.83	<0.0001

Adjusted R^2 = 0.0462. Deviance explained = 50.3%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

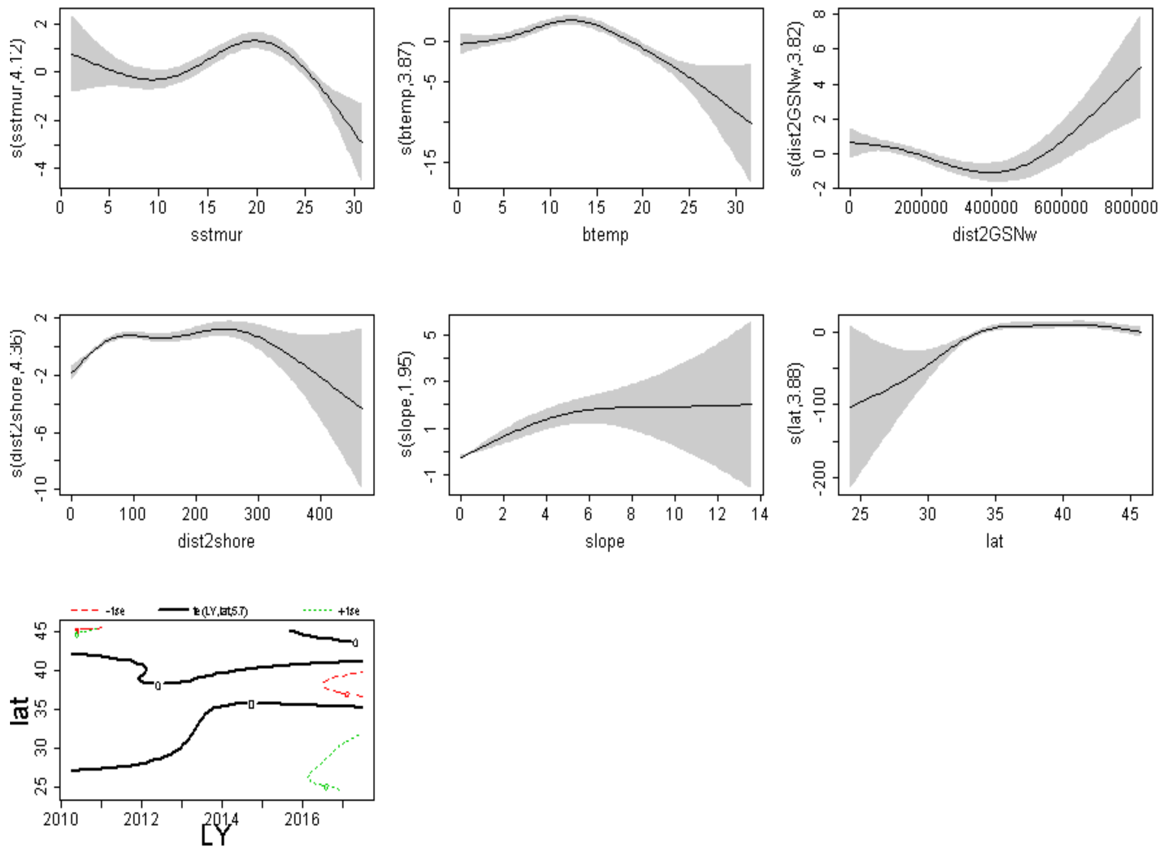

Figure 15-4 Common dolphin density related to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

15.4 Model Cross-Validation

Table 15-4 Diagnostic statistics from the common dolphin density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.358	Excellent
MAPE	Mean absolute percentage error	Non-zero density	99.140	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.169	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.146	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

15.5 Abundance Estimates for AMAPPS Study Area

Table 15-5 Common dolphin average abundance estimates for the AMAPPS study area
Values estimated by the density-habitat model with availability bias correction (aerial 0.649, CV=0.185; shipboard 1, CV=0.0), compared to the 2011 abundance reported in the 2019 stock assessment which does not include availability bias correction.

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	34,295	0.42	15,565–75,566
Summer (June–August)	77,109	0.34	40,325–147,449
Fall (September–November)	80,751	0.37	40,017–162,949
Winter (December–February)	38,748	0.39	18,533–81,011
Summer 2011 U.S. surveys[1]	70,184	0.28	
Summer 2016 U.S. surveys[1]	81,127	0.27	

[1]Hayes et al. 2020

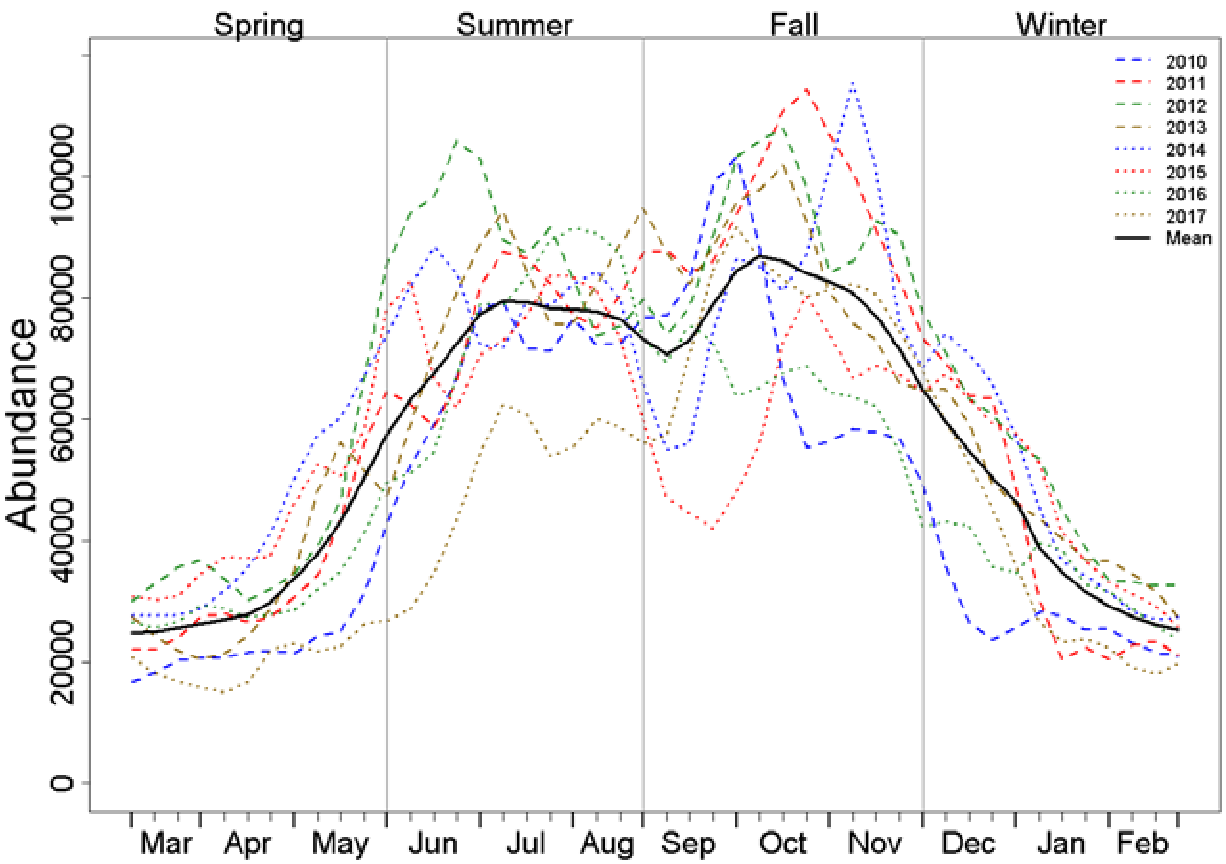

Figure 15-5 Annual abundance trends for common dolphins in the AMAPPS study area

15.6 Seasonal Prediction Maps

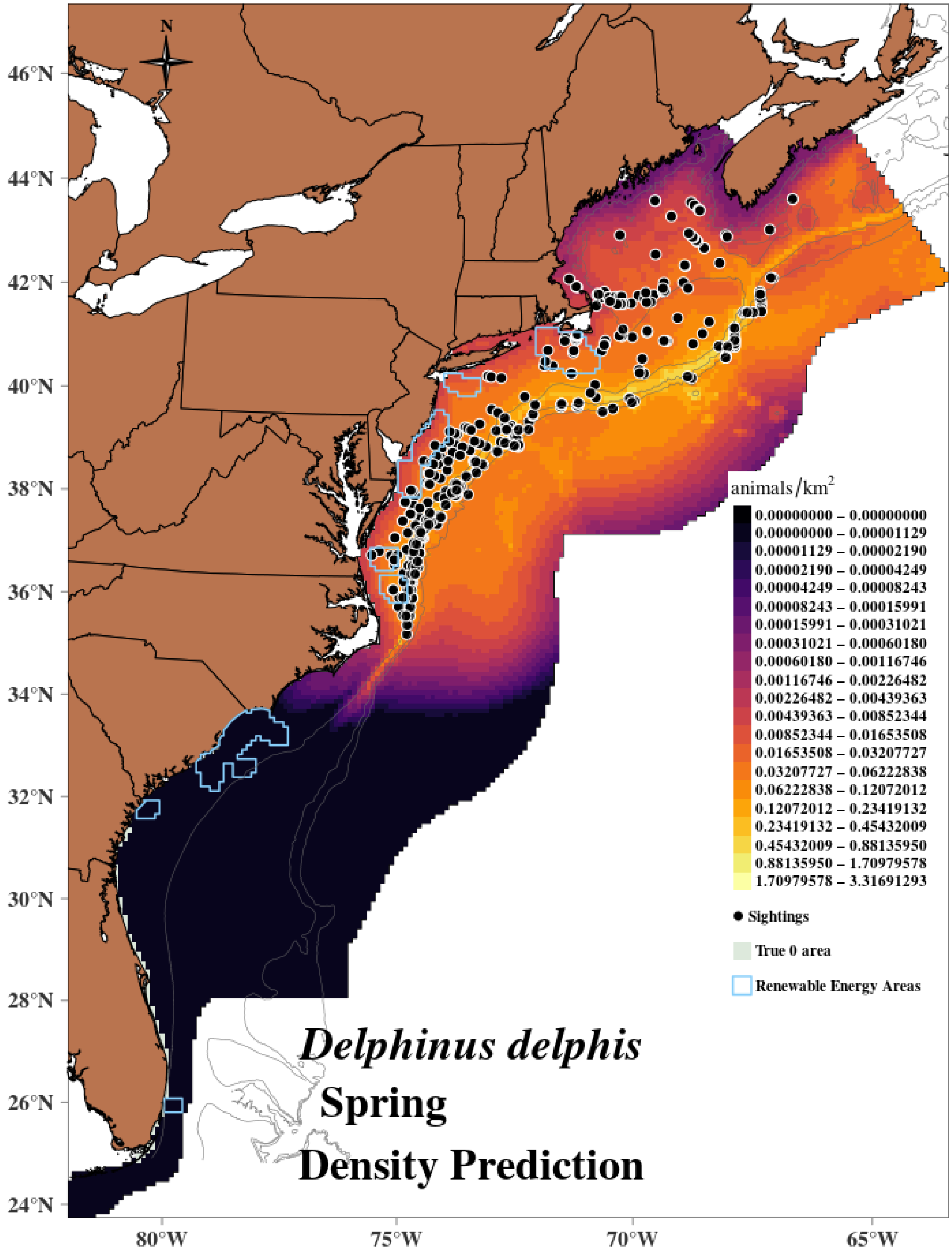

Figure 15-6 Common dolphin spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

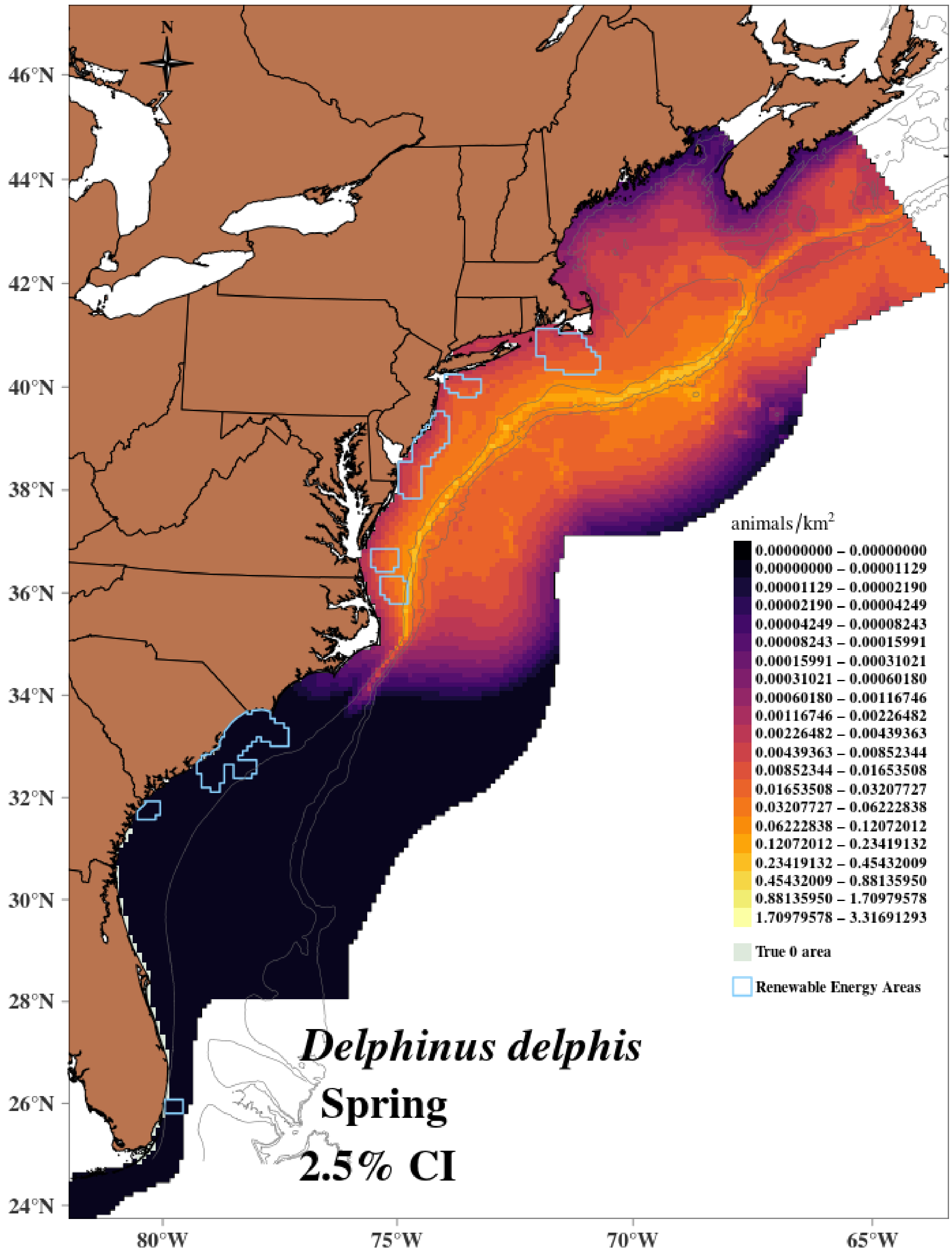

Figure 15-7 Lower 2.5% confidence interval of the spring common dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

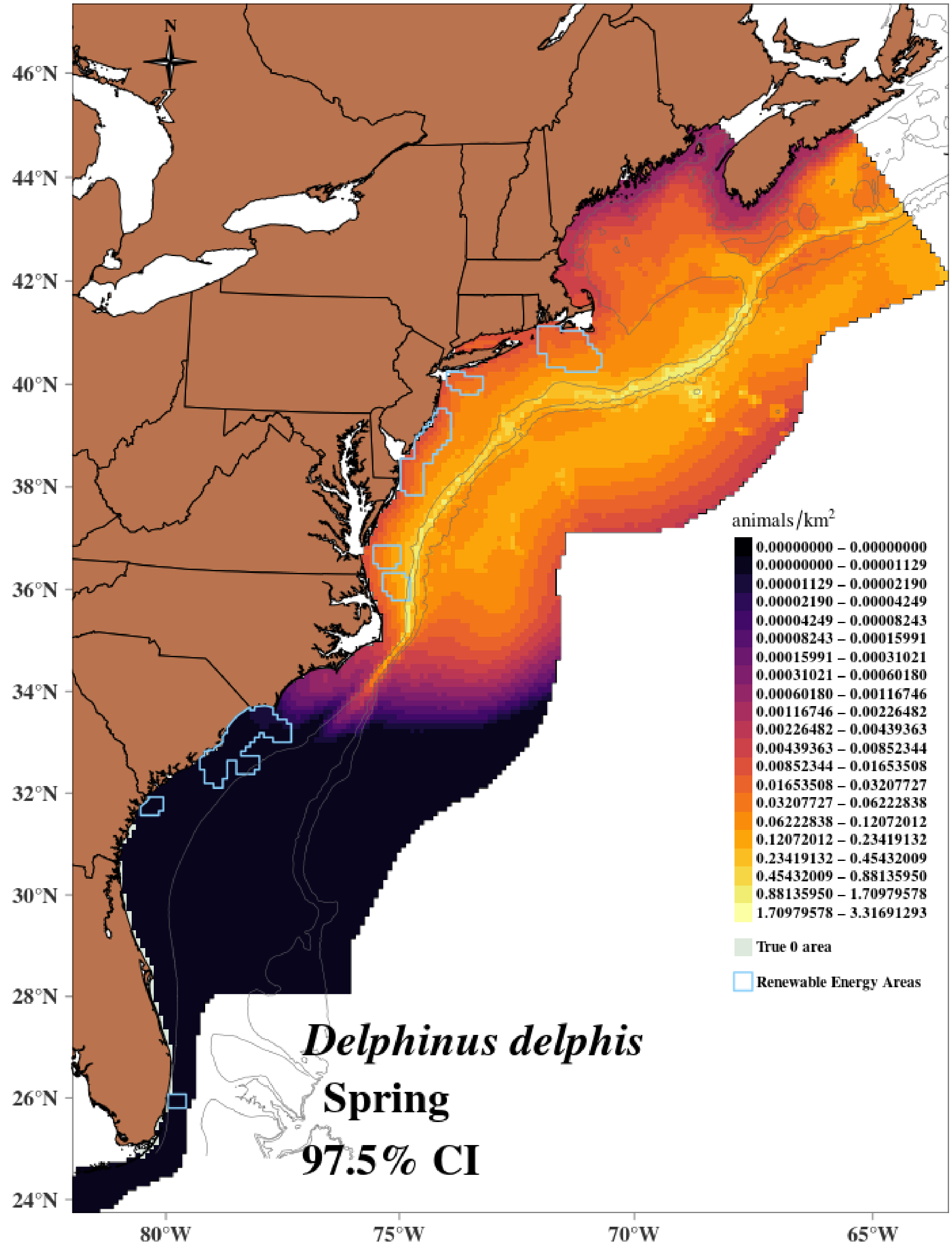

Figure 15-8 Upper 97.5% confidence interval of the spring common dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

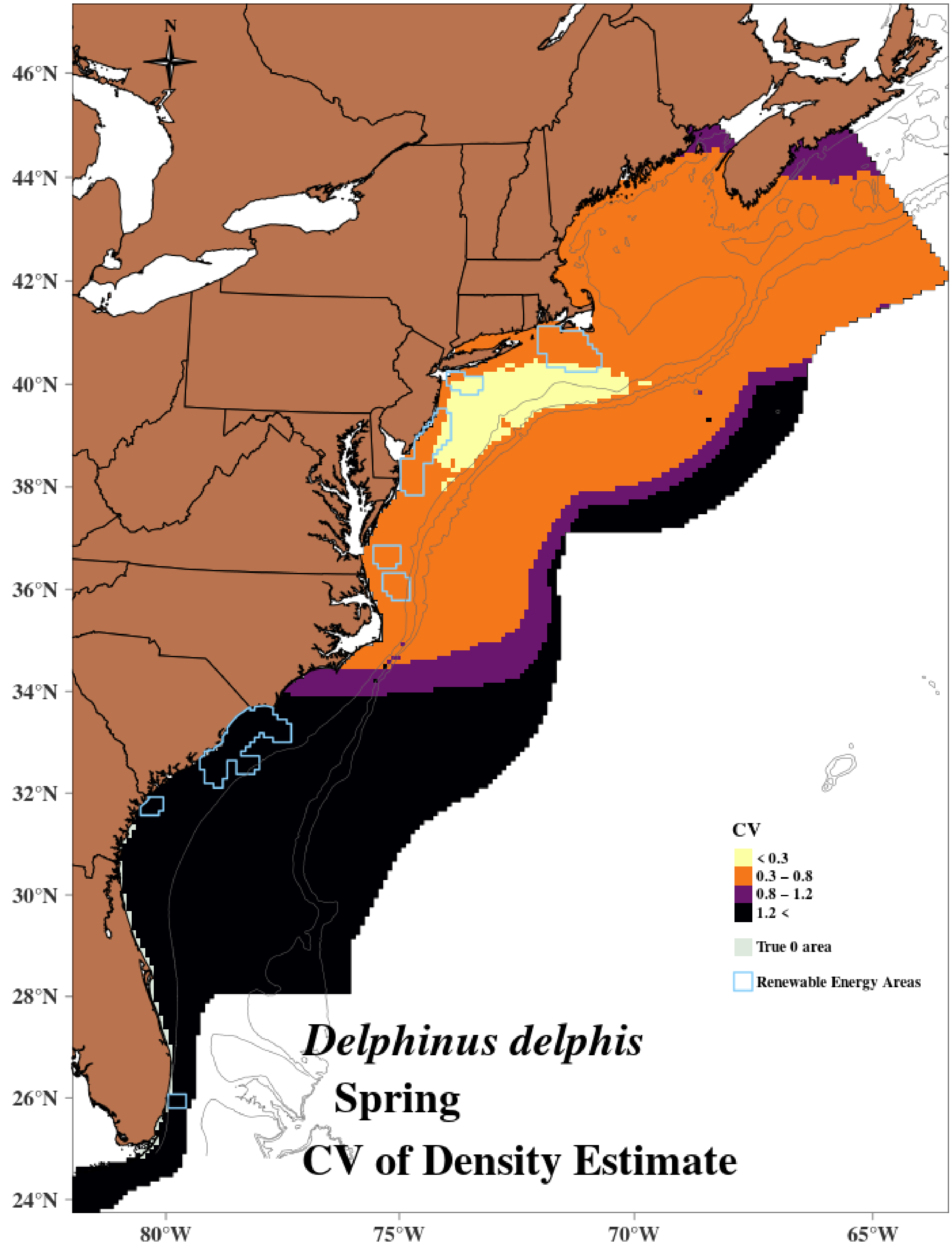

Figure 15-9 CV of spring common dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

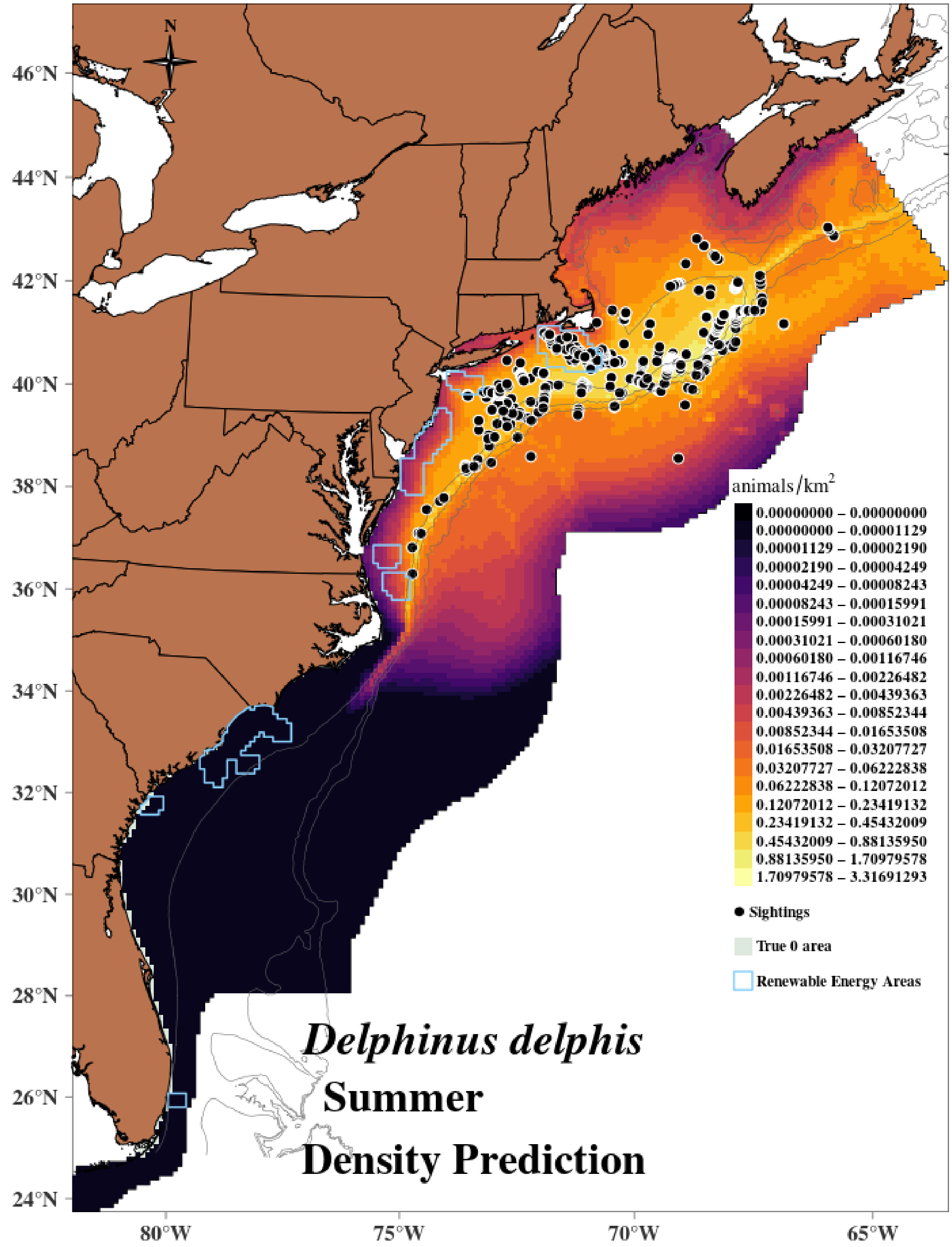

Figure 15-10 Common dolphin summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

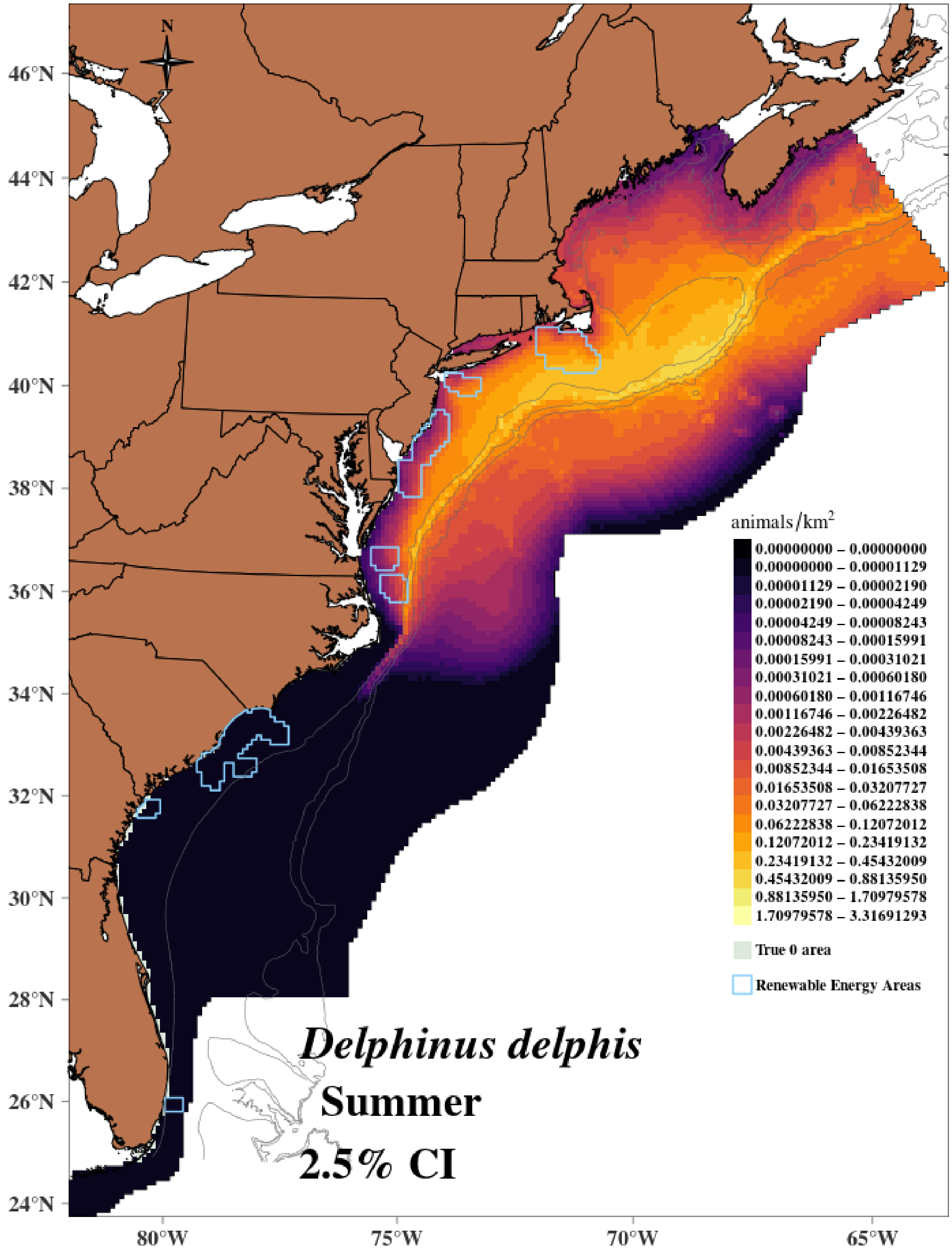

Figure 15-11 Lower 2.5% confidence interval of the summer common dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

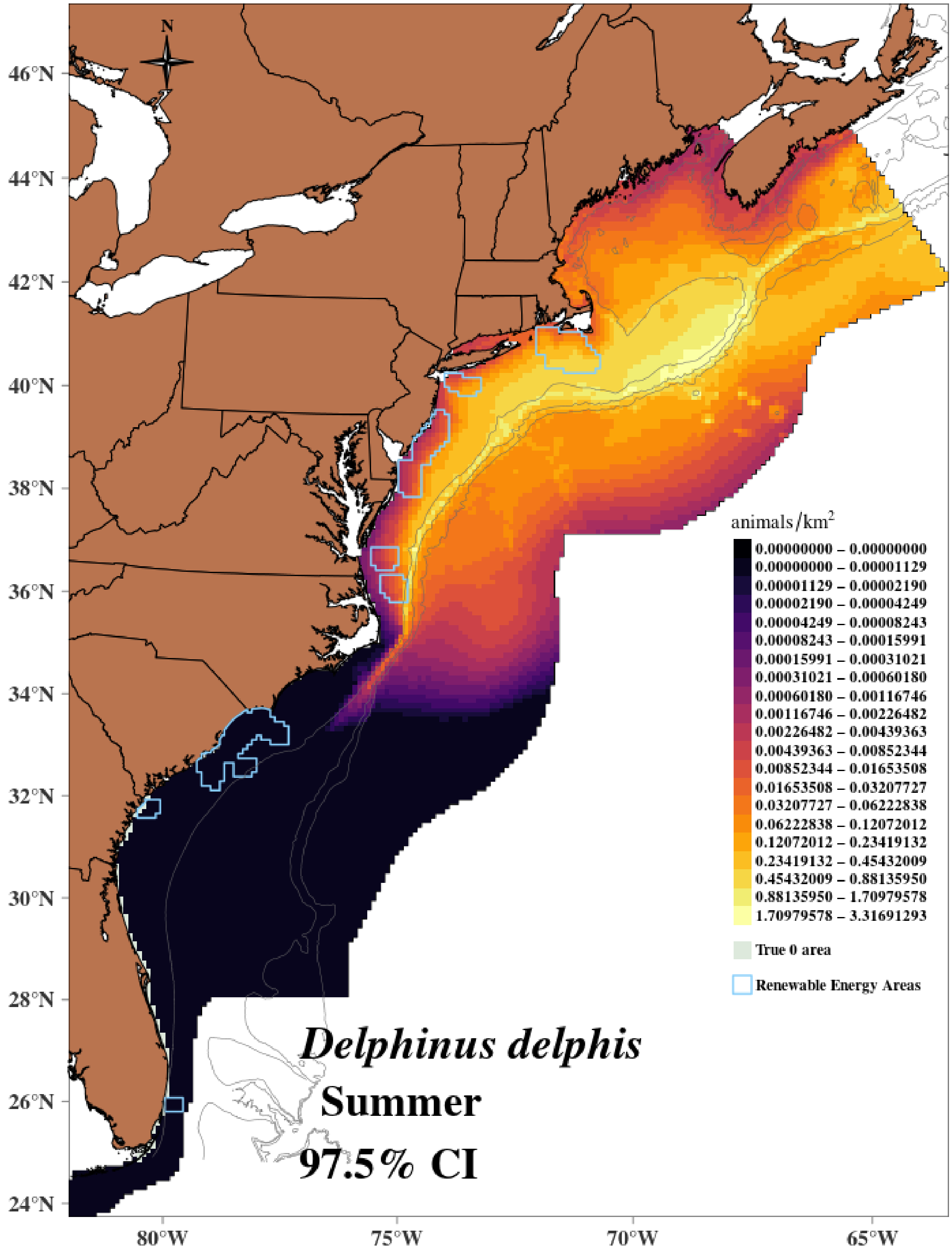

Figure 15-12 Upper 97.5% confidence interval of the summer common dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

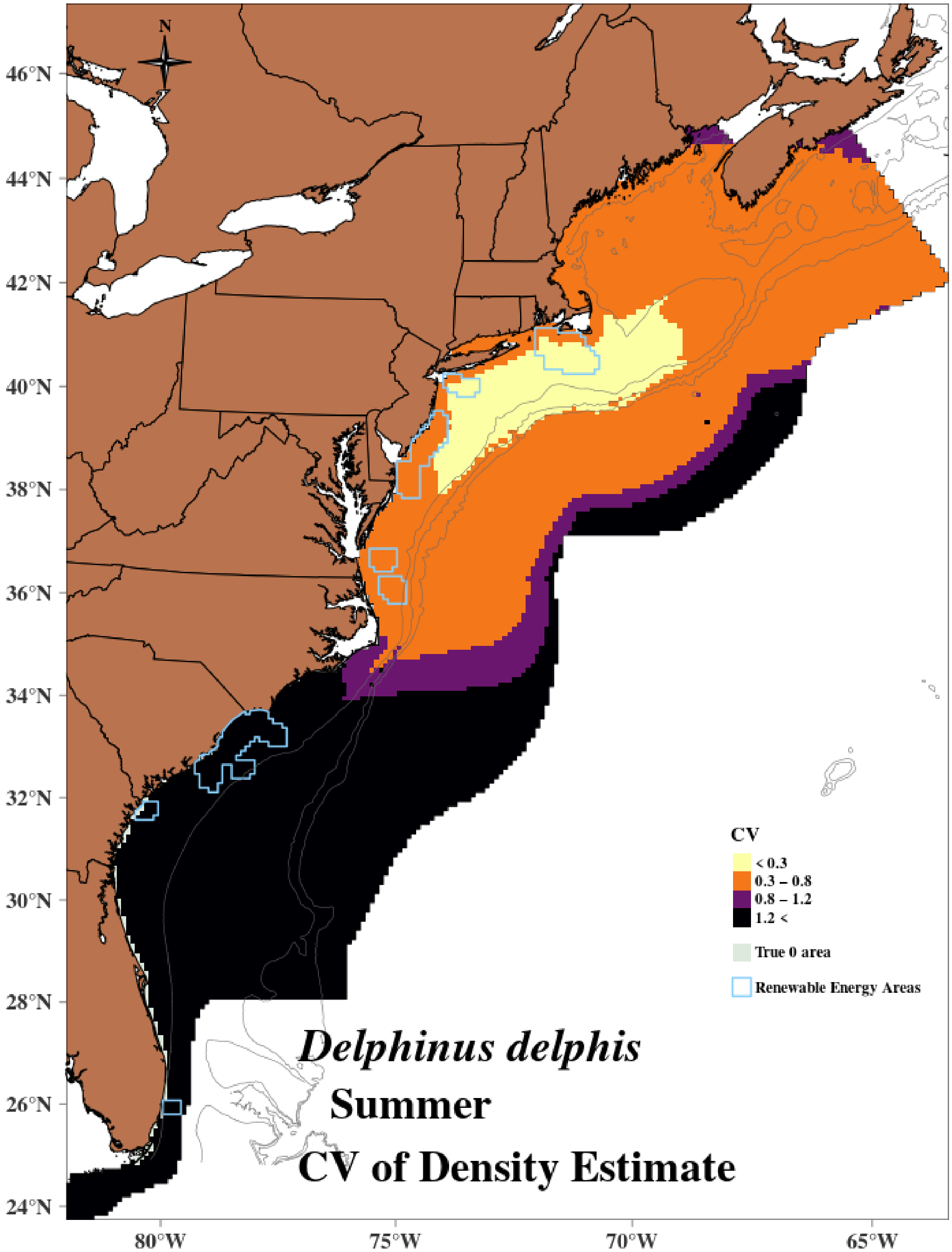

Figure 15-13 CV of summer common dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

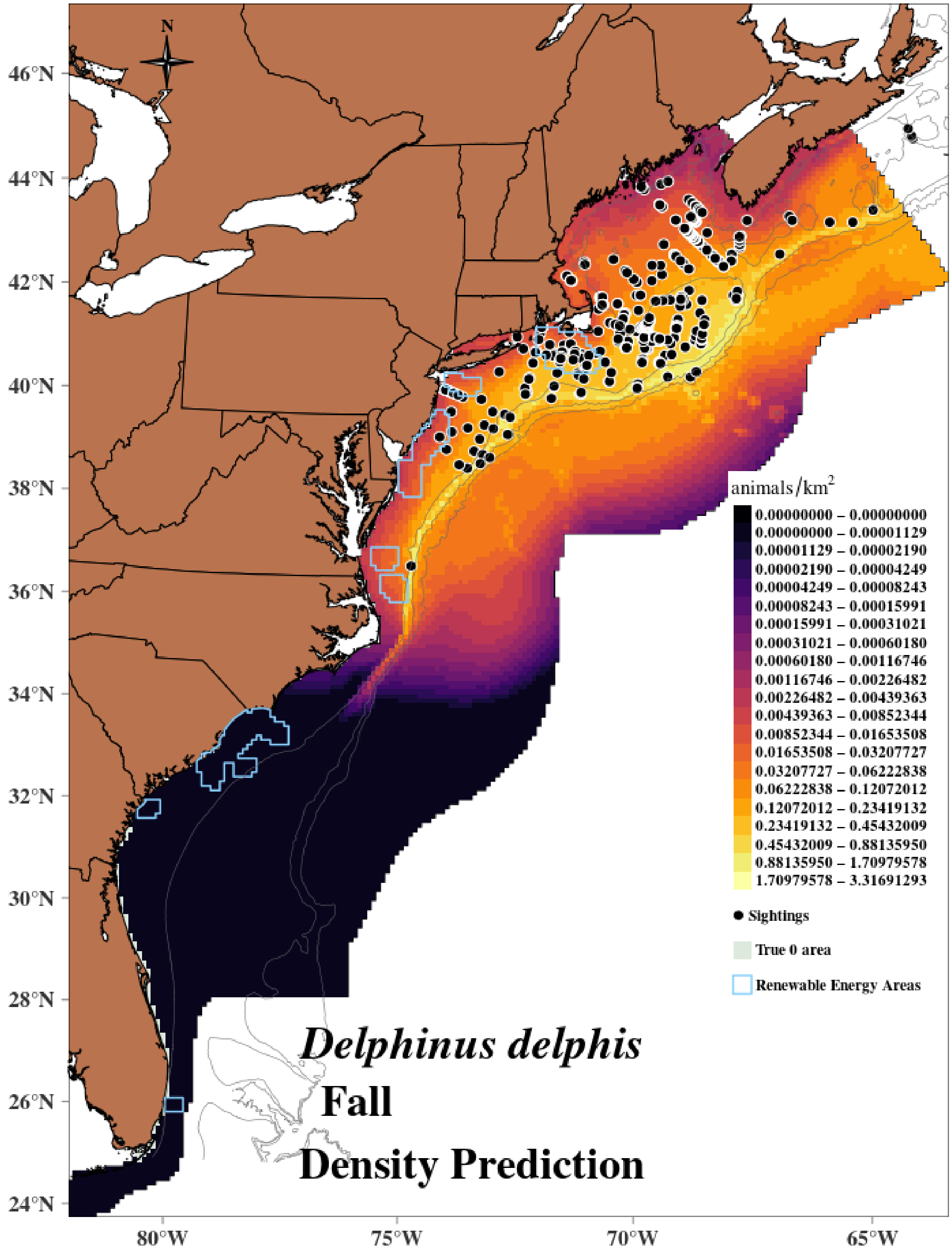

Figure 15-14 Common dolphin fall average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

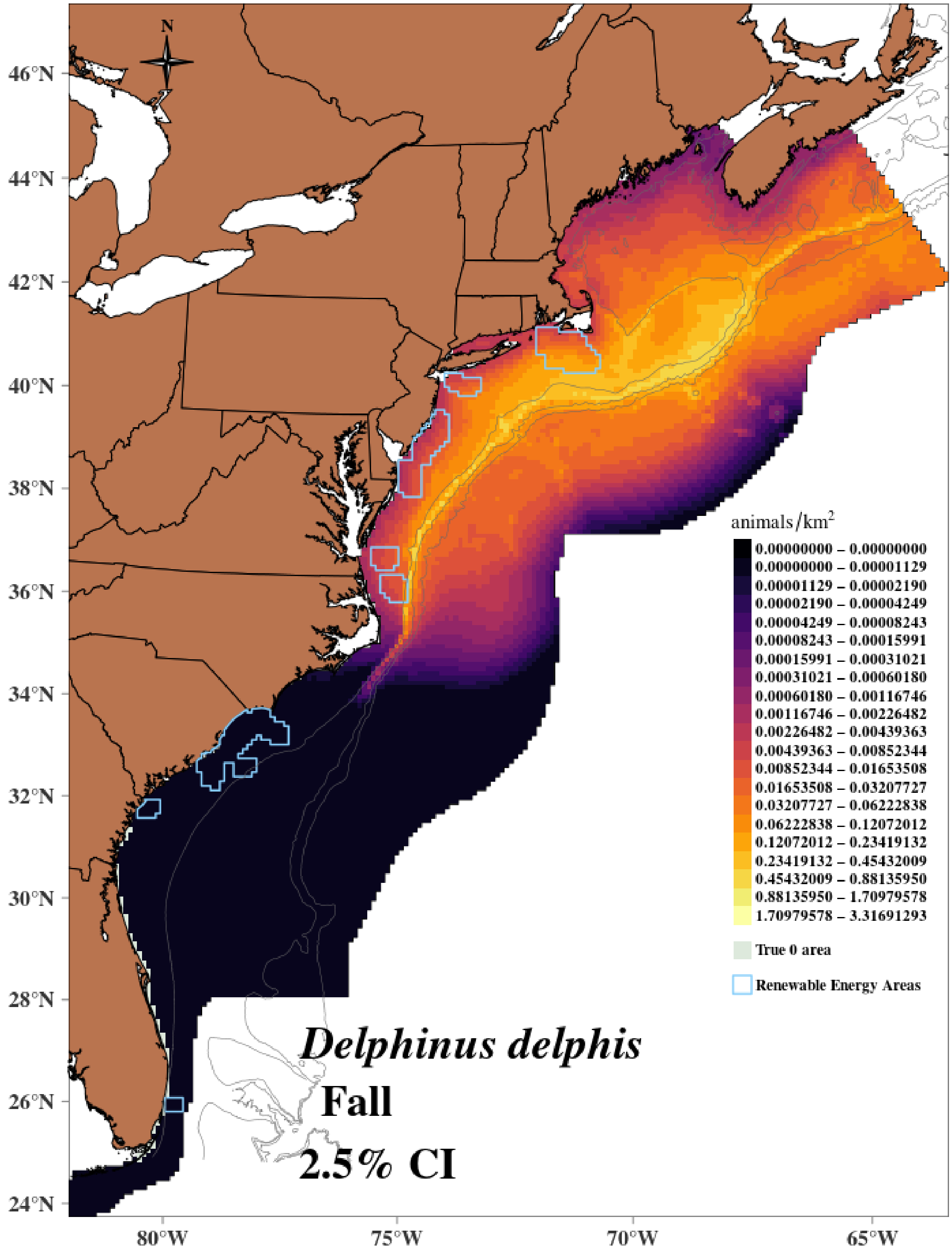

Figure 15-15 Lower 2.5% confidence interval of the fall common dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

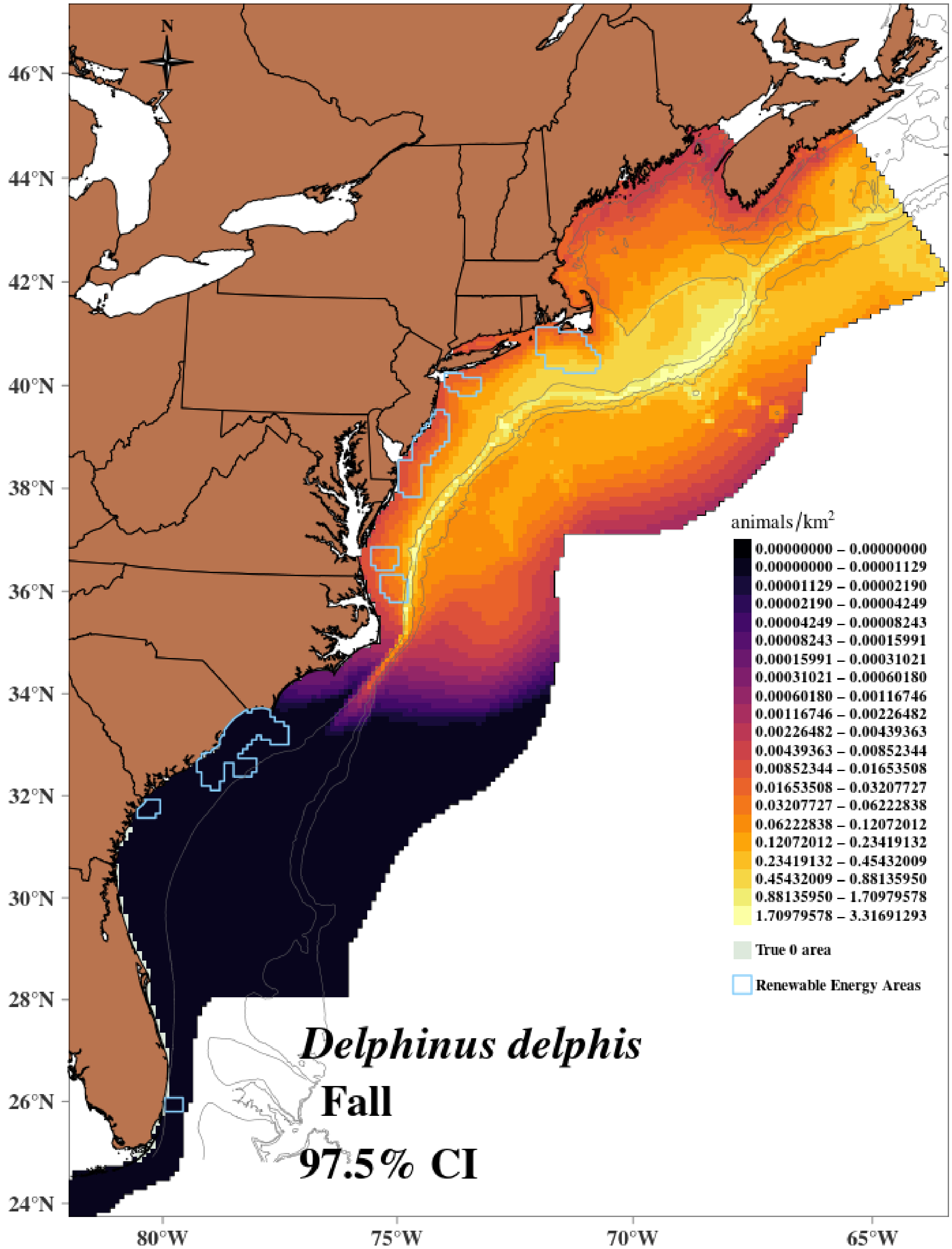

Figure 15-16 Upper 97.5% confidence interval of the fall common dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

