

Chapter 11: Integrating data across survey methods to identify spatial and temporal patterns in wildlife distributions

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Chapter 11 Highlights

Identifying spatial and temporal patterns of species abundance and species richness by combining data from boat-based and digital video aerial surveys

Context¹

Part IV of this report focuses on the comparison and integration of data from boat surveys and digital video aerial surveys to examine wildlife distributions in the Mid-Atlantic and specifically offshore of Maryland. This chapter uses both datasets to identify temporal and spatial patterns of species presence and relative abundance in the Mid-Atlantic Baseline Studies and Maryland Project study areas, including the identification of “persistent hotspots,” or geographic areas with consistently high numbers of animals or species through time, which may indicate important habitat use areas. Temporal patterns of observations of different species and groups within the study area are also presented in this chapter, and can be used to determine potential exposure to offshore development activities at different times of year.

While this chapter examines patterns in areas that were directly surveyed, several other chapters in Part IV incorporate environmental covariates into modeling efforts, in order to identify environment drivers of these distributions and predict relative densities of wildlife across the region (Chapters 12-14). In some instances, one survey method was used to predict abundance of specific taxa (e.g., Chapter 12), while in other cases, the two datasets could be combined using an integrated modeling framework (Chapter 14). Additional chapters in Part IV compare boat and aerial survey methodologies (Chapter 10), highlighting the strengths and weaknesses of the two methods, and provide context for results presented in this chapter.

Study goal/objectives

Identify persistent hotspots of relative abundance and species richness, as well as temporal patterns of species abundance within both boat survey and digital video aerial survey datasets.

Highlights

- To identify persistent hotspots, boat and digital video aerial survey data were combined for locations with sufficient sample sizes where both datasets were available.
- For most taxa, hotspots were most consistently observed in areas within approximately 30-40 km from shore, particularly offshore of the mouths of Chesapeake Bay and Delaware Bay, and in northern Maryland.
- The presence and relative abundance of different species varied widely by time of year.

Implications

Combining data from two different survey approaches can provide a better view of wildlife populations and distribution patterns than either survey method could provide alone. These results may be helpful for informing the siting and permitting processes for future development projects, and for informing mitigation efforts and construction and operations plans.

¹ For more detailed context for this chapter, please see the introduction to Part IV of this report.

Abstract

Data on the abundance of marine birds, mammals, and turtles were collected over a two-year period (2012-2014) as part of the Mid-Atlantic Baseline Studies and Maryland Projects to inform siting and permitting processes for offshore wind energy development. We employed two methods: (1) traditional boat-based surveys, and (2) high resolution digital video aerial surveys. We combined data from both survey methods to examine spatial and temporal patterns of wildlife abundance by calculating persistent hotspots of abundance across all surveys. “Hotspots,” or areas with atypically high effort-corrected counts of a taxon from a given survey, were summed across all surveys to calculate relative persistence. Boat and aerial survey data were combined for locations with sufficient sample sizes where both datasets were available. We also used boat and aerial survey data from both studies to summarize temporal patterns in species observations throughout the annual cycle and compare results between survey methods.

For most taxa, hotspots were most consistently observed in areas within approximately 30-40 km of shore, particularly offshore of the mouths of Chesapeake Bay and Delaware Bay and in northern Maryland. Exceptions to this general rule included sea turtles (*Testudines* spp.), Common Dolphins (*Delphinus delphis*), Common Loons (*Gavia immer*), and alcids (*Alcidae* spp.), all of which tended to have persistent hotspots located farther offshore. The presence and relative abundance of species varied widely by time of year, however, with different species and groups using the Mid-Atlantic region, and areas offshore of Maryland in particular, during non-breeding (summer or winter), breeding, and migratory periods.

Introduction

The Mid-Atlantic region is an important area for a broad range of marine wildlife species throughout the year. This is due to relatively high levels of productivity, fed in part by nutrient inputs from Chesapeake Bay and Delaware Bay, as well as the region’s central location on the eastern edge of the continent and in the middle of an important migratory flyway (Chapter 1; Schofield et al., 2008; Smith and Kemp, 1995). During this study, our main goal was to gather the baseline information on abundance and movements of marine birds, mammals, and turtles required to inform siting and permitting processes for offshore wind energy development in the Mid-Atlantic, as part of the Mid-Atlantic Baseline Studies (MABS) Project and the Maryland Project.

We collected data on bird, sea turtle, and marine mammal abundances and movements over a two-year time period (2012-2014) using a variety of technologies and methods to examine spatial patterns and trends, while simultaneously testing a new technology for the first time in the United States (high resolution digital video aerial surveys; hereafter video aerial surveys). Video aerial surveys are a relatively new method for collecting distribution and abundance data on animals in the marine environment (Thaxter and Burton, 2009). Although they have become a common method of collecting baseline data on marine bird and mammal distribution and abundance for offshore wind energy planning and monitoring in Europe, the U.S. still relies almost exclusively on boat-based and standard (visual observer) aerial survey methods. The MABS and Maryland Projects together are the largest application of video aerial surveys in the U.S. to date. We also conducted boat-based surveys within the

study areas to accompany the video aerial surveys; standardized boat-based surveys are a well-established and widely used method of obtaining density data for birds, sea turtles, and marine mammals (Gjerdrum et al., 2012; Tasker et al., 1984).

Boat and video aerial surveys produced markedly different results for some taxa (Chapter 10), which can present a challenge when interpreting and/or integrating data obtained from the two survey methodologies. These differences also present an opportunity, however, in that the two surveys can provide complementary data that, in tandem, may be used to provide a better overall view of wildlife distributions and relative abundance in the Maryland and MABS study areas. The challenge was to integrate these data in a meaningful way that adds to our understanding of wildlife distributions. Two such integrative efforts are discussed below: the identification of geographic hotspots of persistent abundance, as well as the identification of temporal patterns of persistence and relative abundance of species within the study area.

Both abiotic components (e.g., climatic conditions) and biotic components (e.g., prey and predator distributions) of marine ecosystems can be highly variable in space and time (Kappes et al., 2010; Lehodey et al., 2006; Murphy et al., 1998). Thus, identifying key habitat use areas or locations of high wildlife abundance in the marine environment can be difficult, as such locations may be ephemeral. Several previous studies have attempted to identify hotspots of wildlife abundance in the marine ecosystem; while each study defined hotspots slightly differently, all of these definitions contain an element of temporal as well as spatial persistence. For example, Piatt et al. (2006) define a hotspot for the Short-tailed Albatross (*Phoebastria albatrus*) as a 'relatively small area in which we expect to find animal aggregations repeatedly', while Davoren (2007) defines hotspots of seabirds as 'areas where high abundance of species overlap in space and time'. Suryan et al. (2012) define hotspots of marine predators as 'regions of consistently high abundance of predators relative to the surrounding area in the open ocean'. Other studies have used varying mathematical definitions to identify hotspots. Zipkin et al. (2015) identifies hotspots as locations with 3x the mean abundance for the study region. Santora and Veit (2013) define hotspots as 'locations with anomalies that exceed the mean for the entire study region by 1 standard deviation in a given survey'. Likewise, in this study, we apply a quantitative definition to identify hotspots in a consistent, repeatable way across species and surveys. While most similar to the approach taken by Santora and Veit (2013), our exact definition of hotspots also varies slightly from those above, in order to account for highly non-normal distributions of animal counts across our study area, and with a goal of identifying those hotspots that are most consistent throughout the two years of surveys.

Persistent hotspots thus highlight locations where individuals within a species or species group have been consistently observed in greater than average numbers over time, and may indicate the locations of important habitat (Gende and Sigler, 2006; Santora et al., 2010; Sydeman et al., 2006). In this study, we examined spatial patterns of persistent abundance for a wide range of taxa, including seabirds, marine mammals, sea turtles, rays, and bait fish, which were present within the study area for varying amounts of time or in variable numbers depending on each group's life history traits. Temporal bar charts summarize the temporal patterns of species and species groups within the study area, and allow

for comparison of effort-corrected count data for species and species groups through time and between survey methods. Identification of persistent hotspots, paired with temporal bar charts for taxa of interest, can be used in: (1) marine spatial planning efforts; (2) understanding when and where animals may be affected by anthropogenic activities; and (3) identifying species or taxa in particular need of additional study. These data can be used during permitting processes for future development, as well as for siting projects and designing development plans to minimize wildlife impacts on the Mid-Atlantic Outer Continental Shelf. By pairing persistent hotspot maps with temporal bar charts for species and taxonomic groups of interest, we hope to develop a comprehensive picture of geographic and temporal patterns of wildlife within the study area.

Methods

Between March 2012 and May 2014, we conducted 16 large-scale boat-based visual surveys and 15 large-scale high-resolution digital video aerial surveys within the Maryland and MABS study areas, with additional survey effort within the Maryland study area during Year Two of the study. The broader MABS study area encompasses the coastal area from Delaware to Virginia, extending from 3 nautical miles from the coastline (the boundary between state and federal waters) out to the 30 m isobath or the eastern extent of the Wind Energy Areas (WEAs; Figure 11-1). The Maryland Project funded an expansion of the original Department of Energy (DOE)-funded aerial and boat survey transects to include more of the federal and state waters offshore of Maryland (Figure 11-1). Seven aerial surveys and eight boat surveys of the entire MABS project area were conducted each year. In the second year of surveys (March 2013-May 2014), the Maryland Project extension transects were surveyed along with the broader MABS surveys. An additional aerial survey of just the extension transects and the Maryland WEA transect lines was flown in August of 2013. Further details on the study area and data collection methods can be found in Chapter 3 and Chapter 6.

Several taxa observed during boat and video aerial surveys had insufficient data to calculate persistent hotspots or conduct other spatial analyses, and simple point maps of raw data for several of these taxa are briefly discussed. For taxa with more robust datasets from the boat survey, video aerial survey, or both, additional analyses were conducted. All analyses described below include data collected from both the Maryland Project and the broader MABS study areas.

Persistent hotspot analysis

We adapted the methods of Santora and Veit (2013) to quantify the variance and anomaly persistence of counts for a single species or species group within grid cells across the study area. Aerial and boat survey transects and species observations were binned by Bureau of Ocean Energy Management (BOEM) Outer Continental Shelf (OCS) lease blocks (a 23.0 km² grid, where each cell is 4.8 x 4.8 km) using ArcGIS version 10.2.2 (ESRI, Redlands, CA). The BOEM lease grid was extended west of the Submerged Lands Act boundary (generally 5.6 km from shore) to include the entire Mid-Atlantic Baseline Studies and Maryland Project study area. Binning survey data by grid cell allowed us to standardize for spatial variation in survey effort within each survey, and combine the resulting hotspot determinations from all 31 surveys (including both survey methods) in a unified hotspot persistence analysis.

We limited our analysis to the most commonly observed species or species groups, defined by having a minimum of 700 total observations from a survey method over the entire study period (including both MABS and Maryland study areas). This cut-off point was found to be high enough to show ecologically relevant patterns for most species or groups examined, while eliminating most complications caused by low sample size. The exception to this criterion was cormorants (*Phalacrocoracidae* spp.) observed by boat; although over 700 individuals were observed, over half of these individuals were recorded in three single observations, which prevented the identification of persistent hotspots according to the criteria used in this chapter. Data were grouped and analyzed by family, instead of by individual species, provided that either (1) most observations within a family likely represented a single species (e.g., unidentified storm-petrels and Wilson's Storm-Petrels [*Oceanites oceanicus*] were mapped together as storm-petrels, *Hydrobatidae*), or (2) sample sizes for single species were too small to analyze separately, but large enough to be analyzed when aggregated by family (e.g., alcid).

Defining a hotspot

Boat and video aerial survey data were analyzed independently for hotspot analysis. First, an effort-corrected count was calculated for the species or group of interest per grid cell for each survey. For boat surveys, this was done by dividing the number of individuals observed by the total transect length (km) within each grid cell for each survey. For video aerial surveys, the number of individuals observed was divided by the total surveyed area (km²) within each grid cell per survey. As resulting data were highly non-normal, a gamma distribution was fitted to non-zero effort-corrected counts for each grid cell in a given survey using 'fitdistrplus' package (Delignette-Muller and Dutang, 2015) in the R Statistical Environment (version 1.1-7, R Core Team 2014), and used to assign a probability to each grid cell's value depending on where it fell within the distribution curve for that survey. Fitting a gamma distribution to non-zero effort-corrected counts allowed us to identify cells with high abundance relative to other cells where the taxa was present, on a survey by survey basis. We considered grid cells within the top quartile (>75th percentile in the survey's gamma distribution) of effort-corrected values for a given survey as hotspots for that survey.

Determining persistence

After identifying hotspots for each survey, data were combined in order to index hotspot persistence, or the percentage of time each grid cell was a hotspot across all surveys (within a given survey method). Grid cells that had been surveyed fewer than eight times (i.e., in fewer than half of the surveys) within a survey method were excluded from further analysis. Using these criteria, 168 grid cells were included in further analyses when only boat survey data were analyzed, 410 grid cells were included when only aerial data were analyzed, and a total of 450 cells were included when both boat and aerial data were analyzed and combined in a unified hotspot persistence map for a given species or taxon. In these combined maps, 128 grid cells were surveyed by both methods, 40 cells were surveyed only by boat, and 282 cells were surveyed only by aerial methods (Figure 11-2).

Where only boat or aerial data were analyzed for a given species, the number of times each cell represented a hotspot (hotspot sum) was divided by the number of times the cell was surveyed (survey sum), to calculate persistence as the percentage of surveys in which a cell represented a hotspot for the species or group of interest. For grid cells surveyed by both boat and video aerial survey methods, data

were combined. Due to presumed differences in detection and/or identification rates between these two survey methods, we often observed notably different counts of species between the two datasets (Chapter 10). To account for these differences, we weighted the data by effort-corrected total abundance for each dataset before calculating persistence as described above. Effort-corrected total abundance was calculated by dividing total abundance across all surveys by total area surveyed (km²) across all surveys. Effective strip width for boat survey transects was approximated by multiplying the total transect length by the median distance at which the species/group was observed from the boat, then multiplying by two (to account for the fact that observers surveyed both sides of the boat simultaneously). The resulting ratio of boat to aerial effort-corrected abundance was used to weight data using the following equation:

$$Persistence = \frac{(Hsum_a \times R_a) + (Hsum_b \times R_b)}{(Ssum_a \times R_a) + (Ssum_b \times R_b)}$$

where $R_a:R_b$ is the ratio of aerial to boat effort-corrected abundance, $Hsum$ is number of times a cell was identified as a hotspot by survey method (a , aerial; b , boat), and $Ssum$ is the number of times a cell was surveyed by each method.

Mapping hotspot persistence

Persistence values were broken into four distinct classes for mapping purposes, based on breaks at the 75th, 85th, and 95th percentiles of persistence values for cells that were a hotspot in at least one survey. We presented percentiles of persistence values (rather than the persistence values themselves) in order to facilitate comparison between species with different life histories, which may be present in the study area for varying amounts of time throughout the year.

Special case: Common Loons and Red-throated Loons

Loon abundance data collected by video aerial surveys presented a unique challenge, as only 14% of aerial loon observations were identified to species; the remaining 86% were categorized as unidentified loons, which contained an unknown proportion of either Common Loons or Red-throated Loons (*Gavia stellata*). We used the species identification model with environmental covariates developed as part of the MABS project (Hostetter et al., 2015) to predict the proportions of Red-throated and Common Loons in each grid cell for four aerial surveys (May 2012, December 2012, March 2013, and December 2013). These surveys had high loon abundance, and also had a boat survey conducted within two weeks of the aerial survey (Hostetter et al., 2015). For these four aerial surveys, we summed the predicted counts of Red-throated Loons and Common Loons with the identified counts for each species to calculate hotspot persistence in video aerial data. In remaining aerial surveys, only the identified counts (e.g., birds identified as either Common Loons or Red-throated Loons, but not unidentified loons) were used in determining hotspots for the two species.

Special case: Species Richness

Species richness hotspots were identified using the same analysis methods described above, with two modifications. First, for each grid cell and survey, the datum of interest was considered to be the total count of species observed within the grid cell, rather than the effort-corrected count of an individual

taxon observed within the grid cell. The relationship between survey effort and the number of species observed is not linear, so we did not effort-correct species counts within each grid cell, in order to avoid over-estimating counts in cells with very low effort (Gotelli and Colwell, 2010). However, in order to identify hotspots within datasets with similar effort per grid cell, we separated the sawtooth aerial survey transects from the high density aerial survey transects, which were located in the WEAs and offshore of Maryland (see study area map in Executive Summary and other chapters throughout this report). We independently identified hotspots within the sawtooth aerial data, high density aerial data, and boat data, and species richness hotspots identified from each dataset were weighted equally when combined to map hotspot persistence.

Temporal bar charts

We generated temporal bar charts of effort-corrected count data for boat and video aerial survey data independently, because detection and geographic coverage varied between survey methods (Chapters 5, 7, and 10). The total count of individuals was summed for each species and species group by two-month time period. Thus, each time period included data from two to four surveys over the two-year study. The two-month length of these time periods was found to best serve for data visualization purposes, as it displayed variation in the data presented while also controlling somewhat for variation in effort between periods (see Chapters 5 and 7).

Bar charts were created in Microsoft Excel (Redmond, WA) for all individual species and species groups that were observed more than 10 times within a survey method over the course of the study. Species and group counts were standardized for survey effort for each survey method (boat-based and digital video aerial surveys), using linear kilometers surveyed over each two-month time period. Effective transect strip width varied greatly by taxon for boat survey data, and using linear kilometers rather than total area surveyed allowed for direct comparisons between the two study methods. Percentiles were calculated for all effort-corrected survey data from both survey types for species groups (Table 11-1) and individual species (Table 11-3). Boat and aerial percentile values, represented by bars of increasing height and greater color intensity, are presented adjacent to one another to allow for comparison between the two study methods.