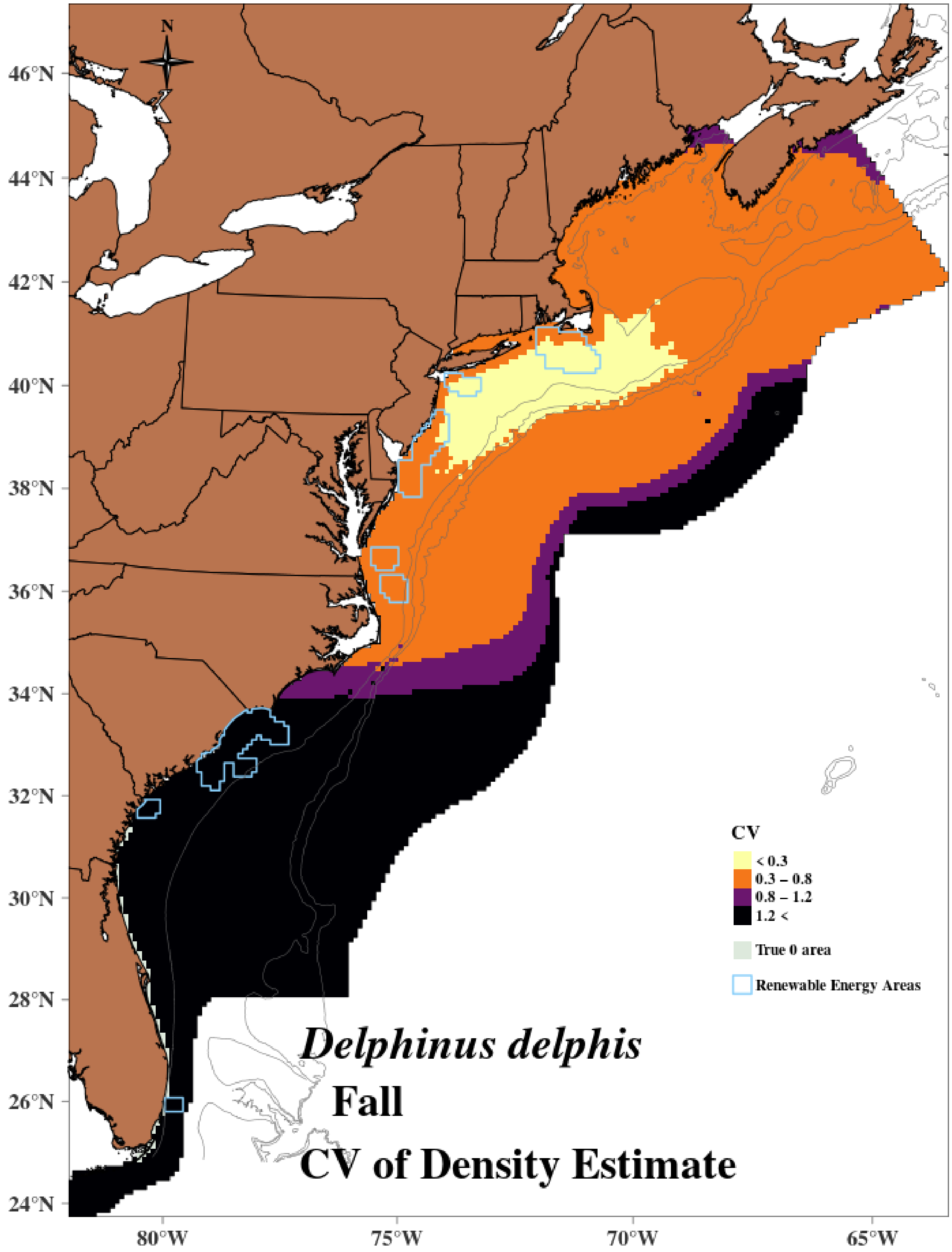

Figure 15-17 CV of fall common dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

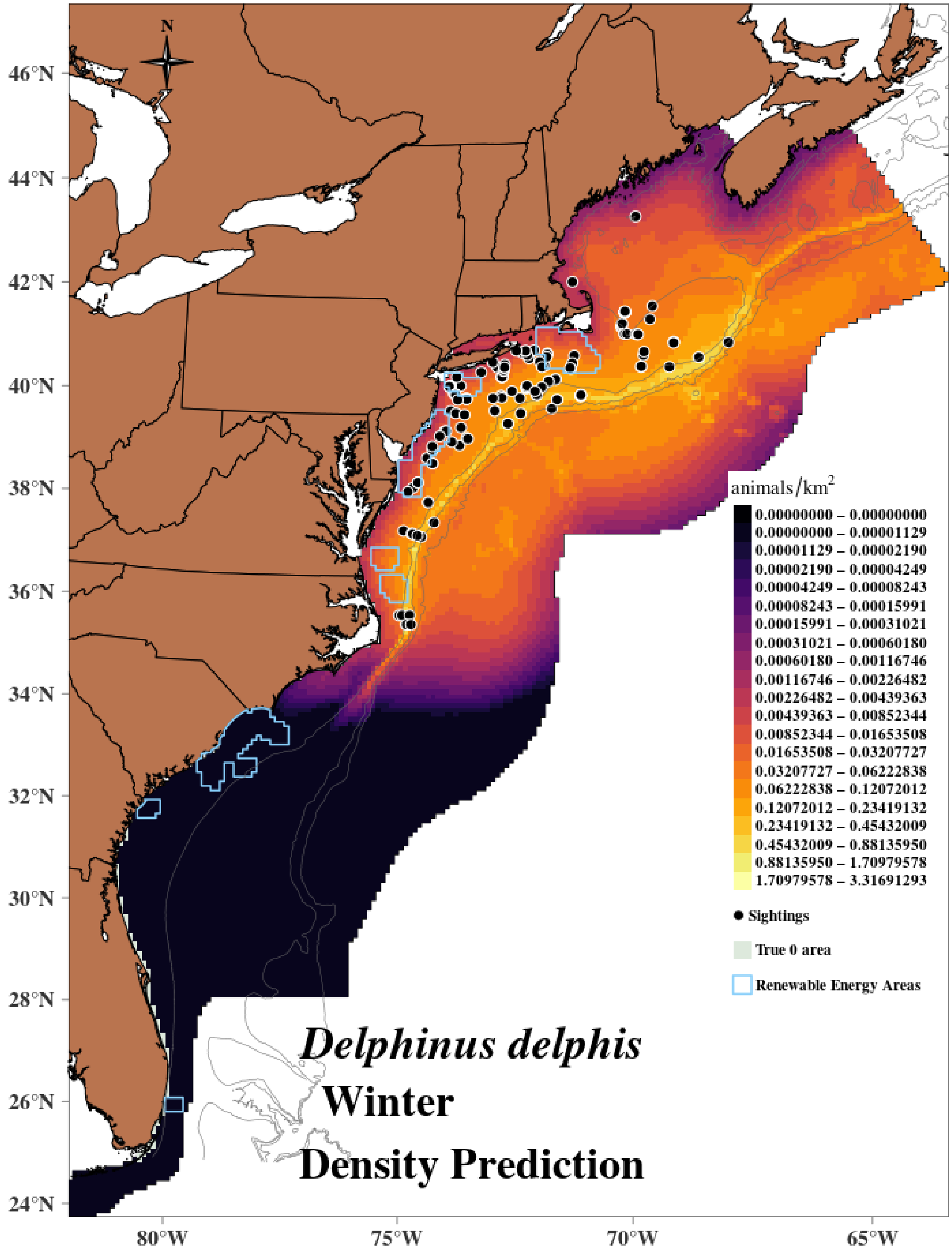

Figure 15-18 Common dolphin winter average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

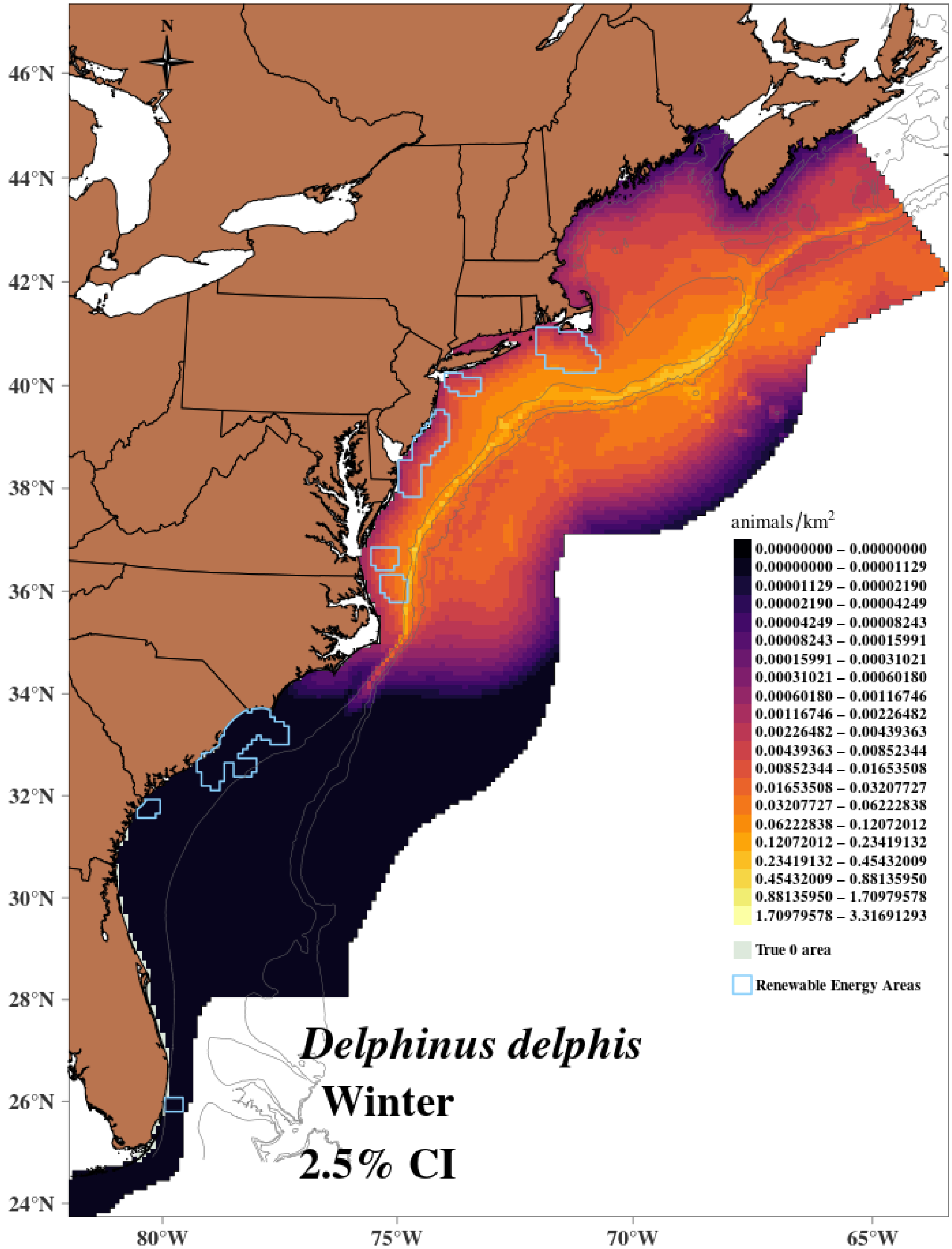

Figure 15-19 Lower 2.5% confidence interval of the winter common dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

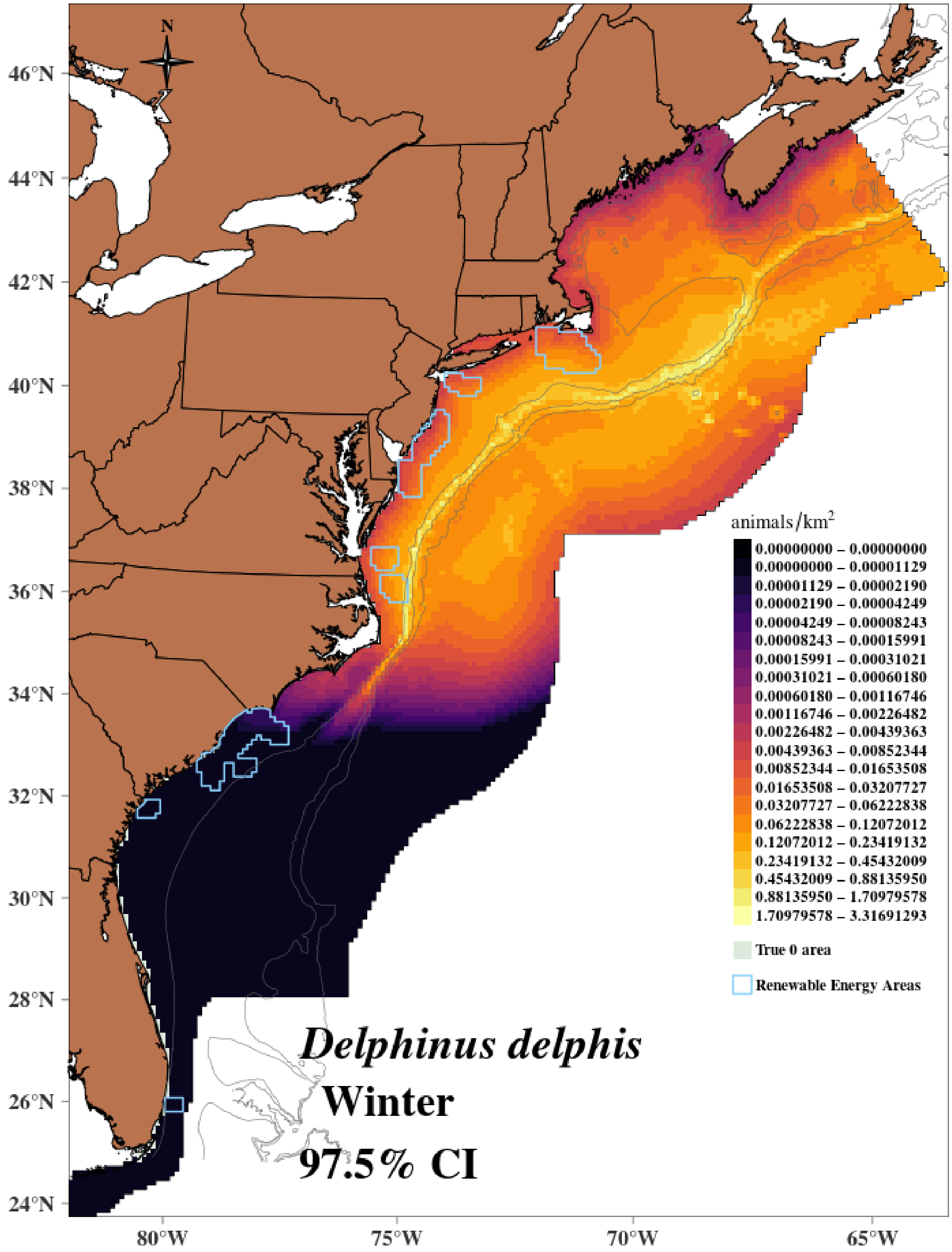

Figure 15-20 Upper 97.5% confidence interval of the winter common dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

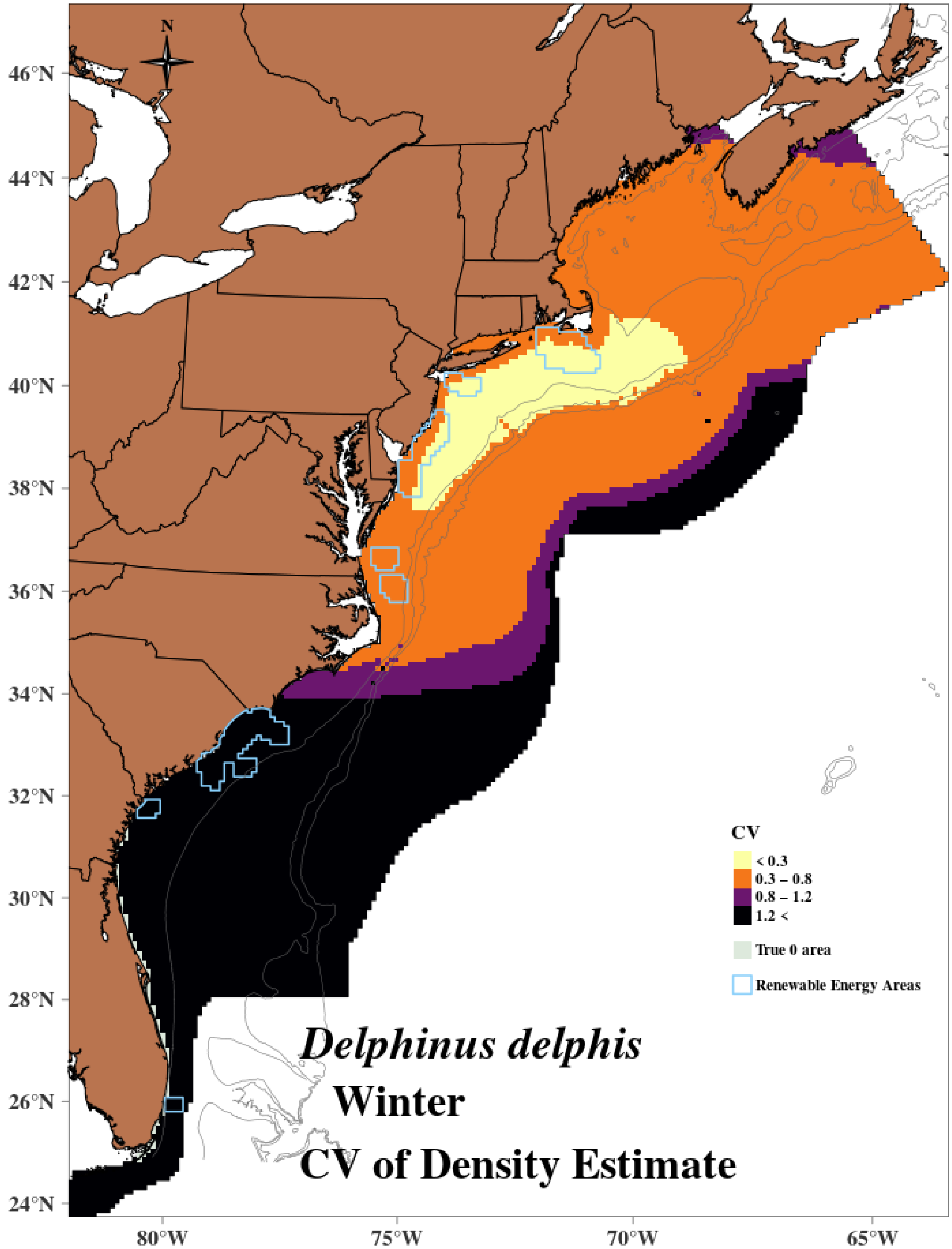

Figure 15-21 CV of winter common dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

15.7 Offshore Energy Development Areas

Table 15-6 Common dolphin average abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar-May)	RI/MA	356.3	0.31	195.7-648.6
	NY	65.8	0.29	
	NJ	118.4	0.31	
	DE/MD	74.6	0.33	40.0 139.0
	VA	131.9	0.36	66.0 263.8
	NC	316.4	0.39	
	NC/SC	0.0	1.74	0.0 0.1
Summer (Jun-Aug)	RI/MA	2,534.7	0.26	
	NY	153.8	0.27	
	NJ	56.9	0.32	
	DE/MD	31.5	0.34	
	VA	17.3	0.40	
	NC	77.4	0.43	
	NC/SC	0.0	2.15	0.0 0.0
Fall (Sep–Nov)	RI/MA	1,785.1	0.26	
	NY	90.7	0.27	.0
	NJ	90.7	0.31	50.0 164.6
	DE/MD	52.6	0.34	
	VA	60.9	0.39	
	NC	143.7	0.45	
	NC/SC	0.0	1.67	0.0 0.0
Winter (Dec–Feb)	RI/MA	515	0.26	
	NY	56.8	0.27	
	NJ	71.9	0.30	
	DE/MD	47.4	0.31	
	VA	113.3	0.34	
	NC	266.2	0.39	
	NC/SC	0.0	1.73	0.0 0.1

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

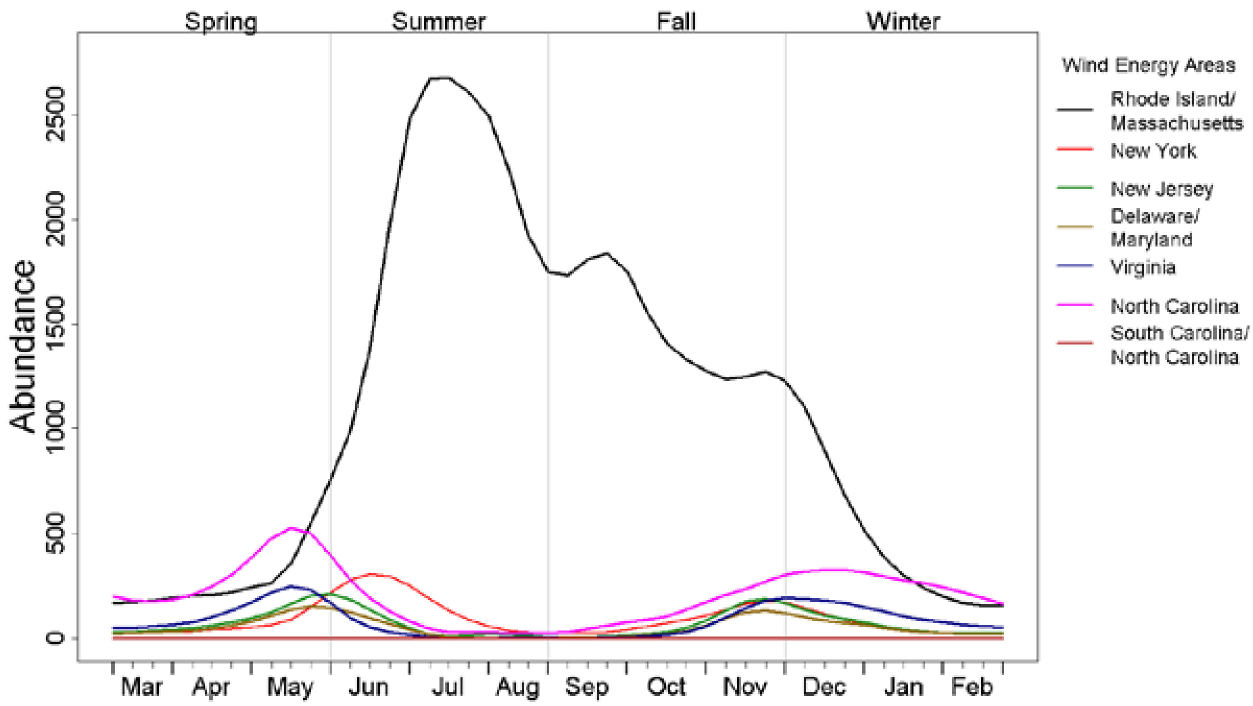

Figure 15-22 Average seasonal abundance of common dolphins in the wind-energy study areas

16 Atlantic Spotted Dolphin (*Stenella frontalis*)

Figure 16-1 Atlantic Spotted Dolphins
Image collected under MMPA Research permit #775-1875. Credit: NOAA/NEFSC/Allison Henry

16.1 Data Collection

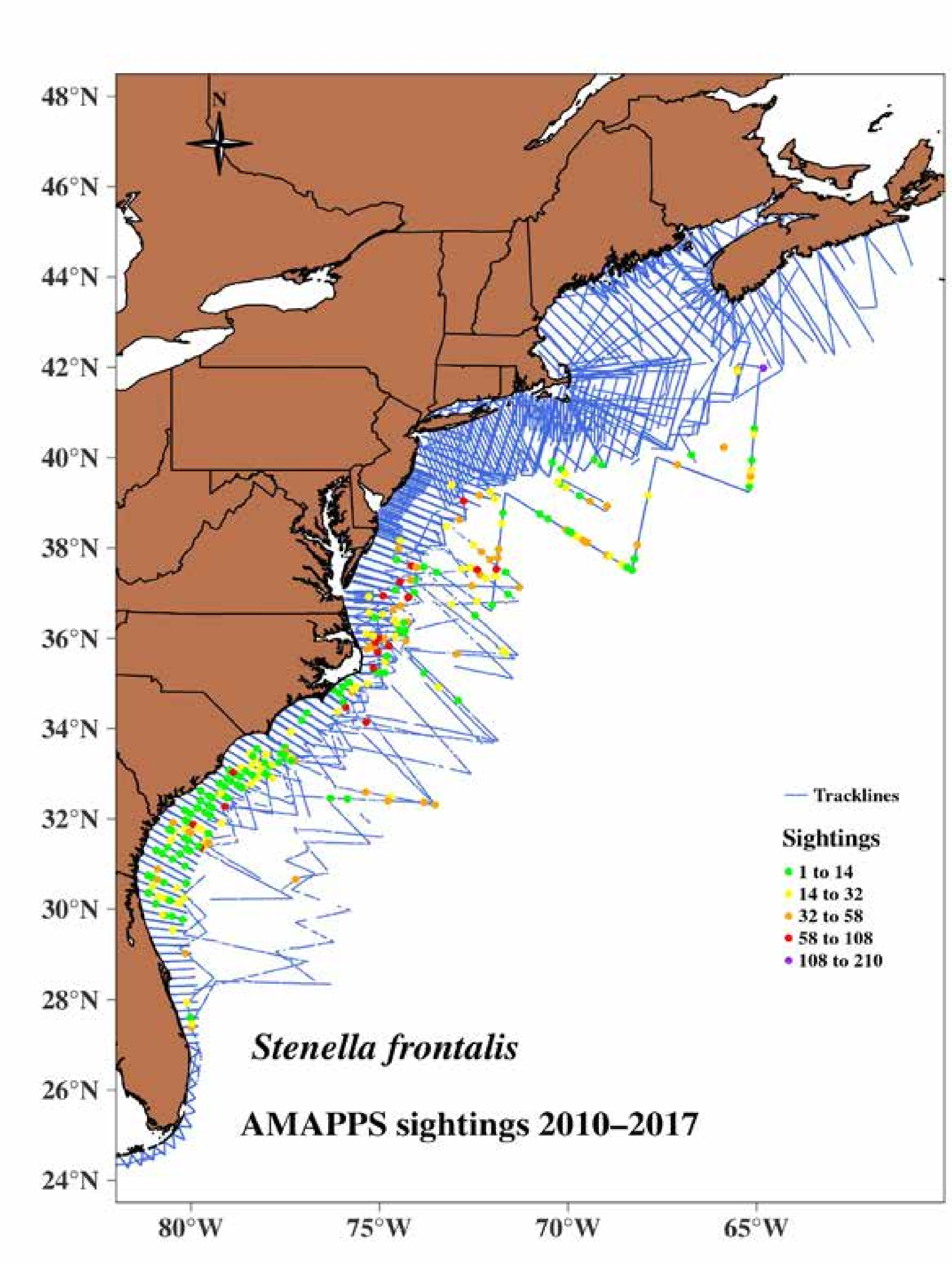

Figure 16-2 Distribution of track lines and Atlantic spotted dolphin sightings 2010 to 2017

Table 16-1 AMAPPS research effort 2010 to 2017 and Atlantic spotted dolphin sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	60	1,760
NE Shipboard	Fall	1,065	3	75
NE Aerial	Spring	13,314	0	0
NE Aerial	Summer	25,867	0	0
NE Aerial	Fall	37,850	0	0
NE Aerial	Winter	12,179	0	0
SE Shipboard	Spring	8,853	0	0
SE Shipboard	Summer	12,968	76	2,817
SE Shipboard	Fall	3,012	31	959
SE Aerial	Spring	41,293	70	1,346
SE Aerial	Summer	28,236	64	1,259
SE Aerial	Fall	18,974	37	580
SE Aerial	Winter	8,950	5	71

16.2 Mark-Recapture Distance Sampling Analysis

Table 16-2 Intermediate parameters in Atlantic spotted dolphin mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 1	distance + sea state + quality	330	distance + glare +quality	LT30-330	HN	0.65	0.10	0.14	0.92	0.90
NE–shipboard group 1	sea state + swell	2000	distance + sea state	2000	HR	0.87	0.08	0.39	0.94	0.92
SE–shipboard group 1	distance + group size	2700	distance + sea state + glare	2700	HR	0.62	0.09	0.23	0.976	0.98

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

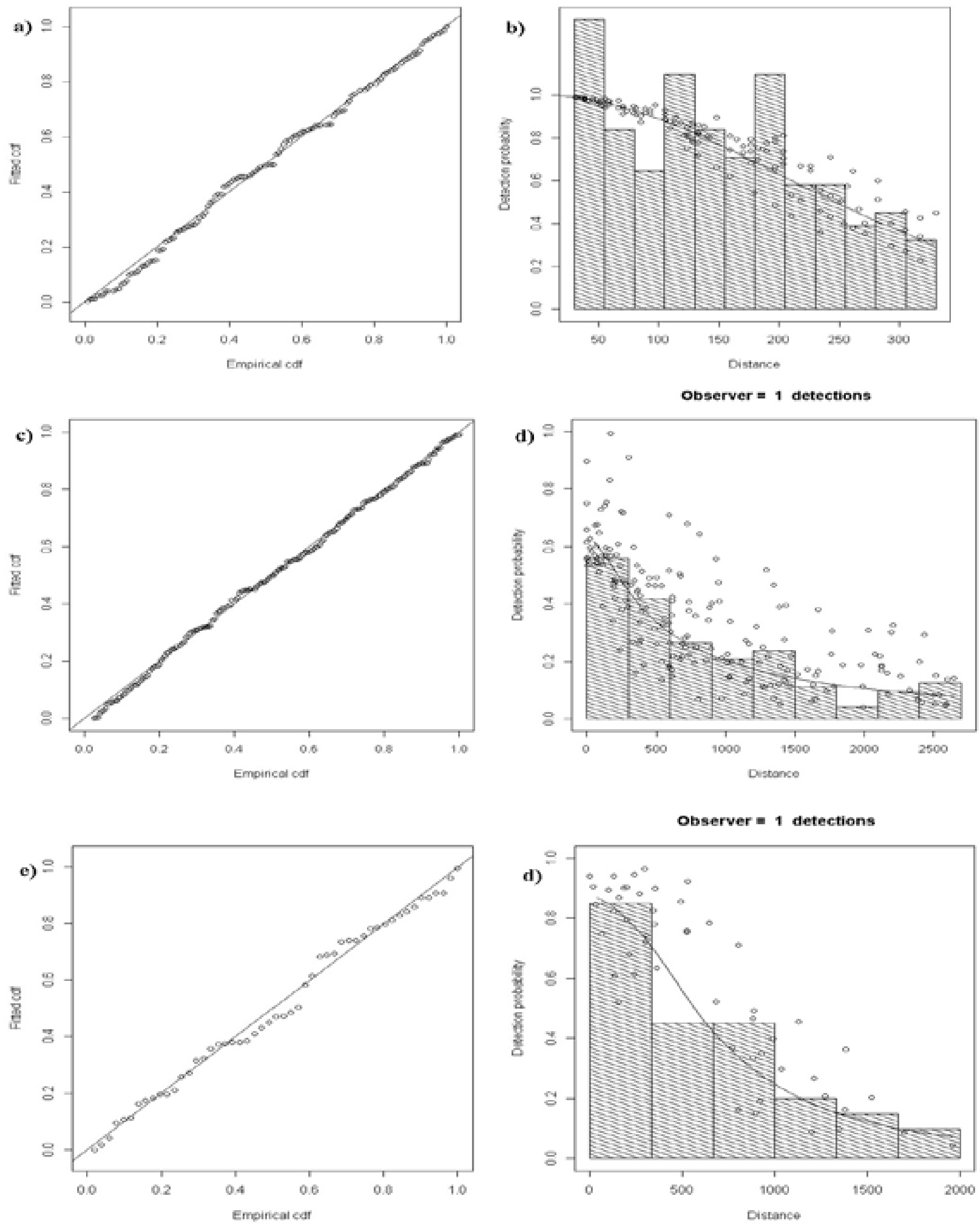

Figure 16-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 1; b) NE-shipboard analysis set 1; c) SE-shipboard analysis set 1.

16.3 Generalized Additive Model Analysis

Table 16-3 2010 to 2017 density-habitat model output for Atlantic spotted dolphins

Covariates	Edf	Ref.df	F	C.dev	p-value
s(chlfma)	0.77	4	0.77	0.39	0.0431
s(btemp)	3.53	4	11.21	4.38	<0.0001
s(mld)	0.99	4	10.99	4.44	<0.0001
s(dist2shore)	1.22	4	13.87	4.48	<0.0001
s(dist125)	1.16	4	24.42	8.12	<0.0001
s(lat)	3.54	4	39.54	15.96	<0.0001

Adjusted R^2 = 0.00124. Deviance explained = 37.8%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

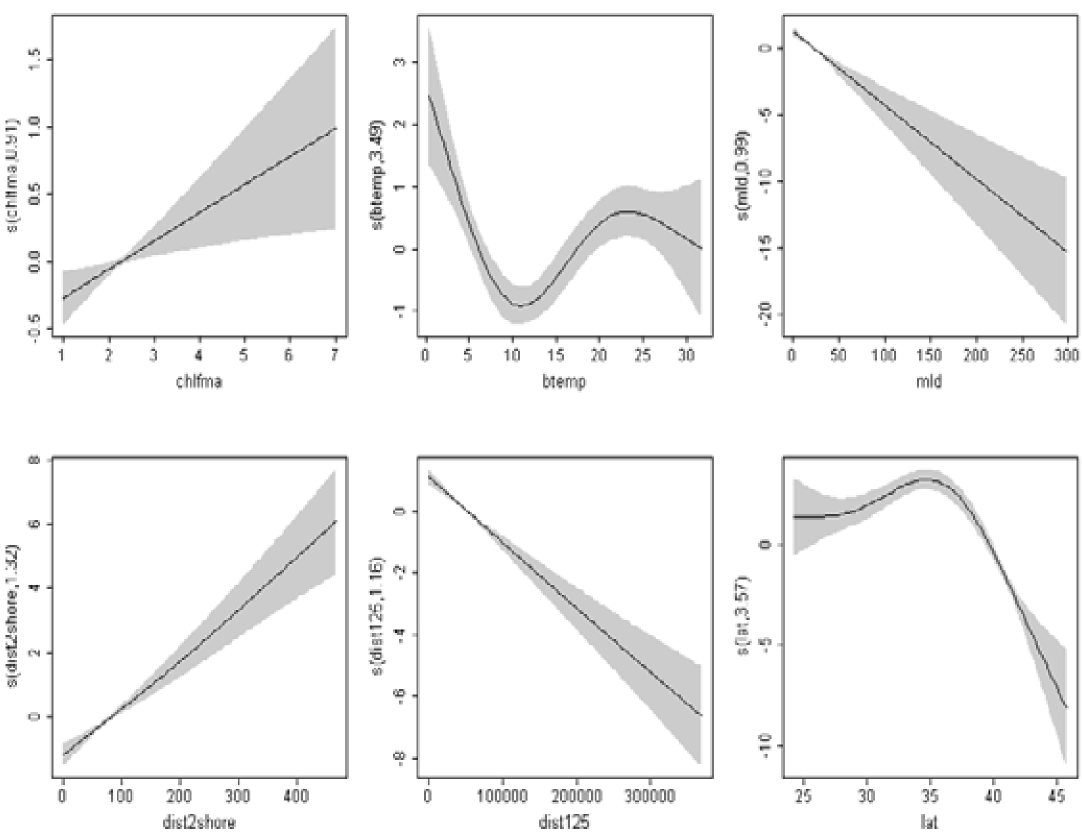

Figure 16-4 Atlantic spotted dolphin density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

16.4 Model Cross-Validation

Table 16-4 Diagnostic statistics from the Atlantic spotted dolphin density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.101	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	95.600	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.123	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.040	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

16.5 Abundance Estimates for AMAPPS Study Area

Table 16-5 Atlantic spotted dolphin average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	17,464	0.32	
Summer (June–August)	44,947	0.30	
Fall (September–November)	20,836	0.33	
Winter (December–February)	3,855	0.40	
Summer 2011 U.S. surveys[1]	44,715	0.43	
Summer 2016 U.S. surveys[1]	39,921	0.27	

[1]Hayes et al. 2020

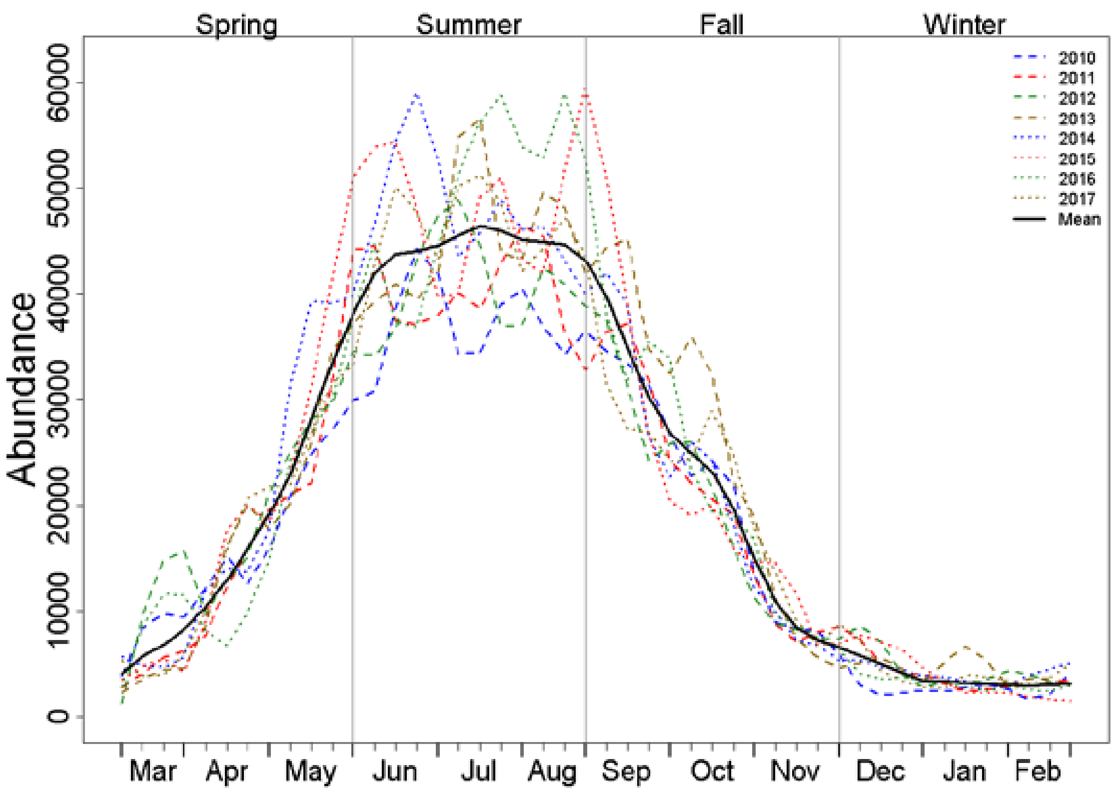

Figure 16-5 Annual abundance trends for Atlantic spotted dolphins in the AMAPPS study area

16.6 Seasonal Prediction Maps

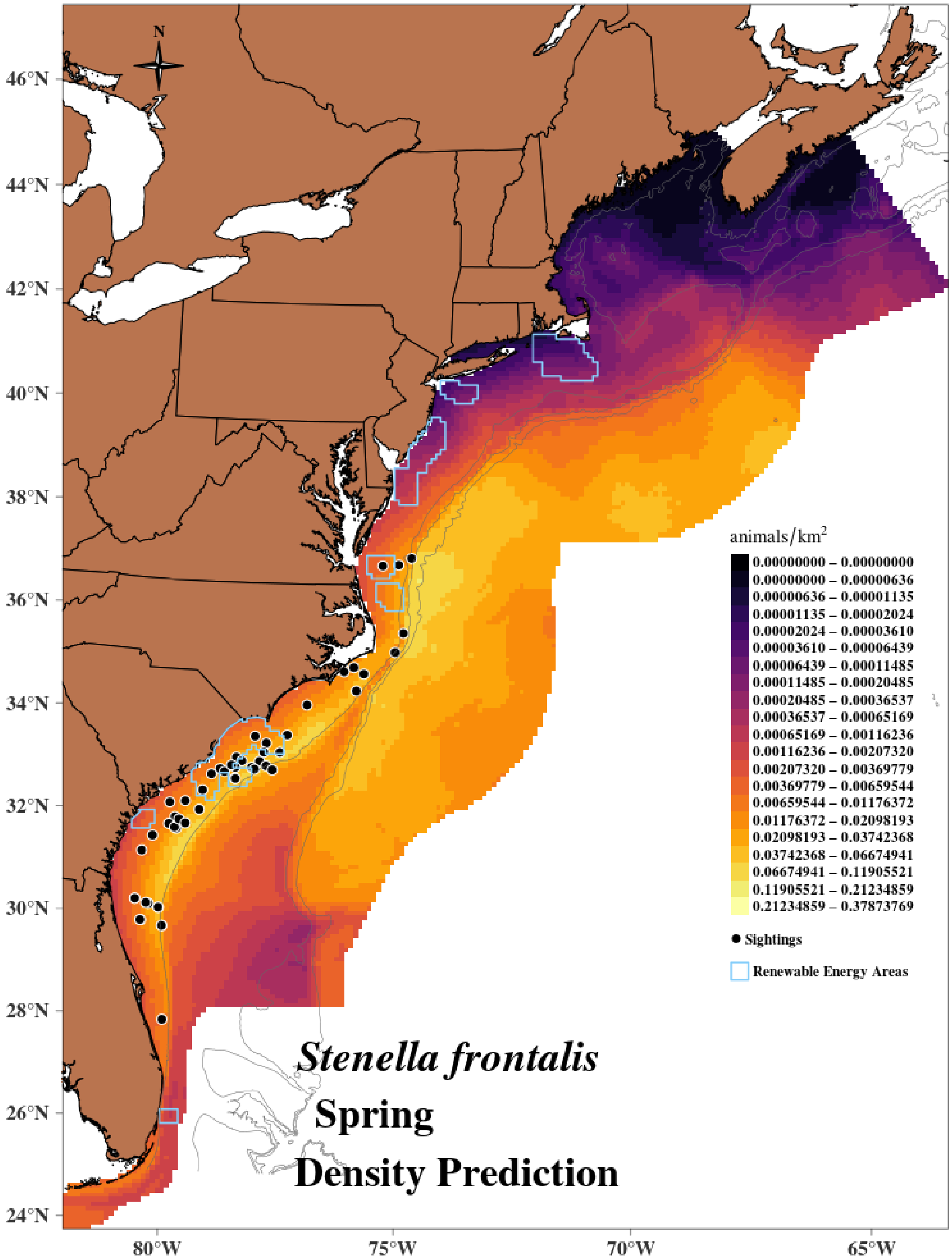

Figure 16-6 Atlantic spotted dolphin spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

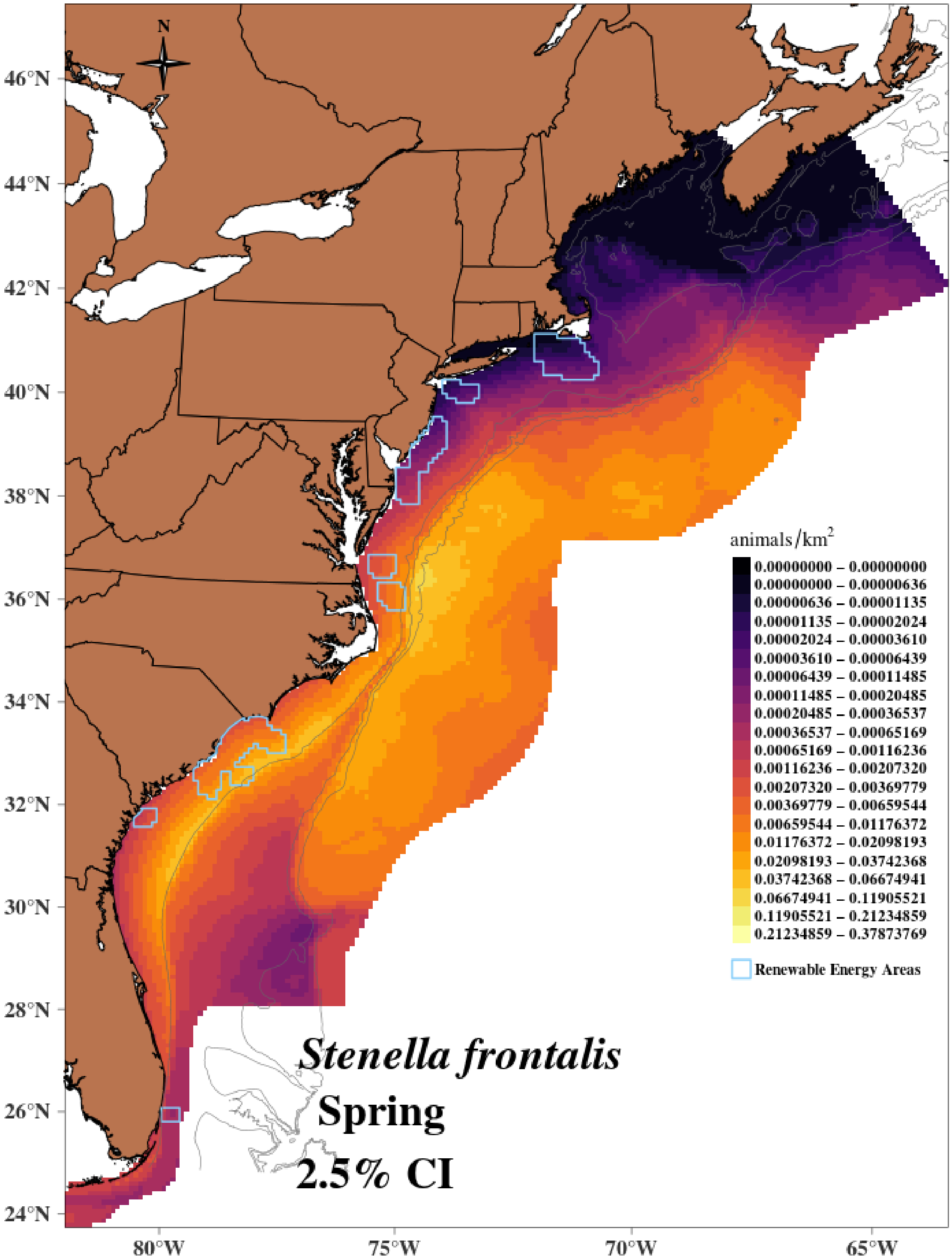

Figure 16-7 Lower 2.5% confidence interval of the spring Atlantic spotted dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

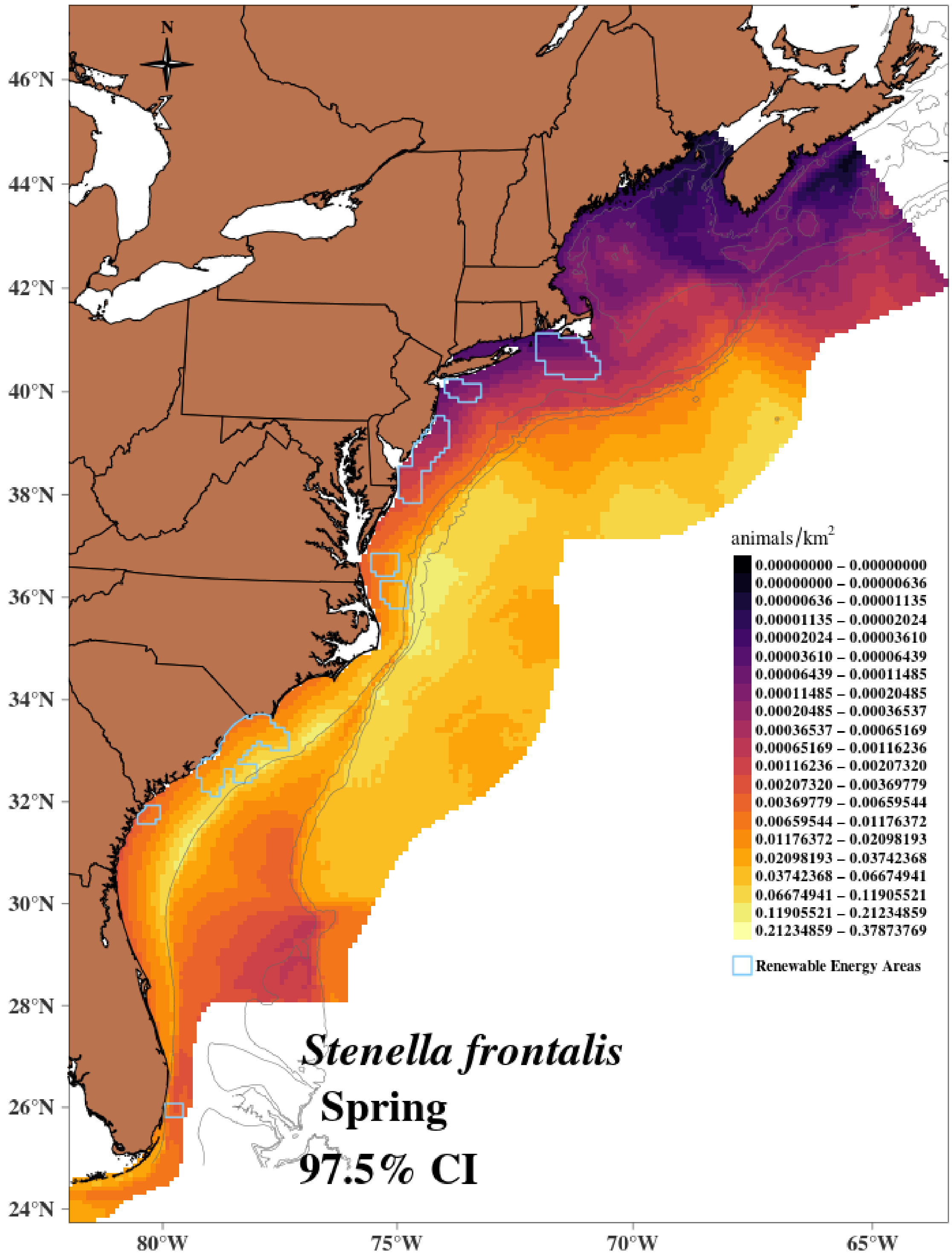

Figure 16-8 Upper 97.5% confidence interval of the spring Atlantic spotted dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