Results

Persistent hotspots were identified primarily for groups of species, rather than for individual species, due to sample size limitations and/or difficulties with species identification. Whenever possible, boat and video aerial survey data were combined to develop joint maps of persistent hotspots of abundance for taxa of interest. Insufficient data from one of the two survey methods, however, led to hotspots being estimated with data from a single survey method for some species groups. Thus, some hotspot maps below include data only from boat surveys (for example, for storm-petrels); some hotspots were calculated solely from video aerial surveys (such as sea turtles and rays); and many others used data from both survey methodologies, weighted by the ratio of effort-corrected counts between the two survey types. Temporal bar charts provide context for the maps of hotspots, illustrating the changes in relative abundance of counts and in species composition for both survey types over time.

Scoters

Scoters, a genus of sea ducks that in the Mid-Atlantic includes Black Scoter (*Melanitta americana*), White-winged Scoter (*M. fusca*), and Surf Scoter (*M. perspicillata*), were observed in 61% of surveys, primarily between September and May (Table 11-2). Though scoters were observed at all longitudes within the Maryland and MABS study areas, observations in the east tended to be sporadic and to involve small numbers of individuals. Scoter flocks, or rafts, were most consistently located in areas within about 30 km of shore, particularly near the mouths of Chesapeake Bay and Delaware Bay (Figure 11-3). Hotspots were also present, though slightly less persistent, in nearshore waters within the Maryland study area. The persistent hotspots of scoter abundance identified in Figure 11-3 were some of the largest and most consistent of any species group examined. Surf Scoters (Figure 11-4) and Black Scoters (Figure 11-5) showed strikingly similar patterns of hotspot persistence to each other and to the family as a whole. Additional information on Surf Scoter movements and habitat use in the Mid-Atlantic is presented in Meattey et al. (2015).

Loons

Loons, including Common Loons and Red-throated Loons, were present in 90% of surveys, with greatest numbers present in the broader study area between November and May (Table 11-2, Table 11-4). Loons do not form large rafts like many sea duck species, and were more likely to be observed individually or in small groups. Hotspots of loon abundance were less persistent between surveys than for scoters, and showed distinctly different patterns between species (particularly when the species identification model using environmental covariates was used to incorporate unidentified loons into hotspot datasets; Hostetter et al., 2015). Red-throated Loons showed highest hotspot persistence close to shore along the length of the MABS and Maryland study areas (Figure 11-6). Common Loon hotspots were scattered across the width of the Outer Continental Shelf, though many of the most persistent Common Loon hotspots were located offshore of the mouth of Chesapeake Bay (Figure 11-7). Additional information on Red-throated Loon movements and habitat use in the Mid-Atlantic is presented in Gray et al. (2015).

Storm-petrels

Storm-petrels were not identified frequently enough from the aerial data to allow mapping persistent hotspots of abundance using those data, but hotspots estimated from boat data for this taxon (primarily Wilson's Storm-petrels), are presented in Figure 11-8. Storm-petrels were observed in 50% of boat surveys, and almost exclusively in summer (Table 11-2). Identified hotspots of relative abundance included both nearshore and offshore locations across the MABS and Maryland study areas (Figure 11-8). Storm-petrels were generally observed individually, rather than in groups, and were abundant for only a few months each year; this led to lease blocks only being considered a hotspot in one out of 16 (6.25%) or two out of 16 (12.5%) boat surveys (that is, 12.5% or 25% of surveys in which the taxon was present in the study area), so persistence classes were consolidated into two categories to display the data for this species group.

Northern Gannets

Northern Gannets (*Morus bassanus*) were observed in 81% of all surveys (13 out of 16 boat surveys and 12 out of 15 video aerial surveys). The species was widely distributed across the MABS and Maryland study areas. The most persistent abundance hotspots for gannets contained large aggregations between

36% and 54% of the time that the species was present in the region, but the majority of grid cells (70%) were identified as an abundance hotspot during at least one survey (Figure 11-9), indicating that Northern Gannet distribution and abundance patterns varied widely between surveys. The most persistent hotspots in the Maryland study area (as well as across the broader MABS study area) tended to be located within about 30-40 km of the shoreline (Figure 11-9). Northern Gannets were consistently observed in high numbers from September to April for both boat and video aerial surveys, with low numbers in July and August (Table 11-2). The two survey methods showed very similar temporal variation for Northern Gannets, indicating that detection rates for this species may have been relatively similar between survey methods. Additional information on Northern Gannet movements and habitat use in the Mid-Atlantic is presented in Adams et al., 2015 and Stenhouse et al., 2015.

Alcids

Family Alcidae, which in the Mid-Atlantic generally includes Dovekies (*Alle alle*), Razorbills (*Alca torda*), Atlantic Puffins (*Fratercula arctica*), and both murrets (*Uria* spp.), were not identified frequently enough from the aerial data to allow mapping persistent hotspots of abundance. Hotspots estimated from boat data for this taxon are presented in Figure 11-10. Alcids were present almost exclusively in winter (Table 11-2). Identified hotspots of relative abundance included both nearshore and offshore locations throughout the MABS study area, with relatively few occurring within the Maryland study area. The largest and most persistent aggregations seemed to occur in the part of the study area located farthest from the shoreline (between about 60-85 km from the coast of southern Virginia; Figure 11-10). Alcids were seldom observed in groups, and the most persistent hotspots for this species were identified in about 30% of the seven boat surveys for which the taxon was present in the study area (2 out of 16 surveys in total).

Gulls and terns

Gulls and terns (Laridae) were observed in all surveys. This is a fairly disparate group in terms of behaviors across species, with some species breeding near the study area, others using this region purely in the non-breeding season, and still others present year-round. Bonaparte's Gull (*Chroicocephalus philadelphia*) and Ring-billed Gull (*Larus delawarensis*), for example, are present primarily in winter, while other gulls are present during fall, winter, and spring (e.g., Laughing Gull, *Leucophaeus atricilla*), and several tern species are present in spring, summer, and fall (Common Tern, *Sterna hirundo*, and Royal Tern, *Thalasseus maximus*). Several gull species use the study area year-round (Herring Gull, *Larus argentatus*, Great Black-backed Gull, *L. marinus*, and Lesser Black-backed Gull, *L. fuscus*; Table 11-4). Likewise, species distributions across the study area vary based on when each species is present. We calculated persistent hotspots for the entire family, as 23% of these aerial observations were not differentiated to subfamily (Chapter 5). But due to the life history and distributional differences between species, we also analyzed data separately for the two main subfamilies (terns, Sterninae; and gulls, Larinae), as well as for the most abundant individual species in our datasets (Bonaparte's Gull, Laughing Gull, Herring Gull, Great Black-backed Gull, and Common Tern).

For the entire family, abundance hotspots were widely distributed throughout the Maryland and MABS study areas, though the most persistent of these were located in the western half of the study area, and

particularly in three locations: the northern shore of Maryland, the mouth of Chesapeake Bay, and the mouth of Delaware Bay (Figure 11-11).

The same patterns of the most persistent hotspots are present in both the gull-specific (Figure 11-12) and tern-specific (Figure 11-13) maps. A comparison of Figure 11-11 to Figure 11-13, however, indicates that the less persistent hotspots located in many offshore areas in the eastern part of the study area were largely driven by gull distributions, with many fewer tern hotspots in areas >20 km from shore.

Examining hotspot persistence of individual species allowed us to further parse patterns shown in the subfamily maps. Hotspot persistence for both Herring Gulls and Great Black-backed Gulls was most similar to hotspot persistence for the gull subfamily; hotspots occurred across the MABS and Maryland study areas, and were most persistent along the north shore of Maryland and at the mouth of the Chesapeake Bay (Figure 11-14; Figure 11-15). Laughing Gull hotspots were also most persistent in nearshore areas, primarily off the coast of Maryland (Figure 11-16). In contrast, Bonaparte's Gull hotspots were notably less persistent within the Maryland study area, as this species was more persistently observed in large numbers in the southern half of the MABS study area, and at a broad range of distances from shore (Figure 11-17).

Common Terns were the only tern species abundant enough to conduct a species-specific hotspot analysis, and they were only observed in large numbers by boat (only one Common Tern was definitively identified over the course of the study in digital video aerial surveys). Common Tern hotspots occurred across the Outer Continental Shelf within the MABS study area, and were most persistent near the mouth of Delaware Bay (Figure 11-18). This differed from the pattern of hotspot persistence observed for terns as a group, which additionally showed high hotspot persistence in Maryland state waters and at the mouth of Chesapeake Bay (Figure 11-13). These differences were likely driven in part by Royal Terns observed from the boat, as well as unidentified terns in both boat and video aerial data (which represented a diverse group of at least six species; Table 11-4) that are mapped in aggregate in Figure 11-13.

Rays

Rays (Batoidea), primarily Cownose Rays (*Rhinoptera bonasus*), were mostly observed in summer and early fall, and were much more frequently observed in video aerial surveys than from the boat (Table 11-2). They were not identified frequently enough from the boat data to allow mapping persistent hotspots of abundance, so only the aerial data are presented in Figure 11-19. Cownose Rays occur in the coastal waters of the western Atlantic Ocean from the northeastern US to Brazil, and migrate seasonally along the Atlantic coast of the US (Goodman et al., 2011). Large and persistent aggregations of rays were commonly observed at the mouth of Chesapeake Bay, the mouth of Delaware Bay, and within about 20-40 km from the coast of Maryland and the north shore of Virginia (Figure 11-19). Further discussion regarding observed Cownose Ray distributions is presented in Chapter 5.

Sea turtles

Sea turtles, including Green (*Chelonia mydas*), Kemp's Ridley (*Lepidochelys kempii*), Loggerhead (*Caretta caretta*), Hawksbill (*Eretmochelys imbricata*), and Leatherback (*Dermochelys coriacea*) turtles, were

mostly observed in warmer months (Table 11-2). They were also much more frequently observed in video aerial surveys than from the boat (Chapter 10), a phenomenon that has been seen for digital aerial surveys elsewhere (Normandeau Associates Inc., 2013). They were not observed frequently enough from boat-based surveys to allow mapping persistent hotspots of abundance, so only the video aerial data are presented in Figure 11-20. Sea turtle species were observed in 80% of video aerial surveys, and were most persistently abundant south of the Maryland study area and farther from shore (Figure 11-20). Further examination of seasonal distribution patterns and possible environmental drivers for this taxon are presented in Chapters 10 and 13.

Dolphins and porpoises

Odontoceti, or toothed whales, were observed throughout the study period, with some summertime increases in observations (Table 11-2). The two survey methods showed similar temporal patterns of relative abundance for toothed whales, indicating that detection rates may have been similar between survey methods (Table 11-2; Chapter 10). Almost all identified observations were either Bottlenose Dolphins (*Tursiops truncatus*) or Common Dolphins. Bottlenose Dolphins were observed primarily in warmer months, were observed across the Maryland and MABS study areas, and made up a higher proportion of the aerial data than the boat data for most time periods (Table 11-4). Bottlenose Dolphins are distributed into coastal and offshore populations in this area of the Atlantic (Kenney, 1990), so we likely saw individuals from both populations represented in these counts. Common Dolphin counts peaked in the winter for both survey types (Table 11-4), and were mostly observed in the eastern part of the study areas. The persistent hotspots identified in Figure 11-21 reflect a combination of these species' distributions. Hotspots for toothed whales within the Maryland study area were most persistent within roughly 40 km of shore, showing a similar pattern to the broader MABS study area. Nearshore hotspots were likely driven by coastal Bottlenose Dolphin populations (Chapter 12), while hotspots located farther offshore may represent a combination of offshore Bottlenose Dolphin and Common Dolphin populations. When mapped independently (using boat data only, as there were too few aerial observations), Bottlenose Dolphin hotspots occurred primarily on the western half of the study area, and were most persistent at the mouth of Delaware Bay and in coastal regions within the Maryland study area (Figure 11-22). Further examination of seasonal distribution patterns and possible environmental drivers for Bottlenose Dolphin distributions are presented in Chapter 12.

Bait balls

Shoals of small fishes that were not individually distinguishable or identifiable during boat and video aerial surveys were recorded as 'bait balls', and each shoal was counted as a single observation regardless of group size. These large groups of forage fish were much more frequently observed in video aerial surveys than from the boat, and only the aerial data were used in calculating areas of persistent abundance. Bait balls were most persistently observed in highest densities in the nearshore regions of the Maryland study area, with less persistent hotspots occurring in nearshore regions off the coasts of Delaware and Virginia (Figure 11-23). In cells with the highest hotspot persistence, the area was identified as an abundance hotspot in roughly half of the surveys in which bait balls were observed.

Persistent hotspots of overall abundance and species richness

When calculated in aggregate for all taxa observed in this study, abundance hotspots were most consistently observed in nearshore areas (within about 40 km from shore). This held true within the Maryland study area as well as within the broader MABS study area, where more persistent hotspots were located near the mouth of Chesapeake Bay, the North Shore of Virginia, and near the mouth of Delaware Bay (Figure 11-24). Hotspots of species richness were consistently located in similar areas (Figure 11-24). While the aggregate abundance hotspot patterns may be largely driven by a few common species groups (such as scoters and gannets), species richness hotspots display habitat use areas that are valuable to large numbers of species through time. In grid cells that were identified as species richness hotspots, up to 10 species were observed in a single survey; the most persistent species richness hotspots were identified in 88% of surveys.

Temporal trends in abundance

Overall, late fall to early spring was identified by both boat and digital video aerial surveys as a time of year with high effort-corrected counts of animals in the study area, though many aquatic animals peaked in abundance in the summer (Table 11-2). Scoters, gannets, and gulls all contributed greatly to overall abundance, regardless of survey method; loons made up a large proportion of the boat data, in the early winter surveys in particular, while rays were highly abundant in the video aerial surveys in the summer and early fall (Table 11-2). Some differences in temporal patterns between the two survey types are likely reflective of differences in detection for the two methods; for example, both Common Loons and Red-throated Loons make up higher proportions of the boat data compared to the video aerial data, as most loons in aerial surveys were not identified to species. There were peaks in abundance of some alcid and tern species that went almost entirely undetected in the video aerial data, while the video aerial surveys were able to detect temporal trends in abundance of several aquatic species that weren't detected or abundant in the boat surveys (Table 11-4).

Distributions of uncommonly observed species

Several other taxa observed during boat and video aerial surveys had insufficient data to calculate persistent hotspots or conduct other spatial analyses. Cormorants made up a relatively large proportion of the boat data (1.6% of total observations within the Maryland study area, and 3.2% of observations within the MABS study area), with a total of 2,035 individuals observed in the MABS study area (149 within the Maryland study area). Despite high abundance, there were relatively few sightings; over half of the total individuals observed were reported in three sightings in May and October 2013 at the mouth of Delaware Bay, and only 38 total sightings were reported (Figure 11-25). Within the Maryland study area, a group of 140 cormorants plus two individuals were reported in May 2013, and an additional 7 were reported in a single sighting in October 2013. Nearly all were identified as Double-Crested Cormorants (*Phalacrocorax auritus*). Only 42 Double-Crested Cormorants were observed by video aerial surveys; 26 of these occurred within the Maryland study area (Figure 11-25). Cormorants were most commonly observed by boat in the spring and fall (Table 11-2).

Passerines made up a small proportion of the aerial data compared to the boat data in both the Maryland and MABS study areas. In the MABS study area, 180 passerines were observed by boat and 17 were observed by video aerial survey methods (representing 22 unique identified species; Chapters 5

and 7); of these observations, only 14 individuals were observed by boat and 2 observed by digital video within the Maryland study area. Peak numbers of passerines were observed in the summer and fall (Table 11-2). Songbirds were observed throughout the study areas, particularly where boat surveys were conducted (Figure 11-26). Swallows (Hirundinidae) were the most frequently observed passerine both in the MABS and Maryland study areas, and were particularly abundant in the coastal waters off of Virginia. Warblers (Parulidae) were most commonly observed in the Maryland and Delaware offshore areas. Only Purple Martins (*Progne subis*) and Barn Swallows (*Hirundo rustica*) were abundant enough for temporal persistence charts, with peaks of observed counts in July-August and March-April, respectively (Table 11-4). Additional discussion of passerine migration (which largely occurs nocturnally) may be found in Adams et al. (2015).

Shorebirds (Charadriiformes) were also observed primarily on boat-based surveys within both study areas; within the broader MABS study area, there were 587 observations of at least 15 species reported by boat, as compared to 74 observations reported in the aerial data. In the Maryland study area, 29 observations of at least 6 species were reported by boat and 46 individuals were observed by digital video (Chapters 5 and 7). Shorebird observations were distributed broadly across both study areas (Figure 11-27). Dunlin (*Calidris alpina*) and Red Phalarope (*Phalaropus fulicarius*) observations peaked in March-April, while Red-necked Phalaropes (*P. lobatus*) were observed primarily in September-October (Table 11-4). Only eight plovers were observed over the course of the study (five Wilson's Plover [*Charadrius wilsonia*], and three Semipalmated Plover [*C. semipalmatus*]), all observed during boat surveys. No identified Red Knots (*Calidris canutus*) were observed, though individuals could have been included among the unidentified shorebirds or unidentified scolopacids (Chapters 5 and 7).

Observations of shearwaters and fulmars (Procellariidae) were more consistent across survey platforms, with 43 individuals of 5 species observed by boat and 57 individuals of 4 species observed by digital video within the Maryland study area (Chapters 5 and 7). Within the broader MABS study area, 325 individuals of six species were observed during boat surveys, and 112 individuals from at least five species were observed during video aerial surveys. Great Shearwaters (*Puffinus gravis*) and Cory's Shearwaters (*Calonectris diomedea*) were most commonly observed in both study areas, typically in the eastern part of the study areas (Figure 11-28). Manx Shearwaters (*Puffinus puffinus*) were mostly observed on boat surveys, and showed a relatively inshore distribution in the Maryland study area. Shearwaters were observed primarily in the spring and fall, while Northern Fulmars (*Fulmaris glacialis*) were observed primarily in winter (Table 11-4).