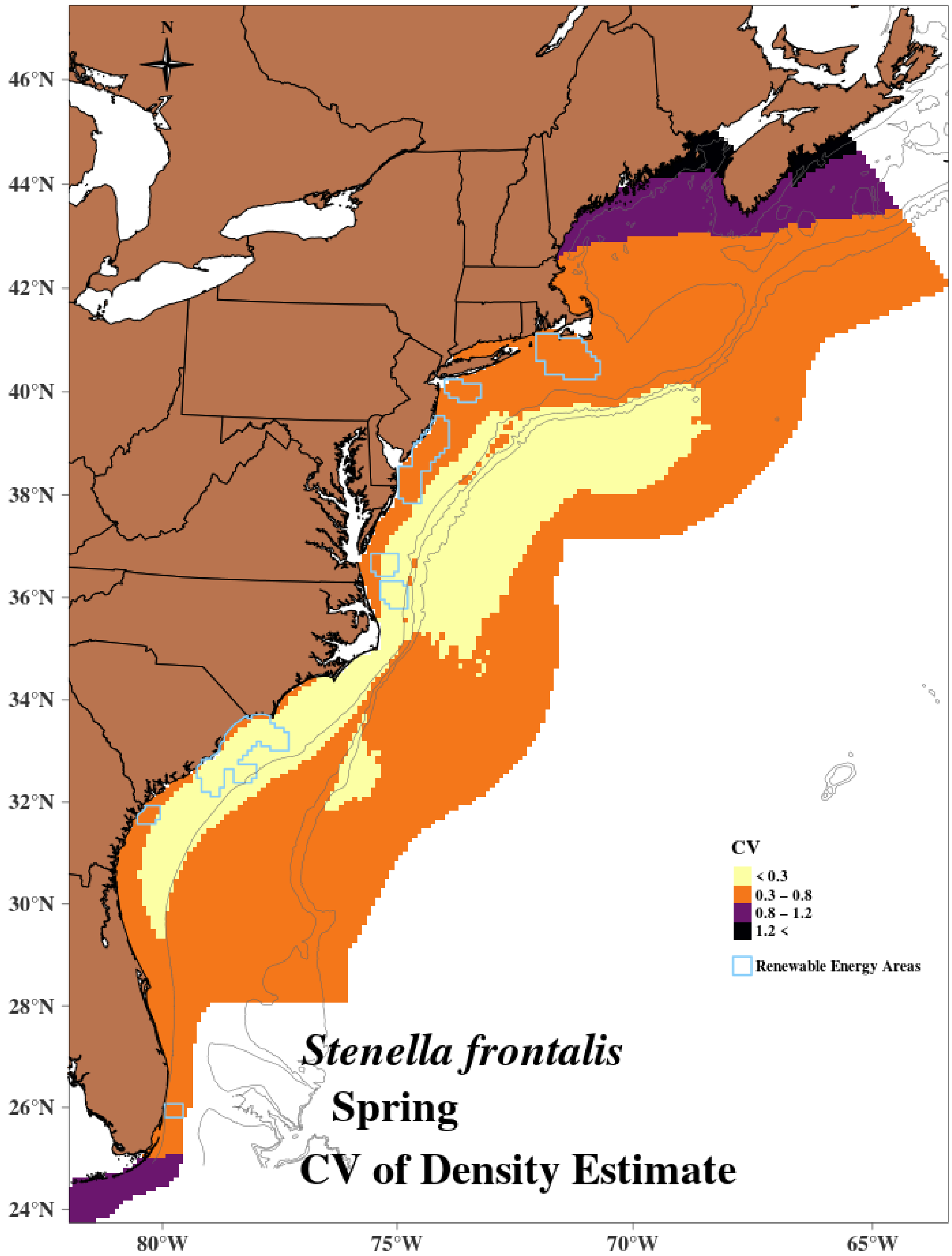

Figure 16-9 CV of spring Atlantic spotted dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

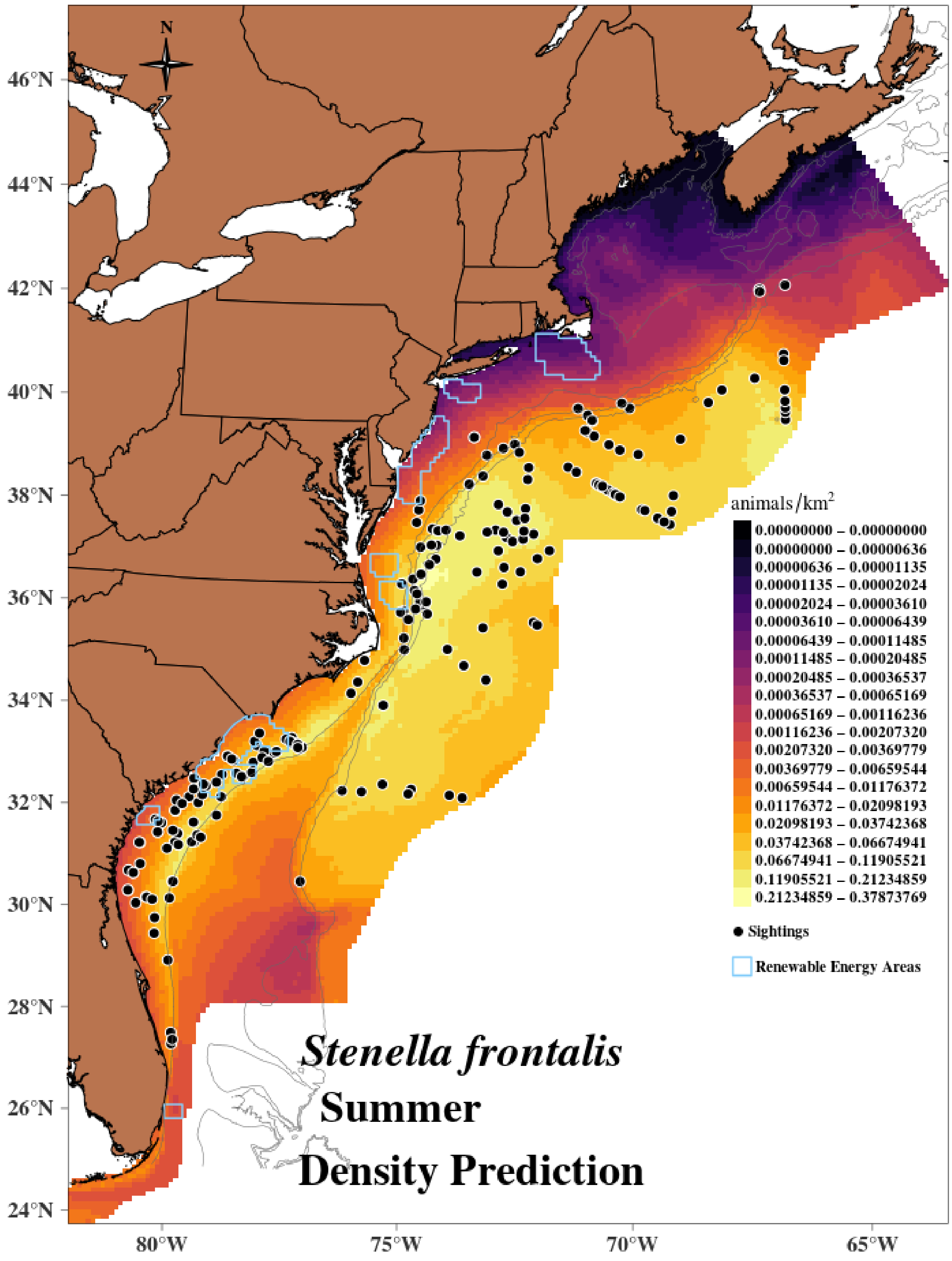

Figure 16-10 Atlantic spotted dolphin summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

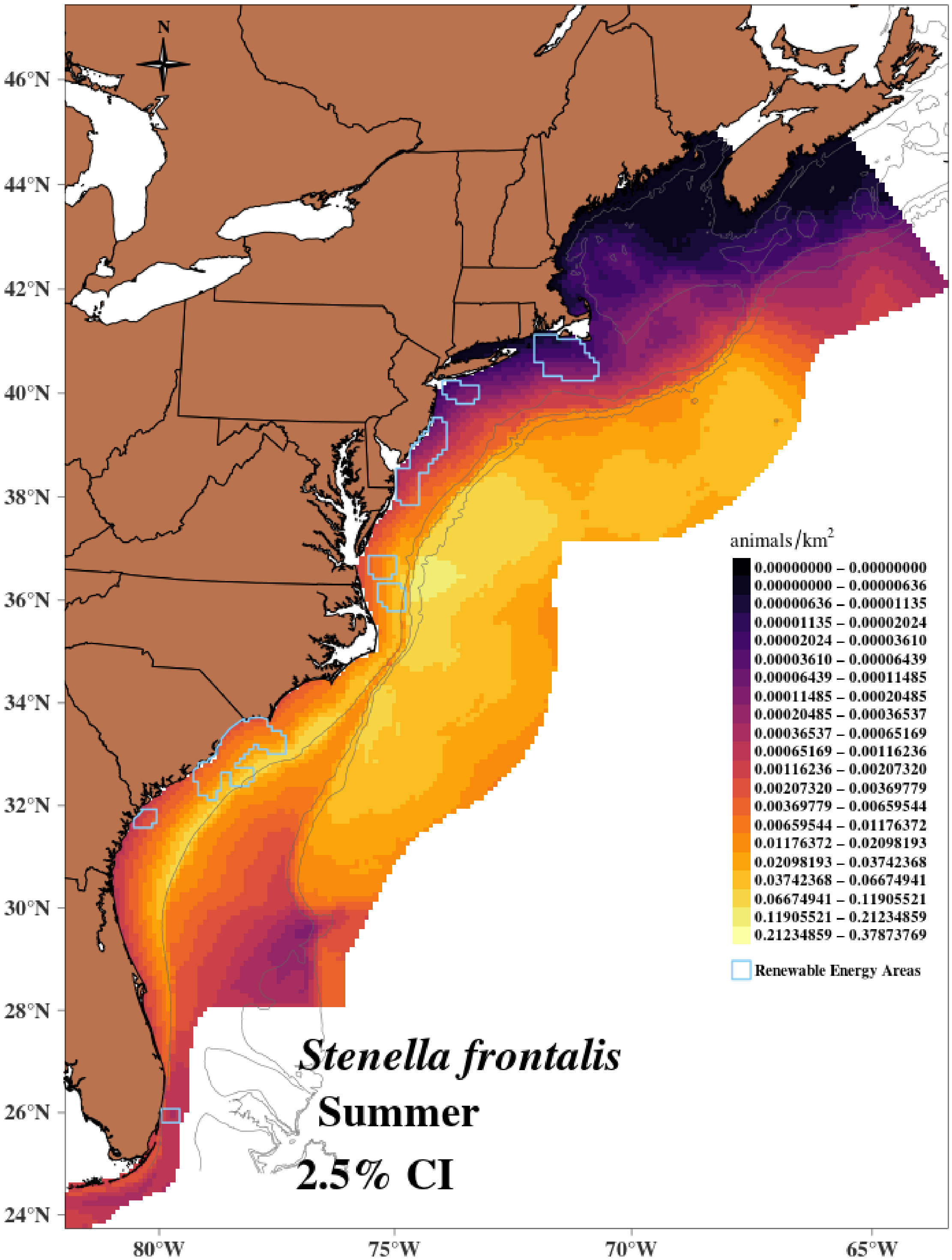

Figure 16-11 Lower 2.5% confidence interval of the summer Atlantic spotted dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

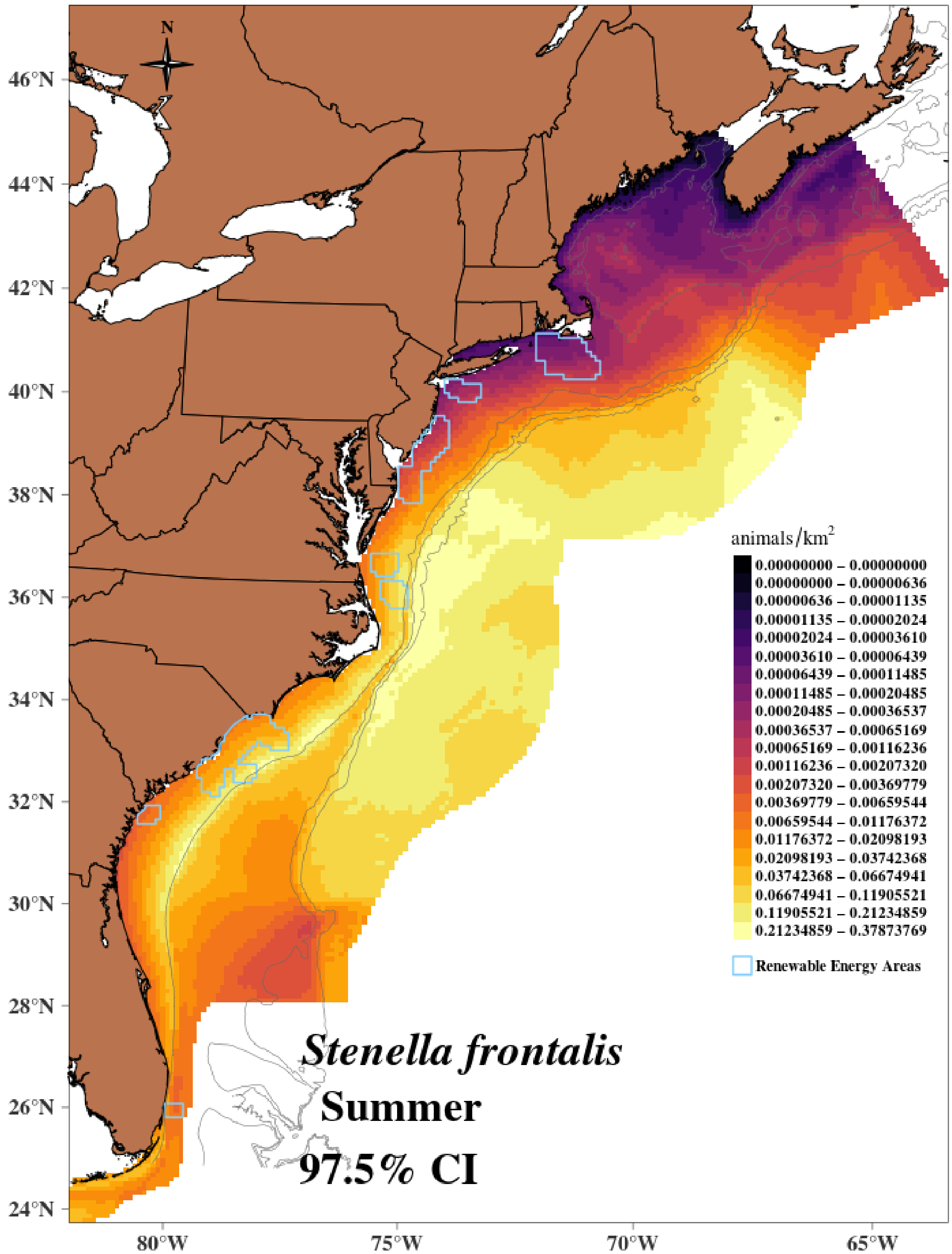

Figure 16-12 Upper 97.5% confidence interval of the summer Atlantic spotted dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

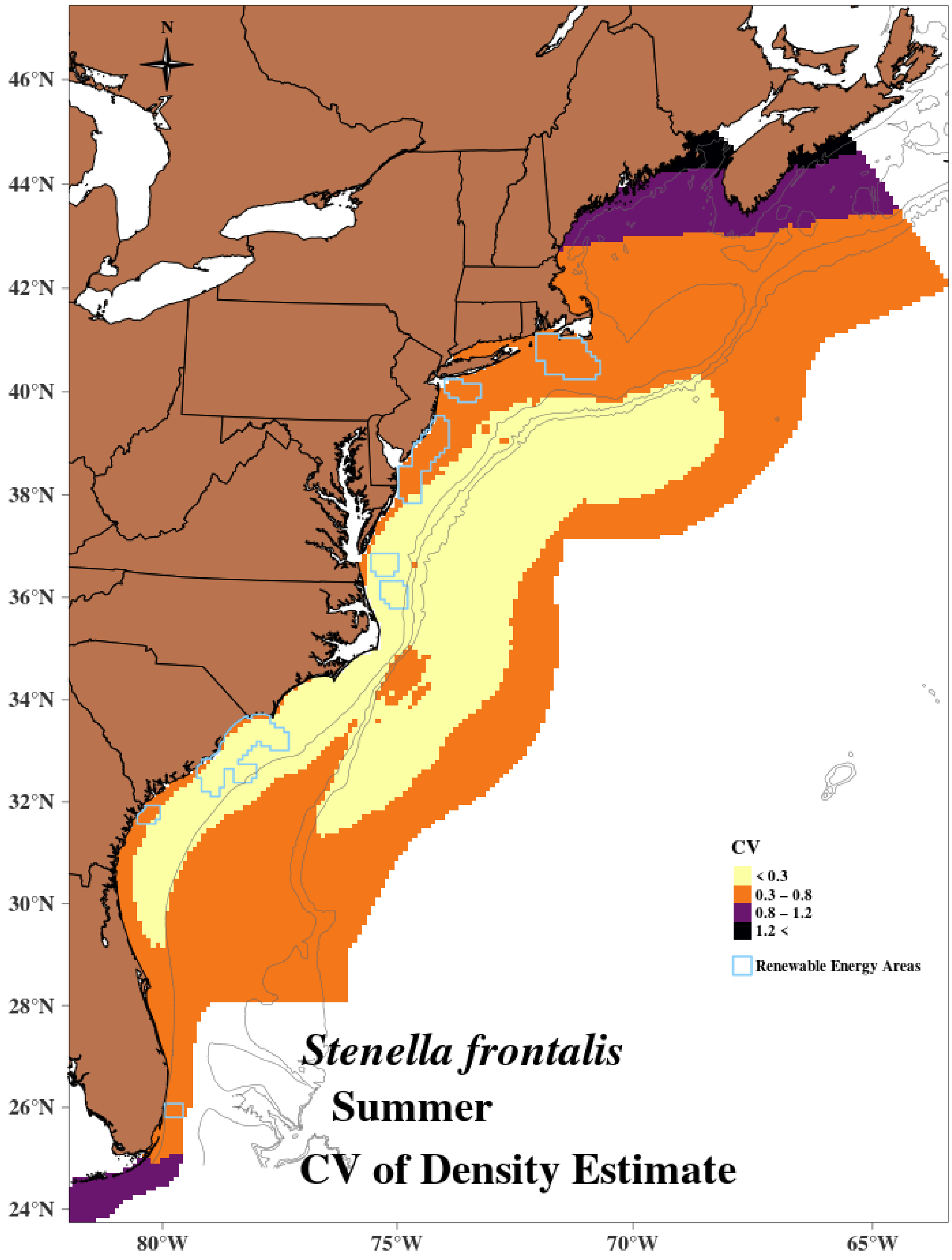

Figure 16-13 CV of summer Atlantic spotted dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

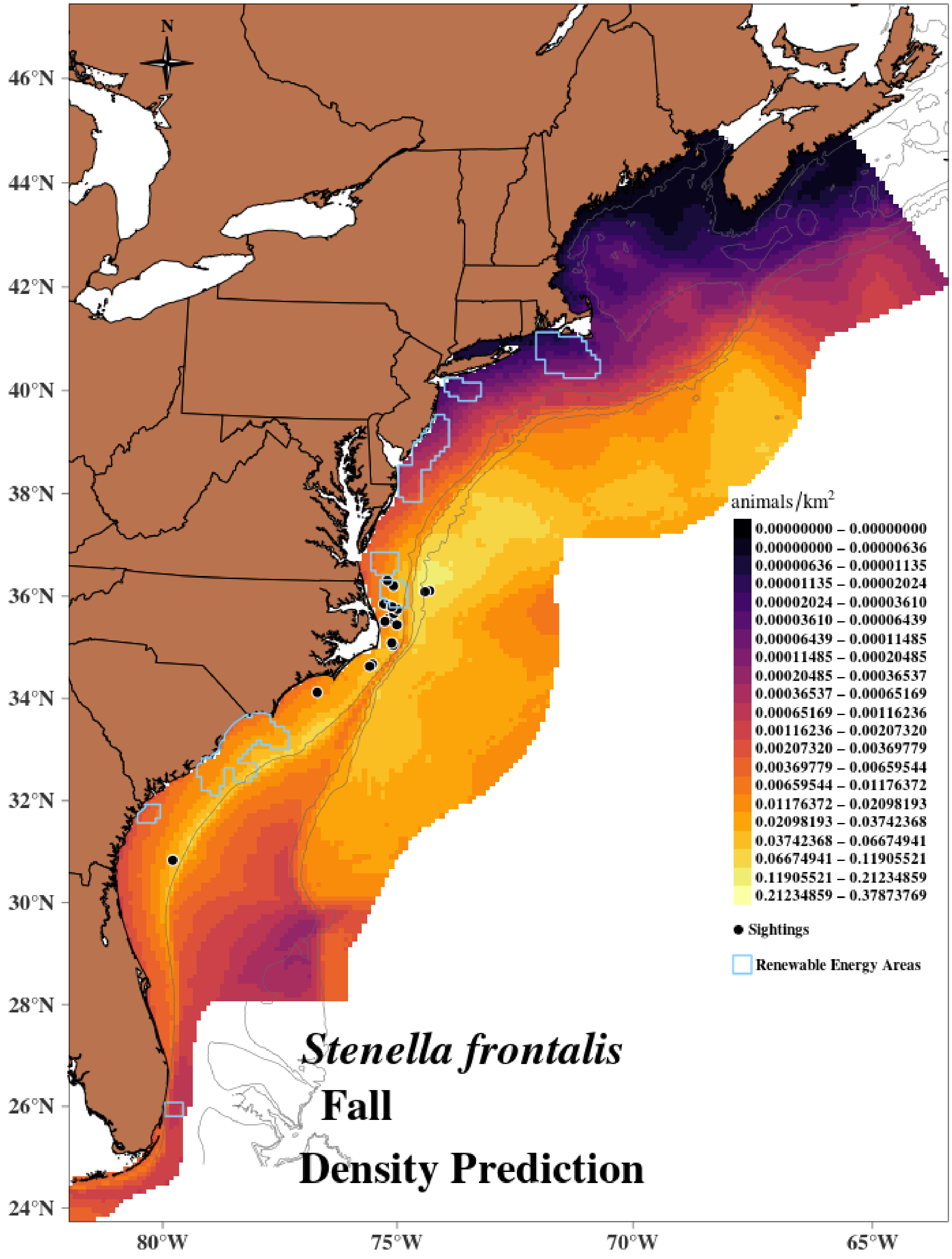

Figure 16-14 Atlantic spotted dolphin fall average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

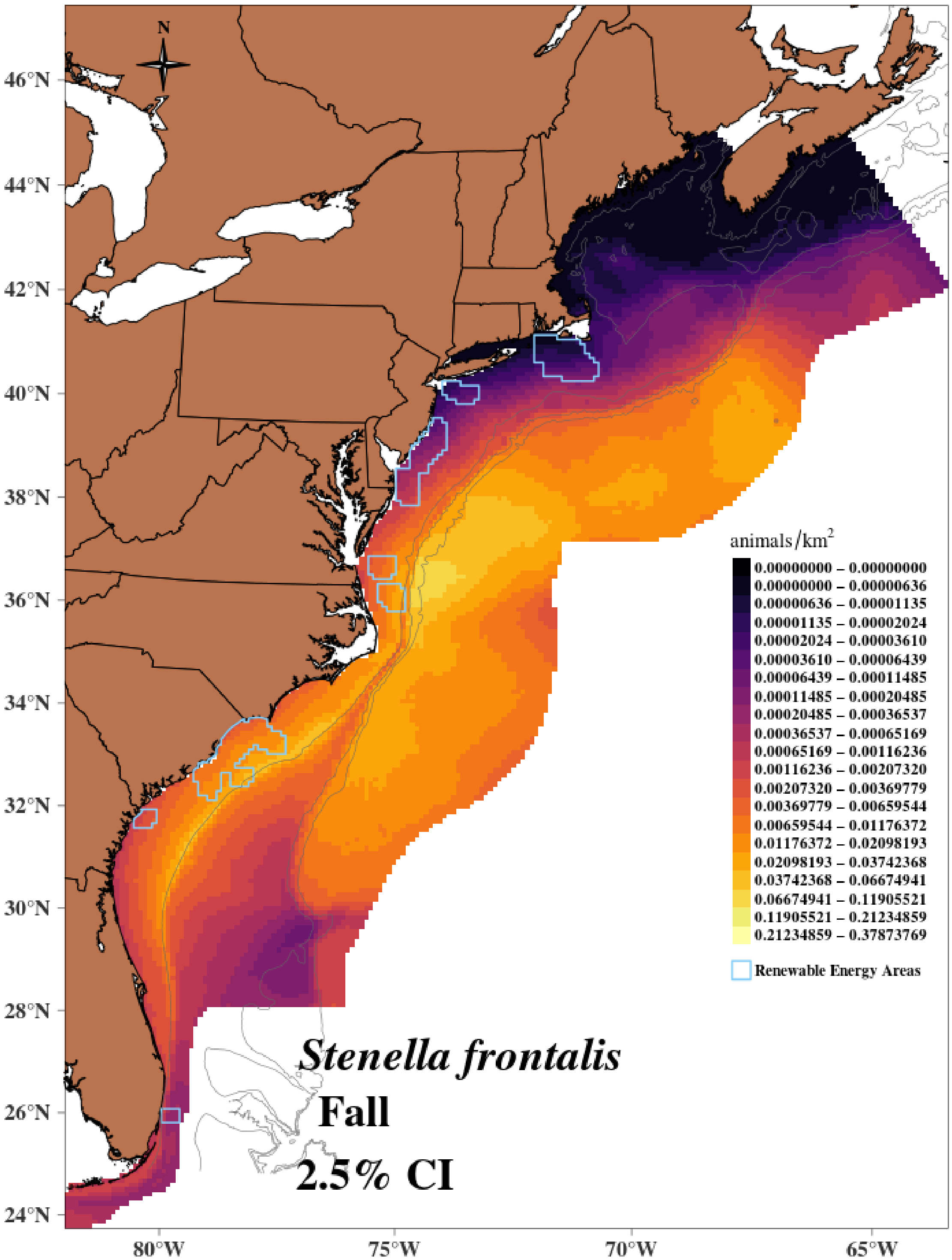

Figure 16-15 Lower 2.5% confidence interval of the fall Atlantic spotted dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

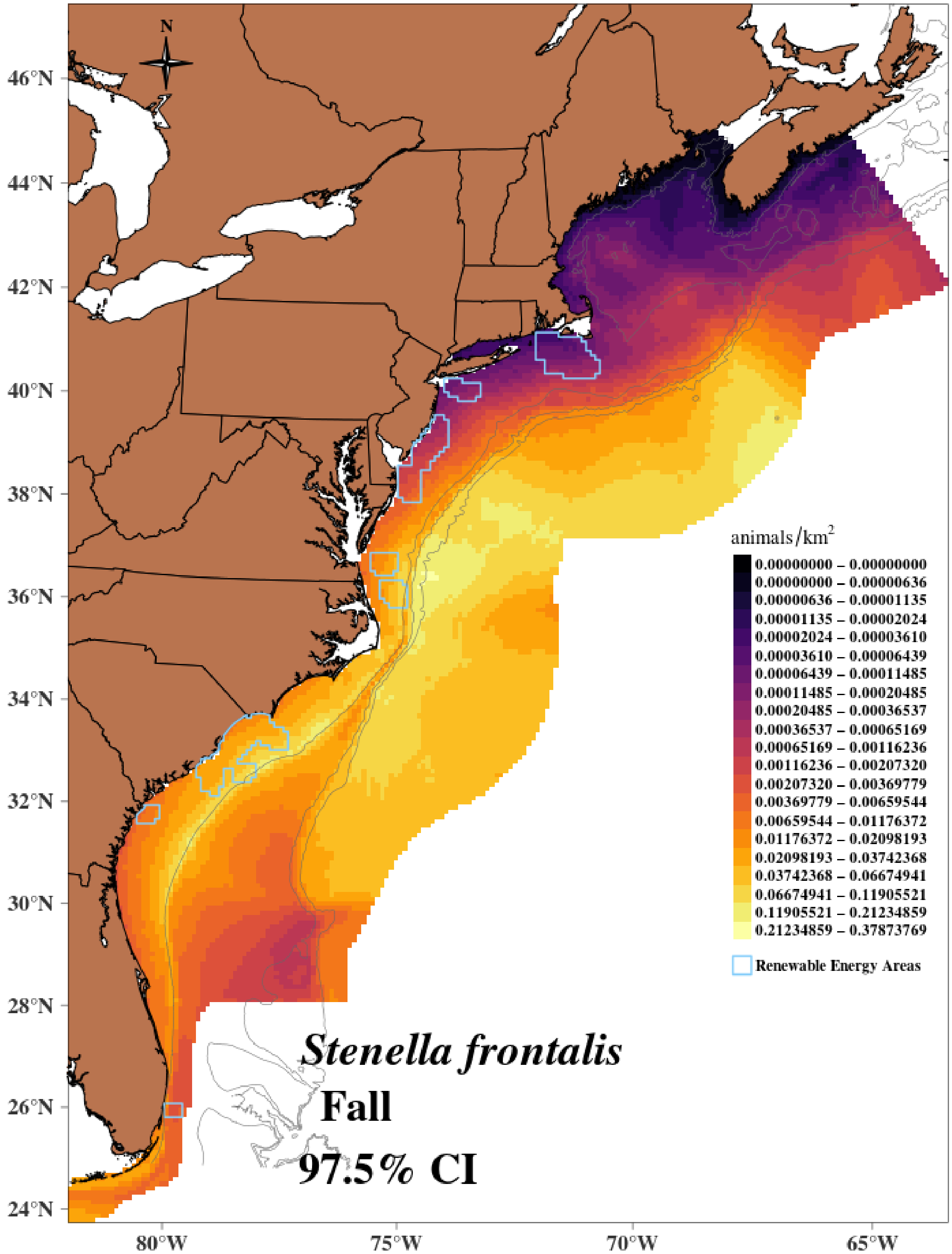

Figure 16-16 Upper 97.5% confidence interval of the fall Atlantic spotted dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

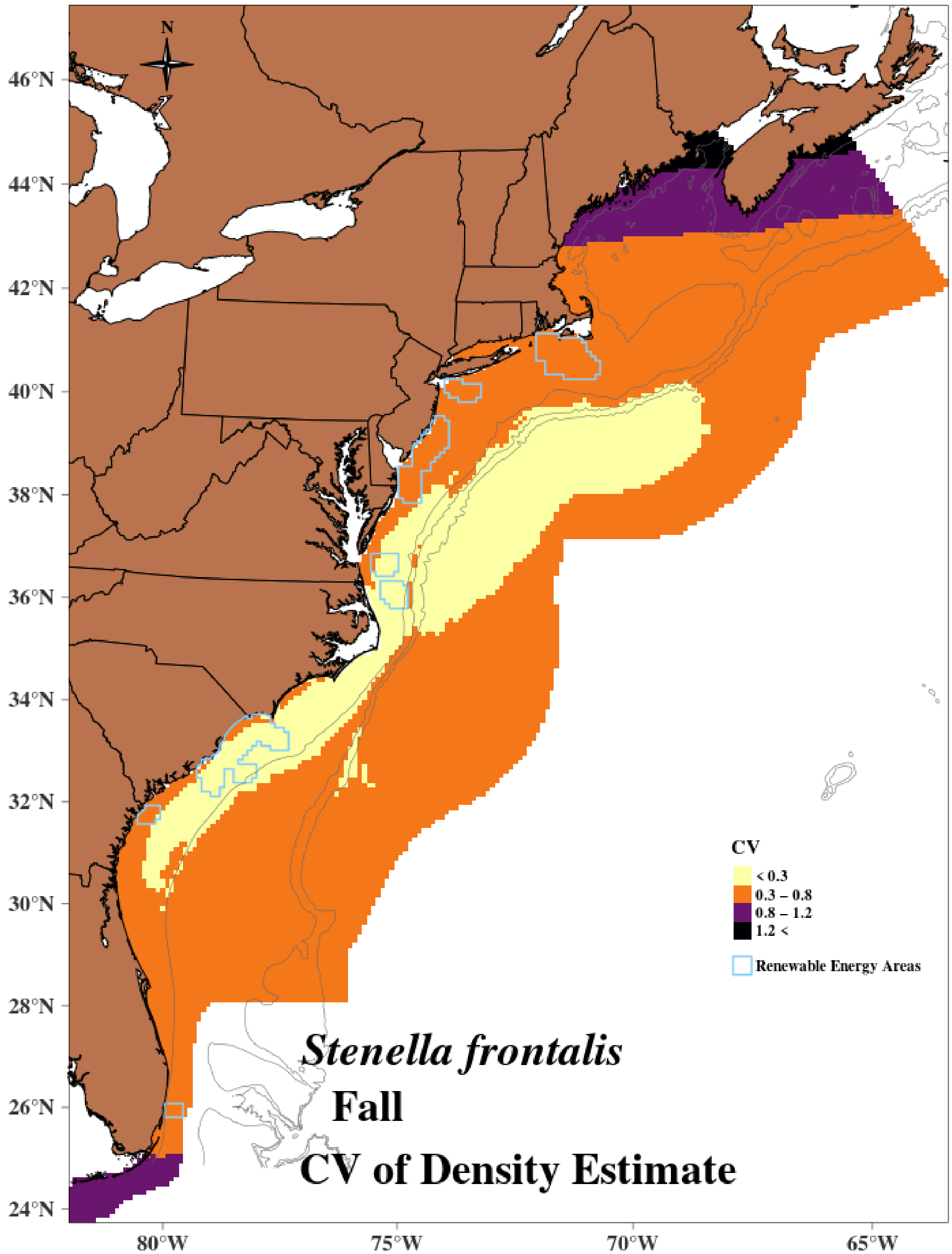

Figure 16-17 CV of fall Atlantic spotted dolphin density estimates

CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

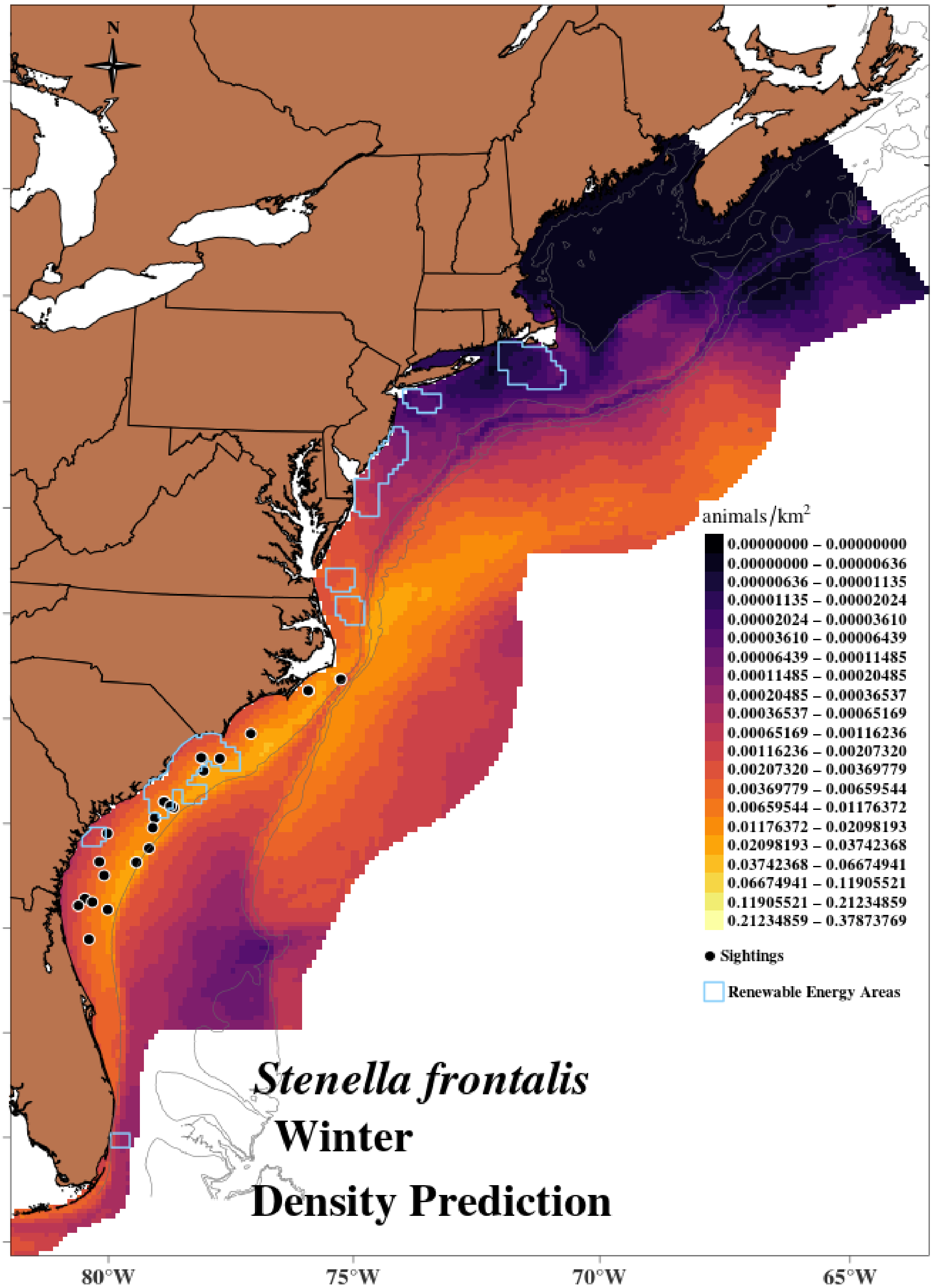

Figure 16-18 Atlantic spotted dolphin winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

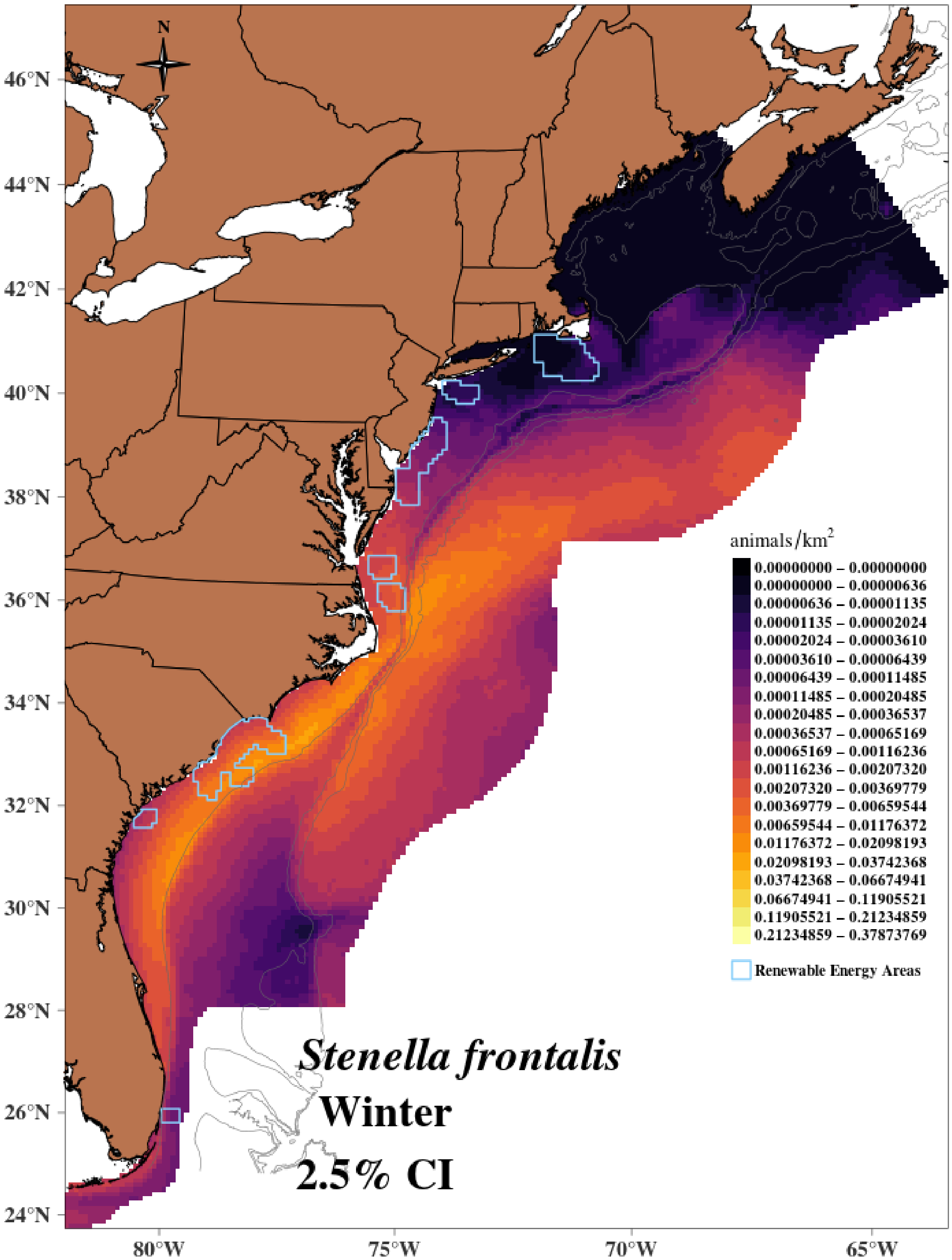

Figure 16-19 Lower 2.5% confidence interval of the winter Atlantic spotted dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

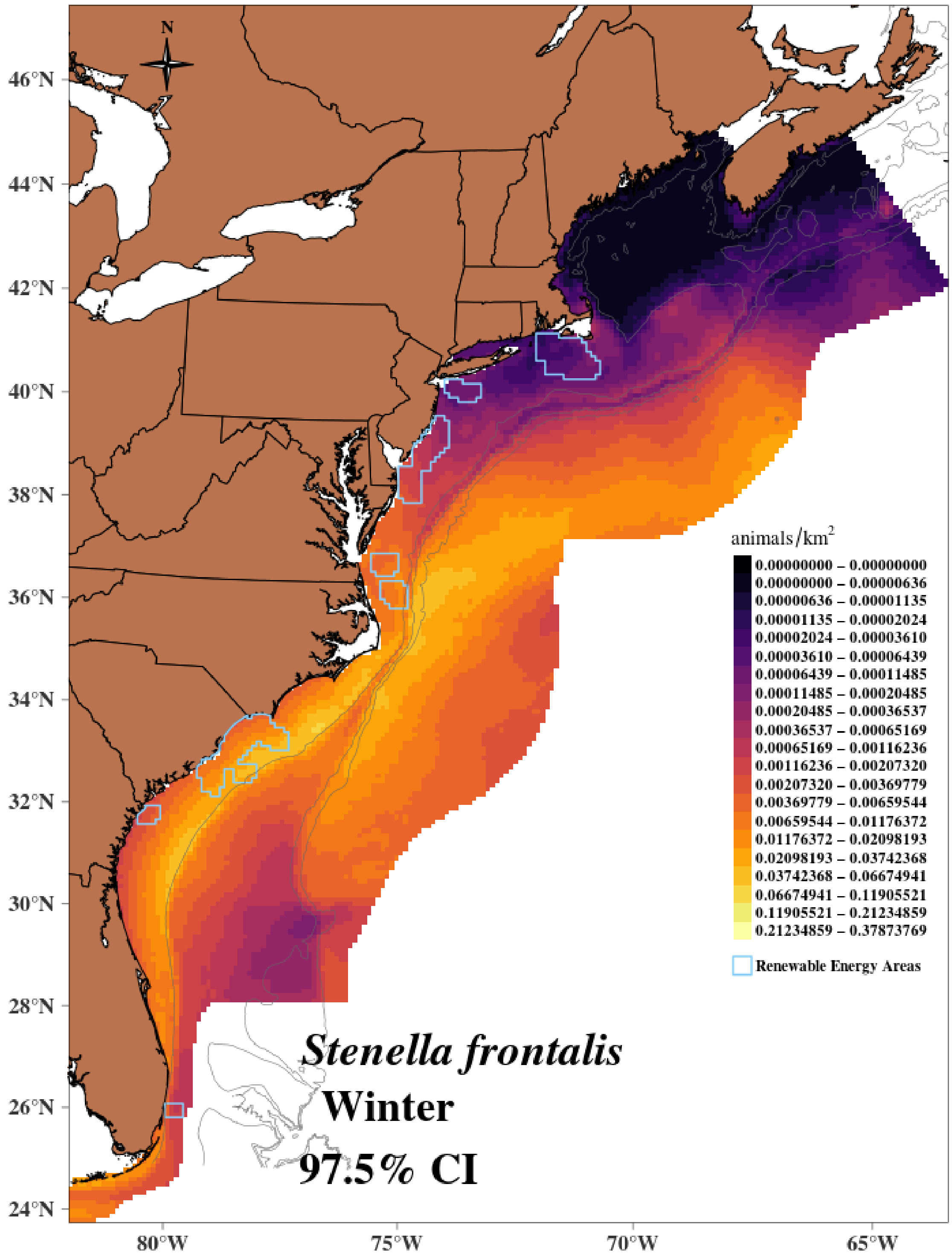

Figure 16-20 Upper 97.5% confidence interval of the winter Atlantic spotted dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

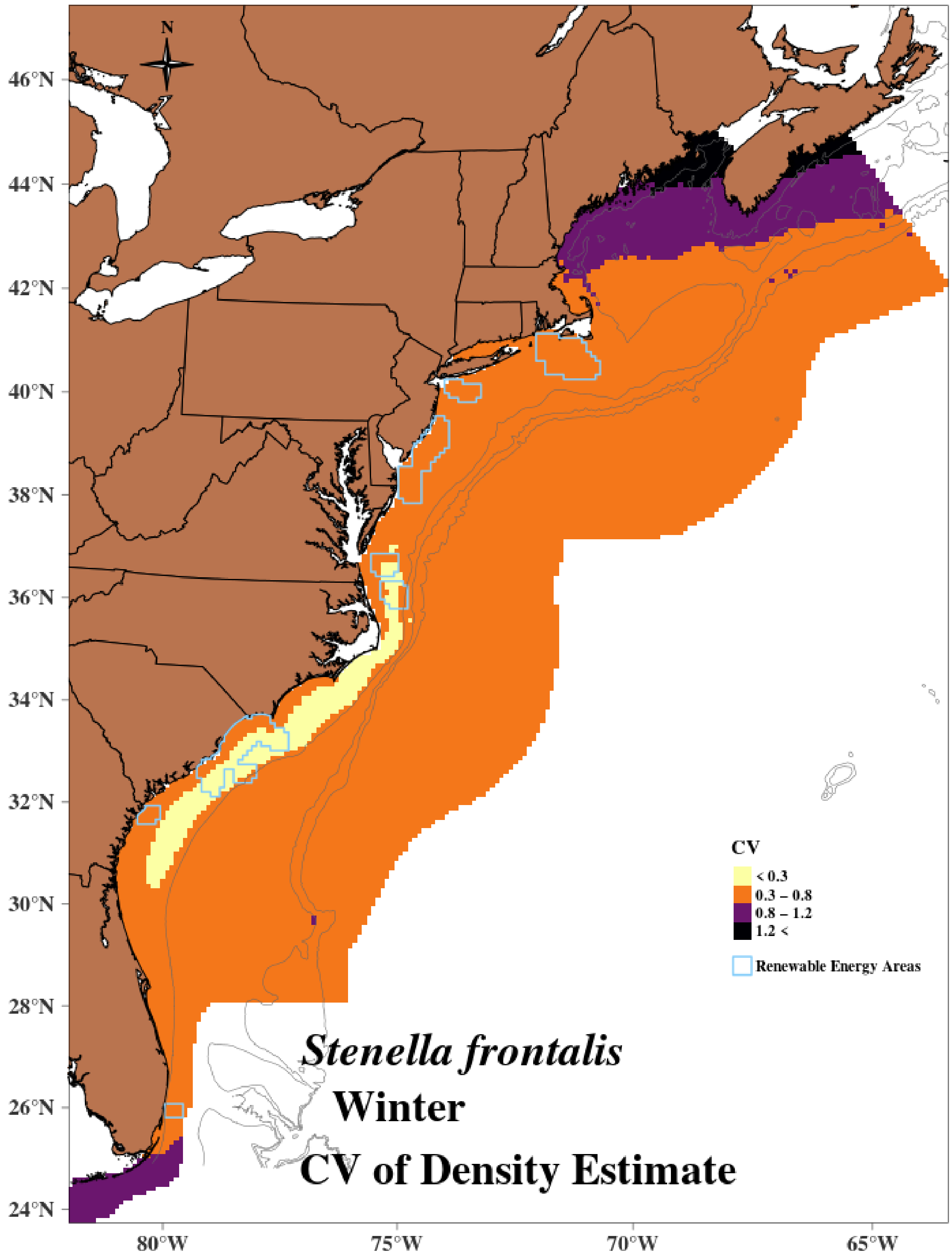

Figure 16-21 CV of winter Atlantic spotted dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

16.7 Offshore Energy Development Areas

Table 16-6 Atlantic spotted dolphin abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	1.1	0.42	
	NY	0.3	0.43	
	NJ	2.1	0.39	1.0 4.5
	DE/MD	4.1	0.35	
	VA	20.6	0.29	
	NC	52.4	0.28	
	NC/SC	328.5	0.24	
Summer (Jun–Aug)	RI/MA	2.0	0.39	1.0 4.2
	NY	0.7	0.41	
	NJ	6.9	0.36	
	DE/MD	13.8	0.31	.0
	VA	69.1	0.26	
	NC	189.5	0.25	
	NC/SC	478.4	0.24	.0
Fall (Sep–Nov)	RI/MA	1.0	0.40	
	NY	0.3	0.43	
	NJ	3.3	0.38	
	DE/MD	6.5	0.33	
	VA	35.6	0.28	
	NC	101.5	0.27	
	NC/SC	359.5	0.27	
Winter (Dec–Feb)	RI/MA	0.3	0.52	
	NY	0.1	0.48	0.0 0.3
	NJ	2.1	0.43	
	DE/MD	3.6	0.39	
	VA	10.7	0.30	6.0 19.1
	NC	18.2	0.30	
	NC/SC	166.5	0.27	

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

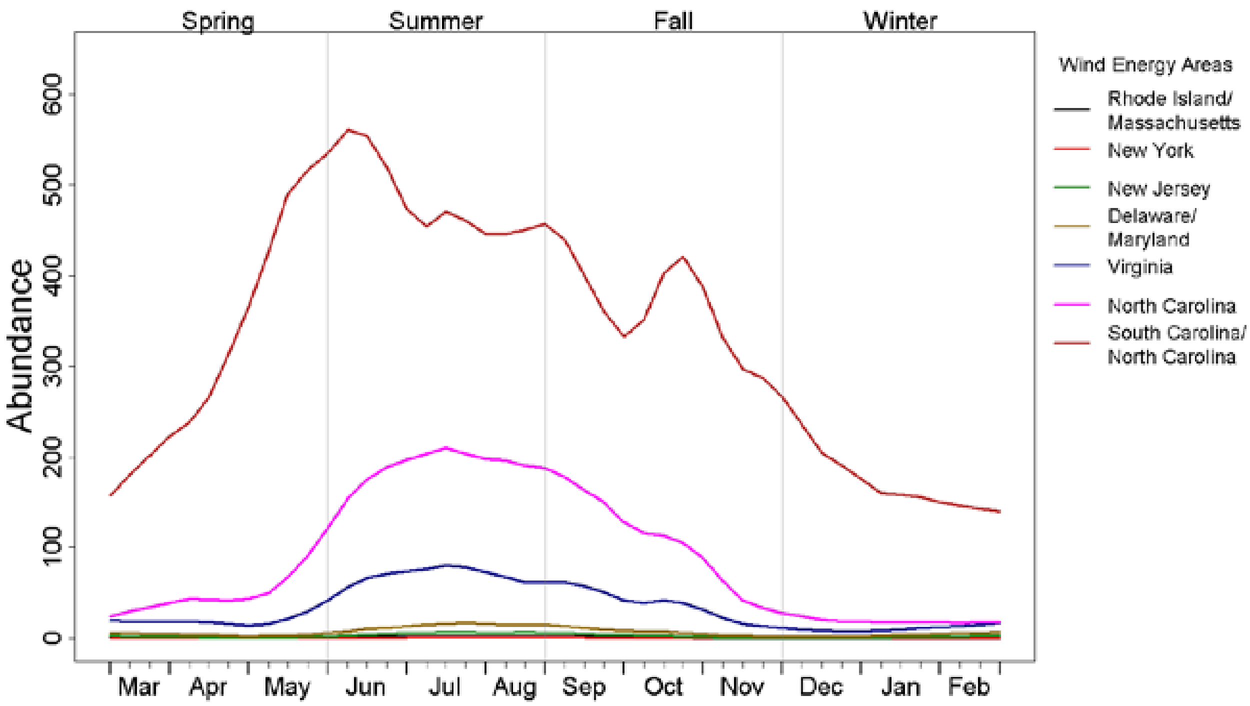

Figure 16-22 Average seasonal abundance of Atlantic spotted dolphins in the wind-energy study areas

17 Striped Dolphin (*Stenella coeruleoalba*)

Figure 17-1 Striped Dolphins
Image collected under MMPA Research permit #17355. Credit: NOAA/NEFSC/Todd Pusser.