Eleven large whales were observed within the Maryland study area, out of a total of 51 that were observed within the broader MABS study area during boat and video aerial surveys (Figure 11-29). Humpback Whales (*Megaptera novaeangliae*), Minke Whales (*Balaenoptera acutorostrata*), and unidentified whales were all observed in the Maryland study area. While North Atlantic Right Whales (*Eubalaena glacialis*) were not detected within the Maryland study area, 8 sightings were made by video aerial surveys within the Virginia WEA and on the sawtooth transects between Maryland and Virginia WEAs; an additional Right Whale was observed east of the Virginia WEA during a boat survey. All sightings were reported to NOAA and the New England Aquarium. Additionally, Fin Whales

(*Balaenoptera physalus*) were generally observed across the MABS study area, but none were observed within the Maryland study area (Figure 11-29). More than half of the large whale sightings within the Maryland and MABS study areas occurred during winter months (Chapter 12).

One Eastern Red Bat (*Lasiurus borealis*) was observed within the Maryland study area by video aerial surveys, in September 2013. Across the broader MABS study area, 17 bats were observed altogether, including two during boat surveys and 15 in video aerial surveys, in September of 2012 (Hatch et al. 2013) and September of 2013. Bats were observed between approximately 16 and 70 km from shore (Figure 11-30), during morning daylight hours (Hatch et al., 2013). Video aerial survey methods allowed for altitude estimation for several of these bats at >200 m above sea level.

Discussion

The presence and relative abundance of species within the MABS and Maryland study areas varied widely by time of year, with different species and groups using the study area during non-breeding (summer or winter), breeding, and migratory periods. We obtained insufficient observations for some taxa to develop useful distribution patterns; however, other useful information can be drawn from the raw data on its own. For example, our nine observations of North Atlantic Right Whales, the most critically endangered large whale along the Atlantic coast of North America, provide an important contribution to our collective knowledge of this species given their small population size and our general lack of detailed data on their movements and habitat use in the Mid-Atlantic. Additionally, raw observation data for bats provides insight into their offshore migration patterns. In 2012, bats were observed during a period with relatively strong tailwinds and average barometric pressure, suggesting that their presence offshore may have been facultative (e.g., taking advantage of favorable migratory conditions), rather than because storms or other factors pushed them offshore. Direction of movement was noted to be southwest in 10 out of the 15 video aerial observations, further suggesting migratory movements. Little is known about the migration and movements of tree bat species in North America, but anecdotal observations of migrating bats over the Atlantic Ocean (particularly during fall migration periods) have been reported since at least the 1890s (Hatch et al., 2013). The observations from this study provide new evidence of bat movements offshore, and offer insight into their flight heights above sea level and the times of day at which such migrations may occur.

For species or groups with sufficient data, we developed products to visualize both temporal and spatial variation in distribution and relative abundance. Calculating persistent abundance hotspots provides a means for identifying locations where individuals of a species or species group are most often found in large aggregations relative to their typical distribution patterns. These areas likely provide important habitat for foraging, roosting, and/or other activities (Gende and Sigler, 2006; Santora and Veit, 2013; Santora et al., 2010; Sydeman et al., 2006). Calculating persistent abundance hotspots can be particularly useful for highly mobile marine wildlife, because this analysis identifies patterns of high abundance that persist over time. For example, while hotspots of Northern Gannet abundance occurred across the study area and throughout the year, the majority of the most consistent hotspots during our surveys occurred at the mouth of Chesapeake Bay. This pattern only emerged when data were aggregated across repeated surveys. Similarly, summarizing aggregated data across survey methods and

across years allowed us to examine temporal patterns of abundance for many species present within the study area. Identifying such patterns may provide useful insight to future siting and permitting processes within the region.

Species of interest were widely distributed across the study area, but for many taxa, larger aggregations were more consistently observed in the western part of the study area, and particularly offshore of the mouths of Chesapeake Bay and Delaware Bay, and in northern Maryland (Figure 17-23). Some exceptions to this general rule included sea turtles, Common Dolphins, Common Loons, and alcids, which were more evenly distributed across the Outer Continental Shelf or were more commonly observed in areas farther from shore. The area offshore of northern Maryland, while likely a real hotspot for many species such as gulls and terns, may have emerged as an important habitat use area in part because this was the only region in which boat and video aerial surveys were conducted in inshore state waters (e.g., within three miles of the shoreline), as well as the only area with high density aerial survey transects in nearshore federal waters (e.g., between state waters and the WEA). While high numbers of some species may be consistently present in other nearshore areas as well, similar surveys were not conducted in nearshore or state waters elsewhere during this study.

In some instances, our analyses revealed unexpected patterns of hotspot persistence that may contribute new information about the distribution and relative abundance of a taxon. For example, large and persistent aggregations of rays (primarily Cownose Rays) were observed at the mouth of the Chesapeake Bay, and it is likely that many of the rays observed in our study area moved into the Chesapeake Bay and its tributaries in the summer months, as found in previous studies (Blaylock, 1993; Fisher, 2010). However, our analyses also reveal persistent hotspots at the mouth of Delaware Bay, and within about 20-40 km from the coast of Maryland and the north shore of Virginia, suggesting that this population may also use Delaware Bay and possibly other locations during the summer. Considering that Cownose Rays are thought to summer exclusively in bays and estuaries (Grusha, 2005), and have been particularly well studied in the Chesapeake Bay (e.g., Smith and Merriner 1985; Smith and Merriner 1987), the hotspots calculated from video aerial survey data in this study include areas much farther north and farther offshore than might have been expected.

Caveats for persistent hotspot analyses

Several characteristics or limitations of persistent abundance hotspot maps should be noted, and carefully considered when using these maps for management or planning purposes. These maps do not indicate a species' full range of habitat use within the study area; rather, grid cells that were never identified as a hotspot simply never had abundance levels 'above the norm' for a particular species and survey. Quite often, blocks that were never identified as a hotspot still consistently hosted individuals of the species of interest. It is also important to note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, these individual grid cell 'persistence' values should be interpreted with caution. Minor changes to the display of these data (for example, slightly changing how a hotspot is defined within a survey, or using different persistence categories for mapping) may change individual grid cell values, though overall patterns of animal distributions remained quite robust to such adjustments.

It should also be noted that taxa of interest aggregate to varying degrees. A hotspot for alcids, for example, includes many fewer individuals than does a hotspot for scoters, because alcid species simply do not flock to the same degree within our study area. Likewise, scoter hotspots were much more consistent through time than were hotspots identified for some other species groups. Hotspot persistence calculations in this study were designed to be reasonably comparable between species, but all values presented in maps represent relative, rather than absolute, abundance.

Finally, it is important to consider the number of surveys conducted and the length of our study period when evaluating hotspot persistence. In this study we analyzed data from 31 surveys conducted over a two year period; although our timeframe was relative brief, we conducted a comparable number of surveys to previous studies examining hotspot persistence. Zipkin et al. (2015), for example, used compiled data from 32 data sets collected over a span of 32 years, while Santora and Veit (2013) used data from 14 surveys conducted over 9 years, and Gende and Sigler (2006) used data from 34 surveys conducted over 3 years. Although our study's timeframe is on the lower end of this spectrum, a recent analysis of interannual variation in wildlife distributions suggests that 2-3 years of surveys may be sufficient to capture longer-term (e.g., decadal) levels of variation (Kinlan et al., 2012). There are also several benefits to expending high survey effort over a relatively short time frame. First, this study design provides extensive data within a relatively small study area. Additionally, our study design provides a complete picture of what is happening year round during the course of the study, compared to studies that only survey within a single season (e.g., Santora and Veit, 2013). Combining data from boat-based (16 surveys) and digital video aerial (15 surveys) methodologies also provides a more complete picture of wildlife distributions than a single survey method, by providing complementary data collected during the same time frame in the same location. One drawback to this study design, however, is that trends of persistence may not be accurately captured for species that are present in the study area for short periods of time throughout the year, and thus have fewer opportunities to be sampled. For example, alcids were present almost exclusively in the winter, and the most persistent hotspots for alcids were only hotspots in two out of 16 boat surveys (alcids were not abundant enough in the aerial dataset to conduct persistent hotspot analysis). For these less commonly observed species, we may simply lack the number of sampling events required to adequately characterize lease blocks as hotspots (Zipkin et al., 2015). Data collected from surveys conducted over a greater number of years would provide greater opportunity for sampling of less commonly observed species, and would perhaps capture finer scale patterns of persistence with greater statistical rigor.

Ecology of persistent hotspots

This study focused on identifying the locations and persistence of hotspots offshore of Maryland and elsewhere on the Mid-Atlantic OCS, and did not examine drivers of hotspot occurrence. In some instances, however, we can infer that distinct populations within a taxon may be partial drivers of observed patterns of hotspot persistence. For example, persistent hotspots of Bottlenose Dolphins were generally located in nearshore regions within the study area. As Bottlenose Dolphins are distributed into coastal and offshore populations in this area of the Atlantic, this pattern was likely partially driven by the consistency of locations and numbers for the coastal ecotype of this species, as compared to the more variable and transient populations offshore (Gannon and Waples, 2004; Kenney, 1990).

Patterns of persistent hotspots for various taxa are also likely driven by environmental factors, as previous studies have shown that persistent hotspots likely indicate locations of important habitat for the taxa examined. Piatt et al. (2006) showed that Short-tailed Albatross hotspots in the Aleutian Islands were closely associated with shelf-edge habitats where upwelling and strong vertical mixing occurred, supporting high primary and secondary productivity. Similarly, Suryan et al. (2012) found that persistently high levels of primary productivity (chlorophyll *a*) are a significant predictor of seabird hotspots. Other studies have shown the relationship between hotspots of prey species and hotspots of marine predators (Gende and Sigler, 2006; Santora et al., 2010).

In our study, the most common persistent hotspots tended to occur in nearshore areas, particularly in northern Maryland and areas near and directly south of the mouths of Chesapeake Bay and Delaware Bay. These nearshore regions, particularly those adjacent to the regional bays, contained the most persistent hotspots of overall abundance and species richness, in addition to persistent hotspots for many individual taxa examined. These areas are likely attractive to a wide variety of high trophic level species, such as seabirds and marine mammals, due to their consistently higher primary productivity relative to the broader study area (Chapter 1; Smith and Kemp 1995; Schofield et al. 2008). These areas typically have the highest levels of chlorophyll *a* in the study area due to their close proximity to highly productive estuarine ecosystems, where strong tidal currents and year-round mixing of saline and fresh waters boost productivity. More generally, in shallow coastal waters sunlight is able to penetrate a high proportion of the water column, fueling photosynthetic activity and phytoplankton growth where nutrients are available (Schofield et al., 2008b; Xu et al., 2011). This primary productivity forms the base of the pelagic food chain on which nearly all species observed during this study rely; thus, these areas likely serve as key wildlife habitats within the study area, and the locations of these areas should be considered carefully in relation to any future offshore development activities in the region.

Our results present an opportunity for future studies to explicitly examine the relationship between the location and persistence of hotspots (as determined in this study) and the potential environmental predictors of such hotspots. Of particular note, future studies could explore the relationship between persistent hotspots of bait balls and those of marine predators; as populations of forage fishes that form bait balls likely serve as a prey base for many upper trophic level predators, the distribution of persistent bait ball hotspots has the potential to help explain the similar nearshore distribution observed for many other taxa. There may also be more direct relationships between hotspots of higher trophic level taxa, as the location and persistence of hotspots are likely influenced by competitive and/or facilitative species interactions (Ainley et al., 2009; Camphuysen and Webb, 1999).

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Figures and tables

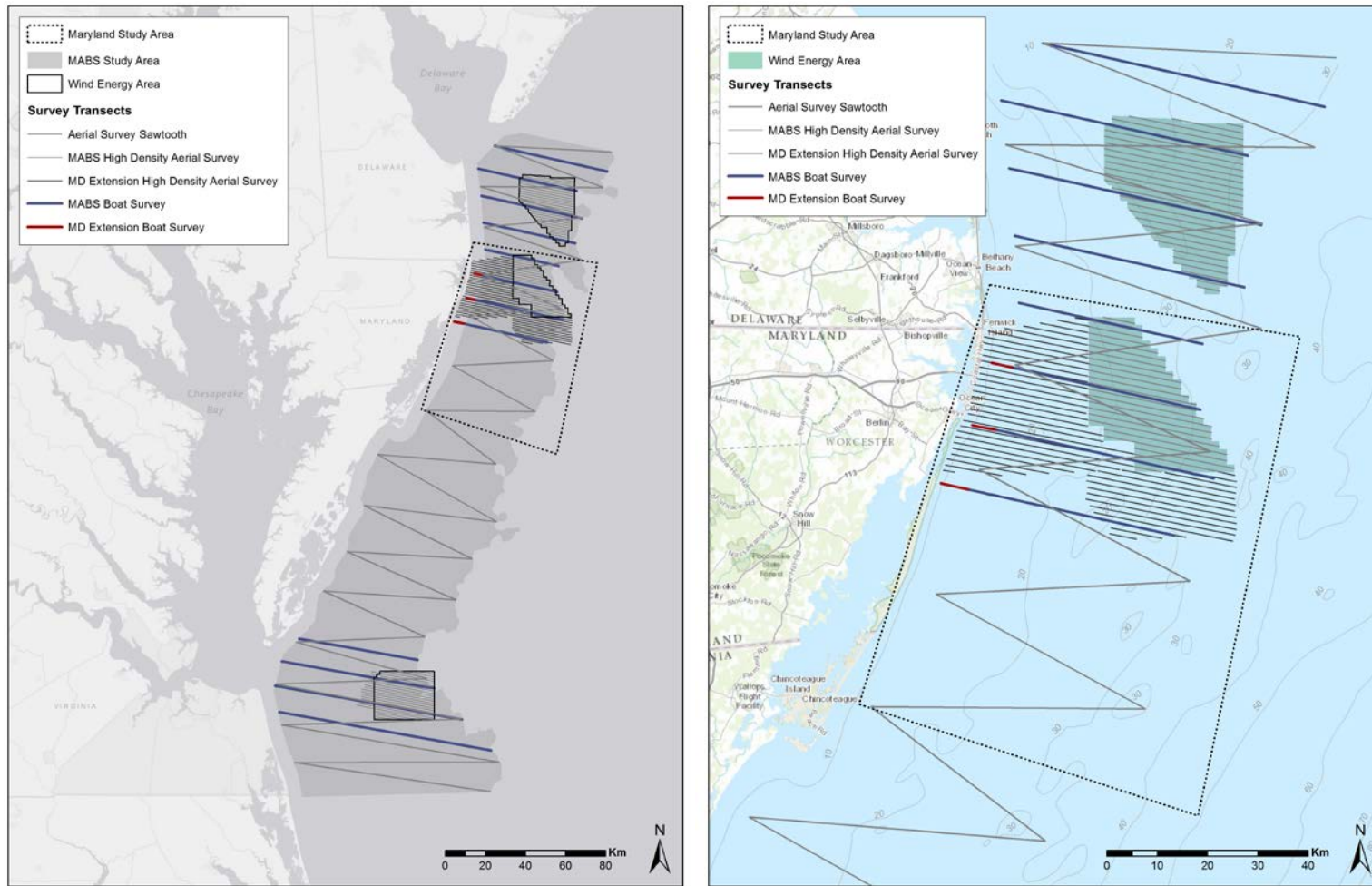


Figure 11-1. Map of boat and aerial survey transects for the Mid-Atlantic Baseline Studies (MABS) and Maryland Projects. The broader Mid-Atlantic study area, or MABS study area (left), includes surveys funded by both DOE and Maryland (2012-2014). The “Maryland study area” (right, black dashed line) includes all boat and aerial survey transects in waters offshore of Maryland (both DOE and Maryland-funded surveys, 2012-2014). The Maryland Project surveys are a subset of the surveys within the Maryland study area that were specifically funded by the state of Maryland in 2013-2014. These surveys included boat survey extensions into state waters (red bars), aerial survey high-density transect extensions west and south of the Maryland WEA (charcoal lines), and a 15th aerial survey of the Maryland WEA and Maryland Project high-density transects in 2013.