17.1 Data Collection

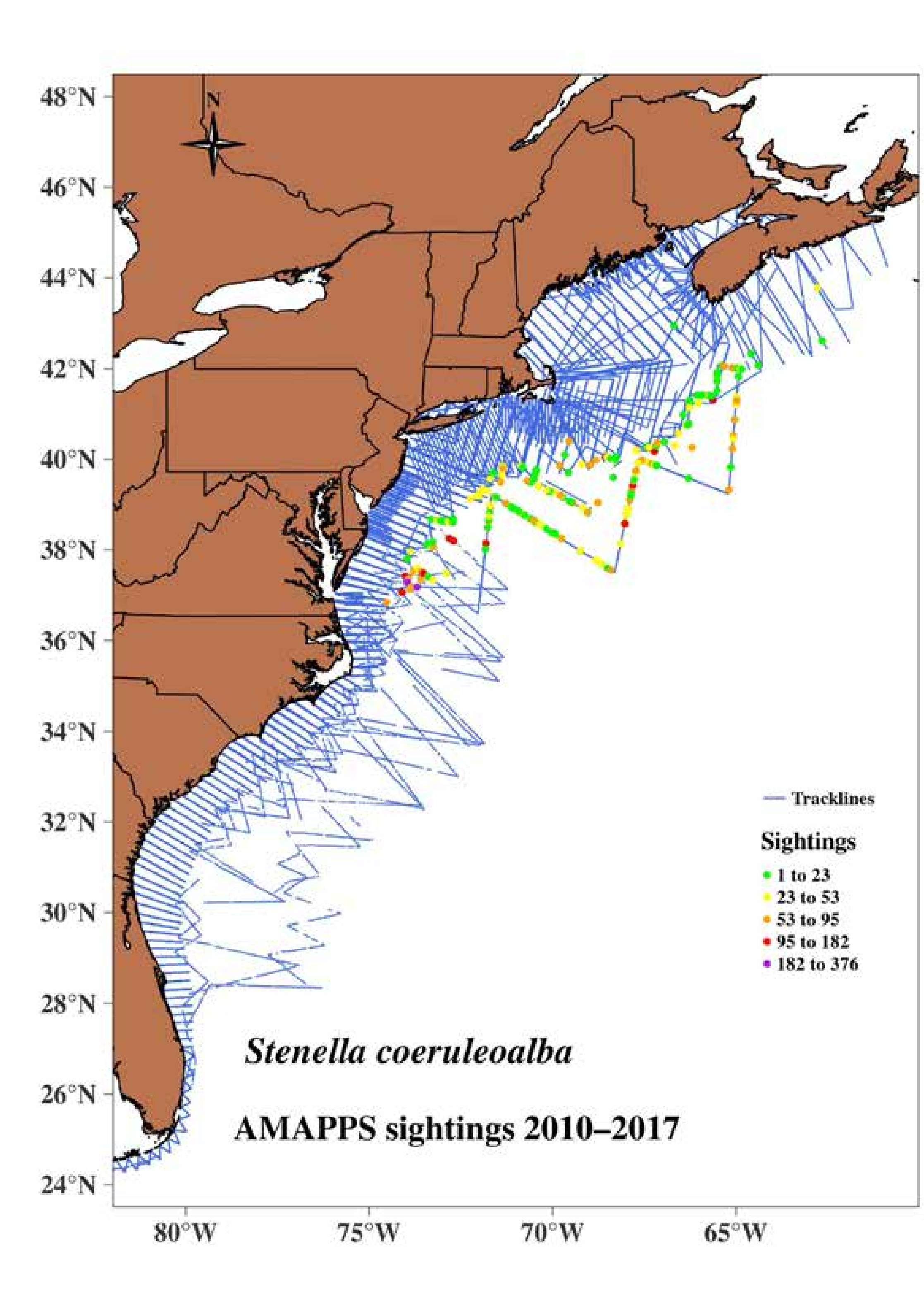

Figure 17-2 Distribution of track lines and striped dolphin sightings 2010 to 2017

Table 17-1 AMAPPS research effort 2010 to 2017 and striped dolphin sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	229	9,511
NE Shipboard	Fall	1,065	8	437
NE Aerial	Spring	13,314	1	100
NE Aerial	Summer	25,867	5	86
NE Aerial	Fall	37,850	8	385
NE Aerial	Winter	12,179	2	50
SE Shipboard	Spring	8,853	4	66
SE Shipboard	Summer	12,968	11	1,397
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	1	110
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

17.2 Mark-Recapture Distance Sampling Analysis

Table 17-2 Intermediate parameters in striped dolphin mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 3	distance + group size + sea state	300	distance + glare	LT20-330	HR	0.78	0.08	0.40	0.99	1.00
NE–aerial group 9	distance * observer + sea state + group size	300	distance + glare + group size	300	HN	0.56	0.10	0.38	0.61	0.84
NE–shipboard group 2	distance * observer + sea state + group size	5000	distance + sea state	5000	HR	0.72	0.07	0.99	0.95	0.94
SE–shipboard group 1	distance + group size	2700	distance + sea state + glare	2700	HR	0.62	0.09	0.23	0.98	0.98

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

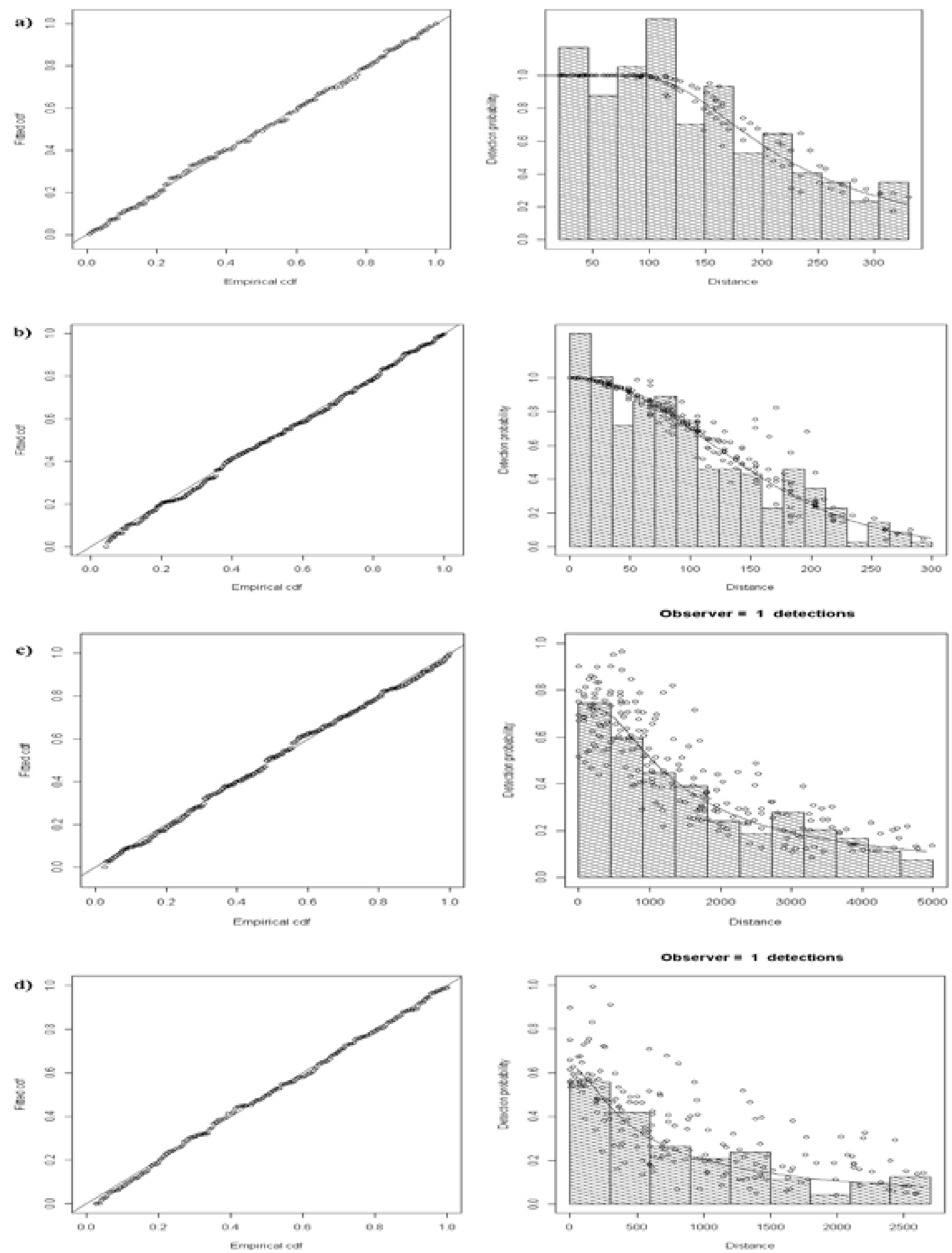

Figure 17-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 3; b) NE-aerial analysis set 9; c) NE-shipboard analysis set 2; d) SE-shipboard analysis set 1.

17.3 Generalized Additive Model Analysis

Table 17-3 2010 to 2017 density-habitat model output for striped dolphins

Covariates	Edf	Ref.df	F	C.dev	p-value
s(chlfma)	1.01	4	4.80	5.96	<0.0001
s(sstfma)	1.08	4	4.85	5.63	<0.0001
s(dist2GSNw)	2.83	4	6.05	2.43	<0.0001
s(btemp)	2.56	4	5.57	2.37	<0.0001
s(depth)	3.70	4	27.45	31.23	<0.0001
s(lat)	2.98	4	13.61	23.99	<0.0001

Adjusted R^2 = 0.0213. Deviance explained = 71.6%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

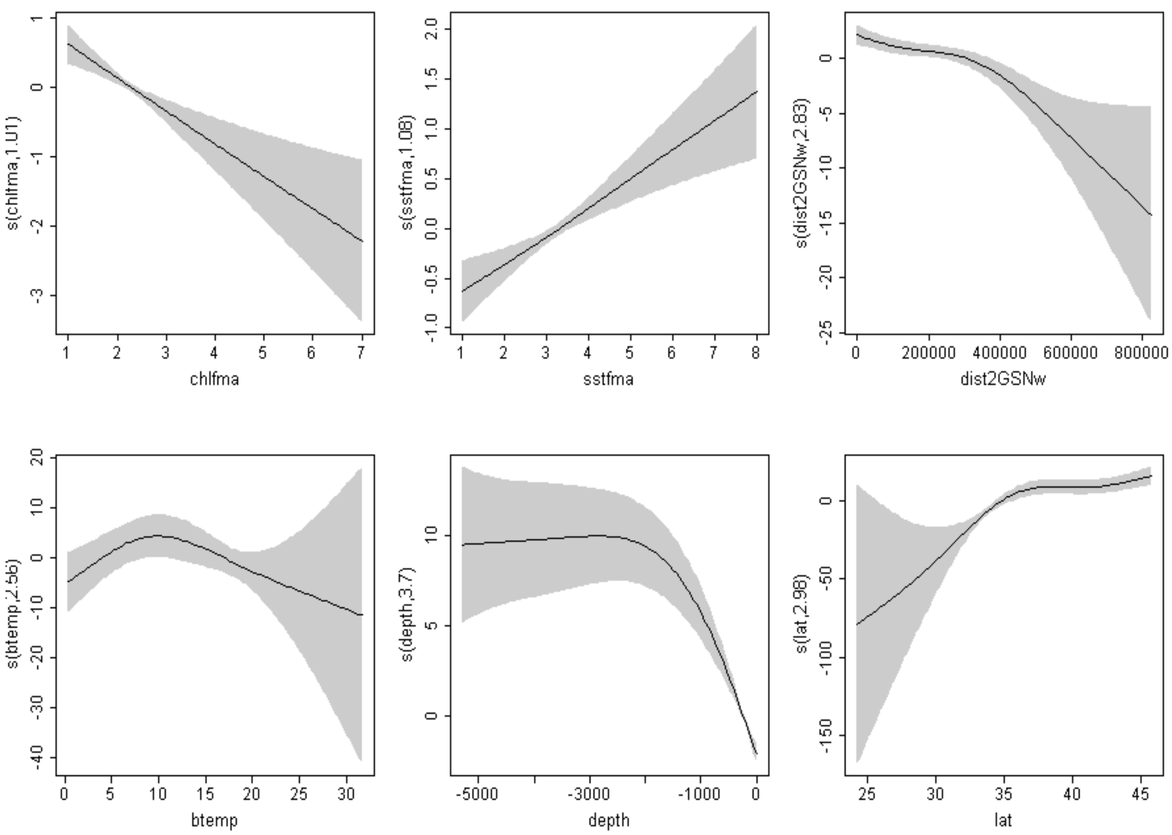

Figure 17-4 Striped dolphin density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

17.4 Model Cross-Validation

Table 17-4 Diagnostic statistics from the striped dolphin density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.233	Fair to good
MAPE	Mean absolute percentage error	Non-zero density	76.875	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.138	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.039	Excellent

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

17.5 Abundance Estimates for AMAPPS Study Area

Table 17-5 Striped dolphin average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	50,904	0.33	27,107–95,593
Summer (June–August)	61,195	0.33	32,587–114,919
Fall (September–November)	48,944	0.34	25,595–93,591
Winter (December–February)	46,238	0.34	24,180–88,417
Summer 2011 U.S. surveys[1]	54,807	0.30	
Summer 2011 U.S. surveys[1]	67,036	0.29	

[1]Hayes et al. 2020

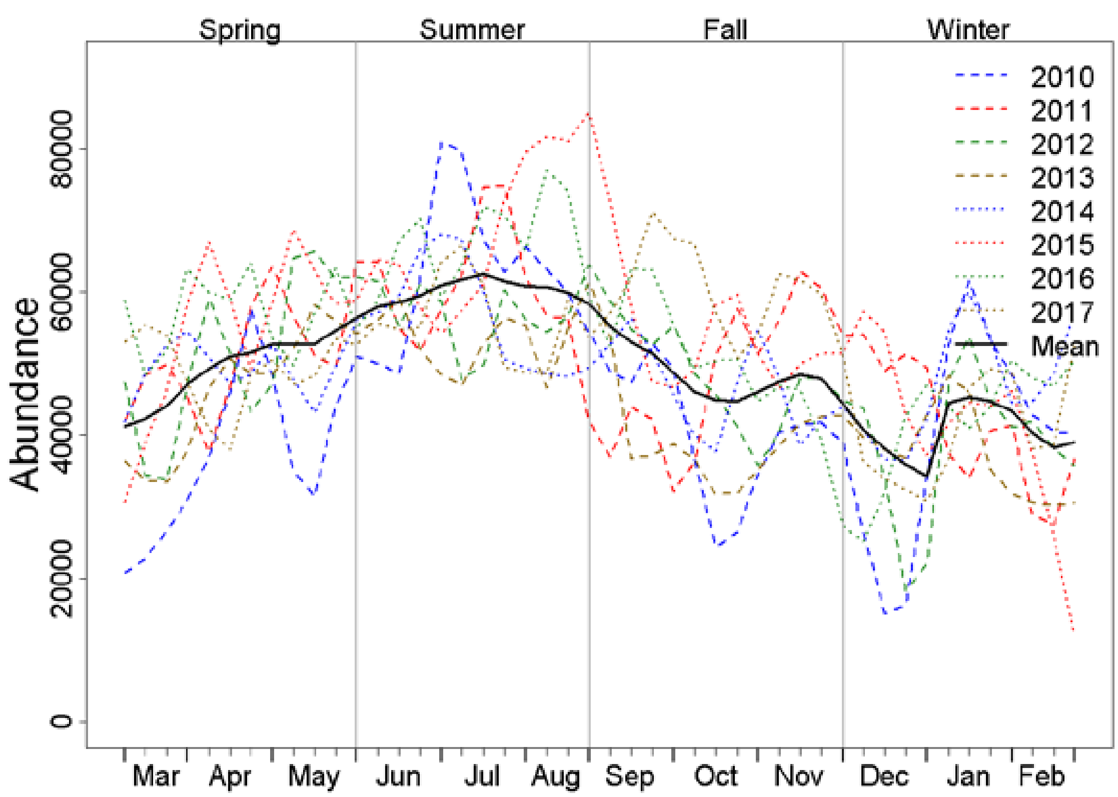

Figure 17-5 Annual abundance trends for striped dolphins in the AMAPPS study area

17.6 Seasonal Prediction Maps

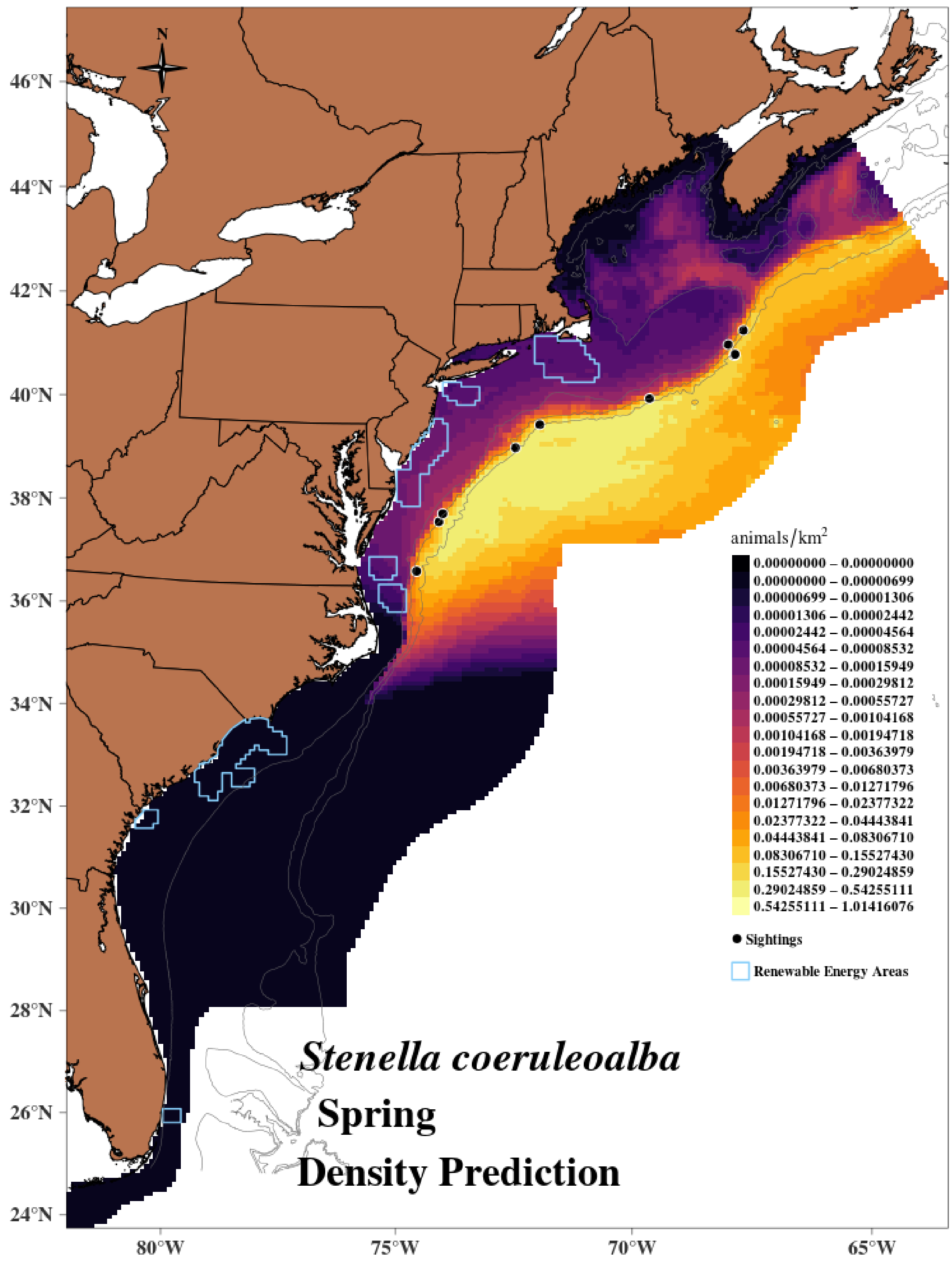

Figure 17-6 Striped dolphin spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

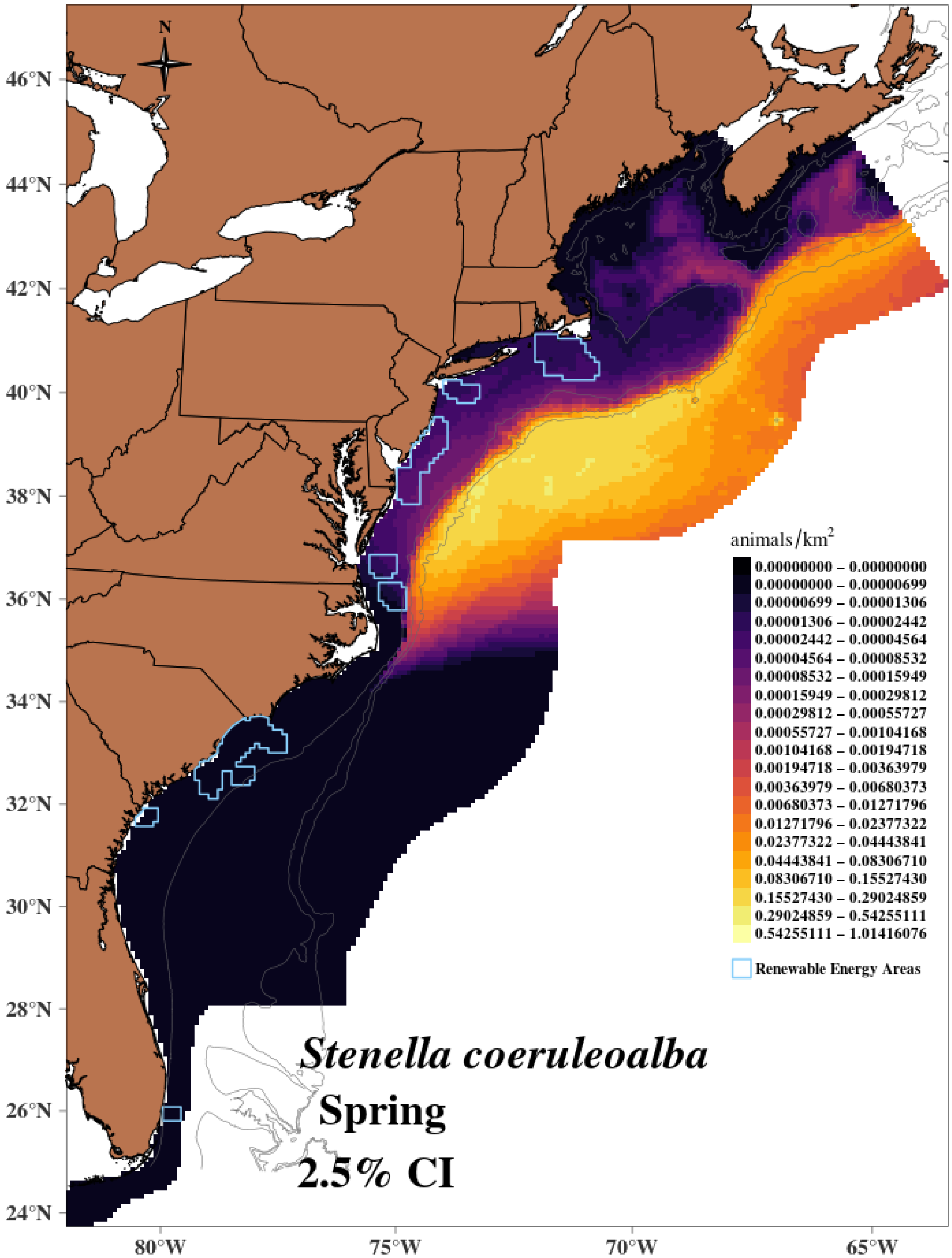

Figure 17-7 Lower 2.5% confidence interval of the spring striped dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

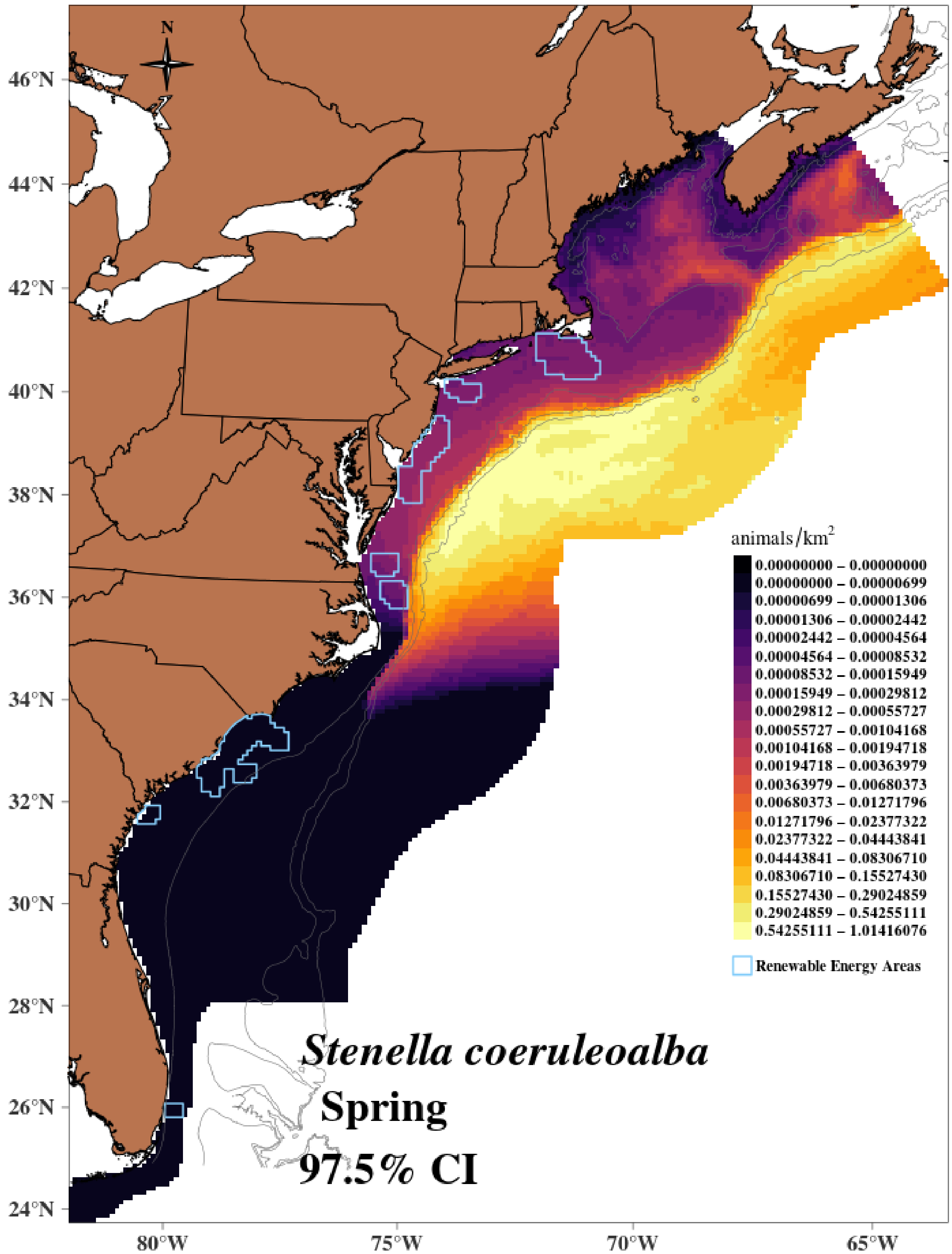

Figure 17-8 Upper 97.5% confidence interval of the spring striped dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

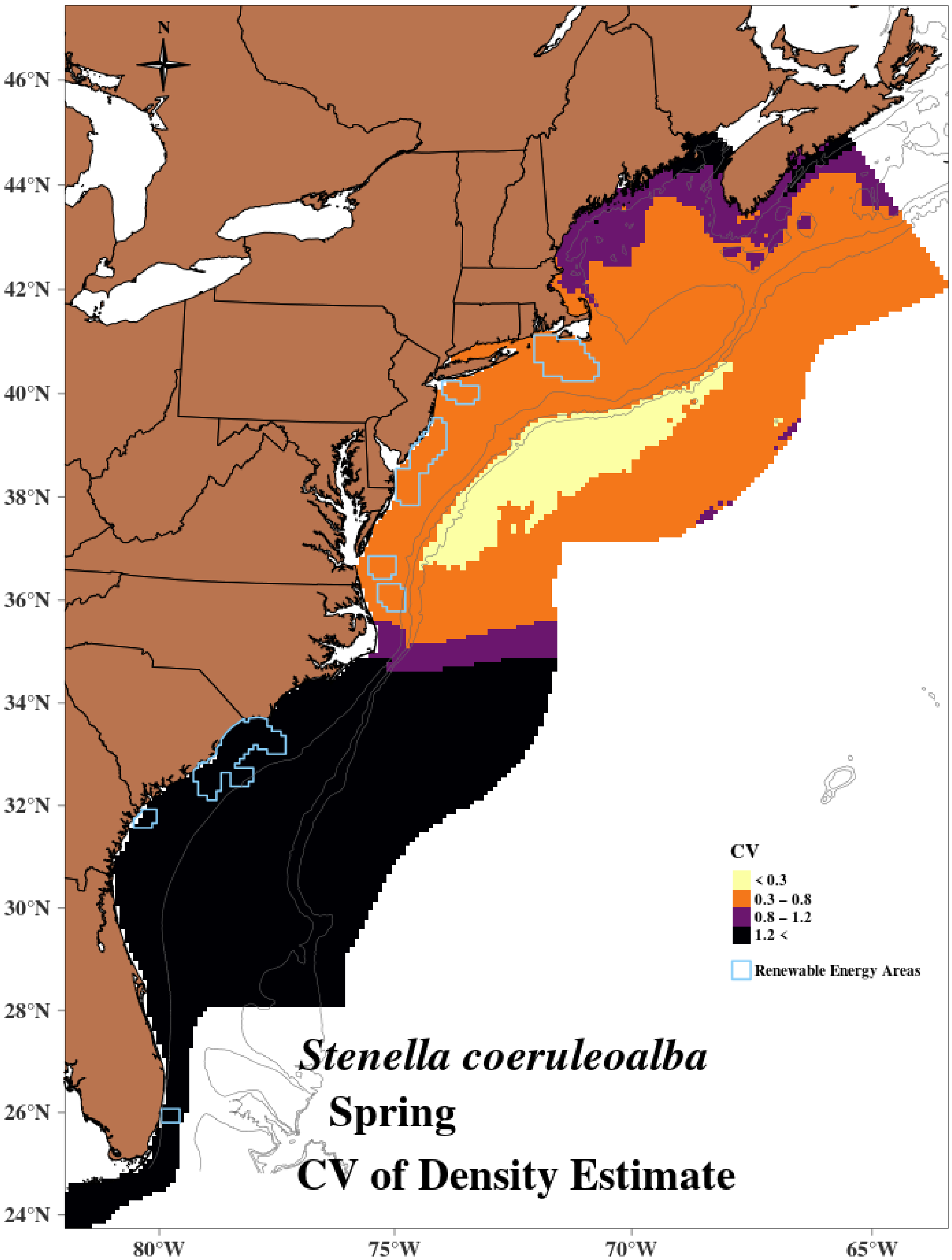

Figure 17-9 CV of spring striped dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

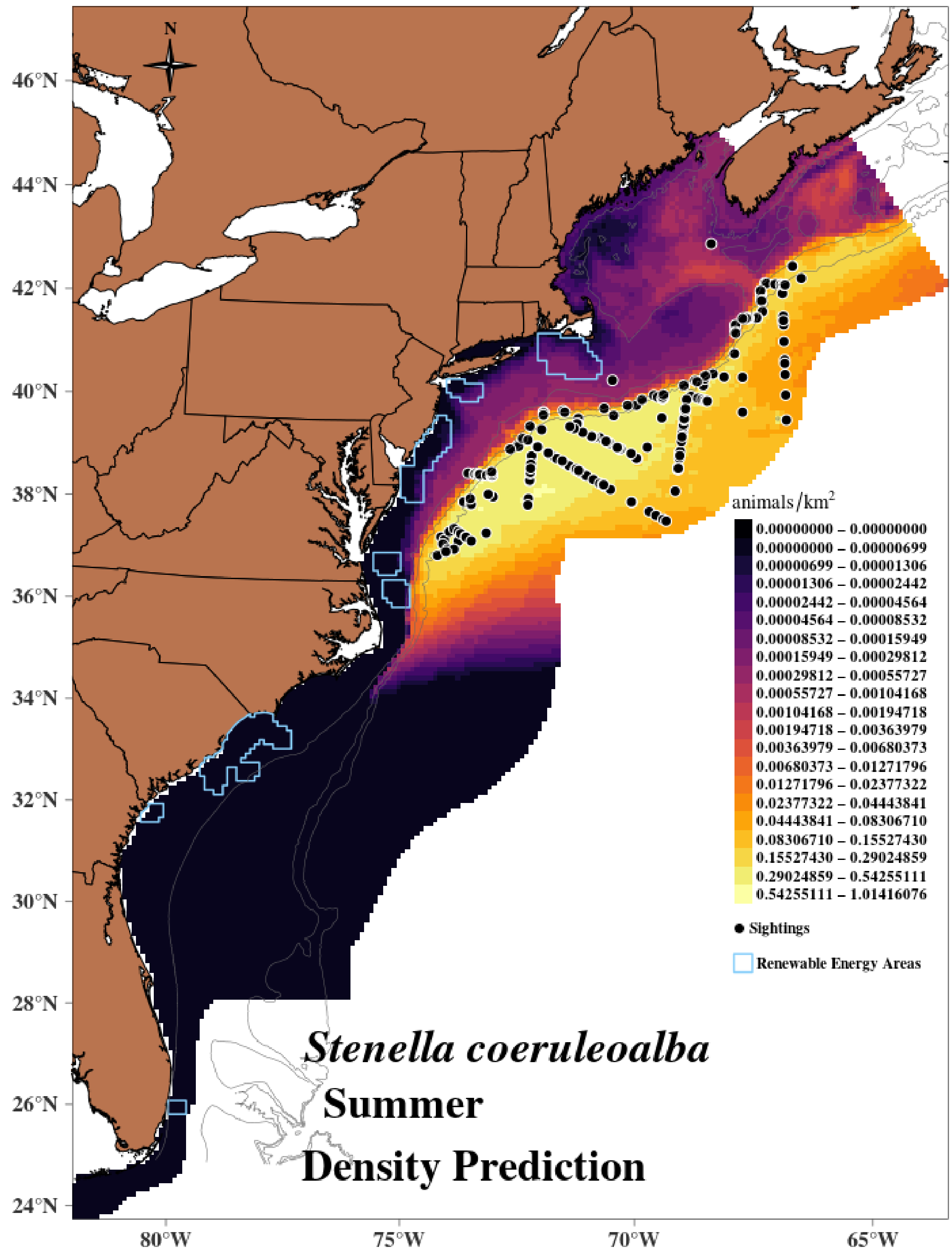

Figure 17-10 Striped dolphin summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

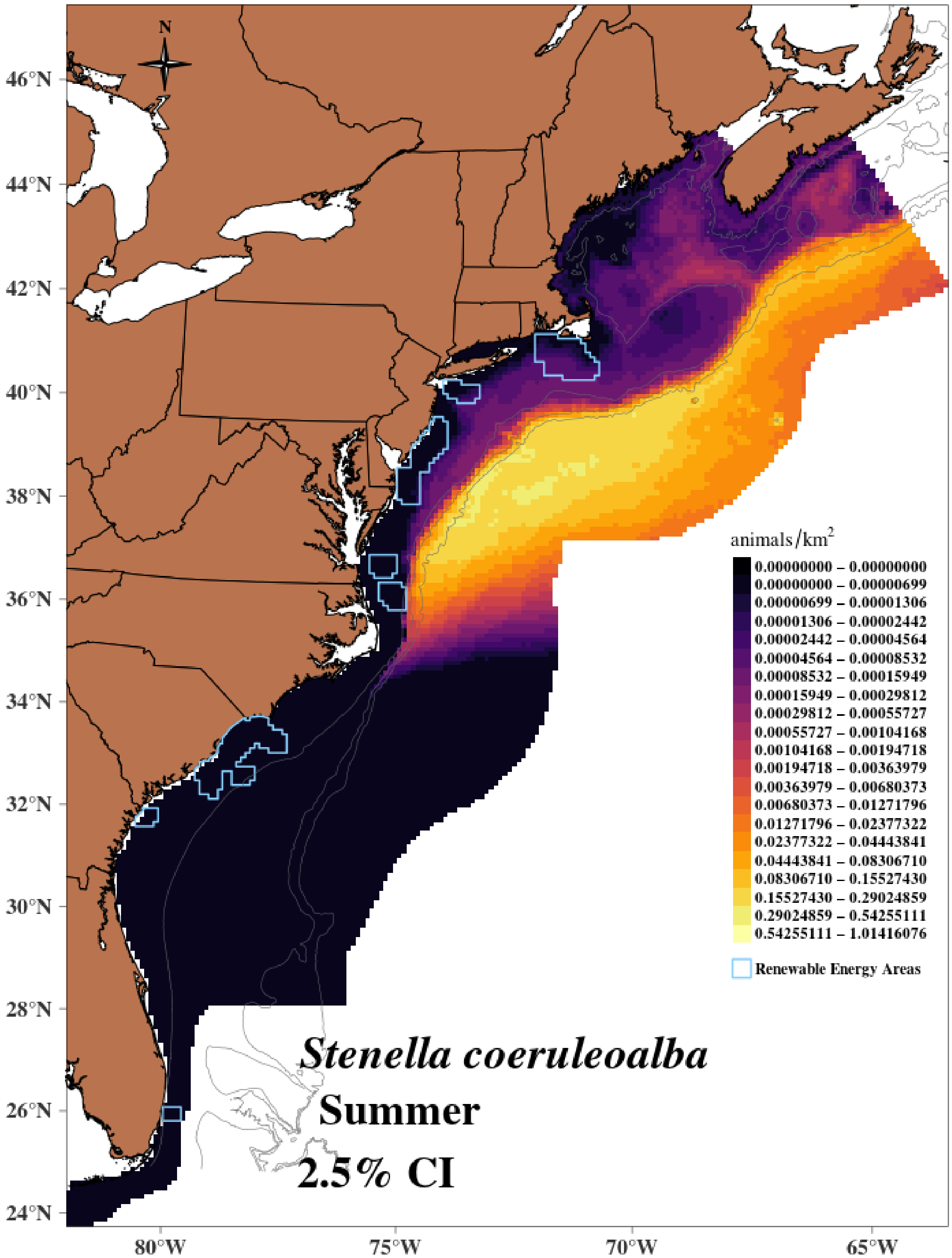

Figure 17-11 Lower 2.5% confidence interval of the summer striped dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

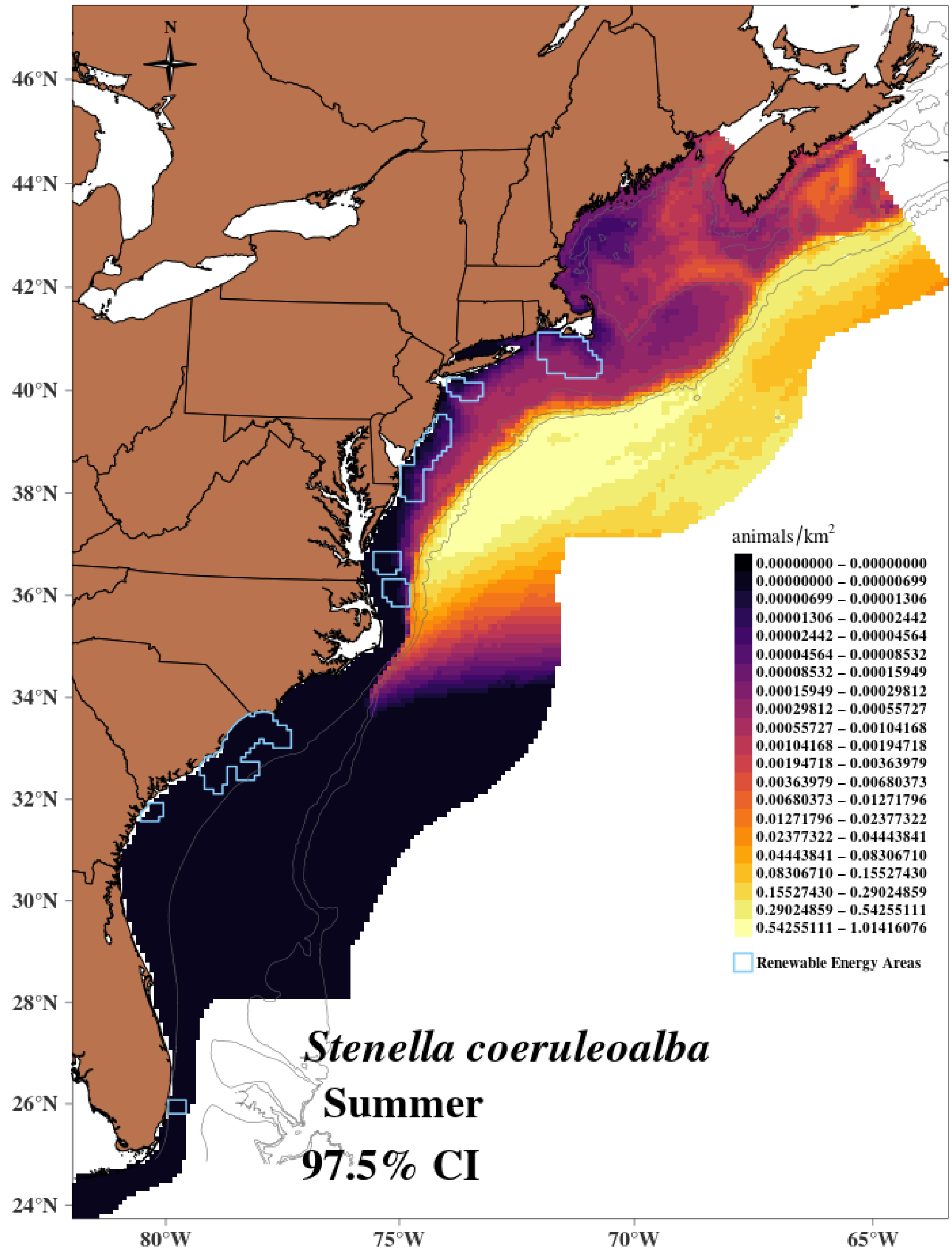

Figure 17-12 Upper 97.5% confidence interval of the summer striped dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

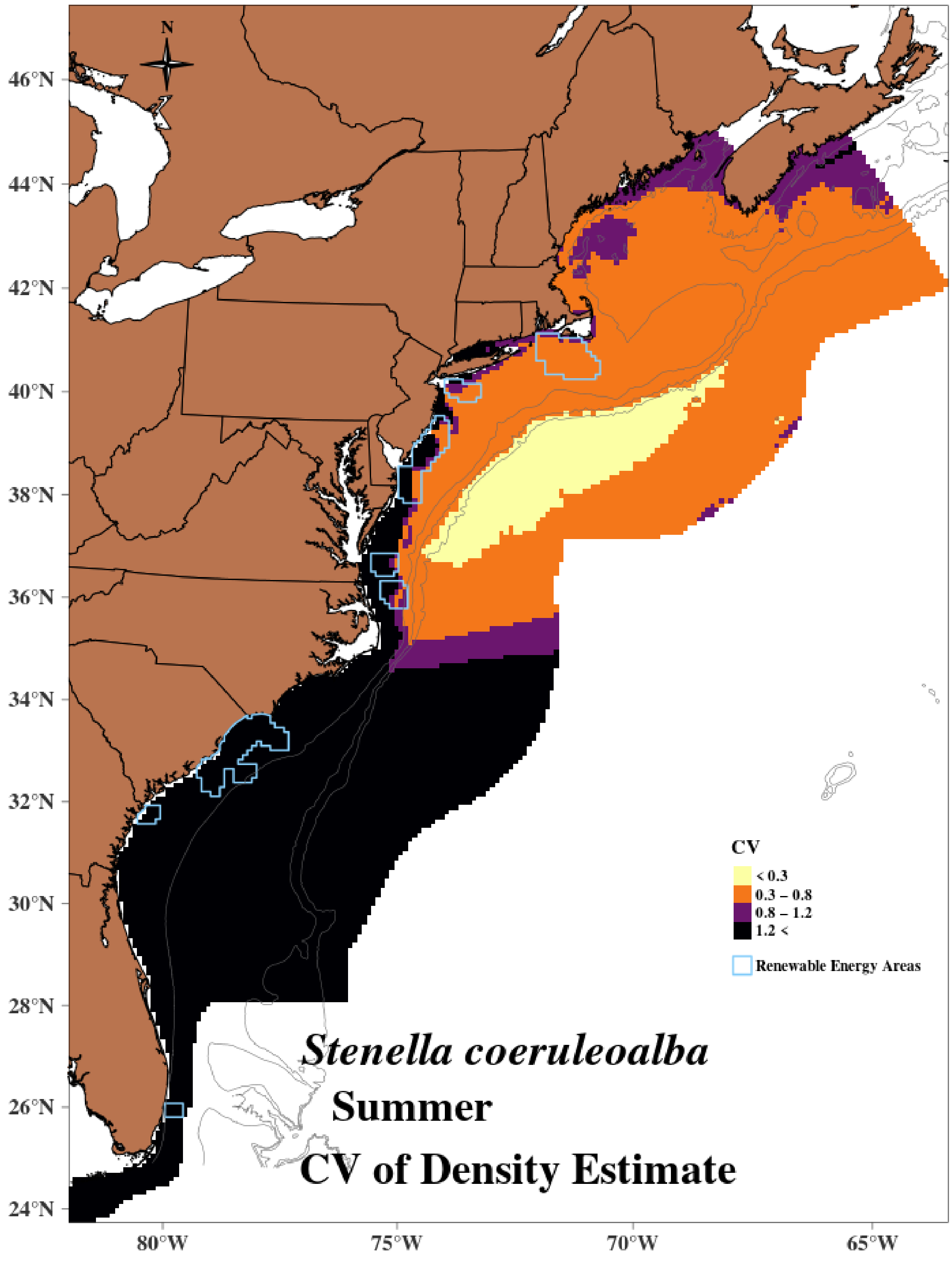

Figure 17-13 CV of summer striped dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

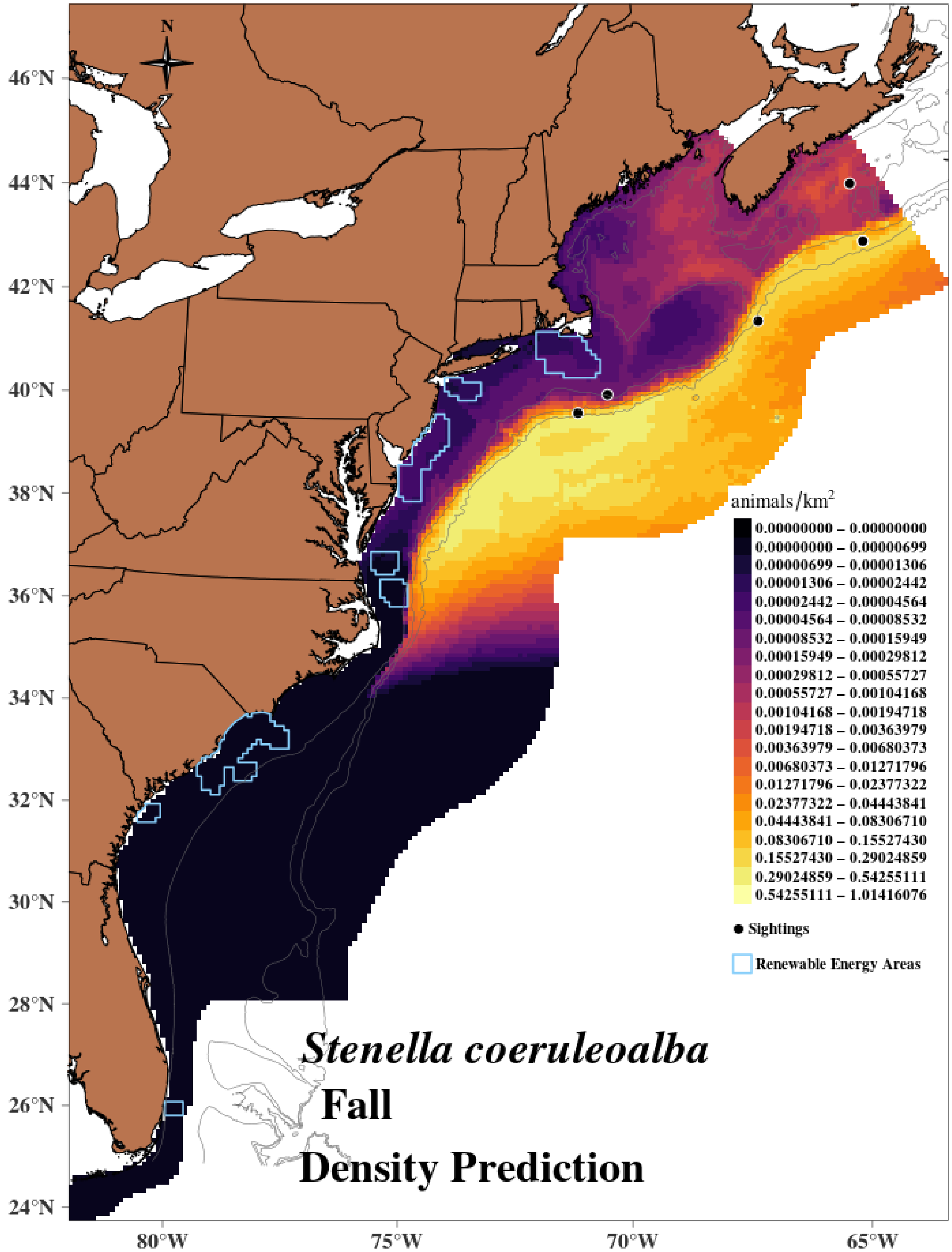

Figure 17-14 Striped dolphin fall average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