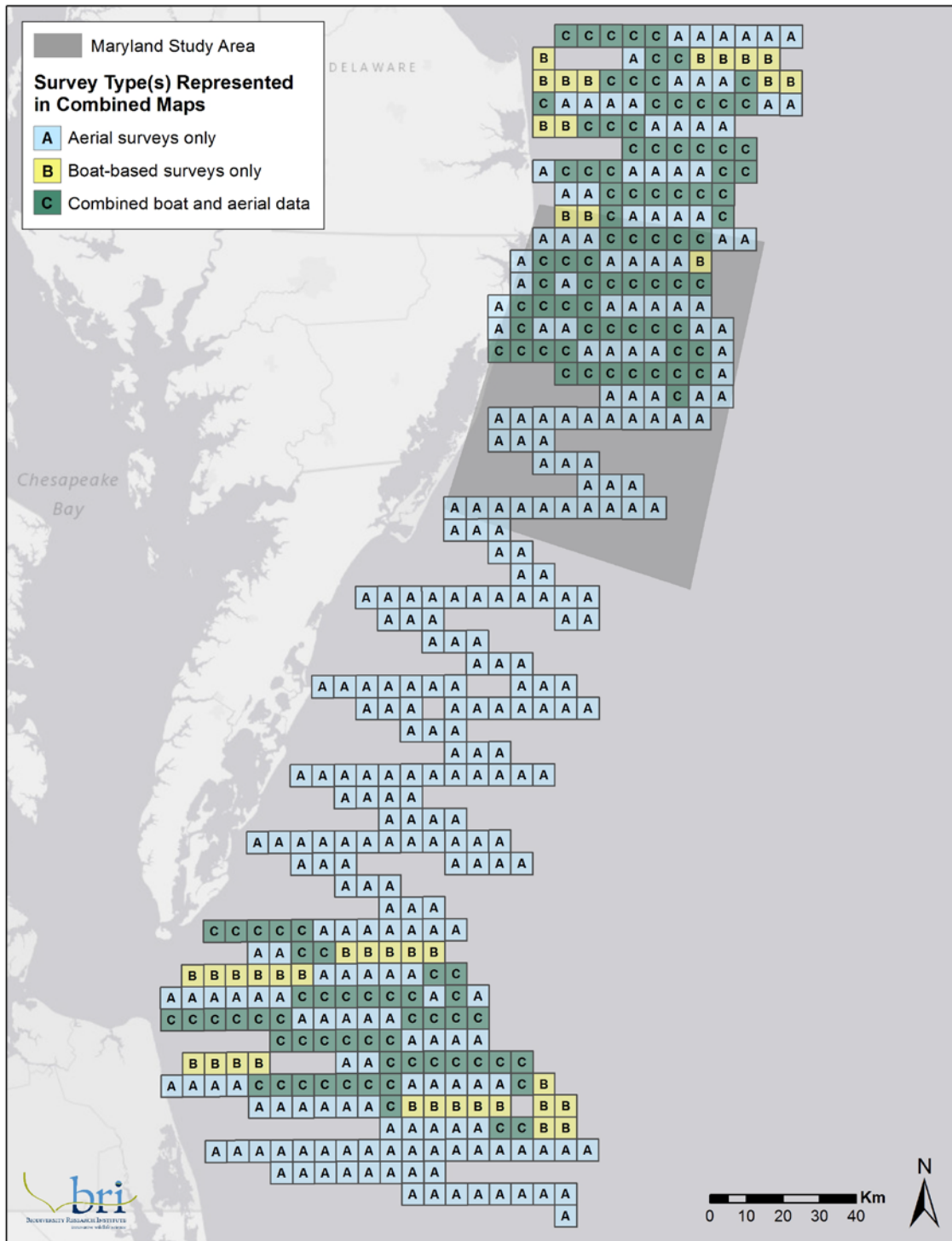


Figure 11-2. Survey method by grid cell for hotspot maps. Sixteen boat-based and 15 video aerial surveys were conducted across the study area, resulting in a total of 450 surveyed grid cells: (A) 262 grid cells surveyed by video aerial surveys only, (B) 40 grid cells surveyed by boat-based surveys only, and (C) 128 grid cells surveyed by both methods.

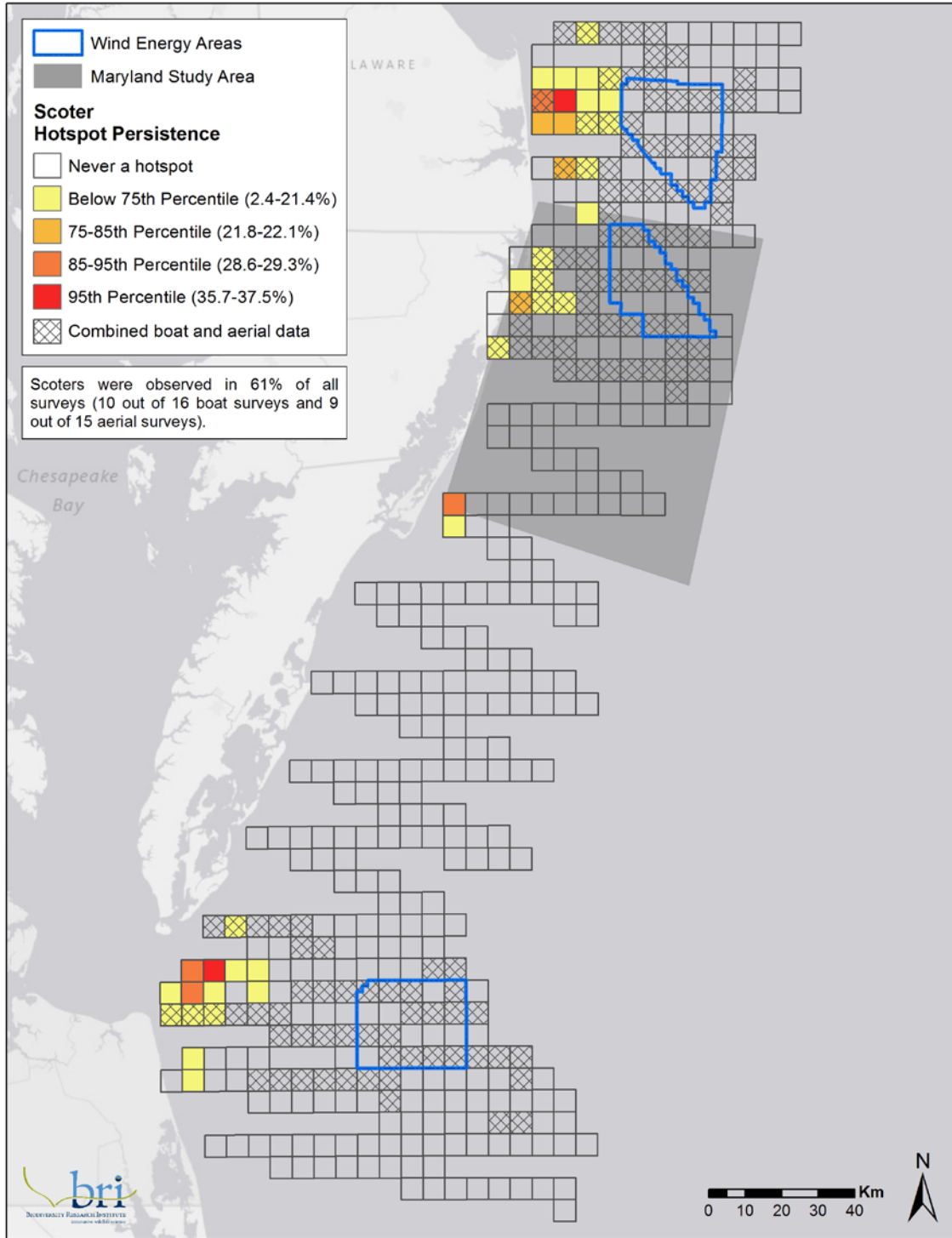


Figure 11-3. Classified persistent abundance hotspots for scoters (*Melanitta spp.*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

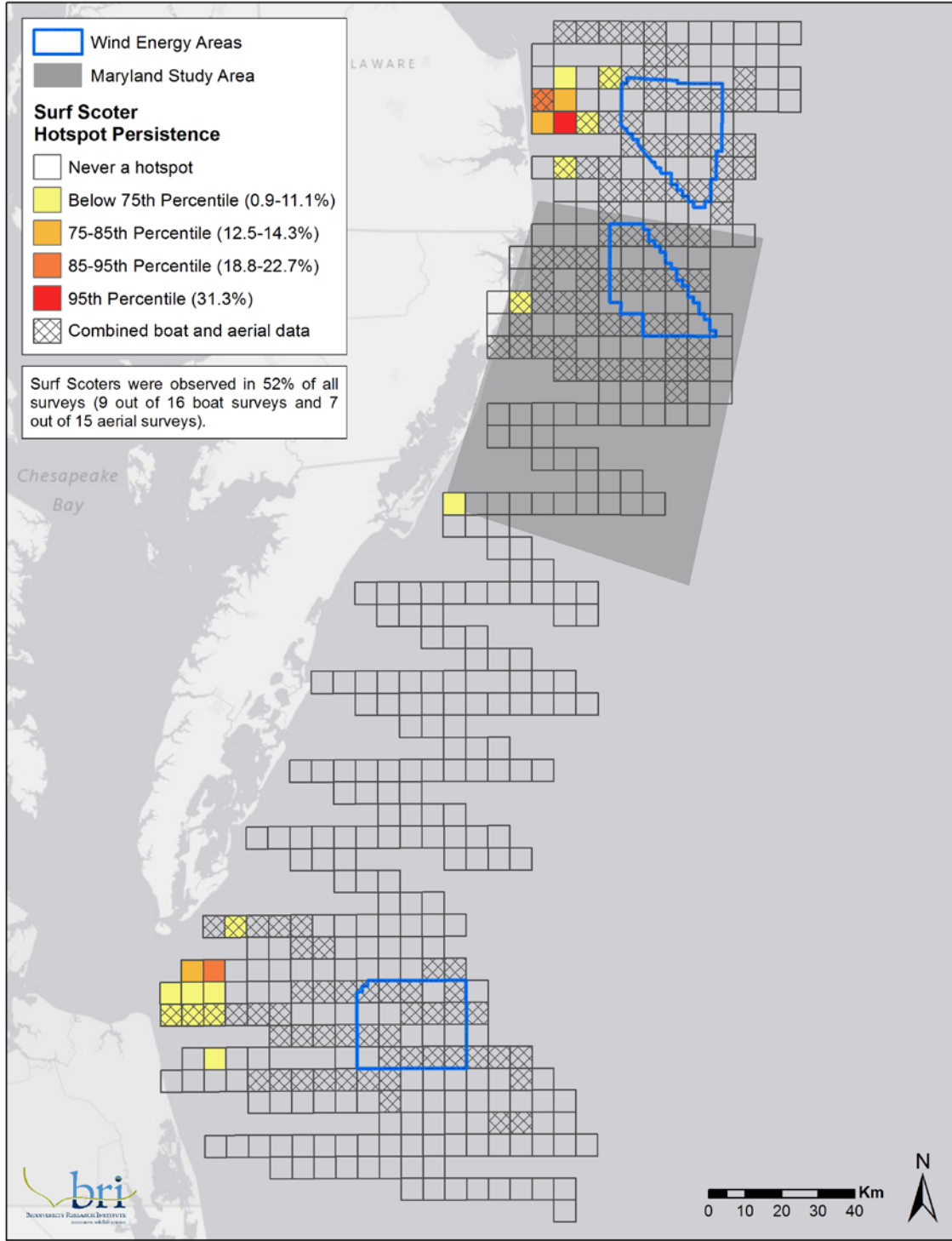


Figure 11-4. Classified persistent abundance hotspots for Surf Scoters (*Melanitta perspicillata*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