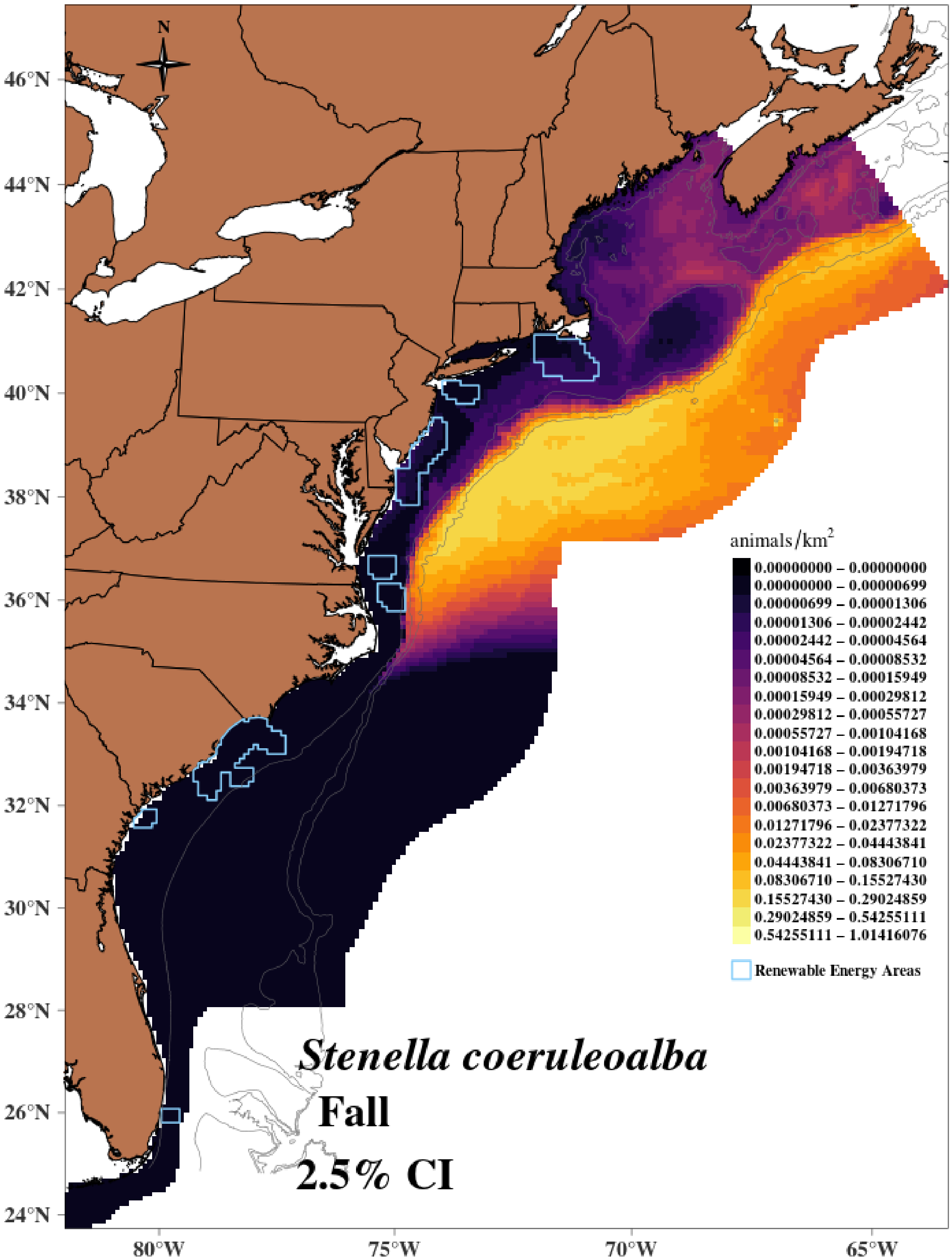

Figure 17-15 Lower 2.5% confidence interval of the fall striped dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

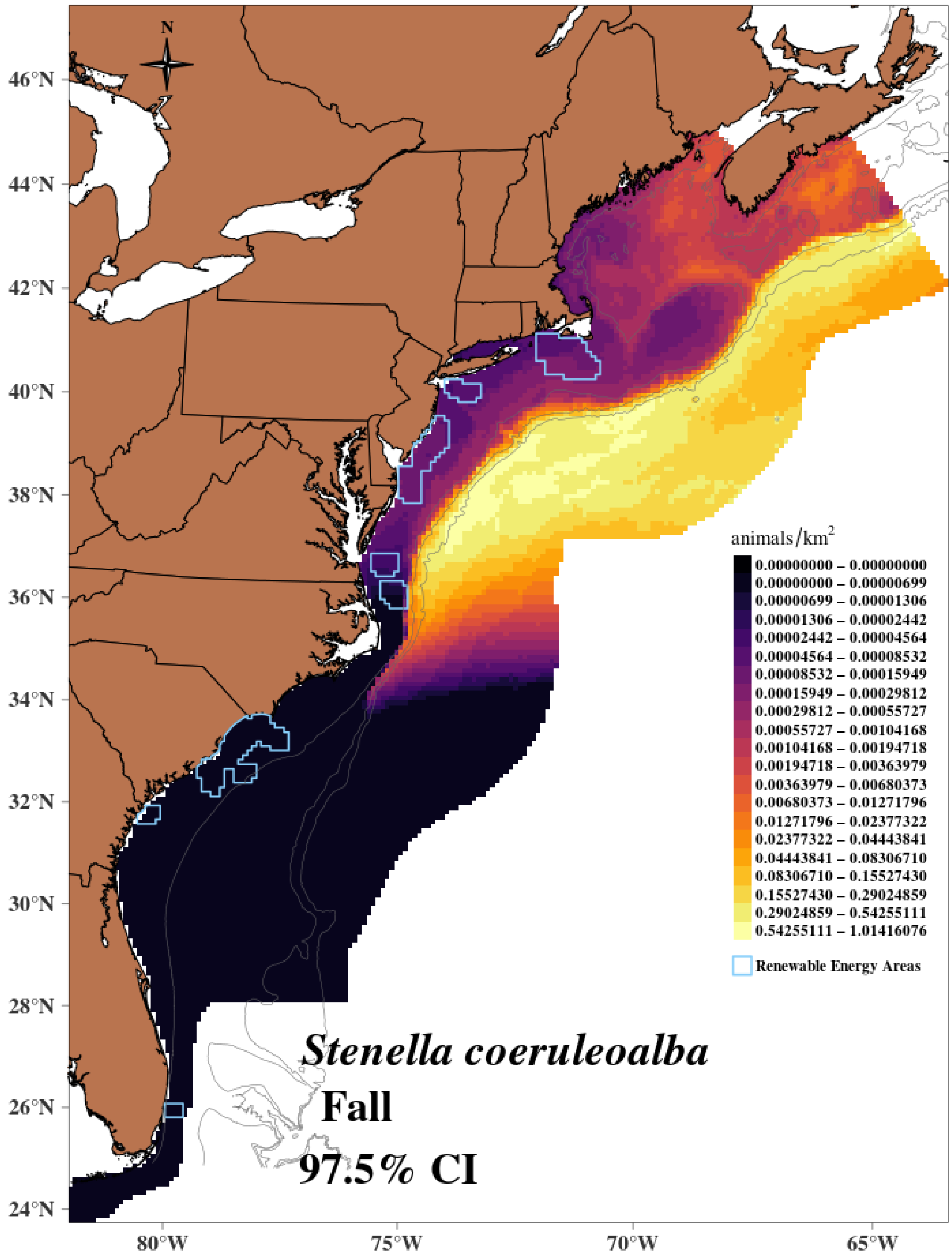

Figure 17-16 Upper 97.5% confidence interval of the fall striped dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

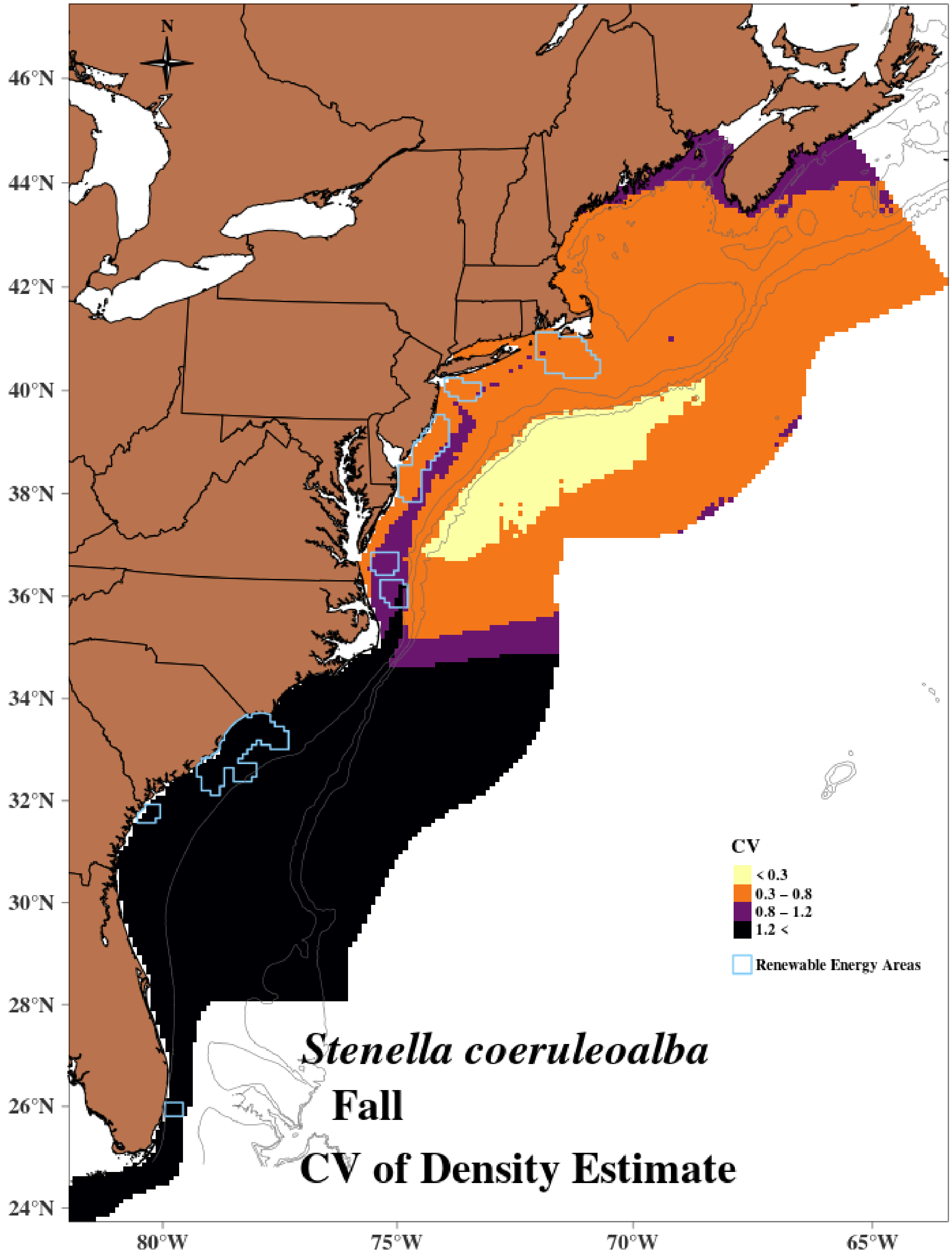

Figure 17-17 CV of fall striped dolphin density estimates

CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

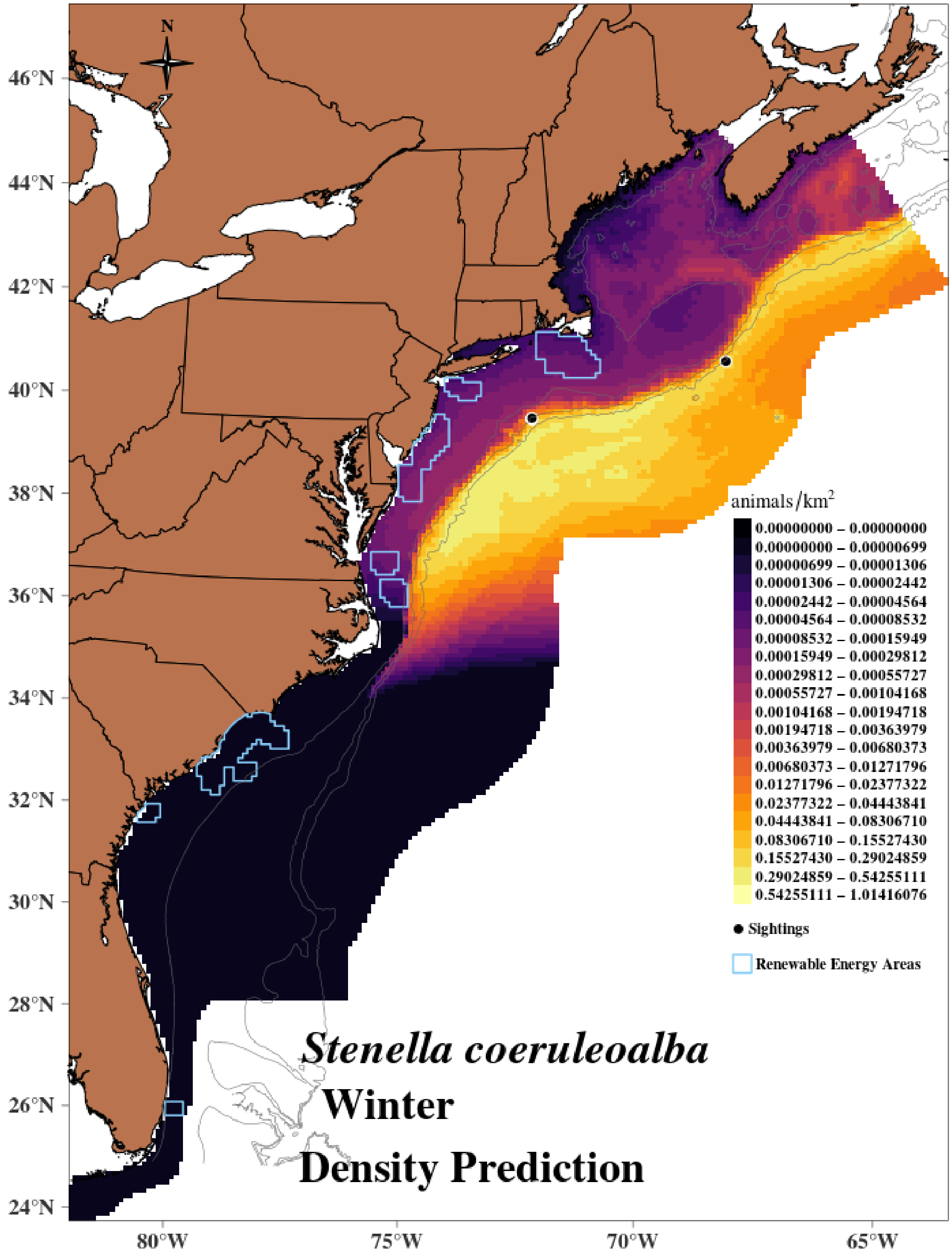

Figure 17-18 Striped dolphin winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.
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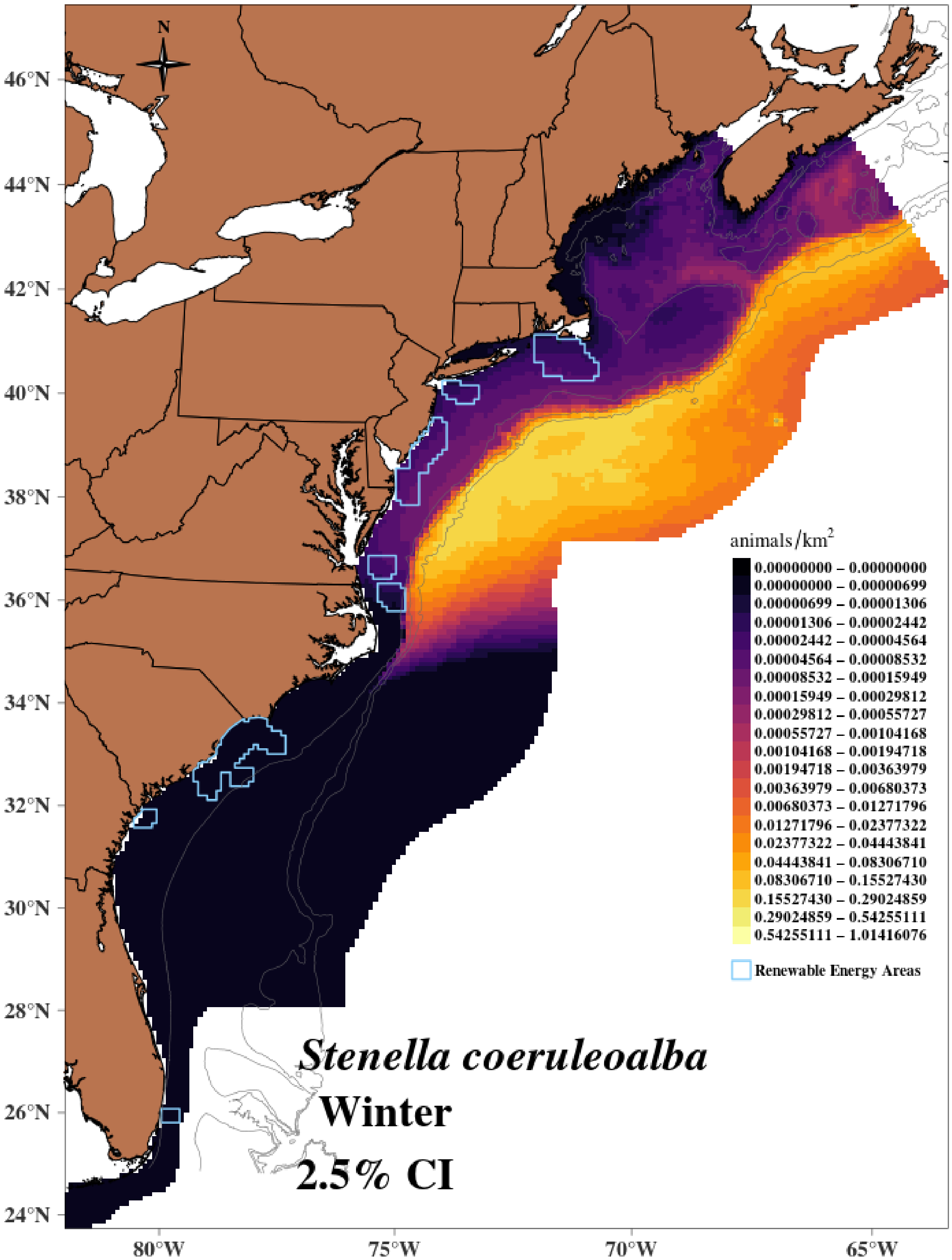

Figure 17-19 Lower 2.5% confidence interval of the winter striped dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

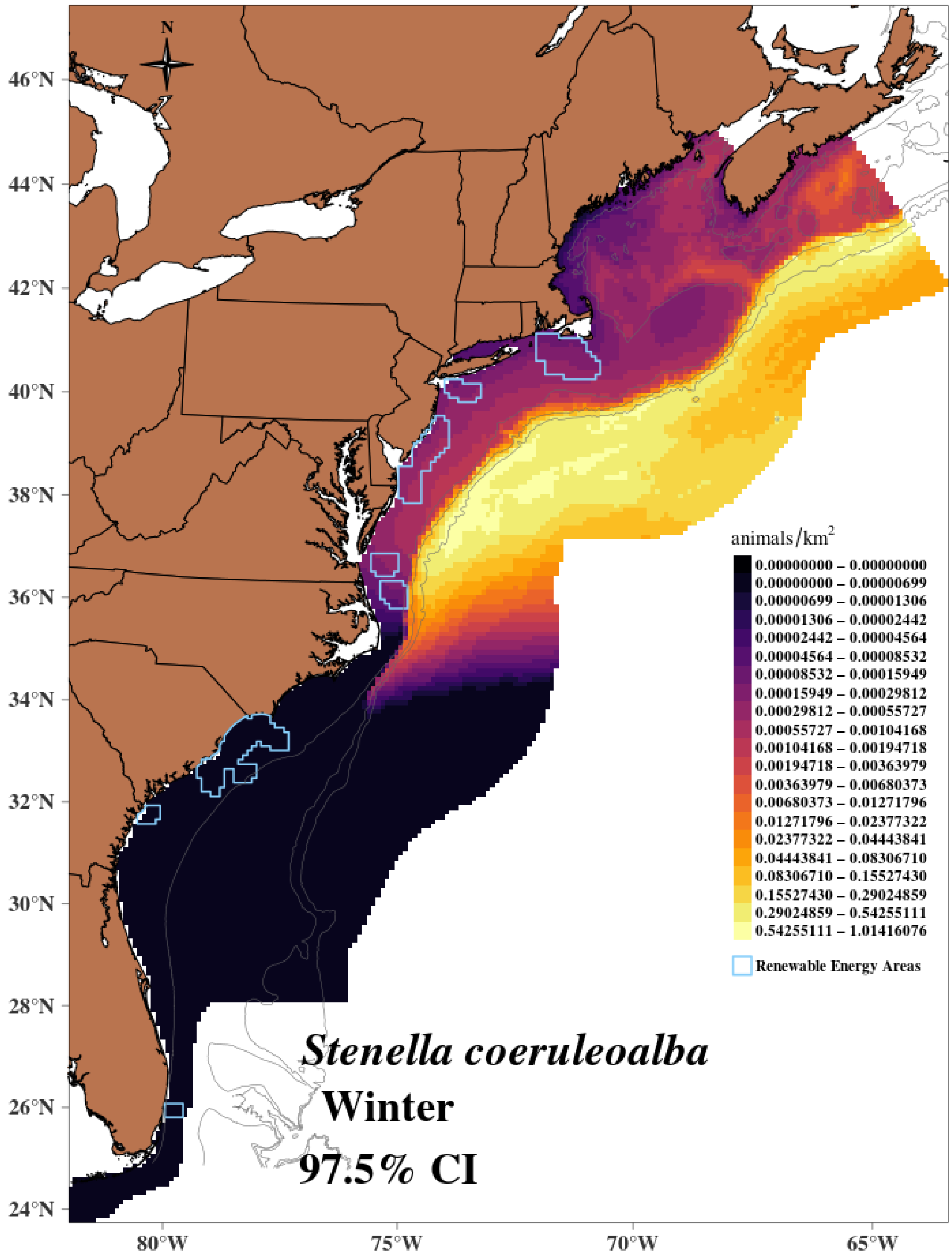

Figure 17-20 Upper 97.5% confidence interval of the winter striped dolphin density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

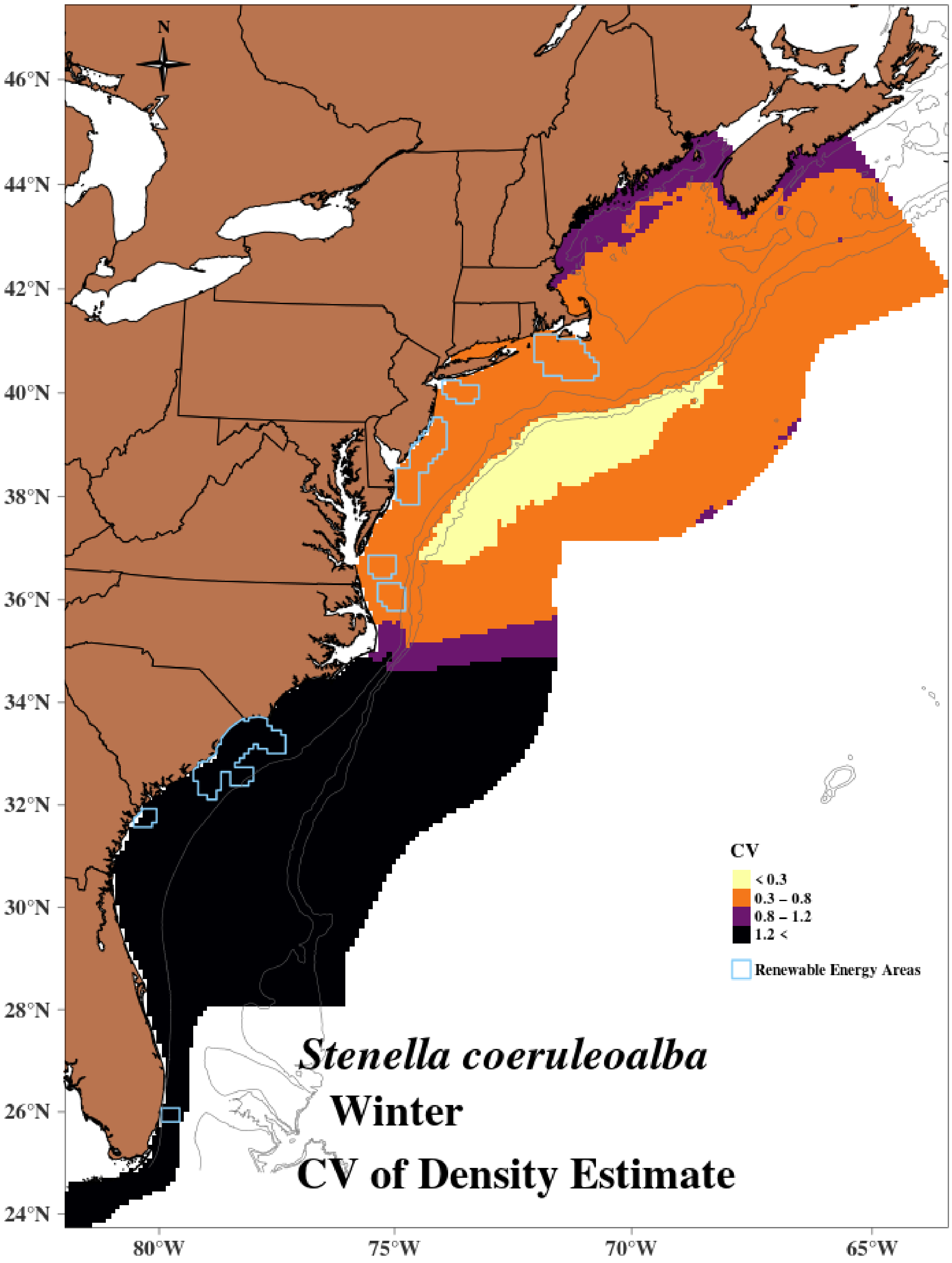

Figure 17-21 CV of winter striped dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

17.7 Offshore Energy Development Areas

Table 17-6 Striped dolphin abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	0.9	0.61	
	NY	0.2	0.61	
	NJ	1.0	0.57	
	DE/MD	0.7	0.58	.0
	VA	0.2	0.63	
	NC	0.1	0.65	0.0 0.4
	NC/SC	0.0	2.52	0.0 0.0
Summer (Jun–Aug)	RI/MA	1.3	0.56	
	NY	0.1	0.60	0.0 0.3
	NJ	0.0	0.93	0.0 0.2
	DE/MD	0.0	0.76	0.0 0.1
	VA	0.0	0.91	0.0 0.0
	NC	0.0	0.84	0.0 0.1
	NC/SC	0.0	8.16	0.0 0.0
Fall (Sep–Nov)	RI/MA	0.5	0.65	
	NY	0.0	0.74	0.0 0.2
	NJ	0.2	0.68	
	DE/MD	0.1	0.70	0.0 0.5
	VA	0.0	0.92	0.0 0.1
	NC	0.0	1.02	0.0 0.1
	NC/SC	0.0	2.74	0.0 0.0
Winter (Dec–Feb)	RI/MA	1.1	0.56	
	NY	0.2	0.61	
	NJ	1.1	0.57	.0
	DE/MD	0.8	0.57	
	VA	0.3	0.60	
	NC	0.1	0.66	0.0 0.4
	NC/SC	0.0	2.49	0.0 0.0

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

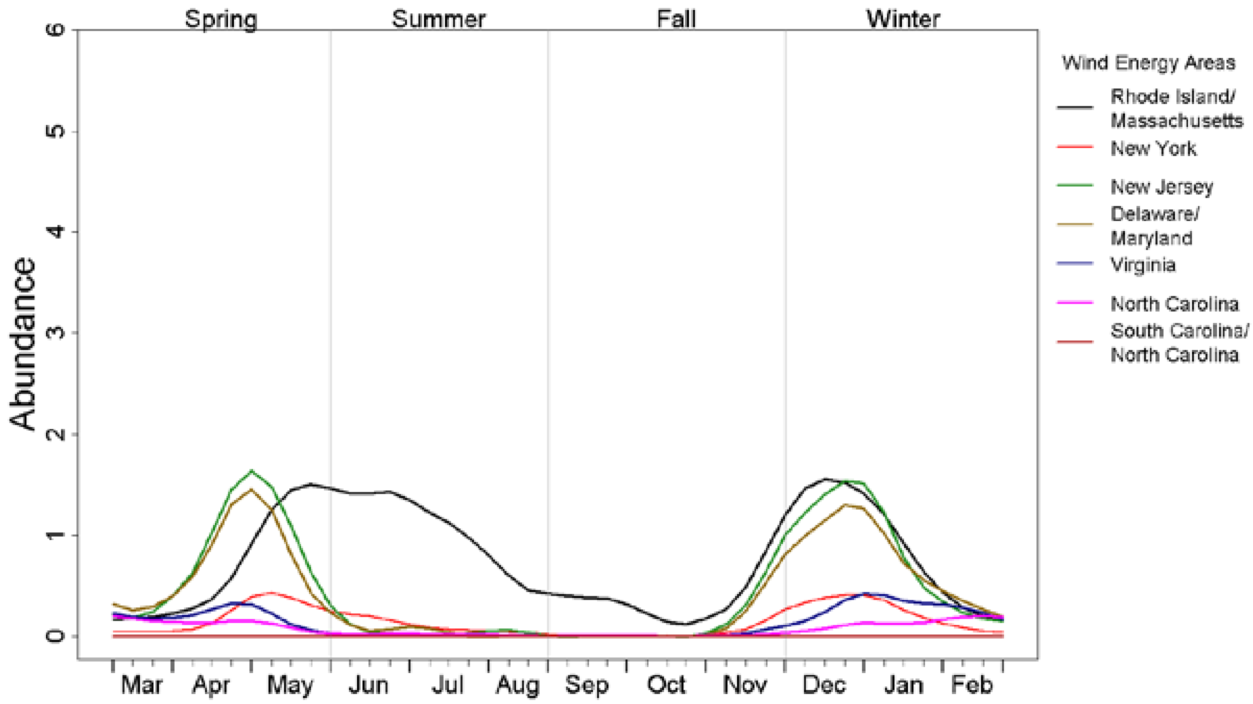

Figure 17-22 Average seasonal abundance of striped dolphins in the wind-energy study areas

18 Common Bottlenose Dolphin (*Tursiops truncatus*)

Figure 18-1 Common bottlenose dolphins
Image collected under MMPA Research permit #17355. Credit: NOAA/NEFSC/Corey Accardo

18.1 Data Collection

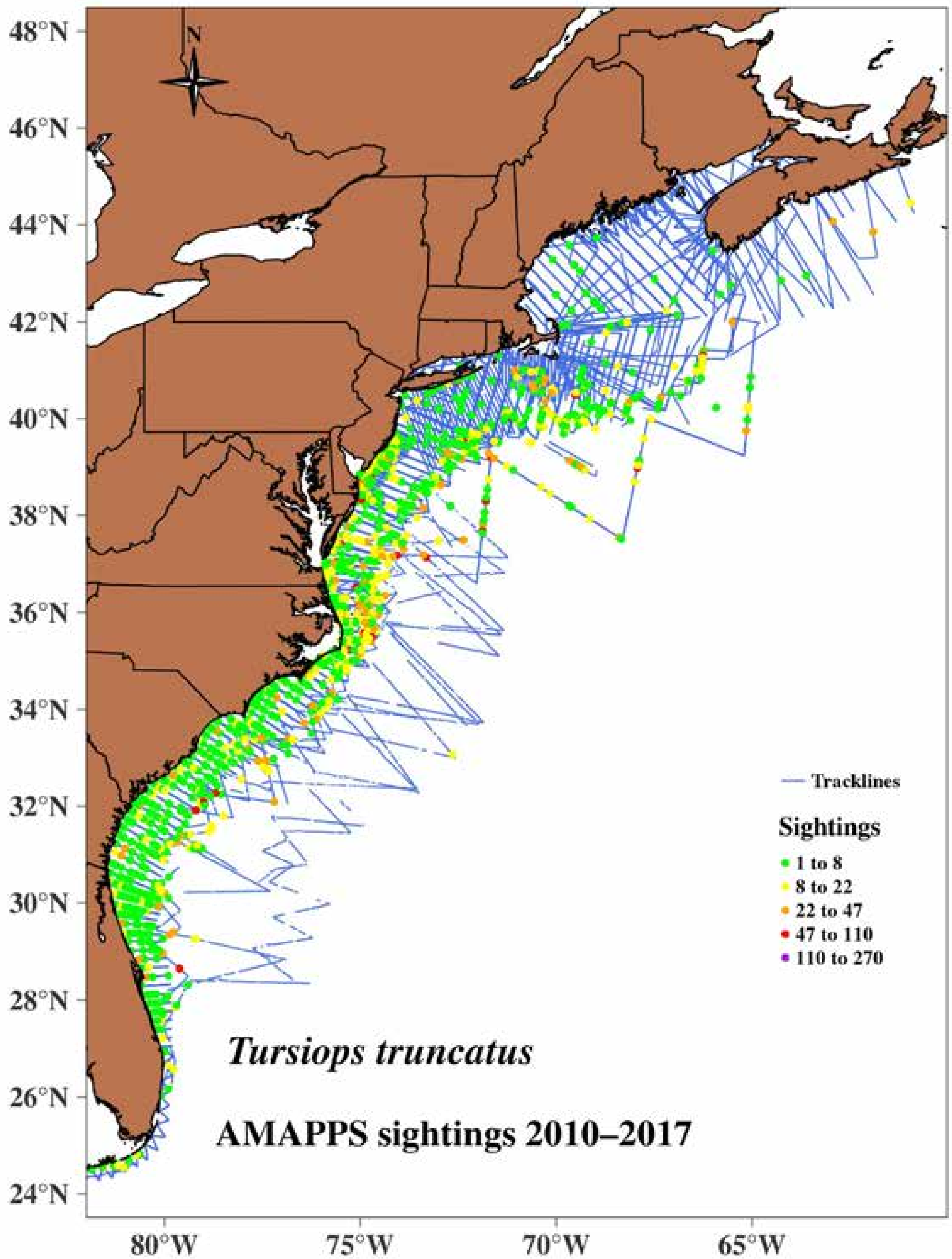

Figure 18-2 Distribution of track lines and common bottlenose dolphin sightings 2010 to 2017

Table 18-1 AMAPPS research effort 2010 to 2017 and common bottlenose dolphin sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	345	3,865
NE Shipboard	Fall	1,065	16	186
NE Aerial	Spring	13,314	38	256
NE Aerial	Summer	25,867	28	178
NE Aerial	Fall	37,850	46	623
NE Aerial	Winter	12,179	7	36
SE Shipboard	Spring	8,853	26	390
SE Shipboard	Summer	12,968	134	2,352
SE Shipboard	Fall	3,012	55	1,213
SE Aerial	Spring	41,293	466	4,139
SE Aerial	Summer	28,236	312	3,144
SE Aerial	Fall	18,974	212	2,233
SE Aerial	Winter	8,950	83	812

18.2 Mark-Recapture Distance Sampling Analysis

Table 18-2 Intermediate parameters in common bottlenose dolphin mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
SE–aerial group 2	distance * observer + group size + sea state	340	distance + glare + group size	340	HR	0.86	0.02	0.12	0.93	0.70
NE–aerial group 4	distance * observer + group size + quality	450	distance + sea state + quality	450	HR	0.62	0.13	0.17	0.99	0.96
NE–shipboard group 3	distance * observer + group size + sea state	4000	distance + sea state	4000	HR	0.59	0.10	0.53	0.86	0.97
SE–shipboard group 2	distance * observer + sea state	2800	distance + glare	2800	HR	0.69	0.09	0.47	0.99	0.95

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

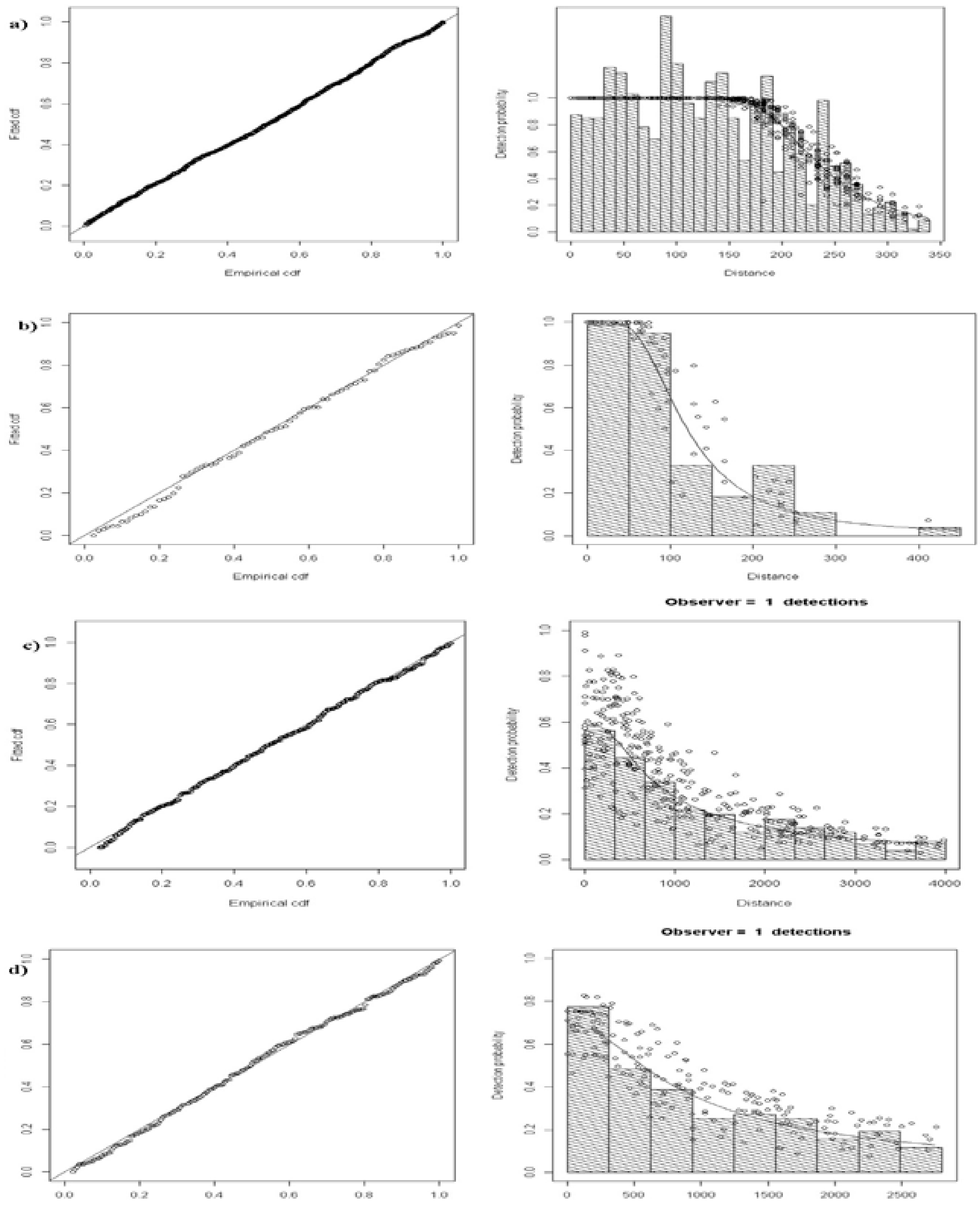

Figure 18-3 Q-Q plots and detection functions from the MRDS analyses
a) SE-aerial analysis set 2; b) NE-aerial analysis set 4; c) NE-shipboard analysis set 3; d) SE-shipboard analysis set 2.

18.3 Generalized Additive Model Analysis

Table 18-3 2010 to 2017 density-habitat model output for common bottlenose dolphins

Covariates	Edf	Ref.df	F	C.dev	p-value
s(chla)	3.37	4	17.00	1.93	<0.0001
s(salinity)	3.25	4	7.42	1.18	<0.0001
s(btemp)	3.73	4	21.51	2.67	<0.0001
s(pp)	3.31	4	8.70	5.40	<0.0001
s(dist2GSNw)	3.86	4	49.59	5.66	<0.0001
s(slope)	3.52	4	19.58	2.41	<0.0001
te(LY,sstmur)	17.57	24	9.41	8.66	<0.0001

Adjusted R^2 = 0.0212. Deviance explained = 27.9%.
Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

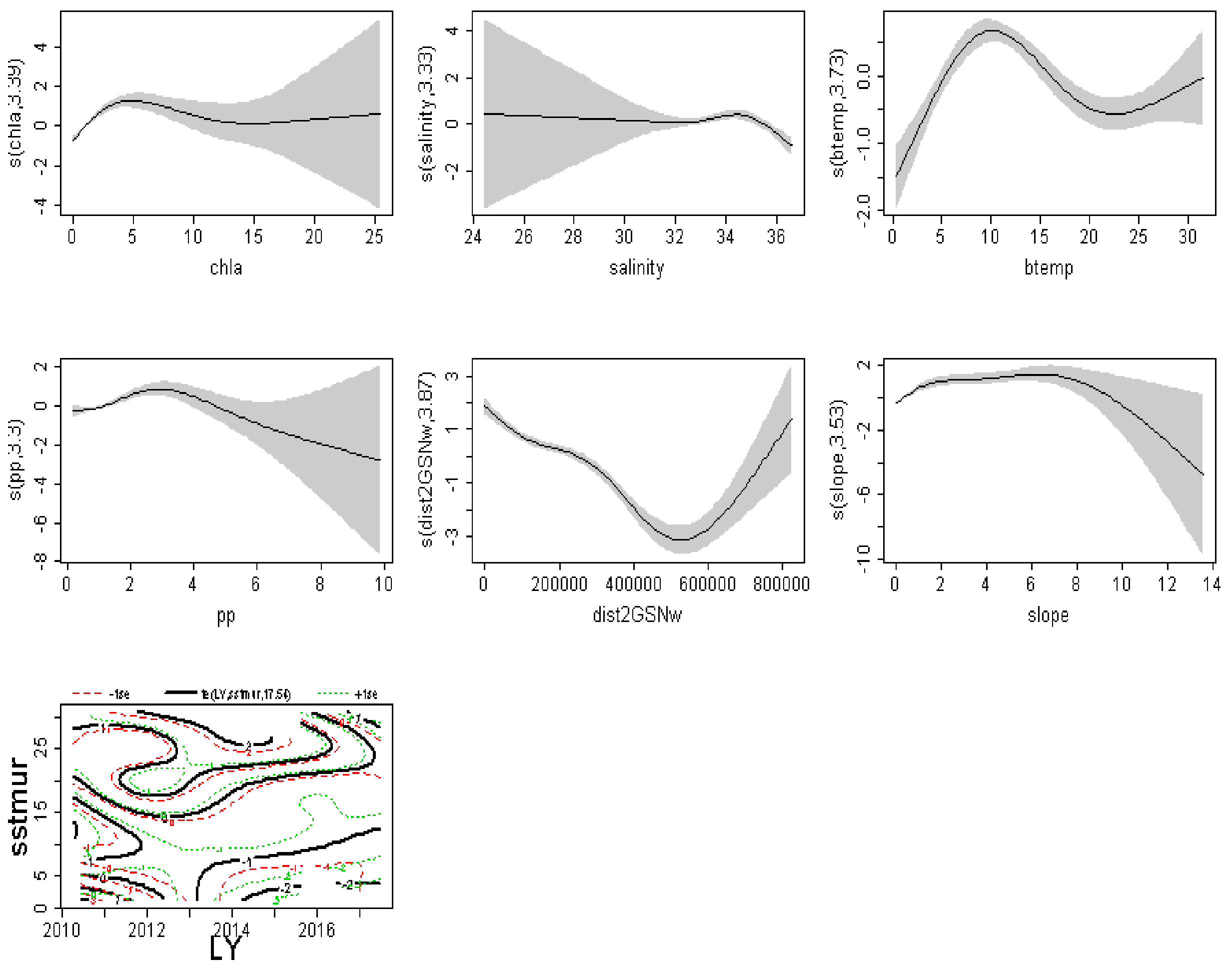

Figure 18-4 Annual abundance trends for common bottlenose dolphins in the AMAPPS study area
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

18.4 Model Cross-Validation

Table 18-4 Diagnostic statistics from the common bottlenose dolphin density-habitat model

Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
RHO	Spearman rank correlation	Non-zero density	0.325	Excellent
MAPE	Mean absolute percentage error	Non-zero density	83.800	Fair to good
RHO	Spearman rank correlation	All data divided in 25 random samples	0.181	Fair to good
MAE	Mean absolute error	All data divided in 25 random samples	0.069	Fair to good

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

18.5 Abundance Estimates for AMAPPS Study Area

Table 18-5 Common bottlenose dolphin average abundance estimates for the AMAPPS study area

Season	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	30,423	0.29	17,431–53,099
Summer (June–August)	55,040	0.27	32,725–92,571
Fall (September–November)	44,812	0.27	26,644–75,369
Winter (December–February)	25,912	0.28	15,123–44,398
Summer 2011 U.S. surveys[1]	77,532	0.40	
Summer 2016 U.S. surveys[1]	61,888	0.23	

[1]Hayes et al. 2020

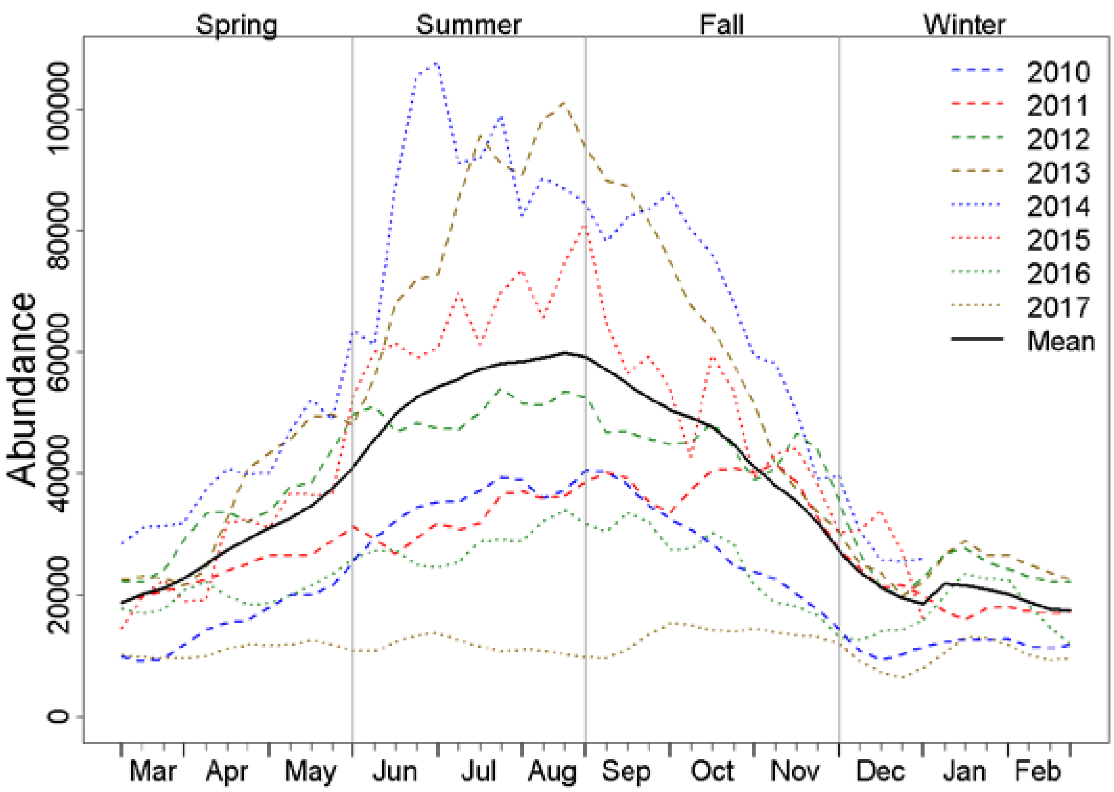

Figure 18-5 Annual abundance trends for common bottlenose dolphins in the AMAPPS study area

18.6 Seasonal Prediction Maps

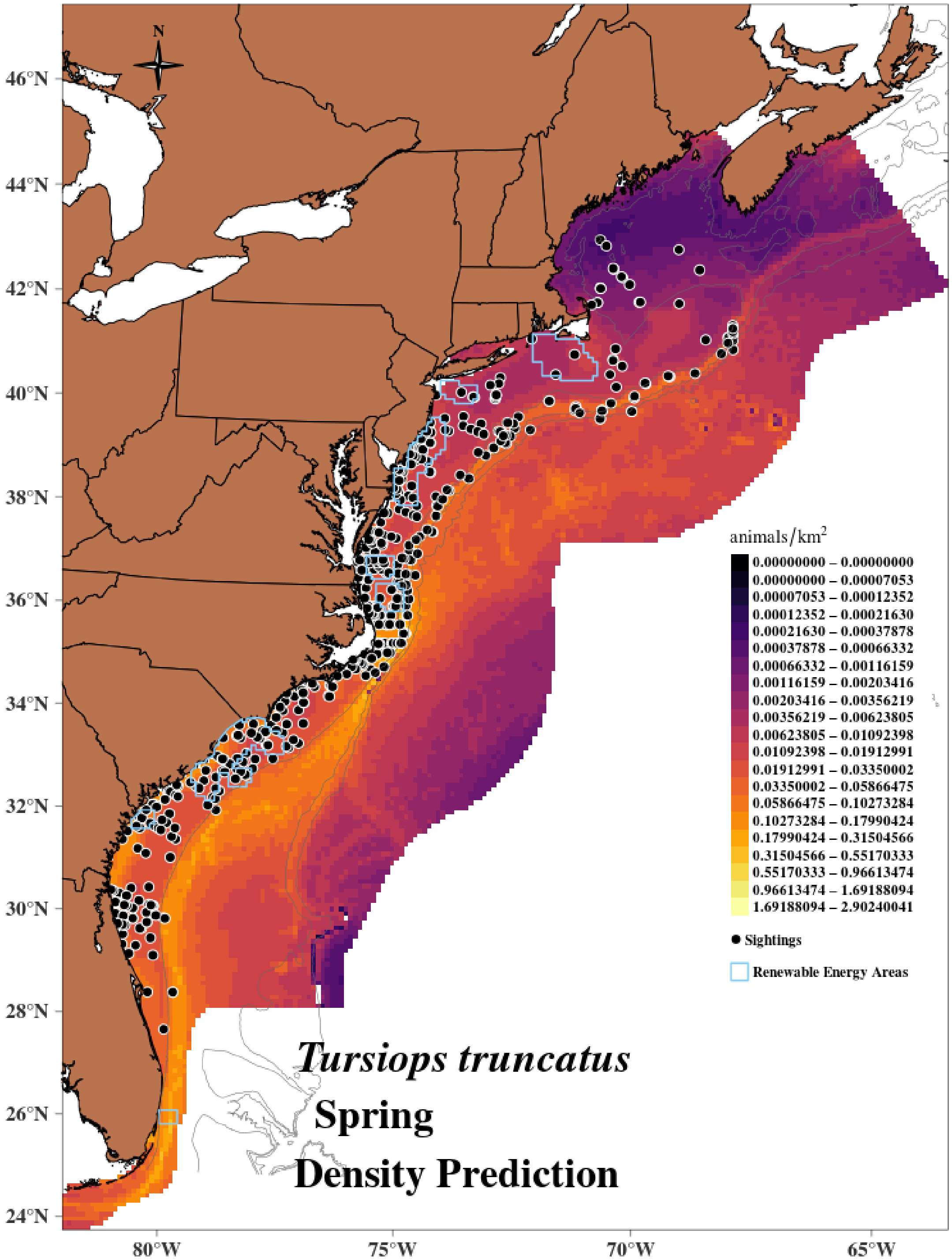

Figure 18-6 Common bottlenose dolphin spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

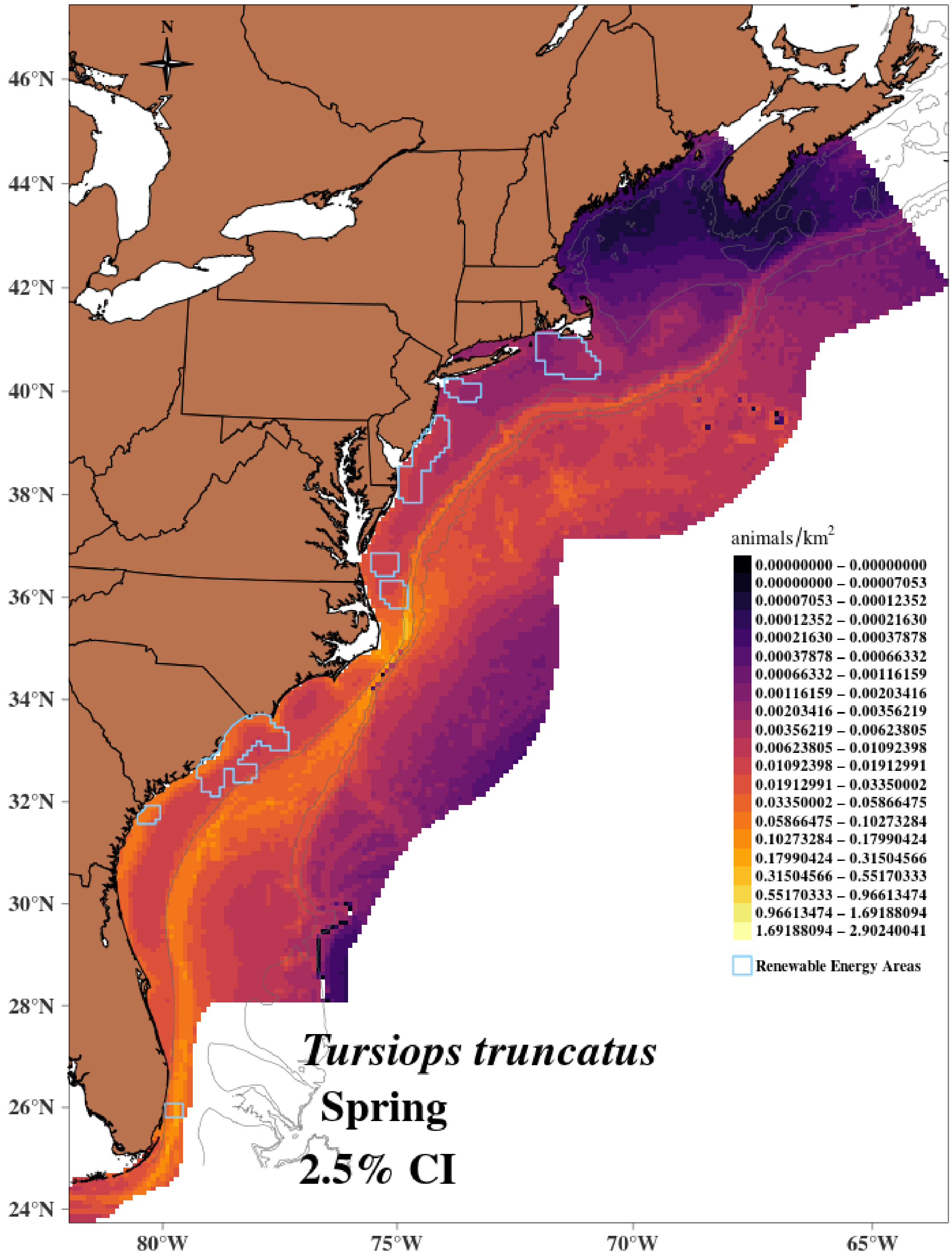

Figure 18-7 Lower 2.5% confidence interval of the spring common bottlenose dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

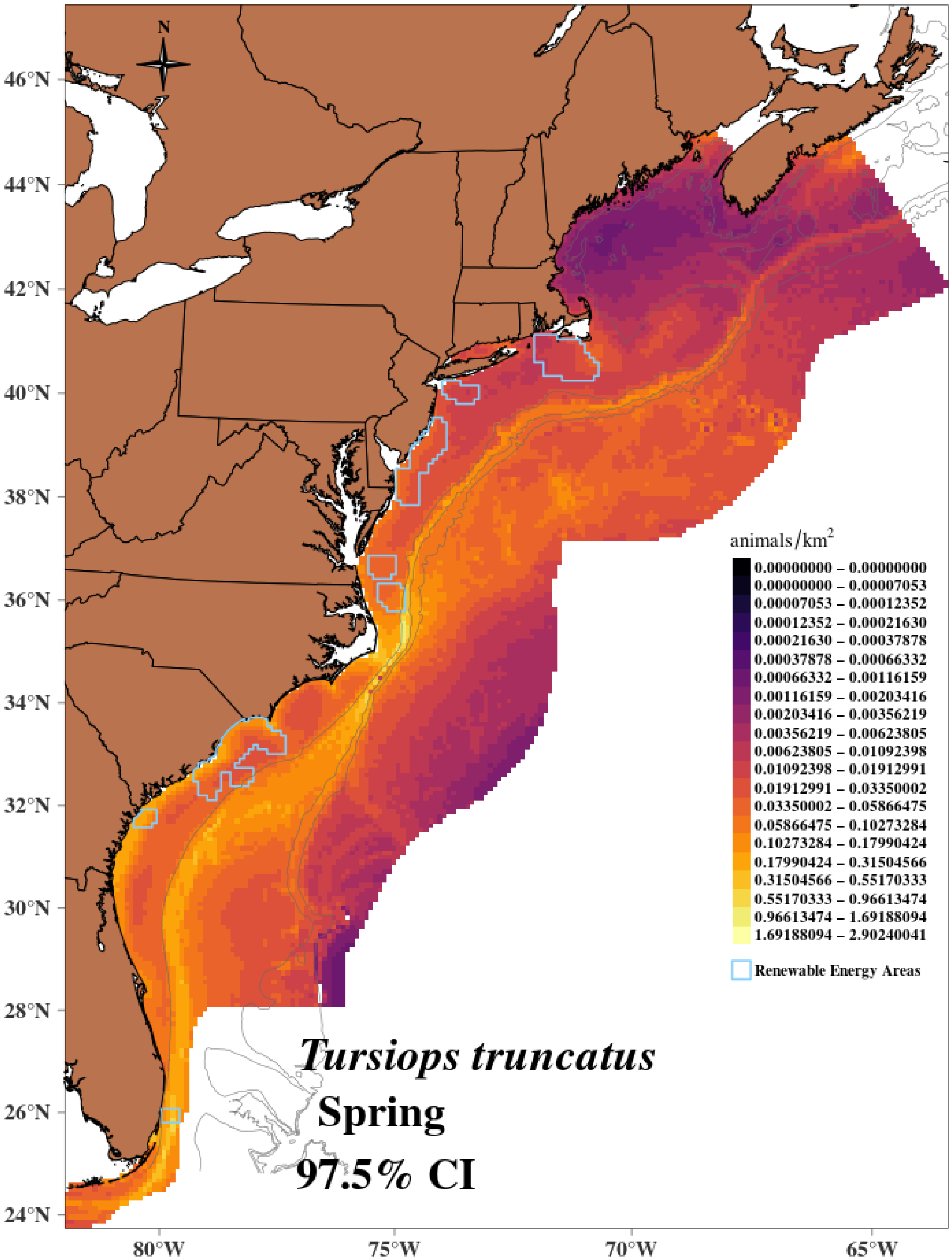

Figure 18-8 Upper 97.5% confidence interval of the spring common bottlenose dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

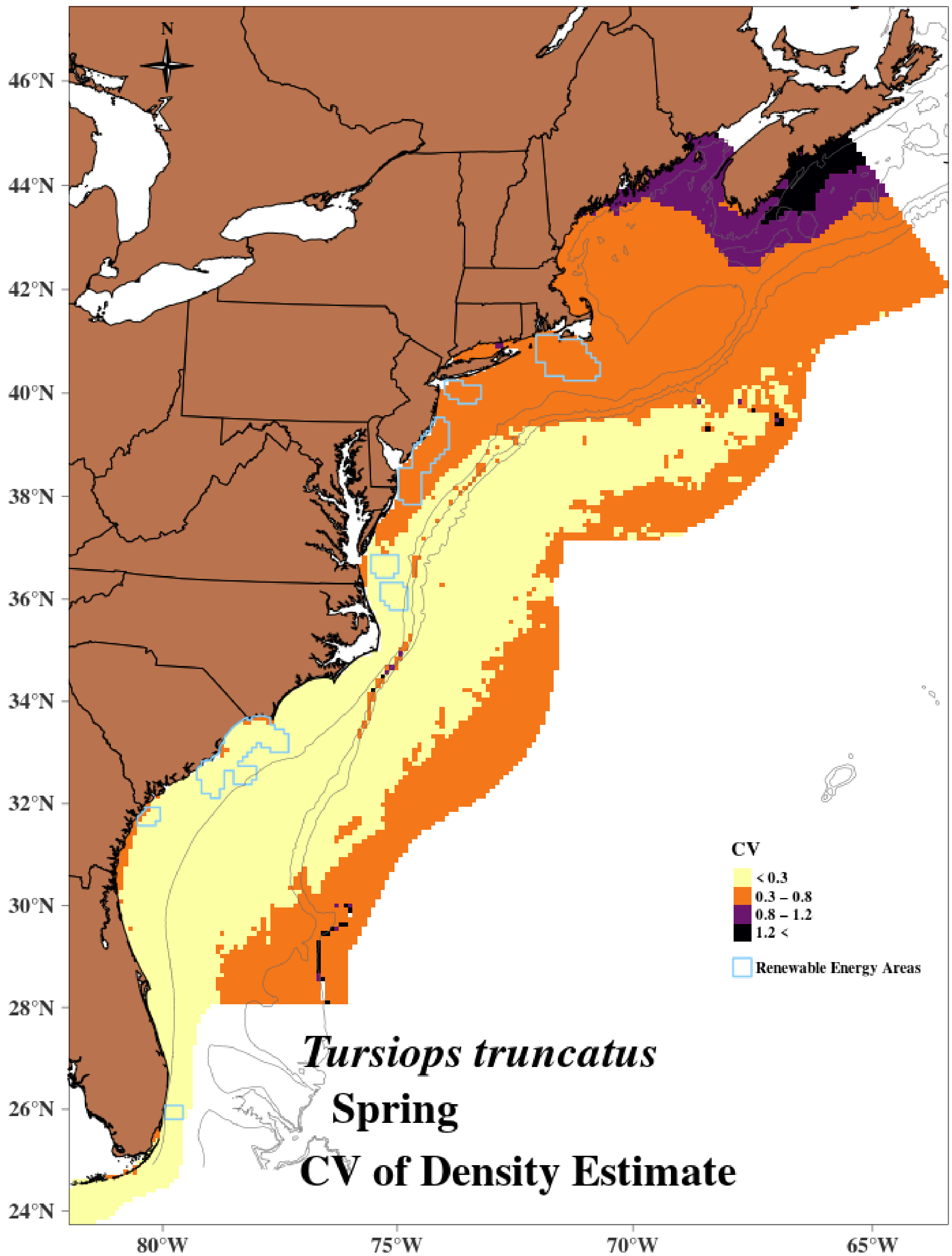

Figure 18-9 CV of spring common bottlenose dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

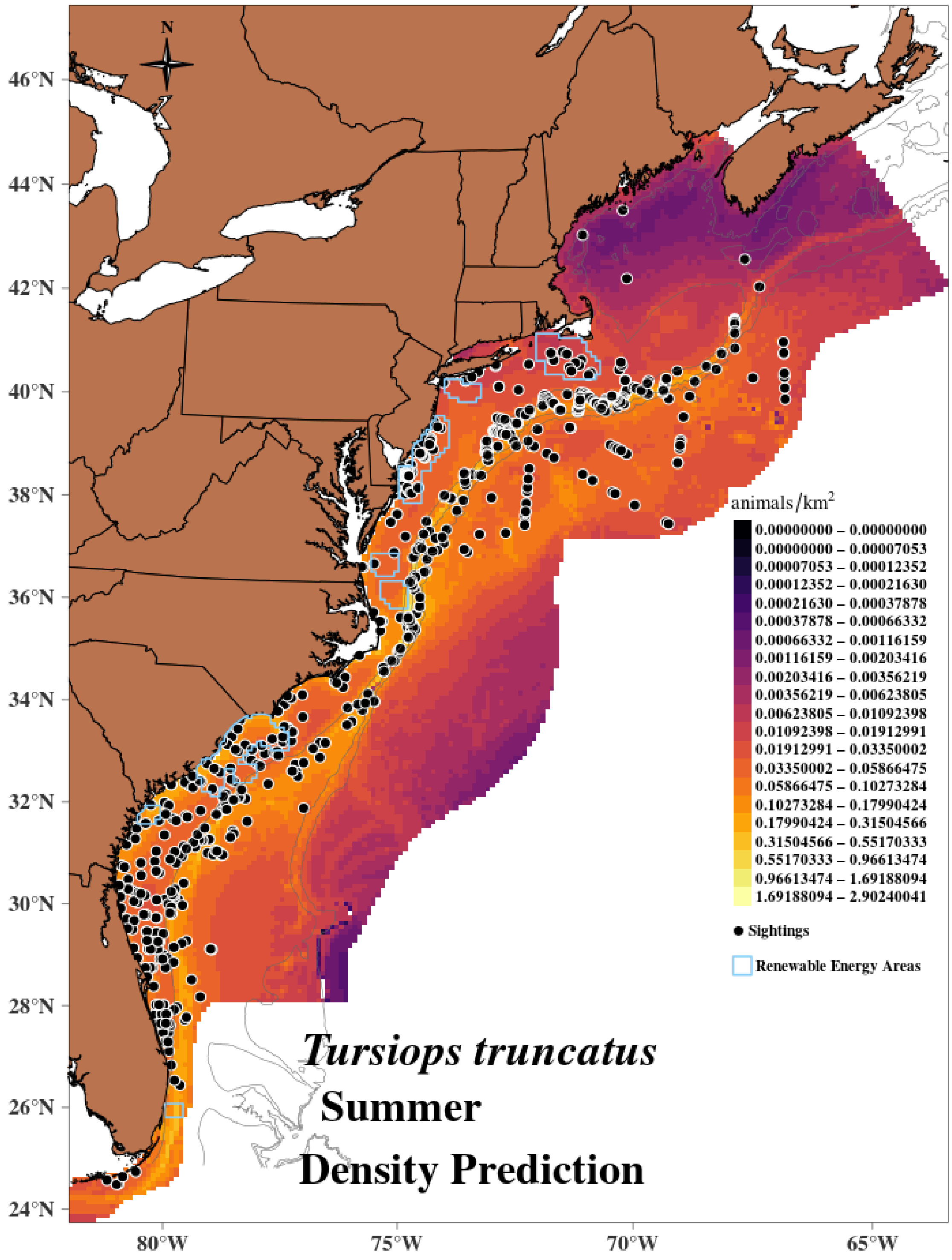

Figure 18-10 Common bottlenose dolphin summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

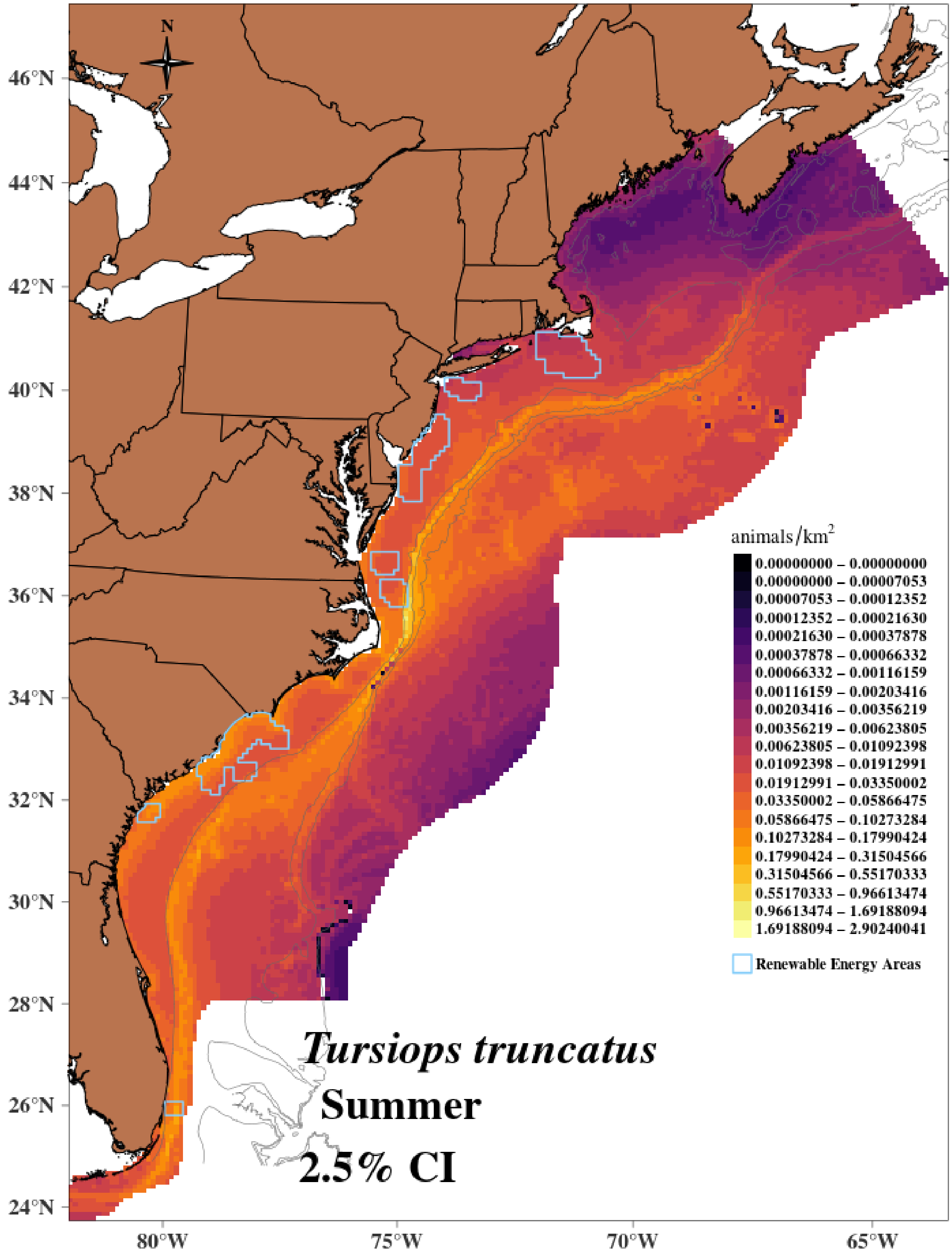

Figure 18-11 Lower 2.5% confidence interval of the summer common bottlenose dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

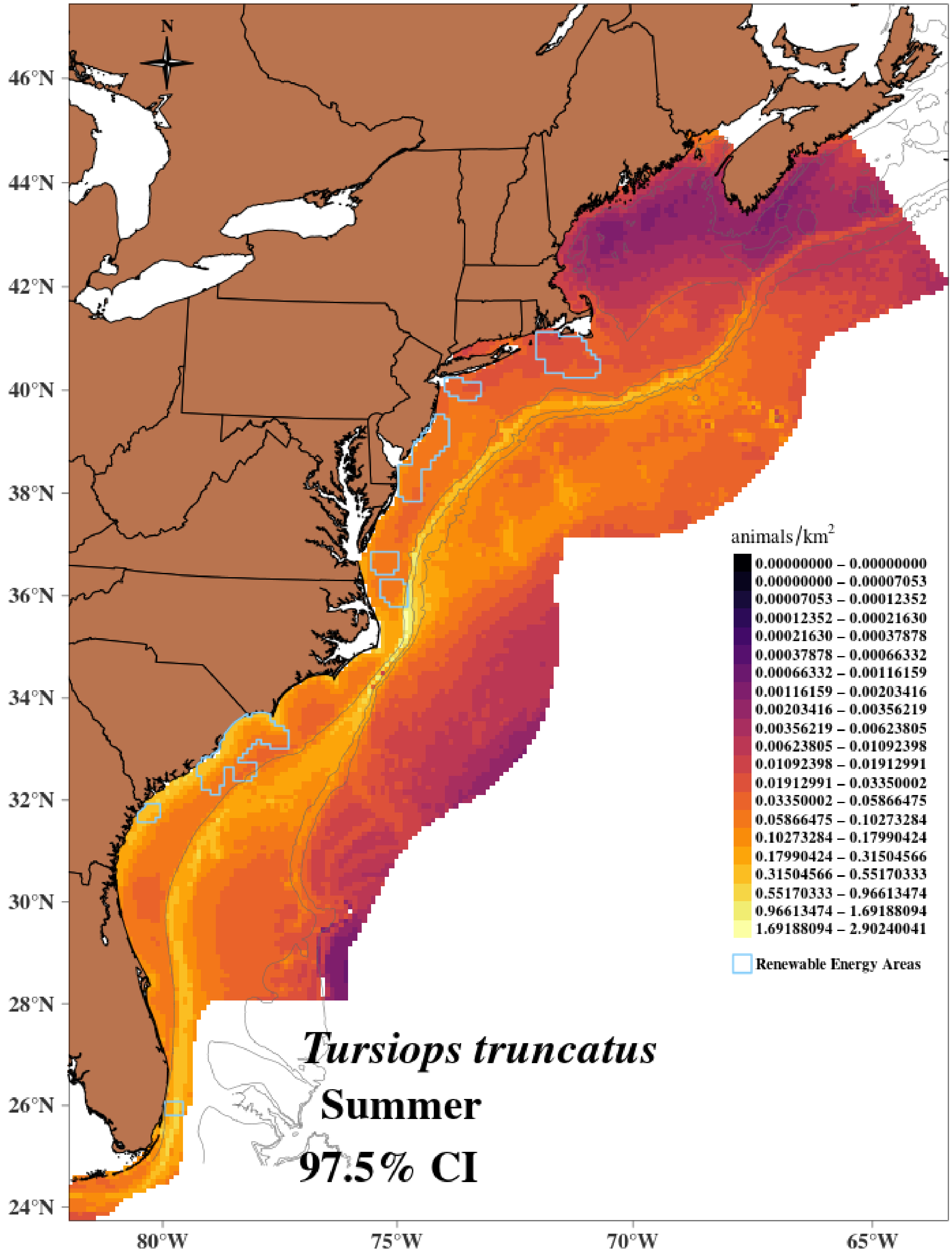

Figure 18-12 Upper 97.5% confidence interval of the summer common bottlenose dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

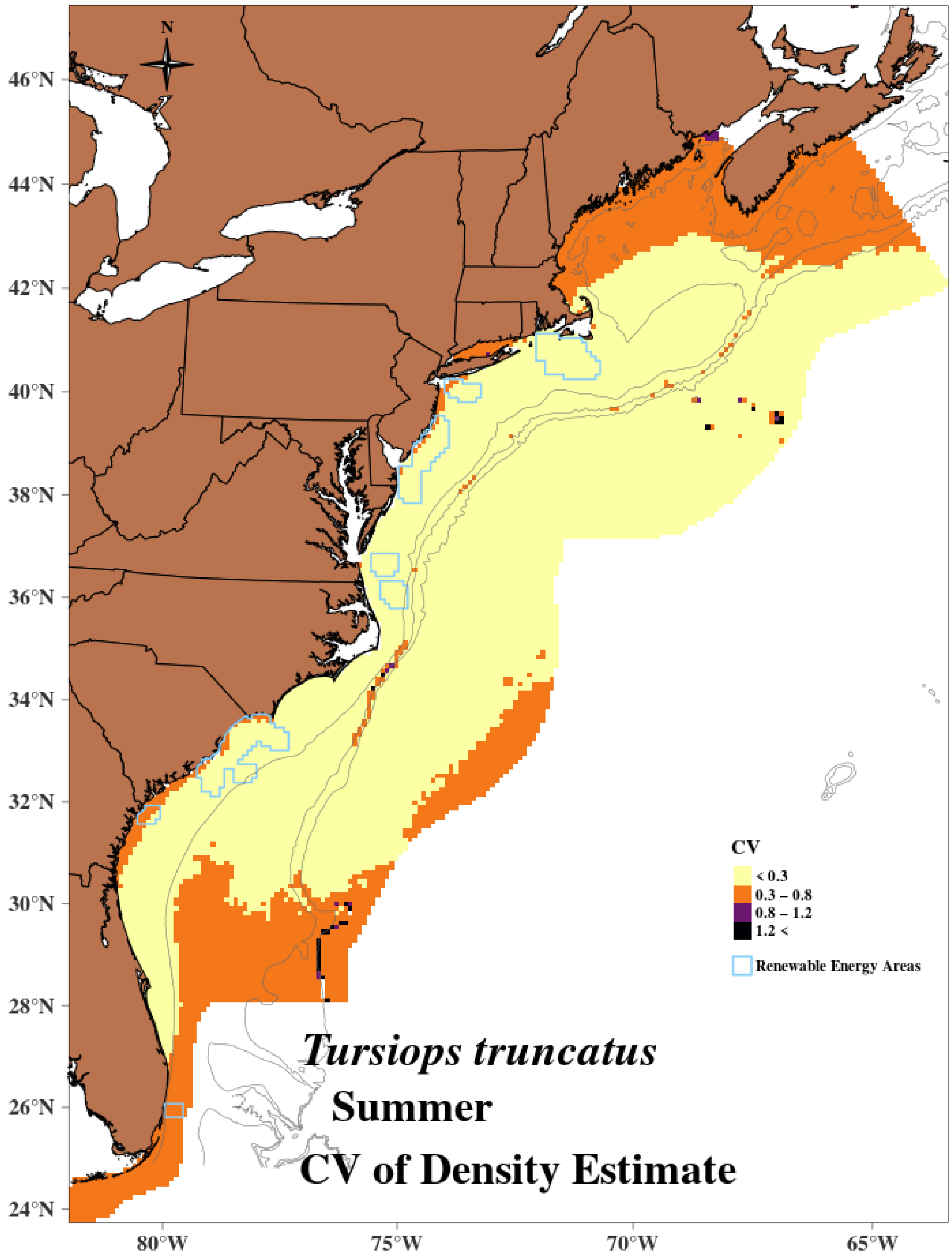

Figure 18-13 CV of summer common bottlenose dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

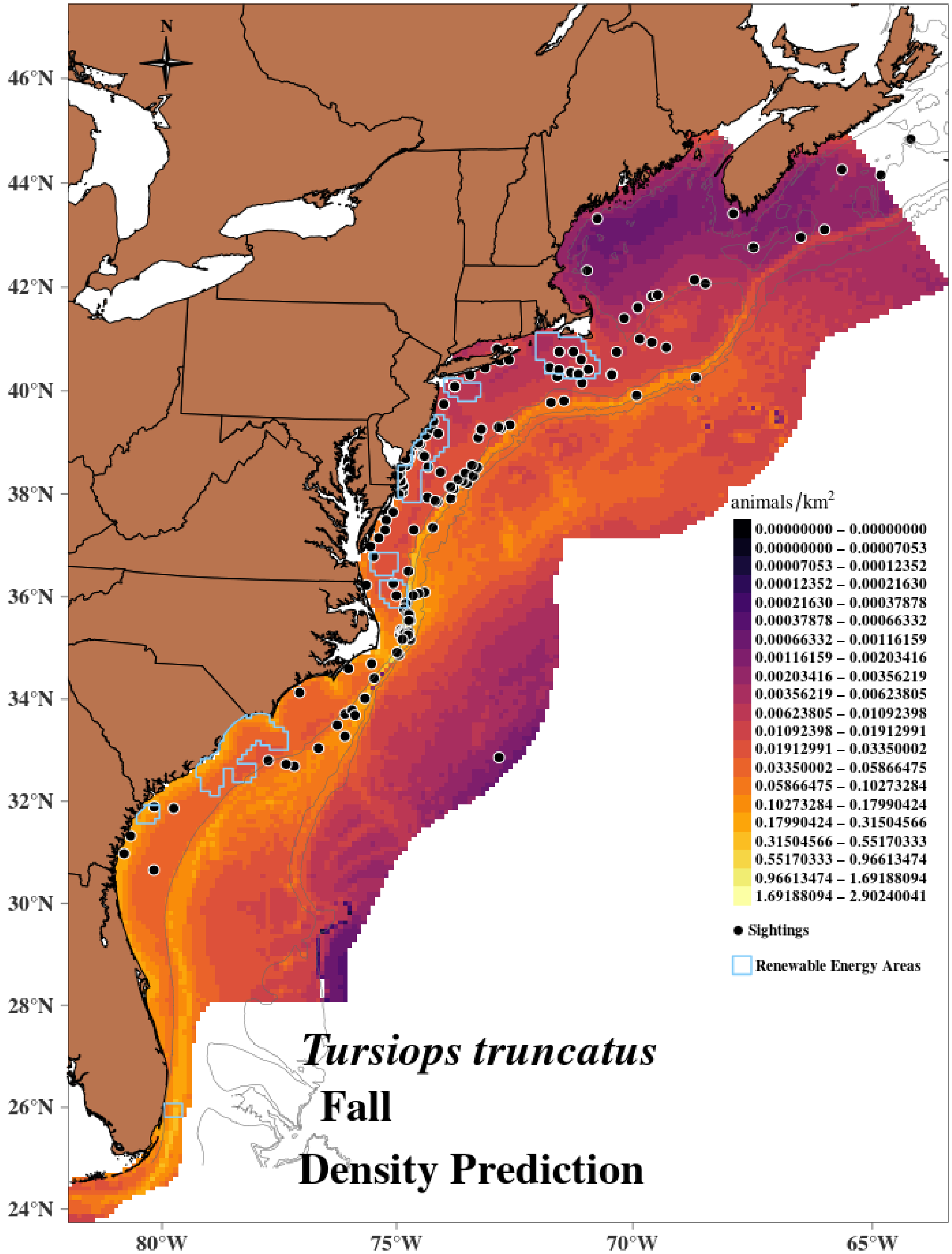

Figure 18-14 Common bottlenose dolphin fall average density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

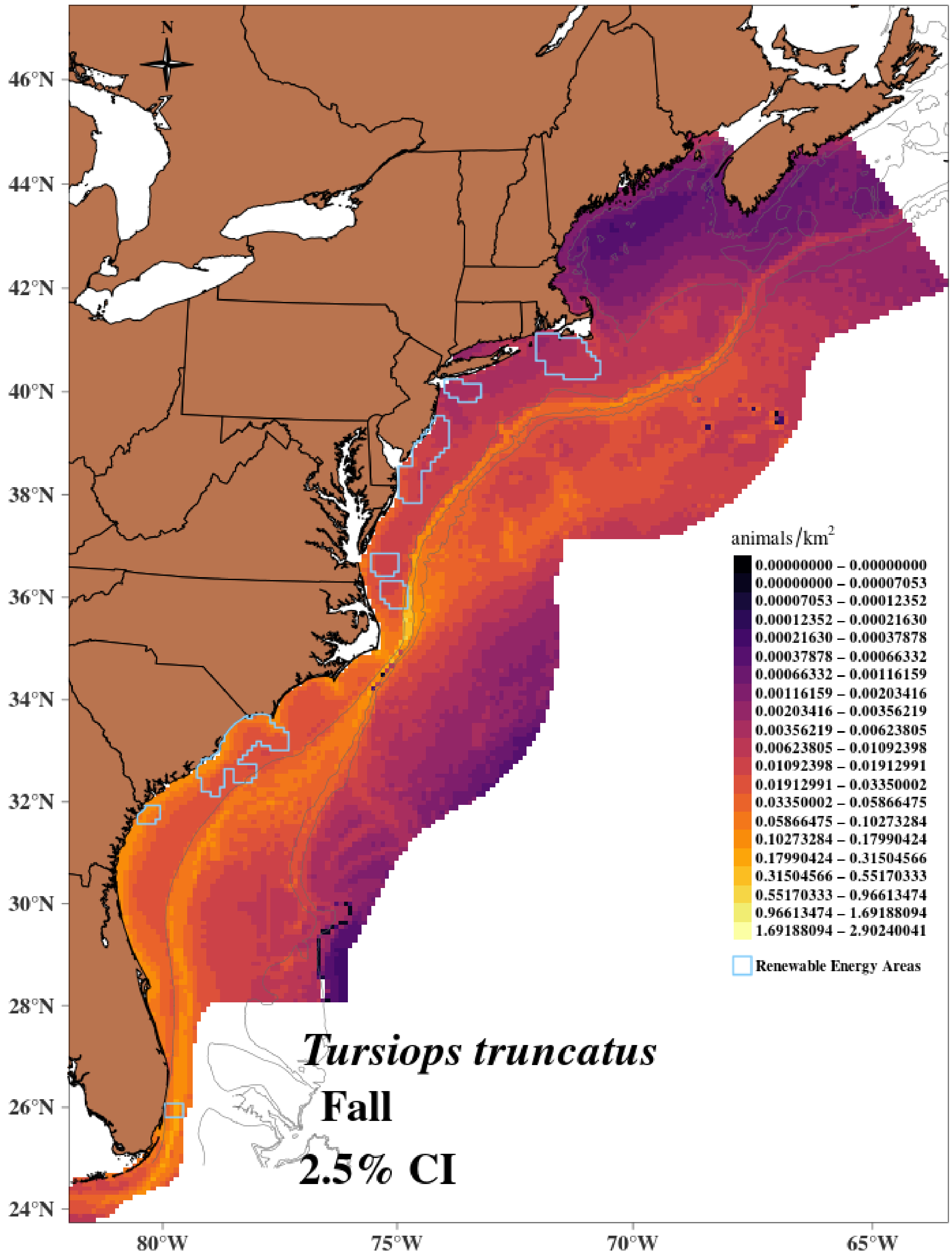

Figure 18-15 Lower 2.5% confidence interval of the fall common bottlenose dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

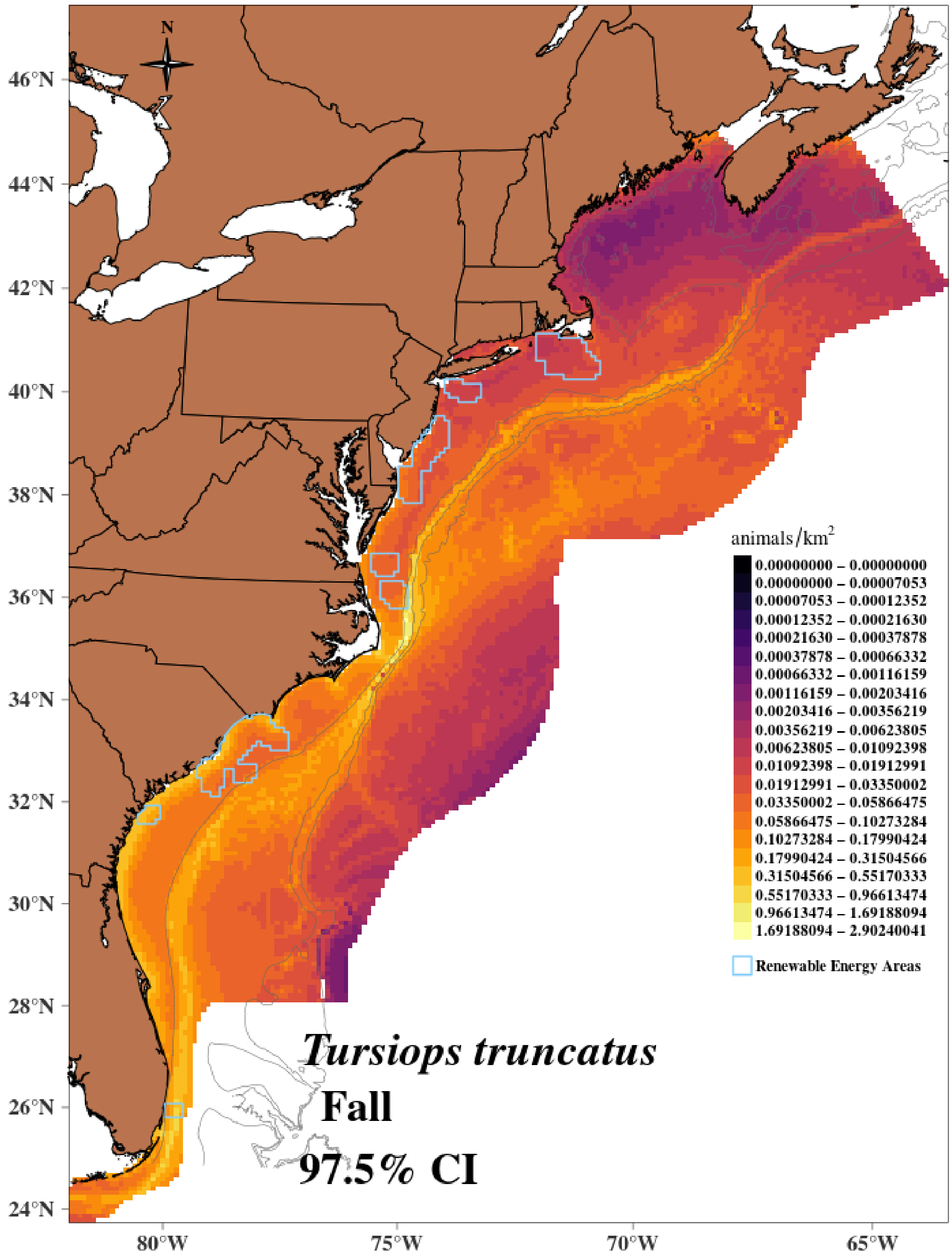

Figure 18-16 Upper 97.5% confidence interval of the fall common bottlenose dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

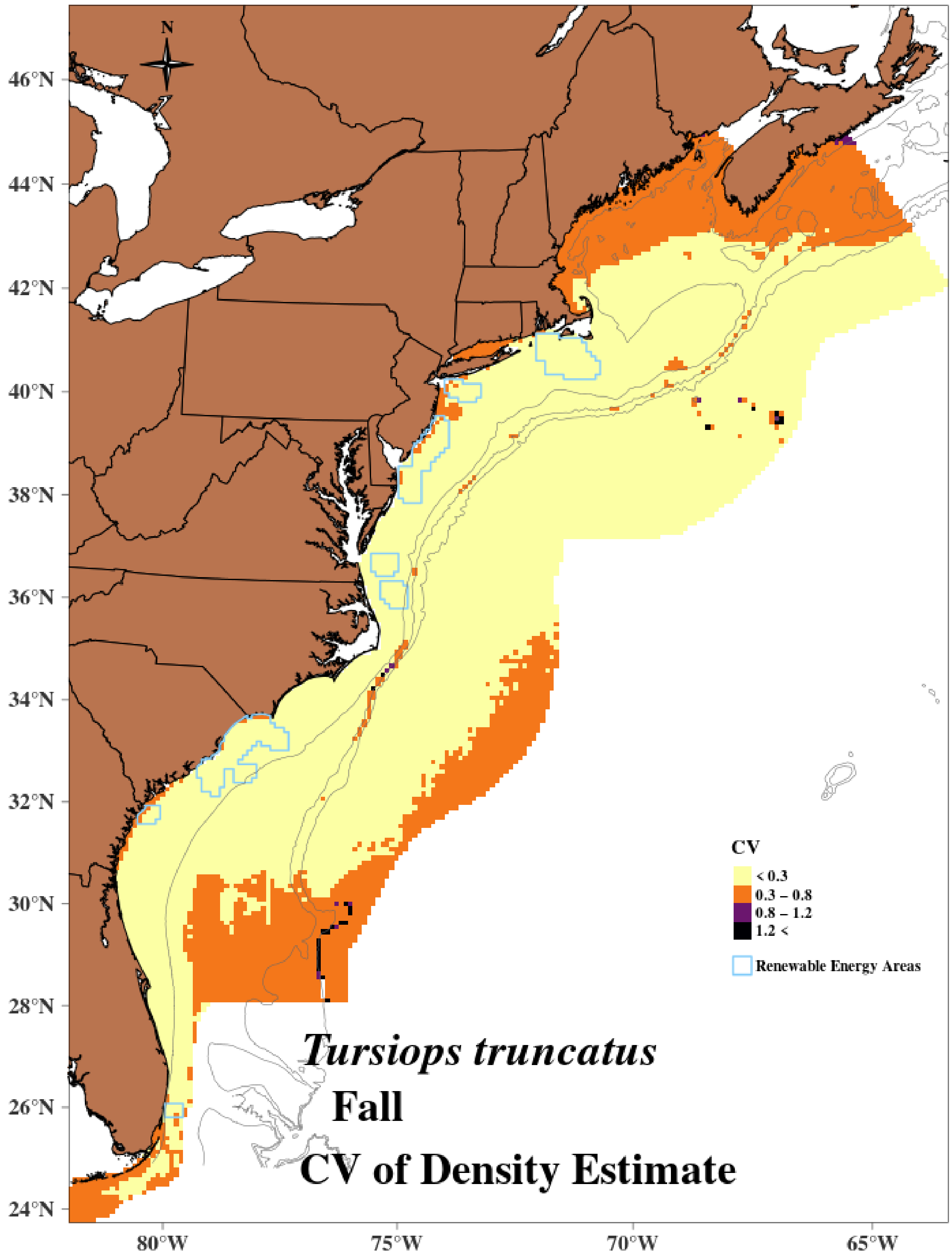

Figure 18-17 CV of fall common bottlenose dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

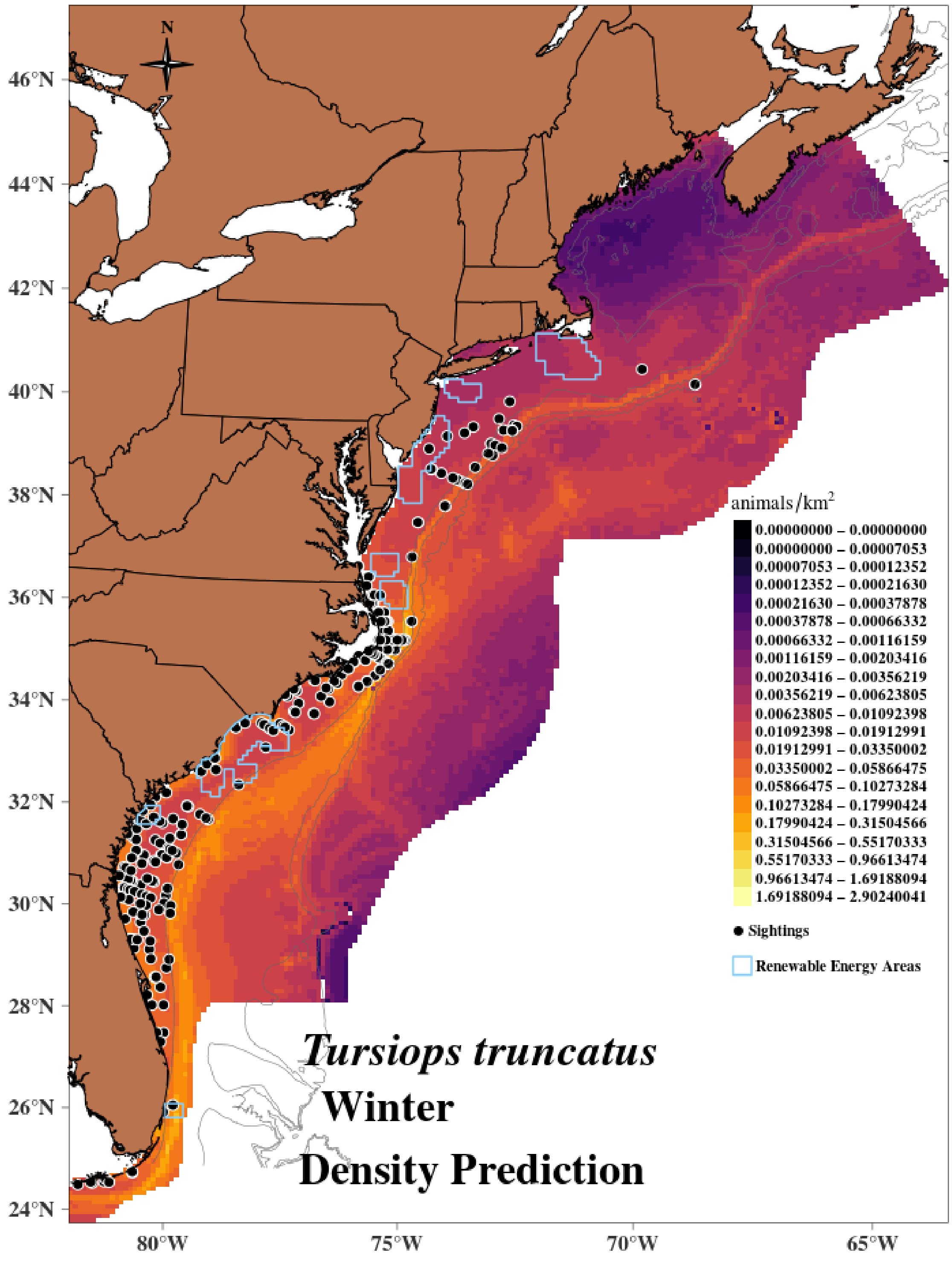

Figure 18-18 Common bottlenose dolphin winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

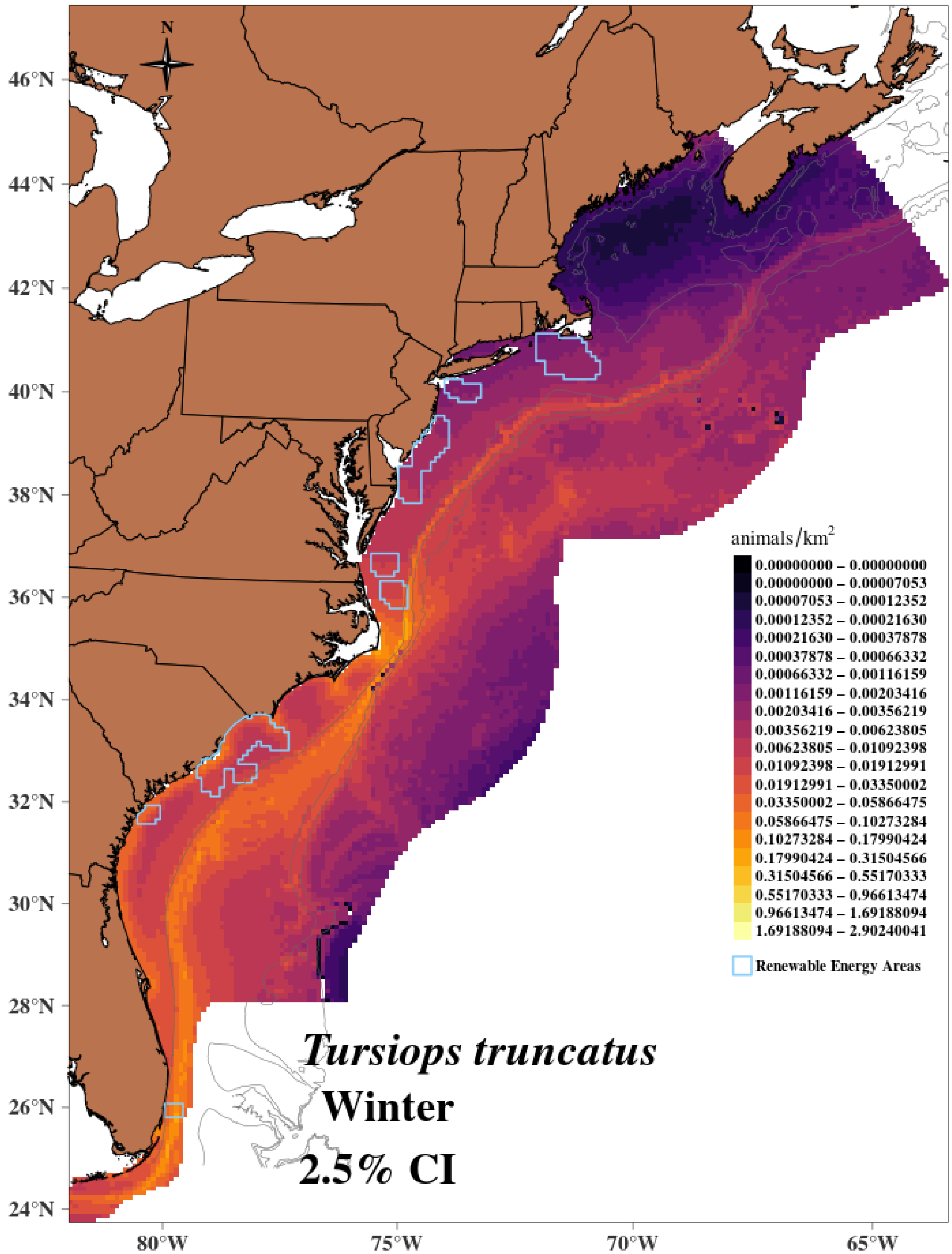

Figure 18-19 Lower 2.5% confidence interval of the winter common bottlenose dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

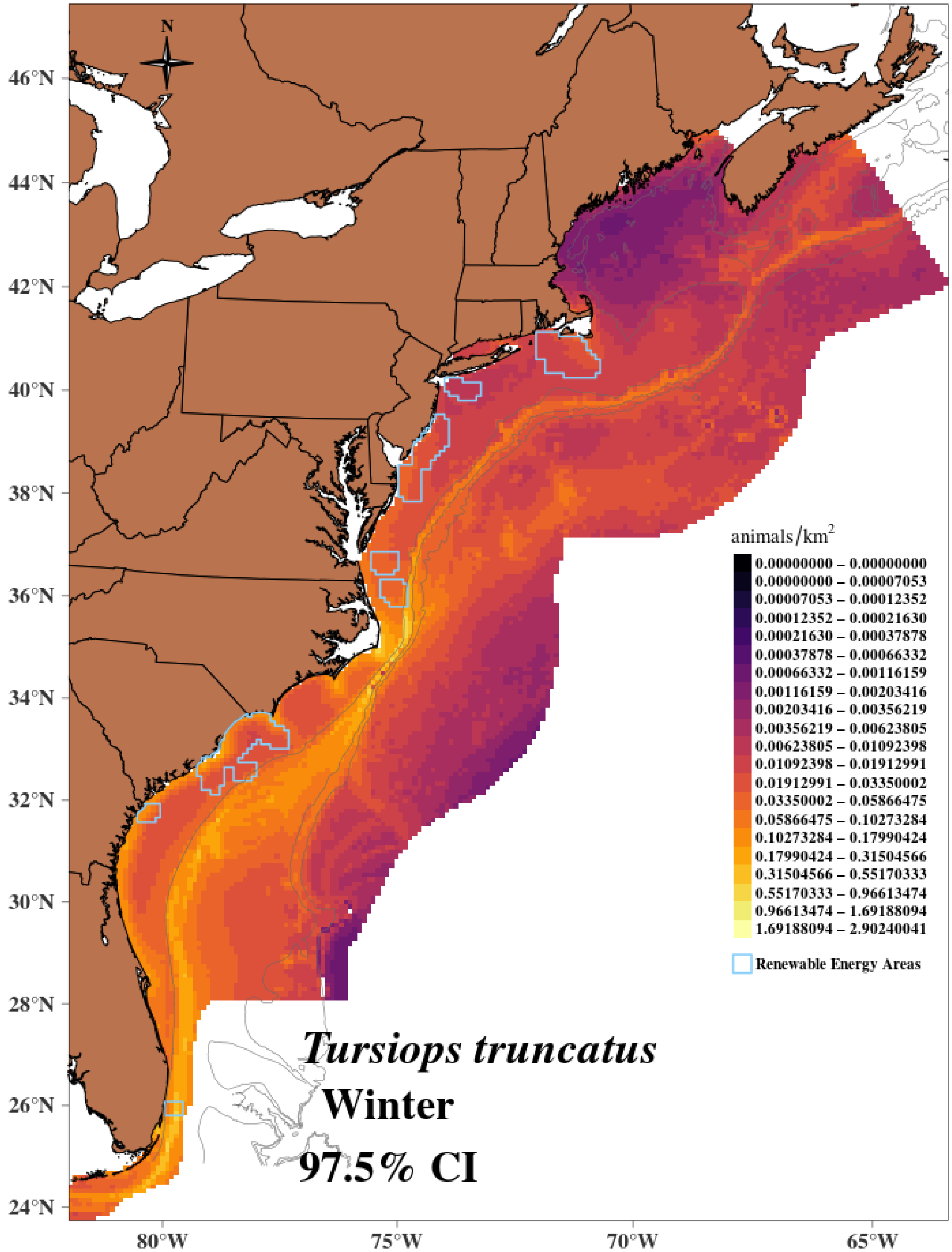

Figure 18-20 Upper 97.5% confidence interval of the winter common bottlenose dolphin density estimates

Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

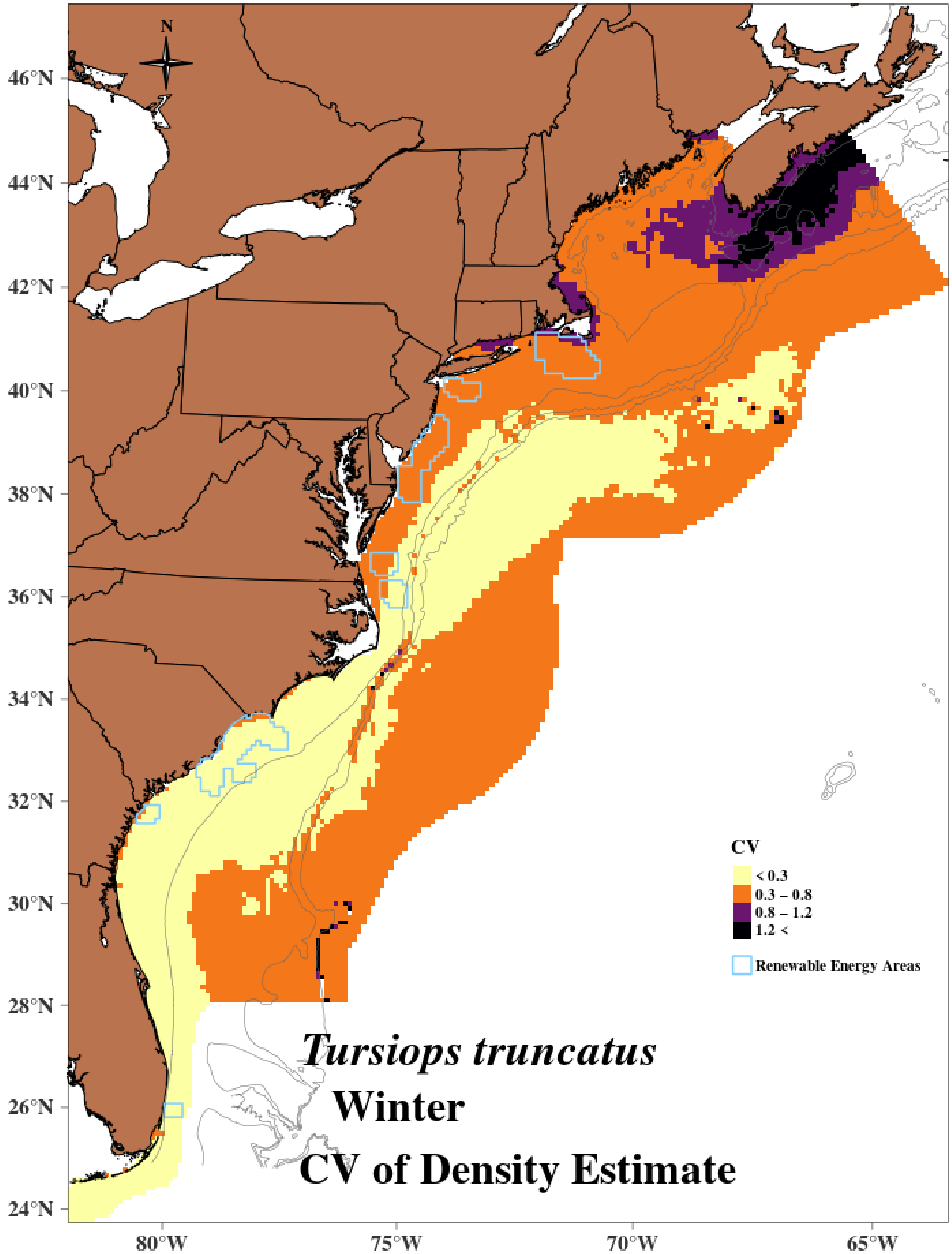

Figure 18-21 CV of winter common bottlenose dolphin density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas.

18.7 Offshore Energy Development Areas

Table 18-6 Common bottlenose dolphin abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	87.6	0.48	36–212.9
	NY	22.4	0.38	10.9–45.8
	NJ	120.8	0.34	62.6–232.9
	DE/MD	87.7	0.33	46.3–166.0
	VA	69.0	0.29	39.5–120.5
	NC	176.1	0.27	104.1–297.8
	NC/SC	754.7	0.27	450–1,265.4
Summer (Jun–Aug)	RI/MA	228.9	0.24	144.4–362.9
	NY	67.9	0.27	40.5–114.0
	NJ	299.7	0.28	176.5–508.9
	DE/MD	197.5	0.26	120.3–324.3
	VA	133.6	0.24	84.7–210.9
	NC	342.9	0.25	213.4–550.9
	NC/SC	1,883.8	0.27	1,112.2–3,190.6
Fall (Sep–Nov)	RI/MA	127.2	0.24	79.3–204.0
	NY	26.3	0.27	15.5–44.6
	NJ	144.8	0.29	83.1–252.1
	DE/MD	123.4	0.28	71.9–211.7
	VA	75.3	0.25	46.1–123.0
	NC	189.5	0.26	114.7–313.1
	NC/SC	1333.6	0.26	812.1–2,190
Winter (Dec–Feb)	RI/MA	83.0	0.60	28.0–245.8
	NY	12.8	0.43	5.7–28.7
	NJ	67.7	0.47	28.4–161.4
	DE/MD	57.3	0.47	24.0–137.3
	VA	60.8	0.34	31.6–116.8
	NC	121.0	0.28	70.0–209.2
	NC/SC	555.7	0.27	330.9–933.2

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

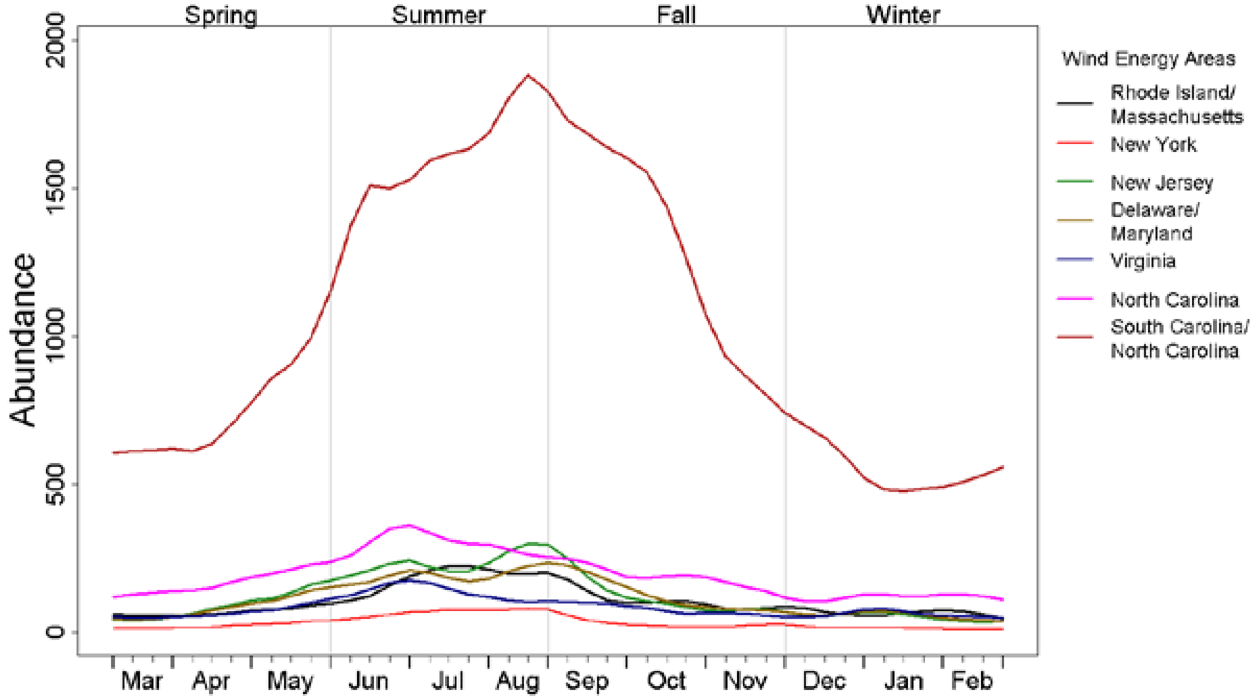

Figure 18-22 Average seasonal abundance of common bottlenose dolphins in the wind-energy study areas

19 Harbor Porpoise (*Phocoena phocoena*)

Figure 19-1 Harbor porpoises

19.1 Data Collection

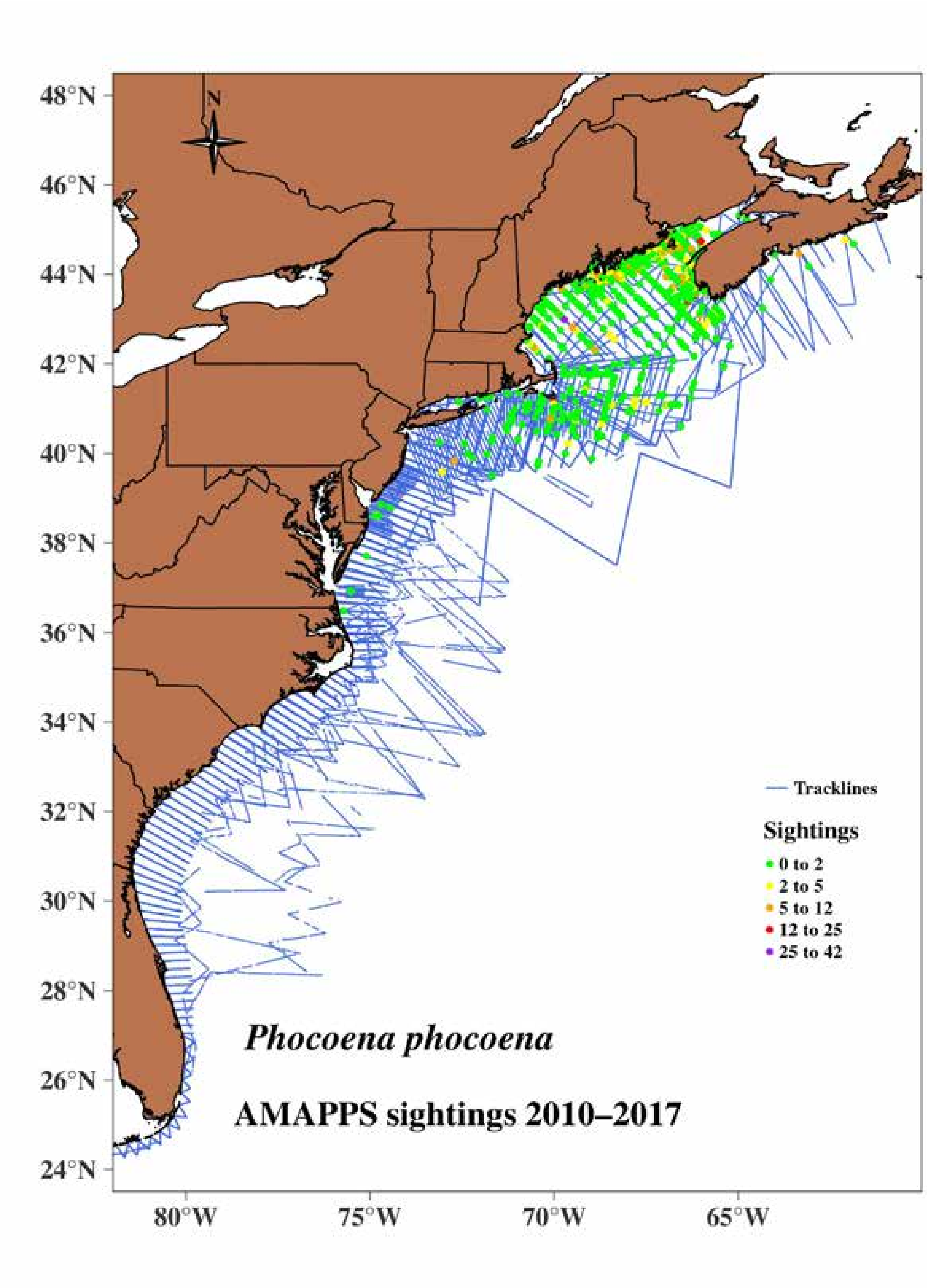

Figure 19-2 Distribution of track lines and harbor porpoise sightings 2010 to 2017

Table 19-1 AMAPPS research effort 2010 to 2017 and harbor porpoise sightings

Survey Region and Platform	Season	Effort (km)	Number of Groups	Number of Animals
NE Shipboard	Summer	37,529	4	6
NE Shipboard	Fall	1,065	0	0
NE Aerial	Spring	13,314	181	264
NE Aerial	Summer	25,867	341	757
NE Aerial	Fall	37,850	390	1,547
NE Aerial	Winter	12,179	135	258
SE Shipboard	Spring	8,853	11	21
SE Shipboard	Summer	12,968	0	0
SE Shipboard	Fall	3,012	0	0
SE Aerial	Spring	41,293	8	13
SE Aerial	Summer	28,236	0	0
SE Aerial	Fall	18,974	0	0
SE Aerial	Winter	8,950	0	0

19.2 Mark-Recapture Distance Sampling Analysis

Table 19-2 Intermediate parameters in harbor porpoise mark-recapture distance sampling (MRDS) models

Analysis Set	MR Model	MR Truncation (m)	DS Model	DS Truncation (m)	Key function	p(0)	p(0) CV	Chi-square p-value	K-S p-value	CvM p-value
NE–aerial group 5	distance * observer	210	distance + sea state + glare	350	HR	0.52	0.10	0.46	0.75	0.78
NE–shipboard group 5	distance * observer + group size	3800	distance + swell	3800	HR	0.52	0.08	0.22	0.71	0.78
SE–shipboard group 2	distance * observer + sea state	2800	distance + glare	2800	HR	0.69	0.09	0.47	0.99	0.95

MR=Mark-Recapture, DS=Distance Sampling, HR=Hazard Rate, HN= Half Normal, LT= Left truncation (in m), CV=Coefficient of variation. Values of p>0.5 for Chi-square, Kolmogorov-Smirnov test (K-S) and Cramer-von Mises test (CvM) indicate good fit. The definition of p(0) is the probability of detecting a group on the track line. Species included in the analysis sets are explained in main text Tables 6-5 to 6-8.

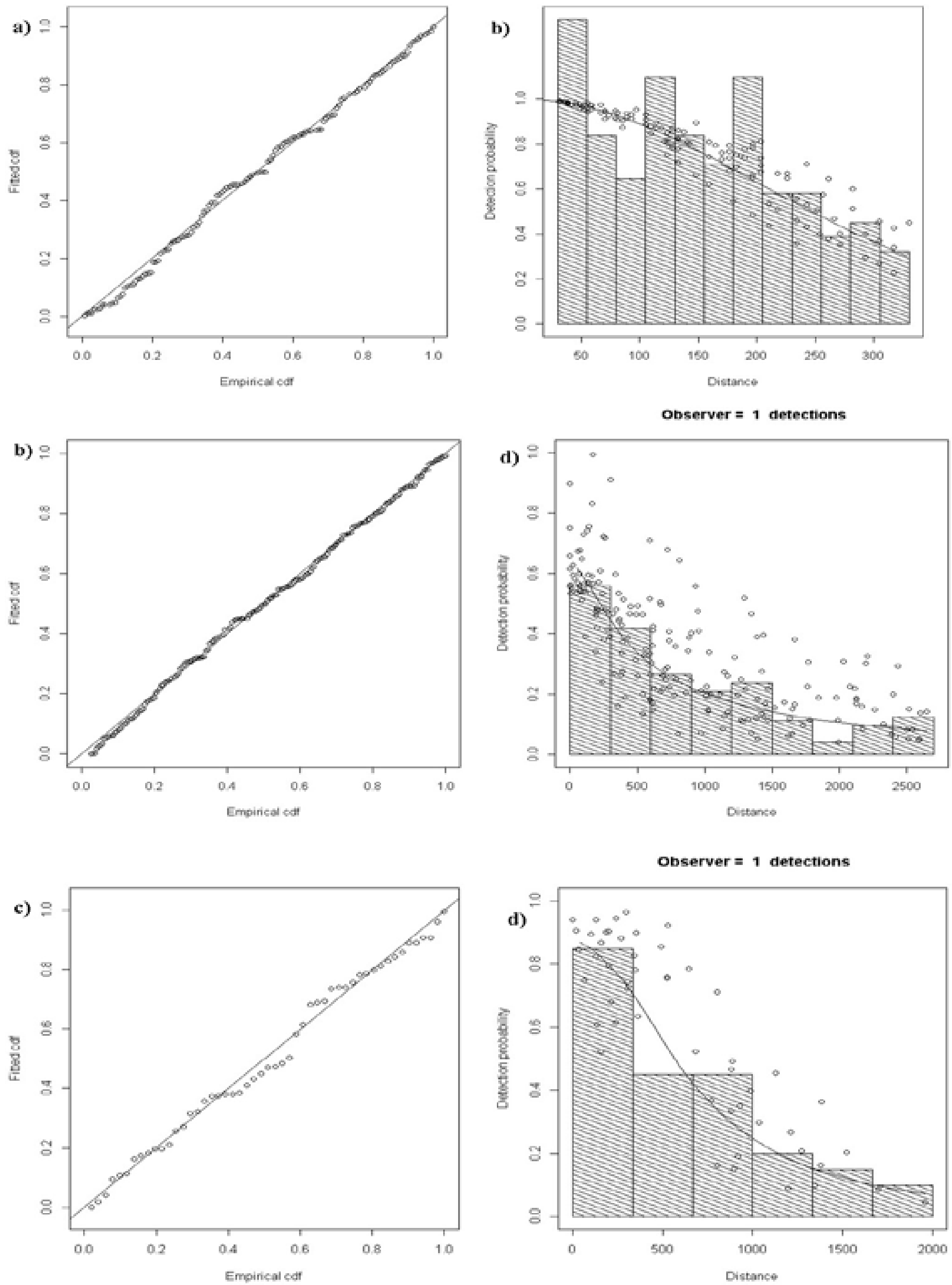

Figure 19-3 Q-Q plots and detection functions from the MRDS analyses
a) NE-aerial analysis set 5; b) NE-shipboard analysis set 5; c) SE-shipboard analysis set 2

19.3 Generalized Additive Model Analysis

Table 19-3 2010 to 2017 density-habitat model output for harbor porpoises

Model	Covariates	Edf	Ref.df	F	C.dev	p-value
November to May – spread out distribution	s(sstfma):LY	2.13	4	3.61	8.68	0.0003
	s(salinity)	1.06	4	6.38	15.47	<0.0001
	s(btemp)	0.77	4	0.69	1.08	0.0557
	s(mlp)	0.98	4	3.43	5.61	0.0001
	Adjusted R^2 = 0.04	Deviance explained = 30.8%				
June to October – compact distribution	s(chlfma):LY	1.78	8	3.71	13.86	<0.0001
	s(mld)	3.27	4	7.67	4.85	<0.0001
	s(dist2shore)	1.01	4	3.52	3.29	0.0001
	s(dist200)	3.08	4	7.07	4.42	<0.0001
	s(lat)	1.91	4	19.86	29.29	<0.0001
	Adjusted R^2 = 0.05	Deviance explained = 55.7%				

Includes the estimated degrees of freedom (Edf), reference degrees of freedom (Ref.df), contribution to the deviance (C.dev) explained for each habitat covariate and its associated p-value. Covariate abbreviations explained in main text in Tables 6-1 and 6-2.

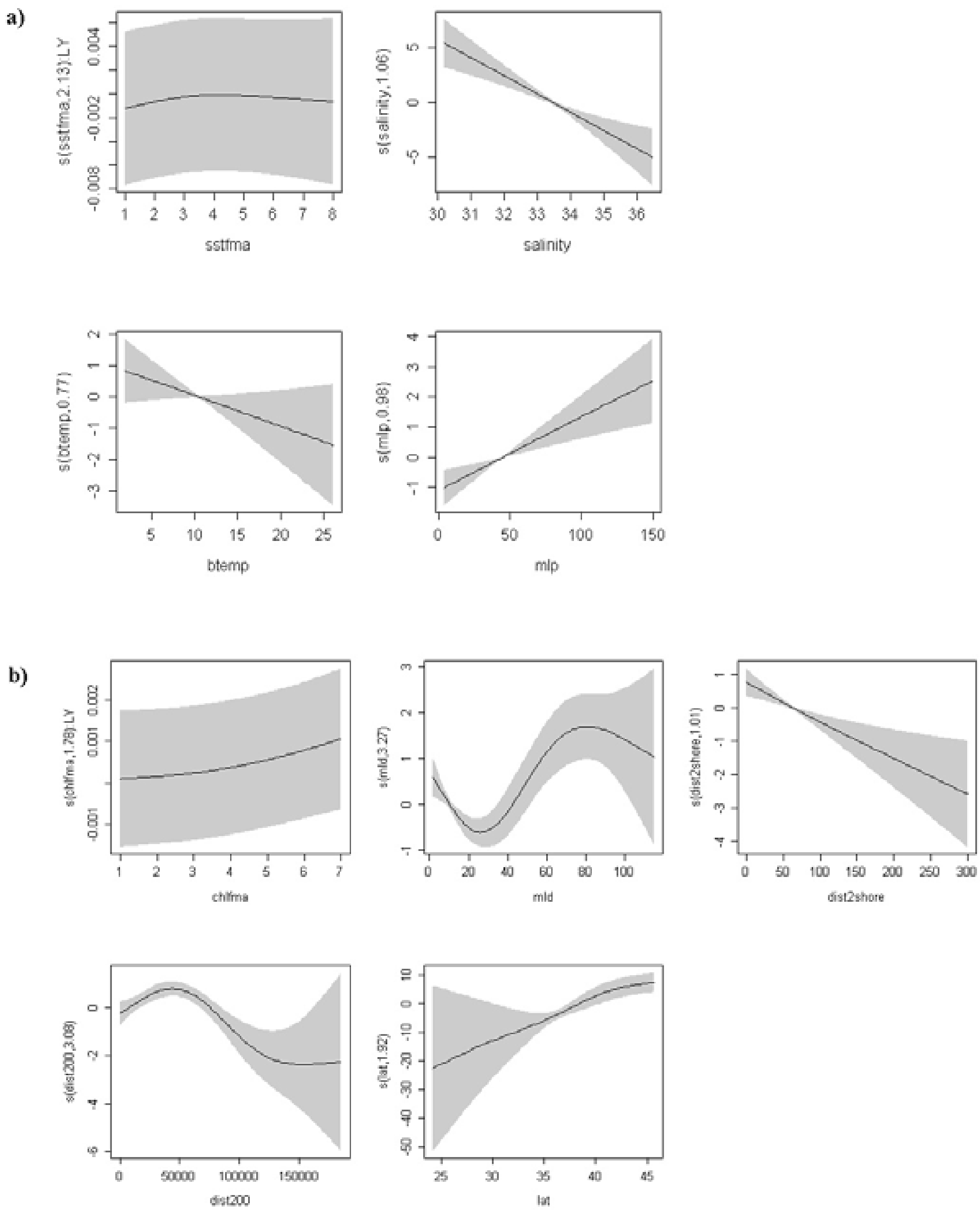

Figure 19-4 Harbor porpoise density relative to significant habitat covariates
Plots represent the partial smooths and interaction terms of the density-habitat model, where the shaded regions represent the 95% credible intervals. Covariate abbreviations explained in main text in Tables 6-1 and 6-2. Plots in (a) are from the November to May (spread out distribution) model, and (b) are from the June to October (compact distribution) model.

19.4 Model Cross-Validation

Table 19-4 Diagnostic statistics from the harbor porpoise density-habitat model

	Diagnostic Statistic	Description	Calculated with	Model Values (x)	Score
November	RHO	Spearman rank correlation	Non-zero density	0.318	Excellent
to May –	MAPE	Mean absolute percentage error	Non-zero density	94.432	Fair to good
spread out	RHO	Spearman rank correlation	All data divided in 25 random samples	0.157	Fair to good
distribution	MAE	Mean absolute error	All data divided in 25 random samples	0.143	Excellent
June to	RHO	Spearman rank correlation	Non-zero density	0.318	Excellent
October –	MAPE	Mean absolute percentage error	Non-zero density	81.184	Fair to good
compact	RHO	Spearman rank correlation	All data divided in 25 random samples	0.181	Fair to good
distribution	MAE	Mean absolute error	All data divided in 25 random samples	0.377	Fair to good

RHO: Poor= x<0.05; Fair to good =0.05<=x<0.3; Excellent= x>0.3
MAPE: Poor= x>150%; Fair to good= 150%>=x>50%; Excellent= x<=50%
MAE: Poor= x>1; Fair to good = 1>=x>0.25; Excellent= x<=0.25

19.5 Abundance Estimates for AMAPPS Study Area

Table 19-5 Harbor porpoise average abundance estimates for the AMAPPS study area

Season	Time Period	Average Abundance	CV	95% Confidence Interval
Spring (March–May)	2010–2013	54,660	0.66	16,820–177,632
	2014–2017	29,006	0.58	10,095–83,342
	2010–2017	41,813	0.63	13,464–129,850
Summer (June–August)	2010–2013	113,483	0.25	70,040–183,873
	2014–2017	60,388	0.26	36,580–99,691
	2010–2017	86,569	0.25	53,429–140,265
Fall (September–November)	2010–2013	69,395	0.34	36,290–132,698
	2014–2017	39,137	0.32	21,223–72,172
	2010–2017	54,264	0.33	28,896–101,903
Winter (December–February)	2010–2013	38,731	0.63	12,472–120,279
	2014–2017	27,454	0.53	10,353–72,801
	2010–2017	33,086	0.59	11,335–96,574
Summer 2011 U.S. surveys[1]		79,883	0.32	
Summer 2016 U.S. surveys[1]		75,079	0.38	

[1]Hayes et al. 2020

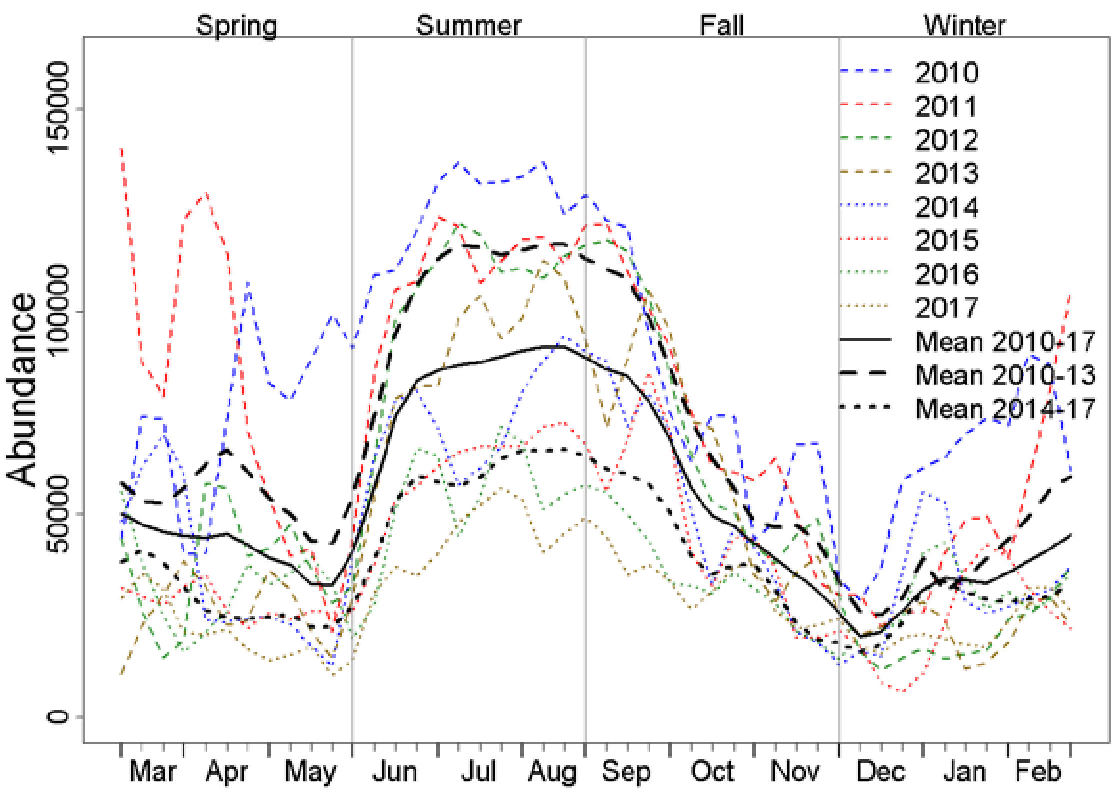

Figure 19-5 Annual abundance trends for harbor porpoises in the AMAPPS study area

19.6 Seasonal Prediction Maps

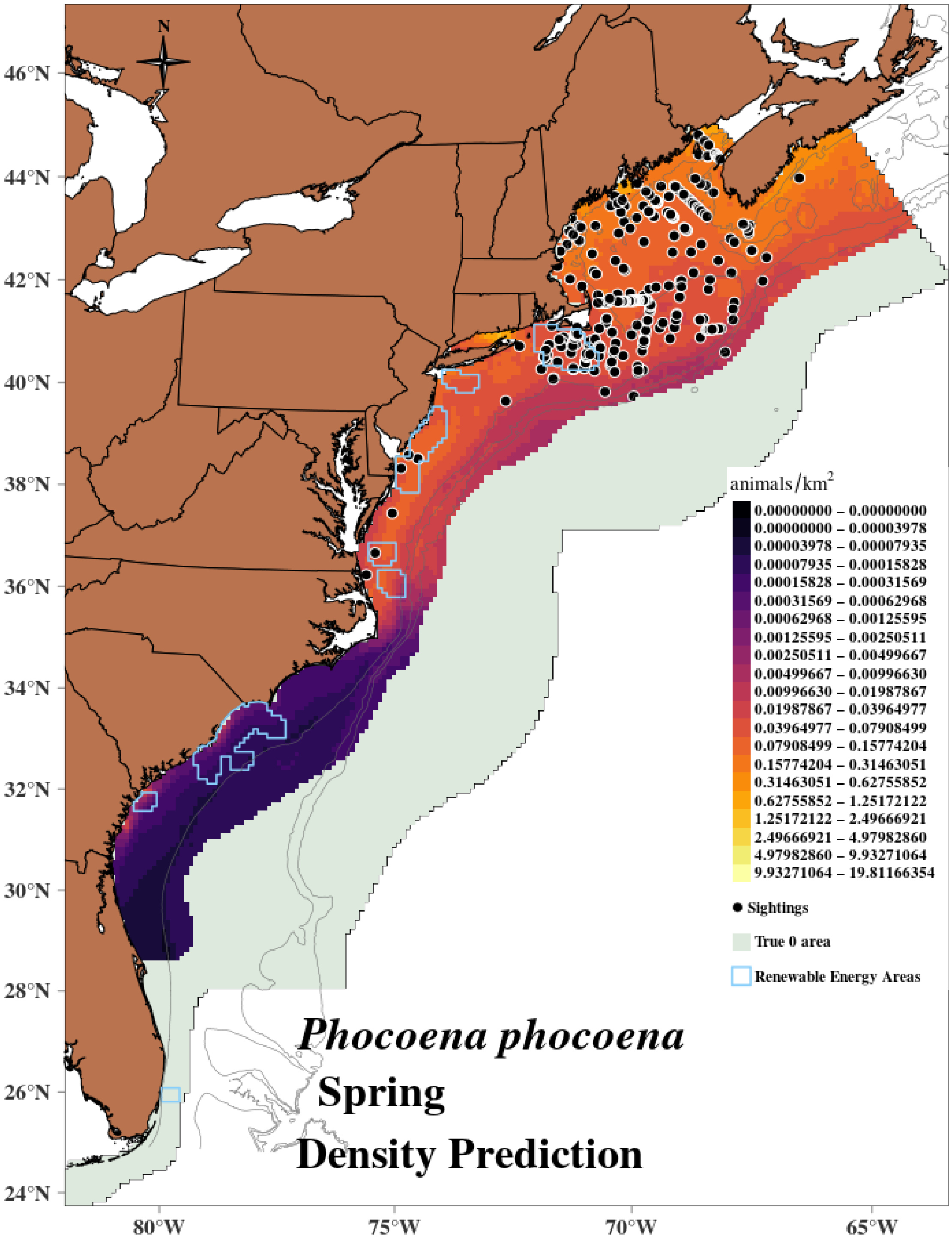

Figure 19-6 Harbor porpoise spring average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

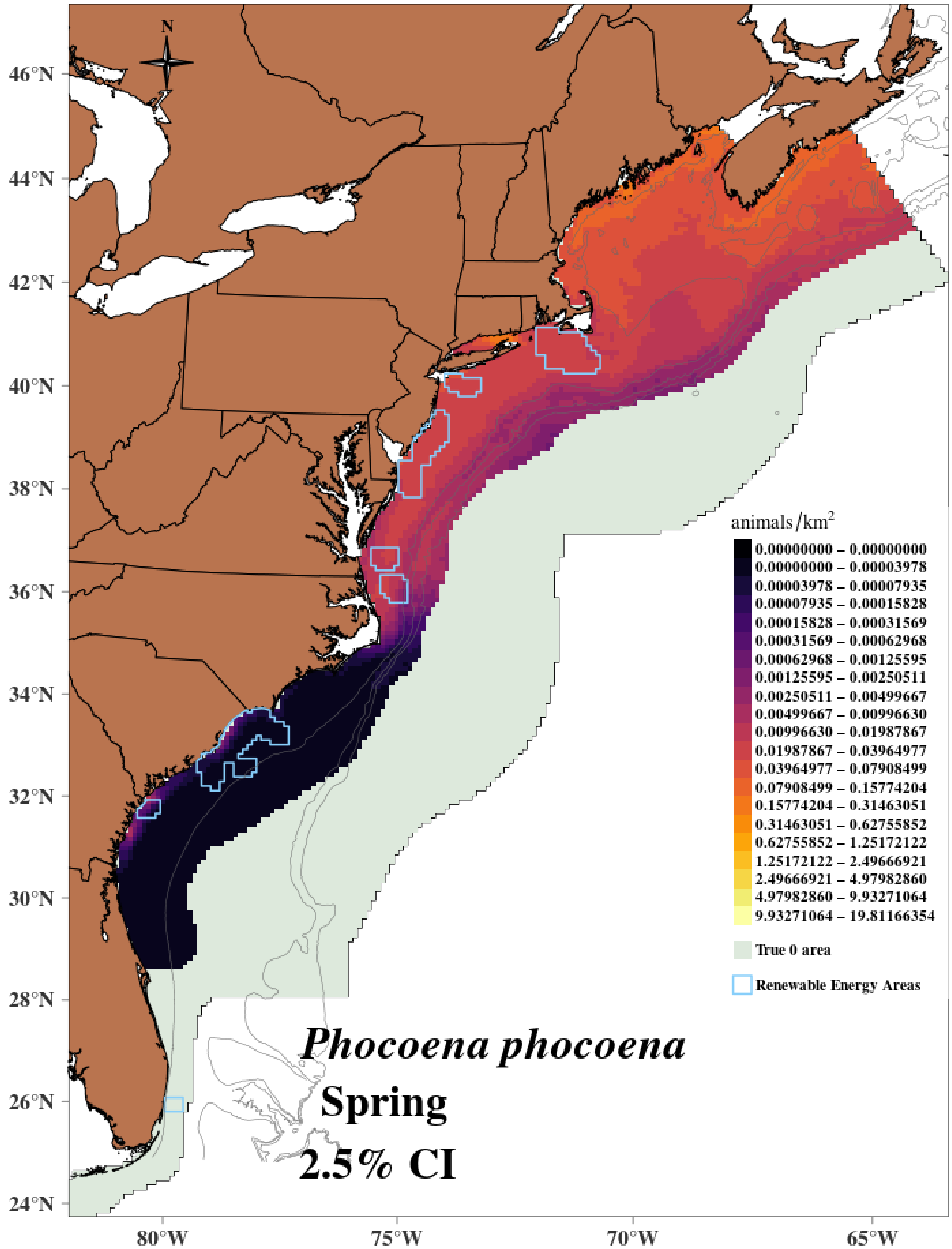

Figure 19-7 Lower 2.5% confidence interval of the spring harbor porpoise density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

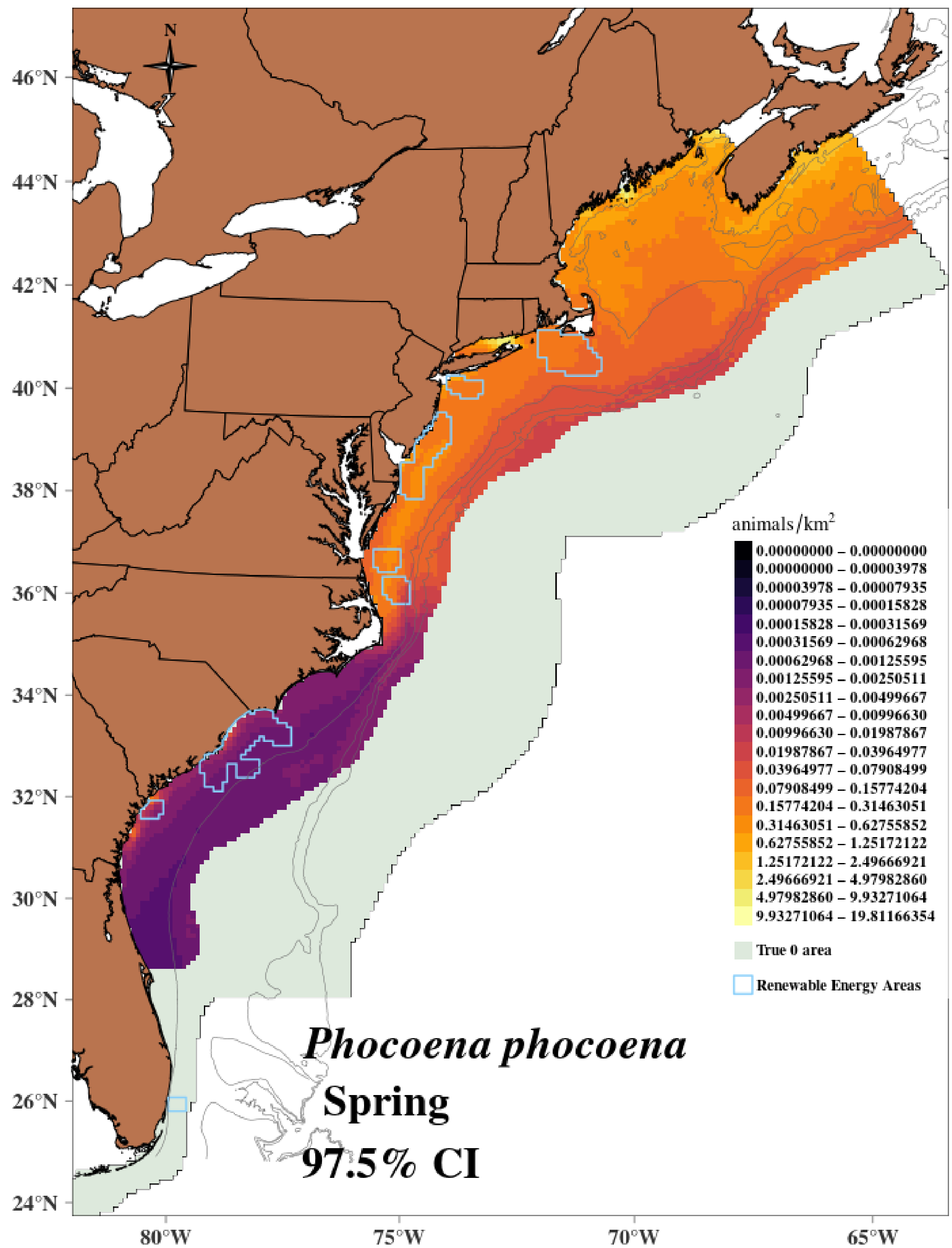

Figure 19-8 Upper 97.5% confidence interval of the spring harbor porpoise density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

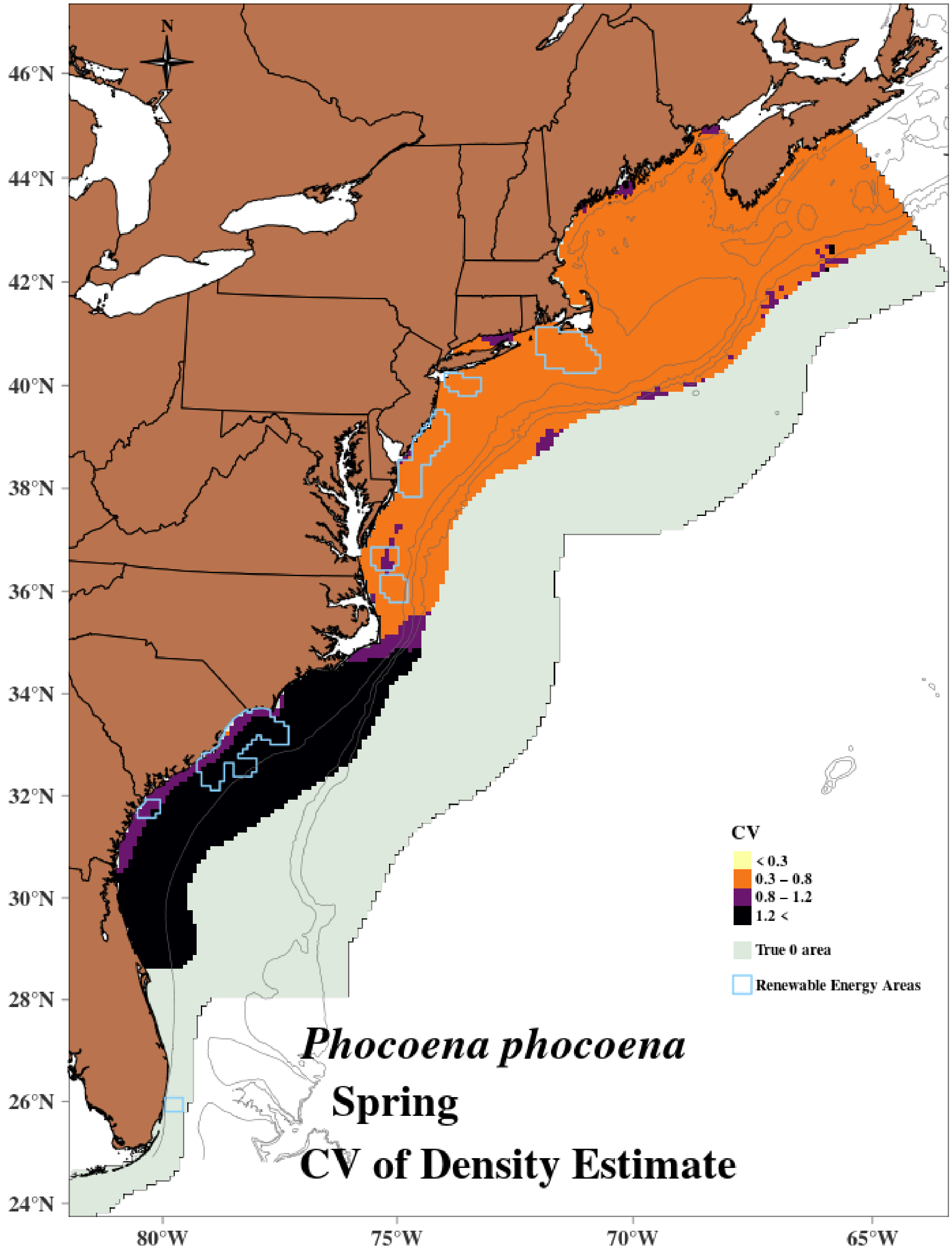

Figure 19-9 CV of spring harbor porpoise density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

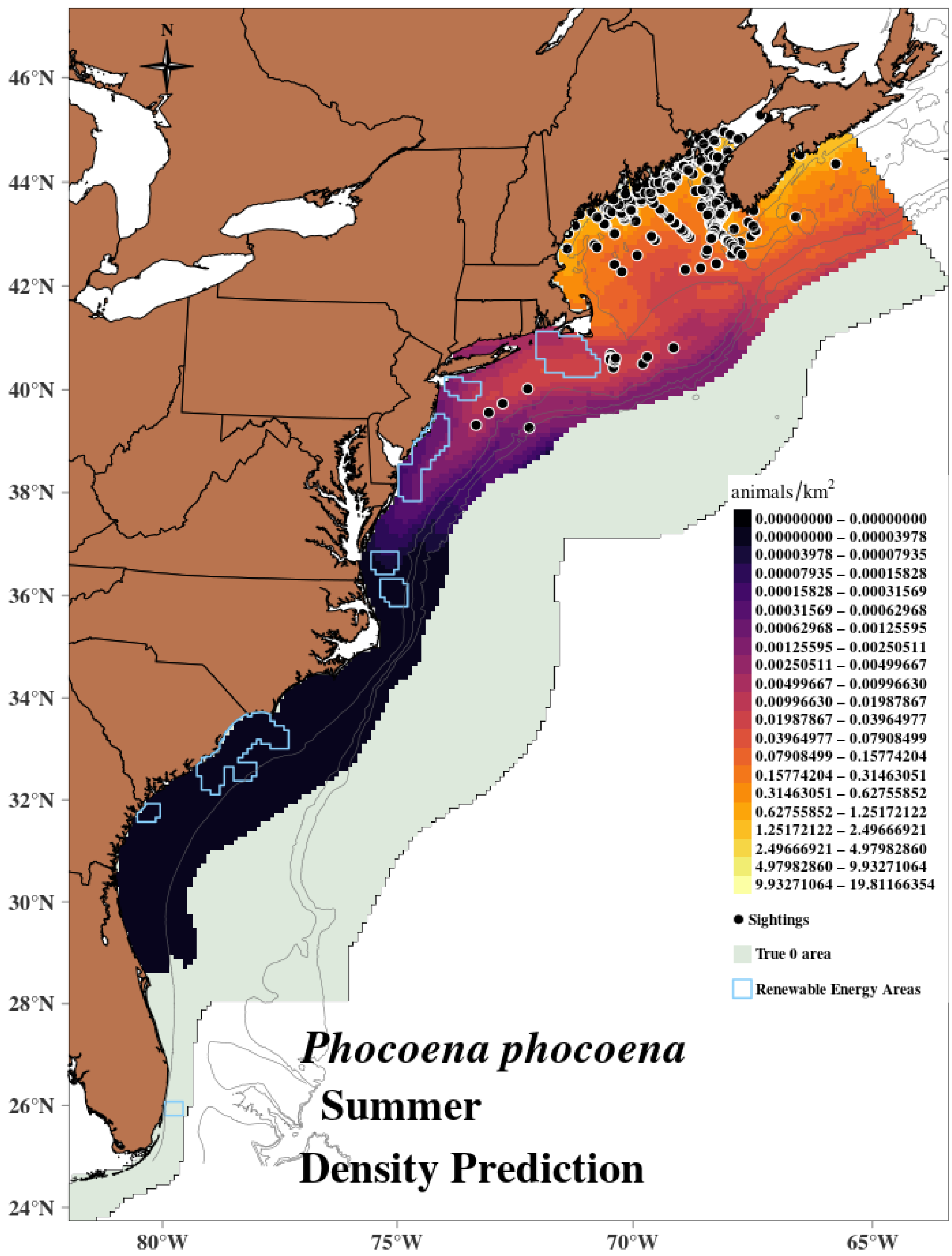

Figure 19-10 Harbor porpoise summer average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

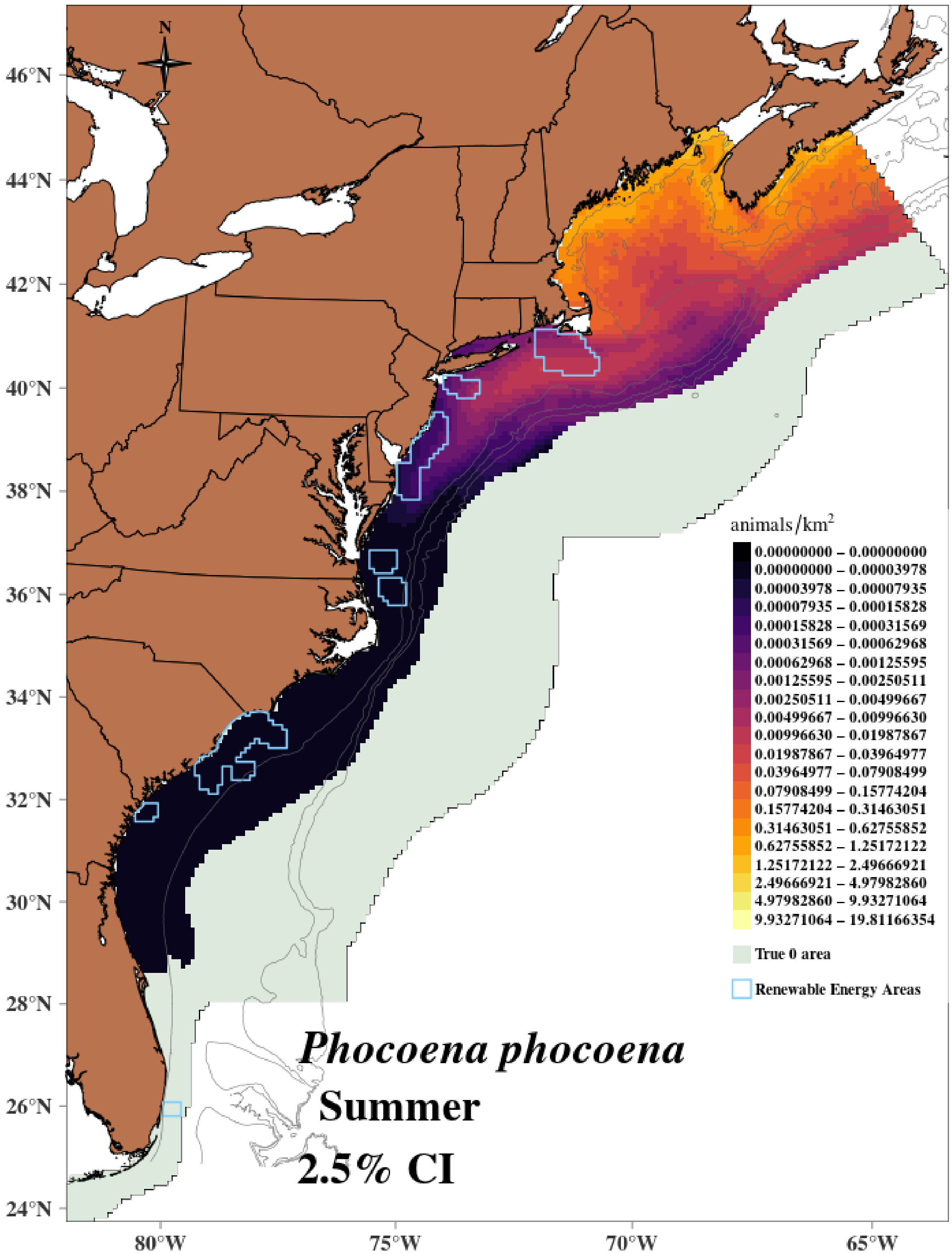

Figure 19-11 Lower 2.5% confidence interval of the summer harbor porpoise density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

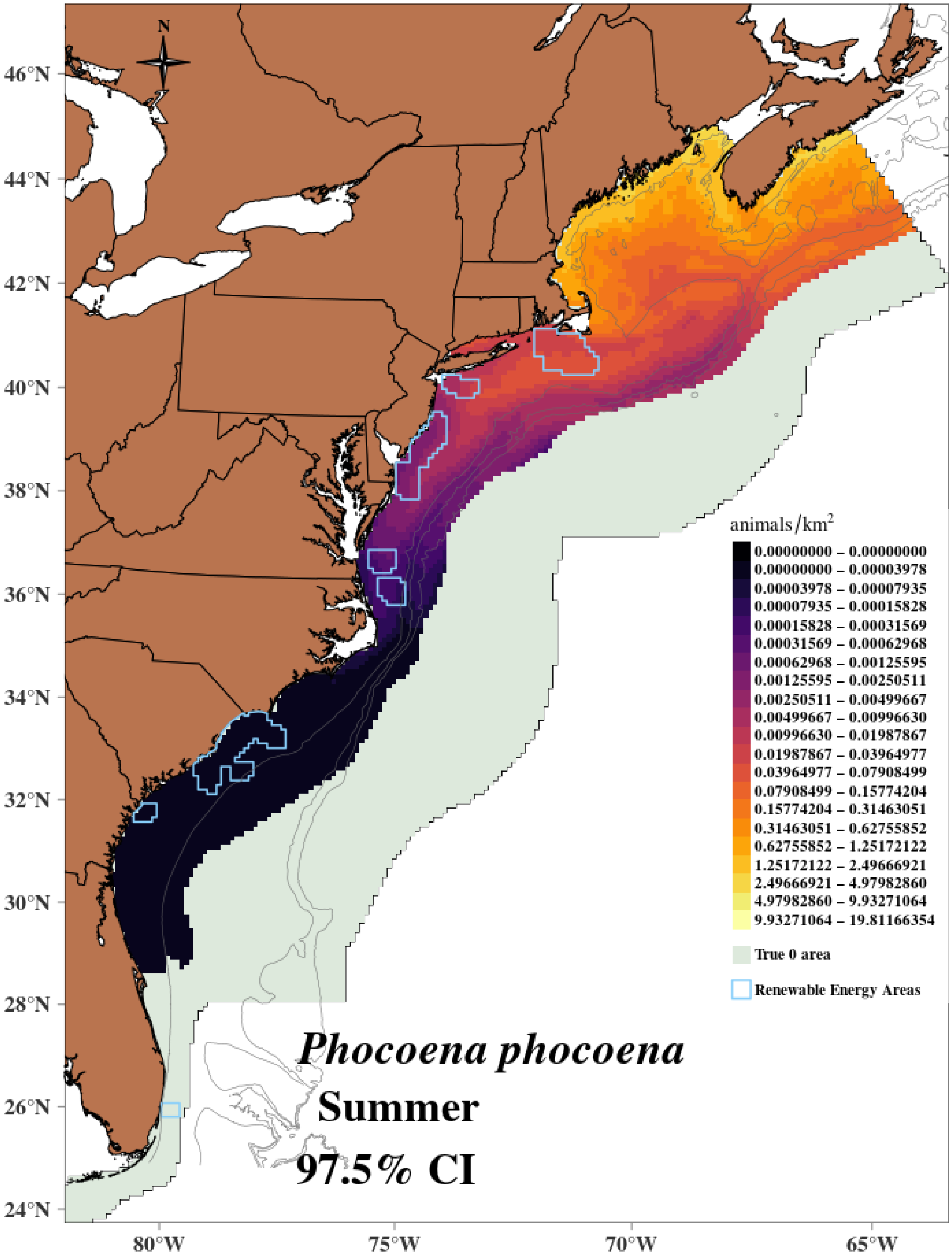

Figure 19-12 Upper 97.5% confidence interval of the summer harbor porpoise density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

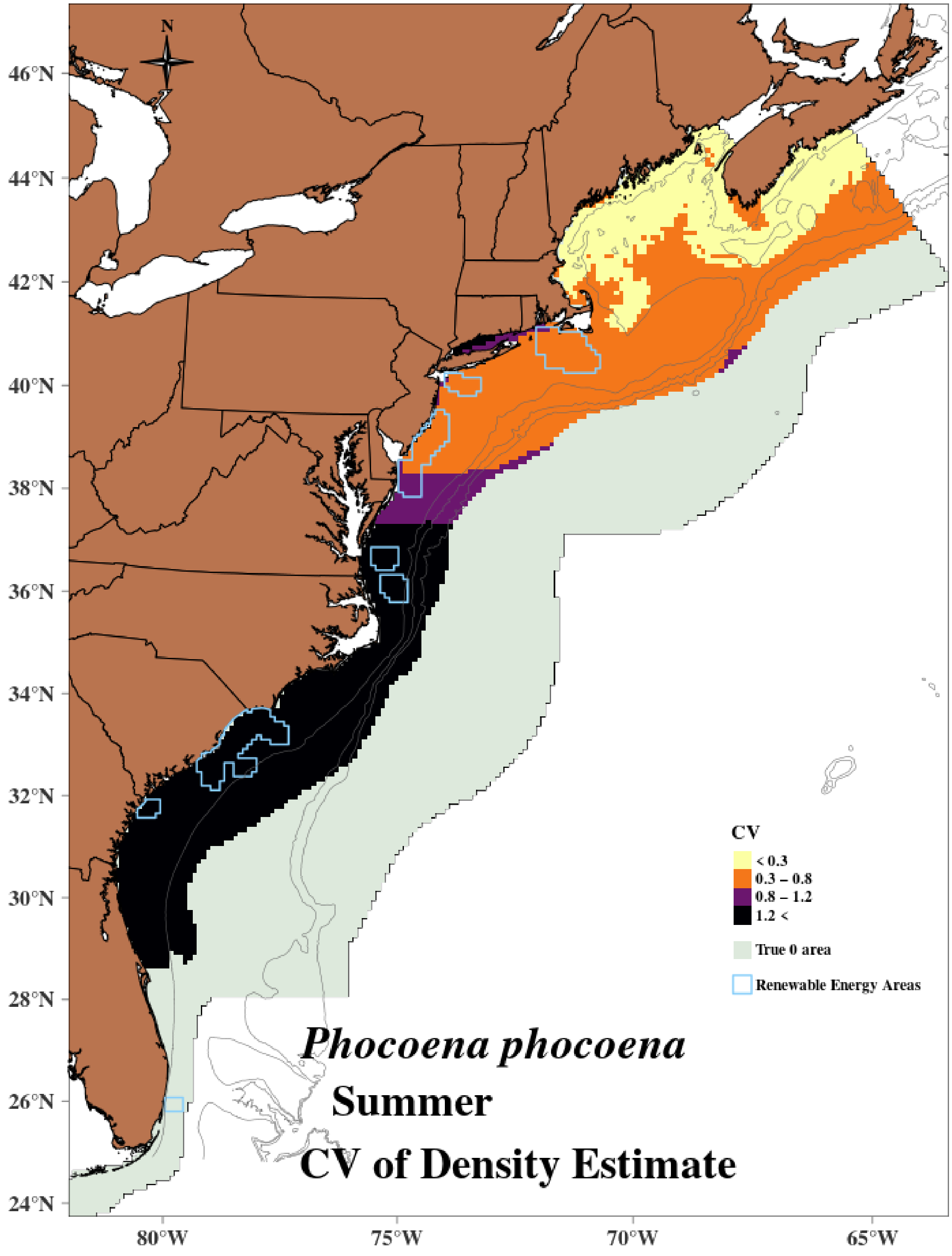

Figure 19-13 CV of summer harbor porpoise density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

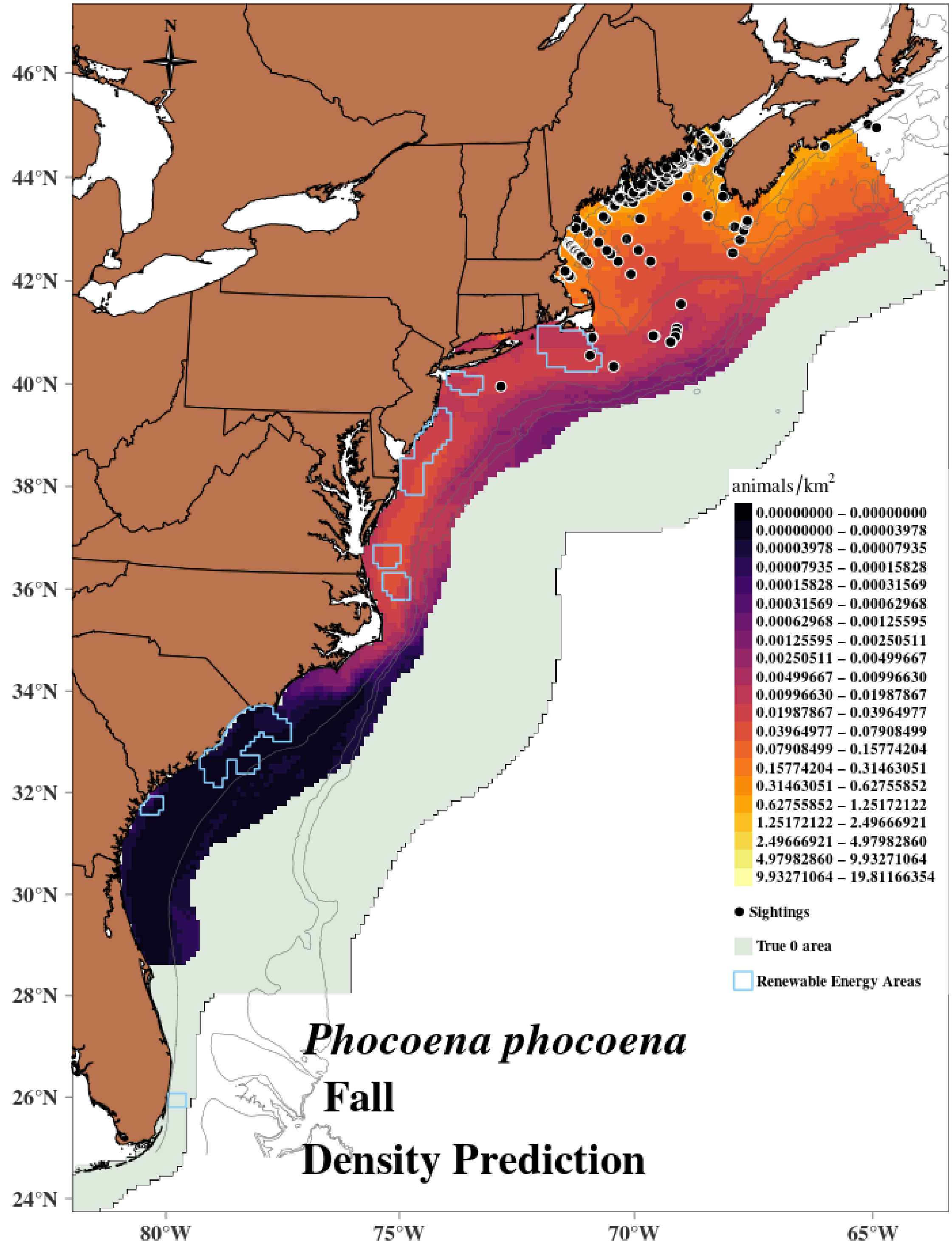

Figure 19-14 Harbor porpoise fall average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

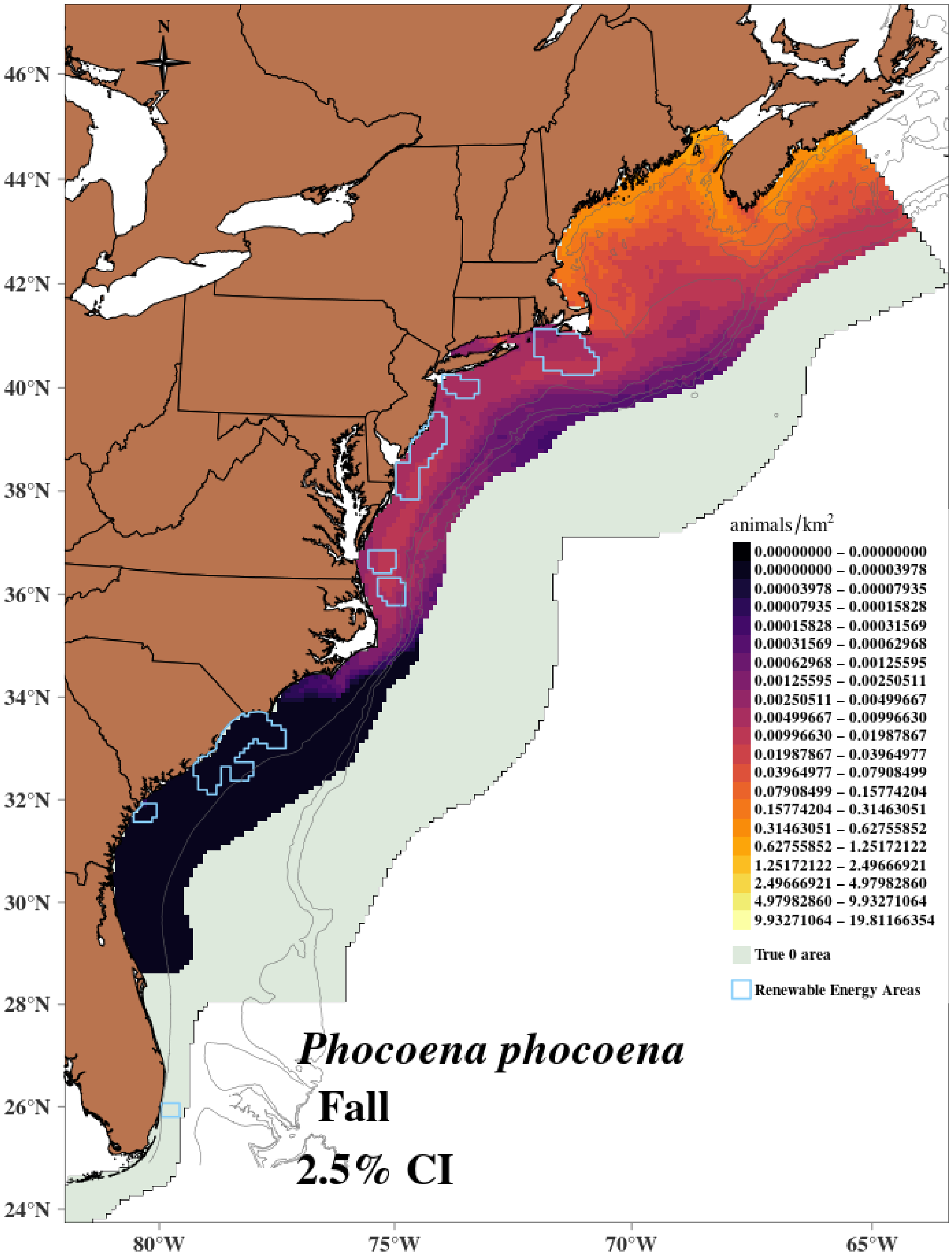

Figure 19-15 Lower 2.5% confidence interval of the fall harbor porpoise density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

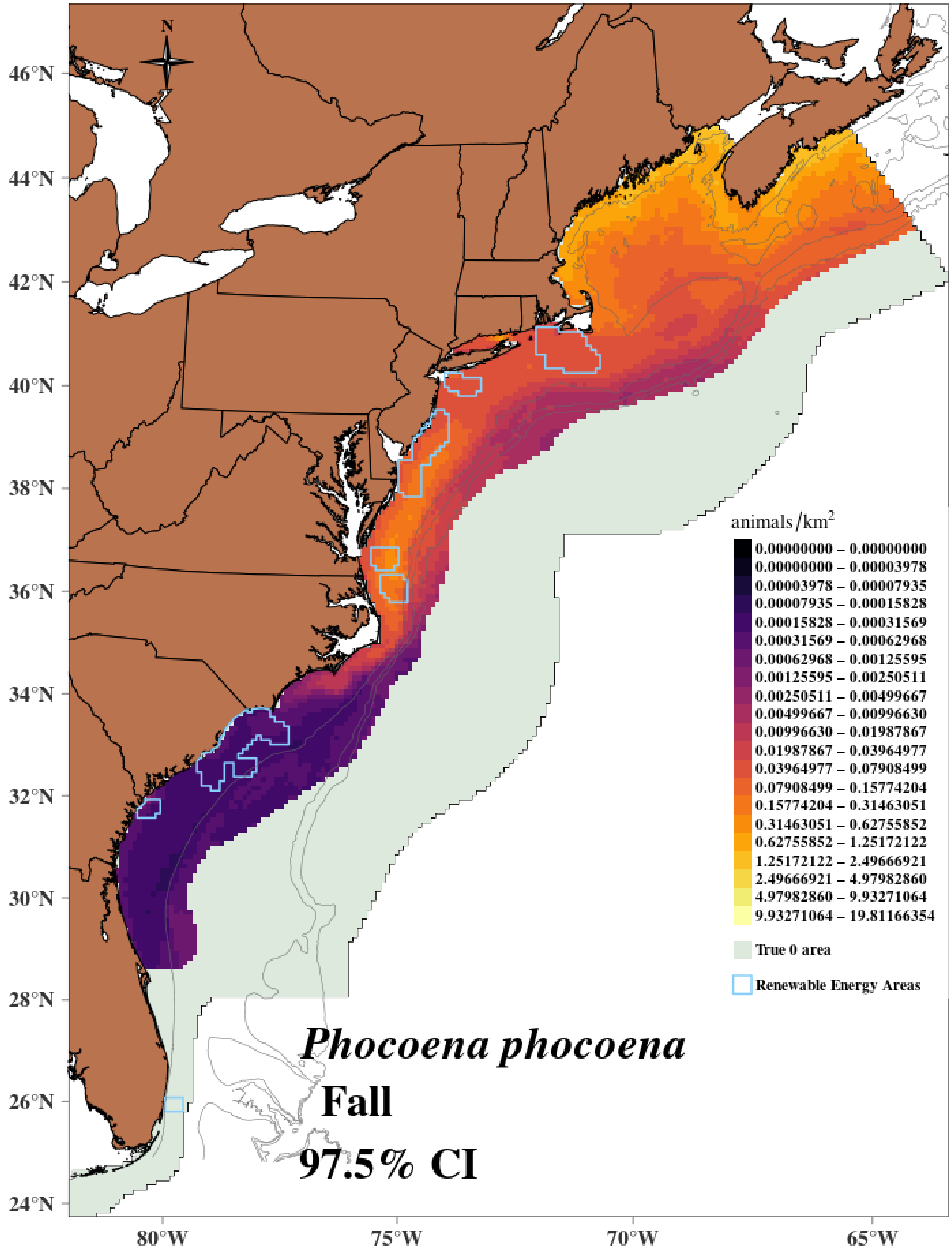

Figure 19-16 Upper 97.5% confidence interval of the fall harbor porpoise density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

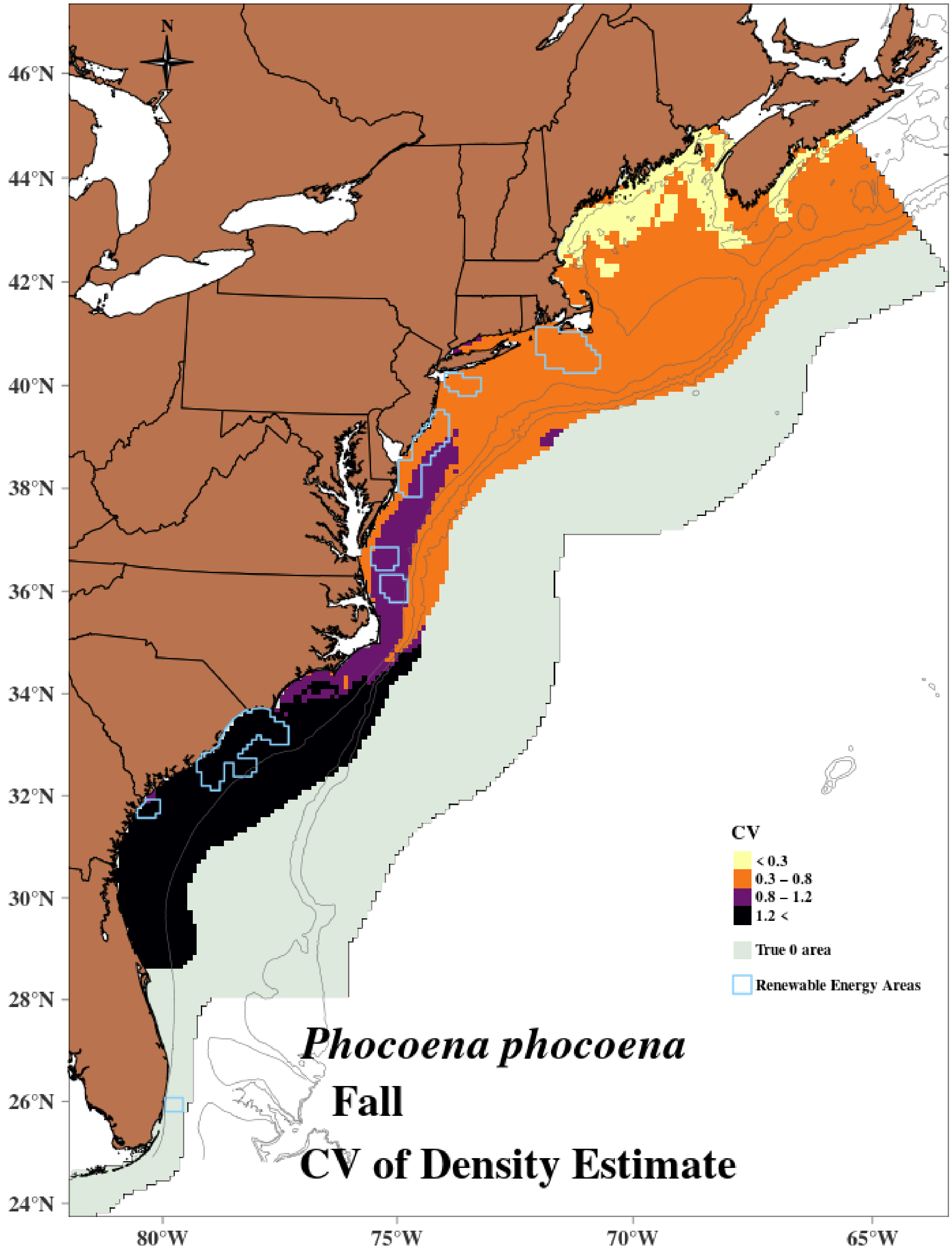

Figure 19-17 CV of fall harbor porpoise density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

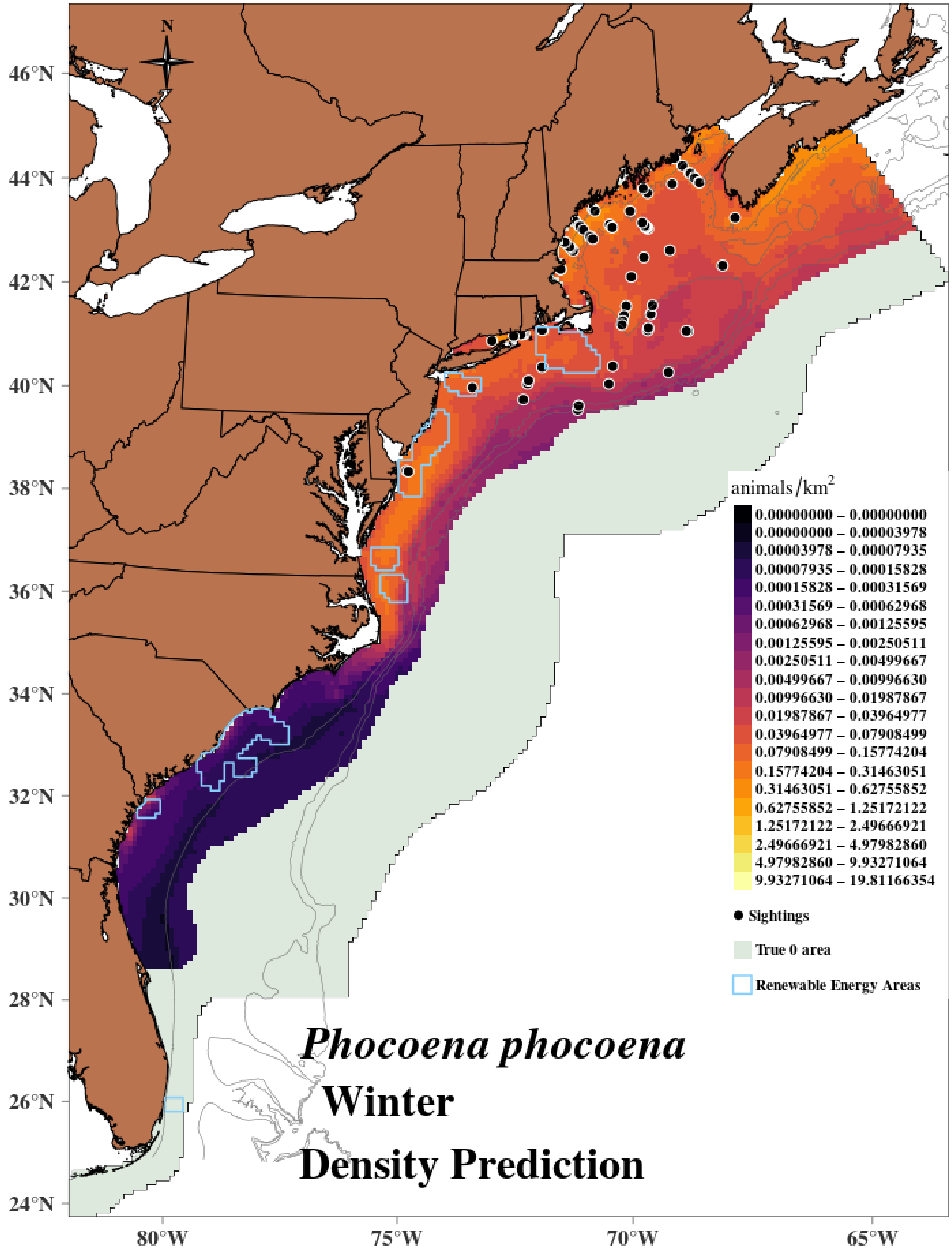

Figure 19-18 Harbor porpoise winter average density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Circles indicate locations of animal sightings. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

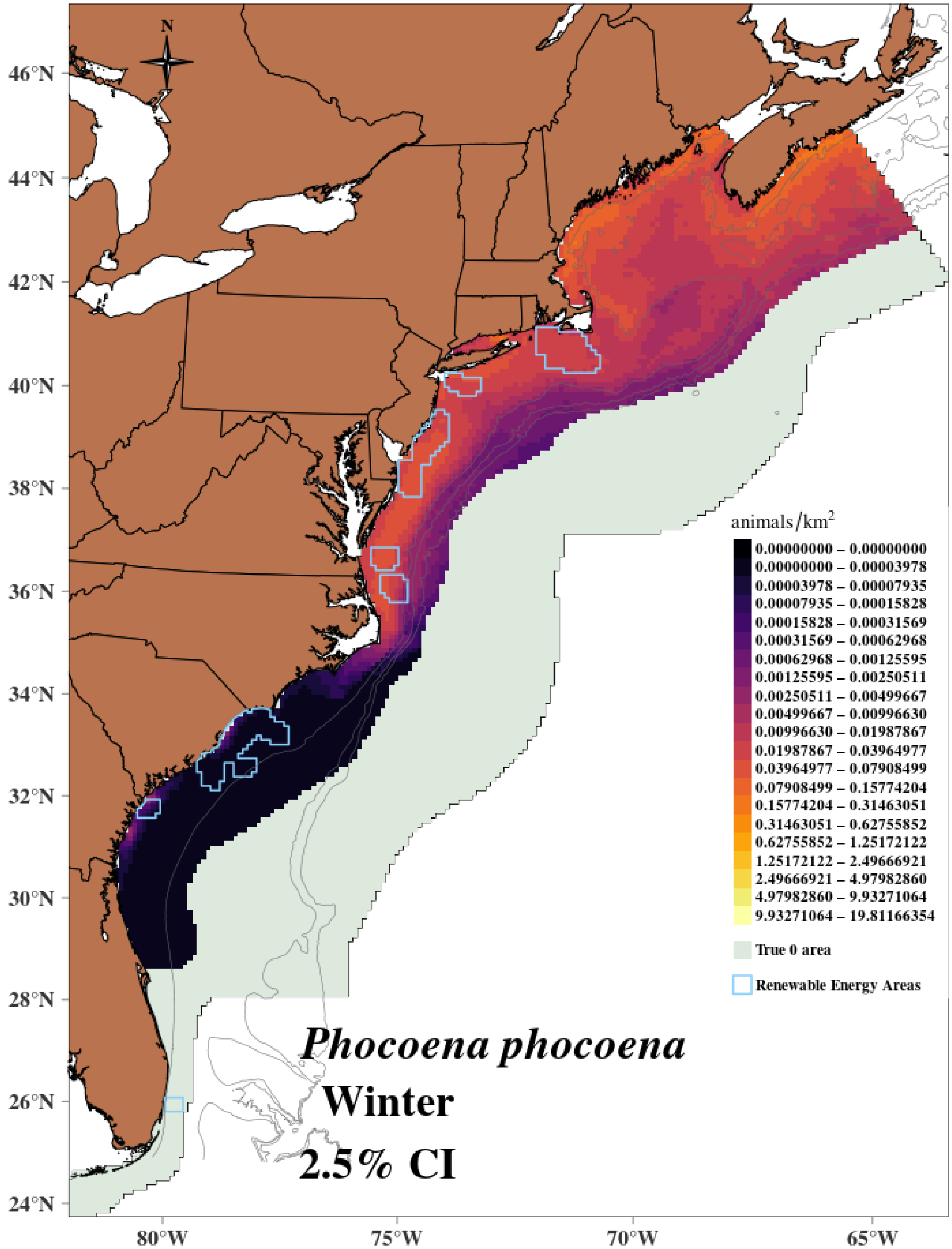

Figure 19-19 Lower 2.5% confidence interval of the winter harbor porpoise density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

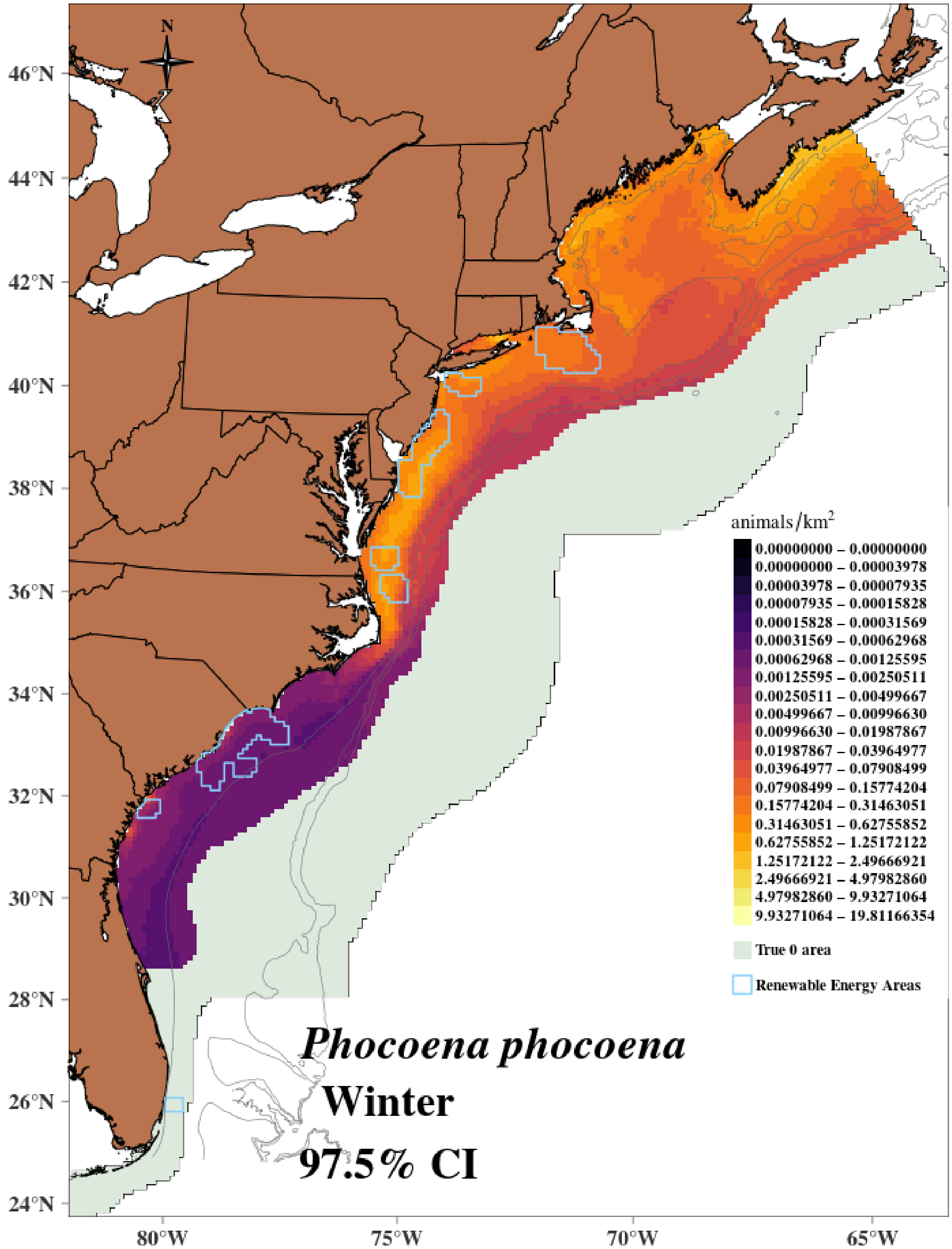

Figure 19-20 Upper 97.5% confidence interval of the winter harbor porpoise density estimates
Densities are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

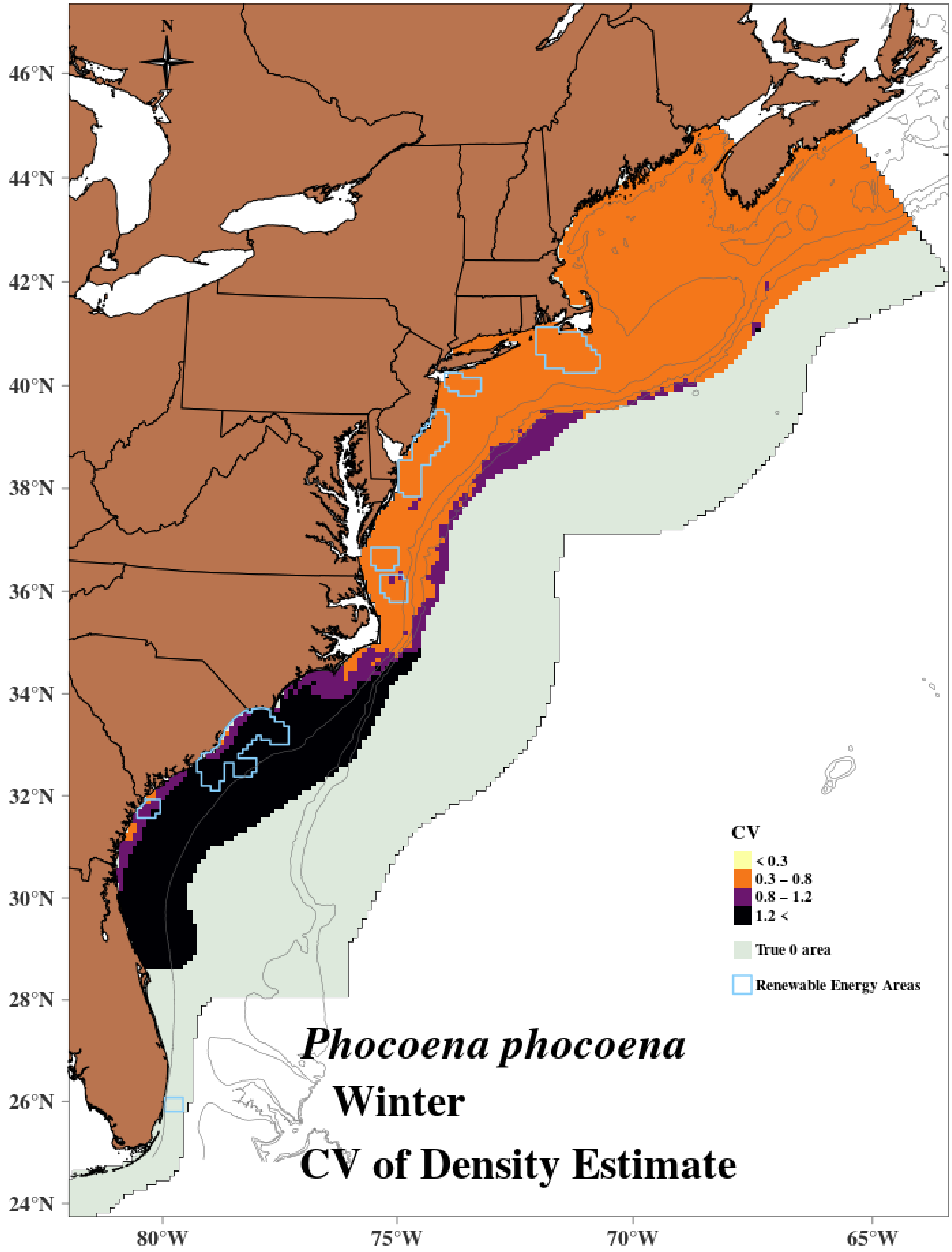

Figure 19-21 CV of winter harbor porpoise density estimates
CV's are for grid cells of 10 km x 10 km with the exception of the coastal region. Light gray lines indicate the 100, 1,000 and 2,000 m depth contours. Blue polygons indicate locations of wind-energy study areas. Light green region indicates the region within the AMAPPS study area where we assumed the density was 0.

19.7 Offshore Energy Development Areas

Table 19-6 Harbor porpoise abundance estimates for wind-energy study areas

Season	Wind-Energy Study Area	Abundance*	CV	95% Confidence Interval*
Spring (Mar–May)	RI/MA	837.0	0.52	321.3–2,180.1
	NY	267.0	0.62	87.2–817.6
	NJ	641.6	0.68	190.6–2,160.0
	DE/MD	389.2	0.72	110.0–1,377.3
	VA	196.7	0.78	50.6–764.0
	NC	148.7	0.74	40.6–543.8
	NC/SC	7.5	1.03	1.4–39.7
Summer (Jun–Aug)	RI/MA	256.8	0.41	118.1–558.3
	NY	16.4	0.48	6.7–40.5
	NJ	6.1	0.66	1.9–19.7
	DE/MD	2.2	0.83	0.5–8.9
	VA	0.1	1.50	0.0–1.2
	NC	0.1	1.86	0.0–0.6
	NC/SC	0.0	4.50	0.0–0.0
Fall (Sep–Nov)	RI/MA	265.3	0.52	102.2–688.4
	NY	61.6	0.65	19.3–196.8
	NJ	193.0	0.74	53–703.5
	DE/MD	148.9	0.79	37.8–586.5
	VA	145.0	0.96	29.8–704.9
	NC	129.7	0.98	25.9–650.9
	NC/SC	0.5	1.48	0.1–4.4
Winter (Dec–Feb)	RI/MA	917.3	0.53	344.4–2,443.0
	NY	309.5	0.59	105.8–905.1
	NJ	968.3	0.62	316.2–2,965.3
	DE/MD	703.7	0.70	203.9–2,428.9
	VA	422.8	0.72	119.0–1,501.8
	NC	312.1	0.76	83.1–1,171.8
	NC/SC	3.9	1.13	0.7–23

***** We rounded the mean abundance and 95% confidence interval to the nearest tenth of an animal. If this resulted in a zero for the mean abundance, we calculated the CV using the actual abundance value as estimated by the density-habitat model and then rounded to the nearest tenth. If a wind-energy study area is not included, then we assumed the abundance was zero.

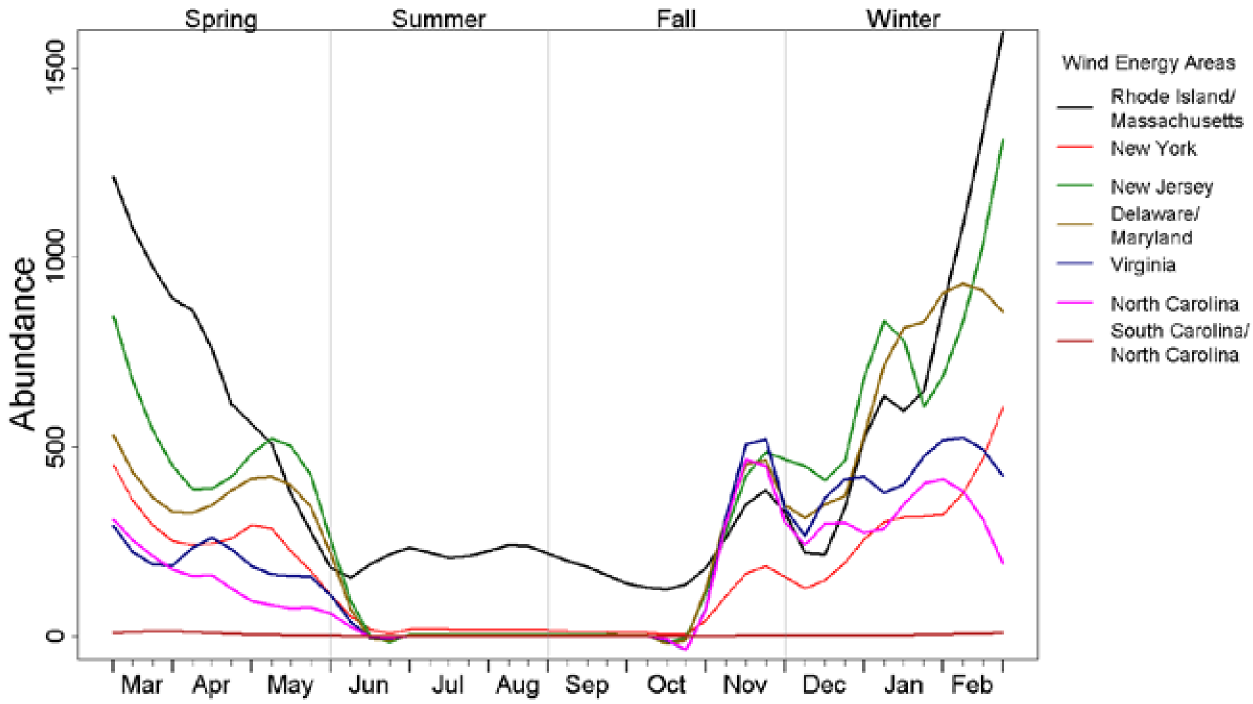

Figure 19-22 Average seasonal abundance of harbor porpoises in the wind-energy study areas

20 References

Hayes SA, Josephson E, Maze-Foley K, Rosel P. eds. 2020. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments–2019. NOAA Tech Memo NMFS NE 264; 479 pp.

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The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

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