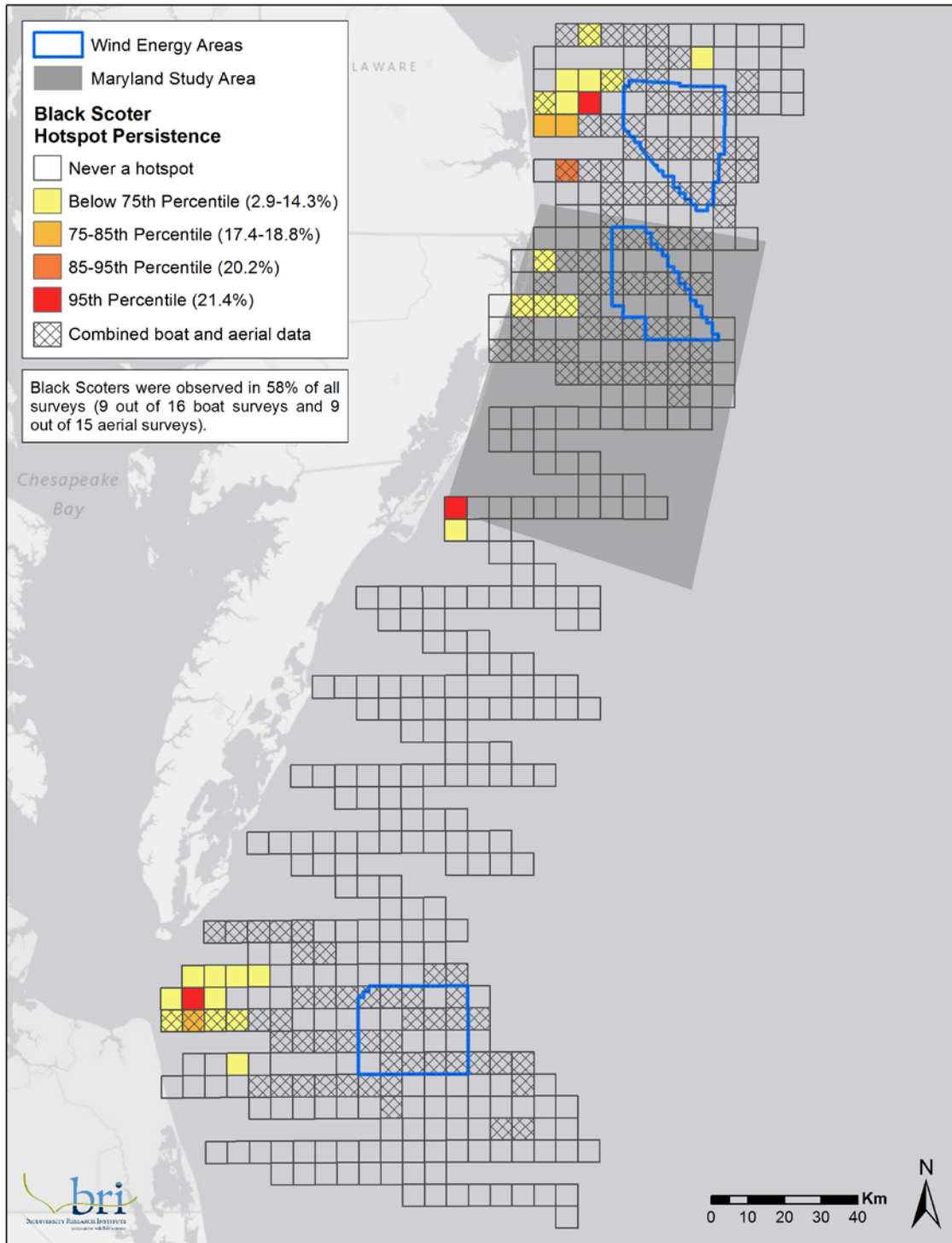


Figure 11-5. Classified persistent abundance hotspots for Black Scoters (*Melanitta americana*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

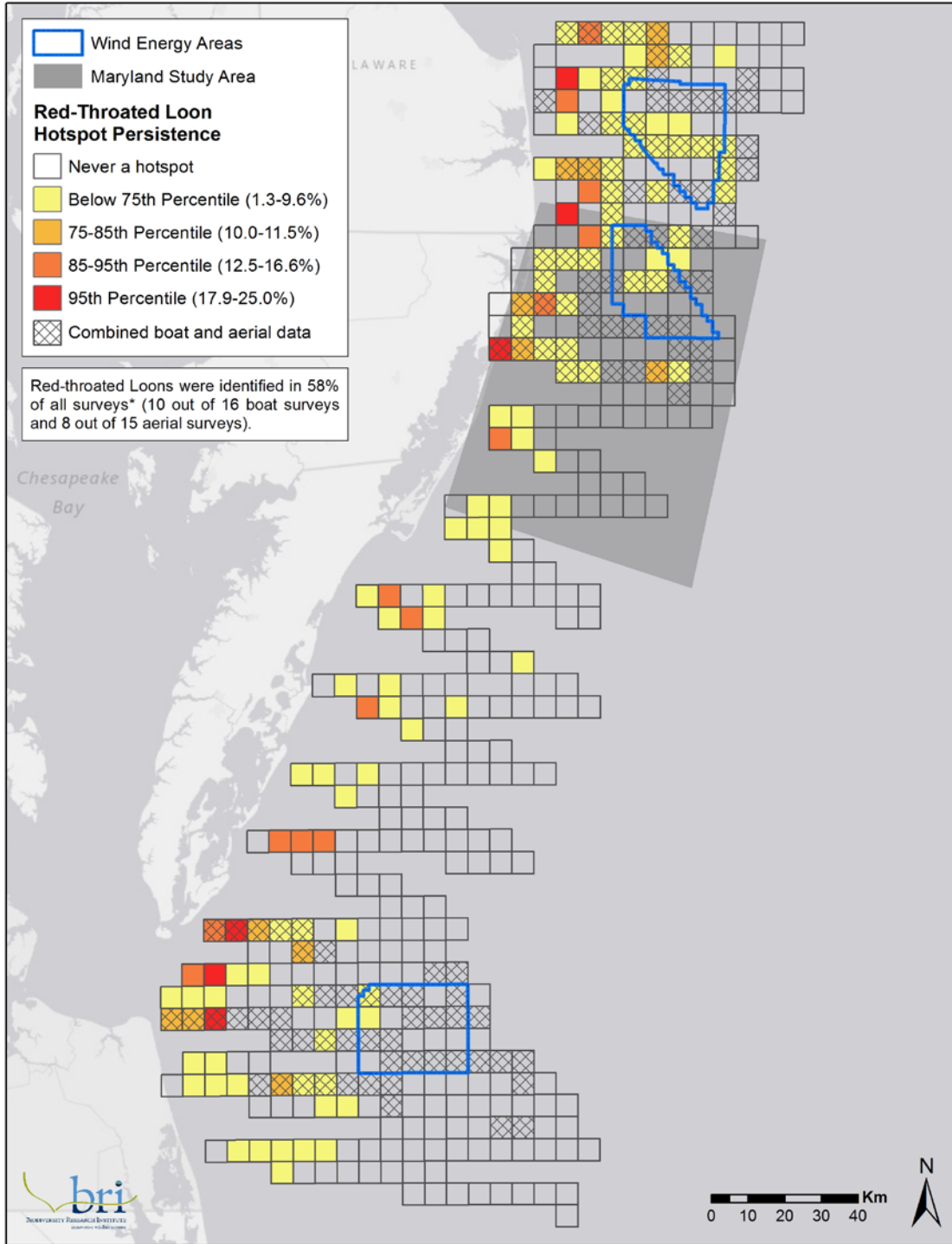


Figure 11-6. Classified persistent abundance hotspots for Red-throated Loons (*Gavia stellata*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. *Red-throated Loons were identified to species in 7 aerial surveys, and were predicted to be present in one additional survey using the species identification model (Hostetter et al., 2015). Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

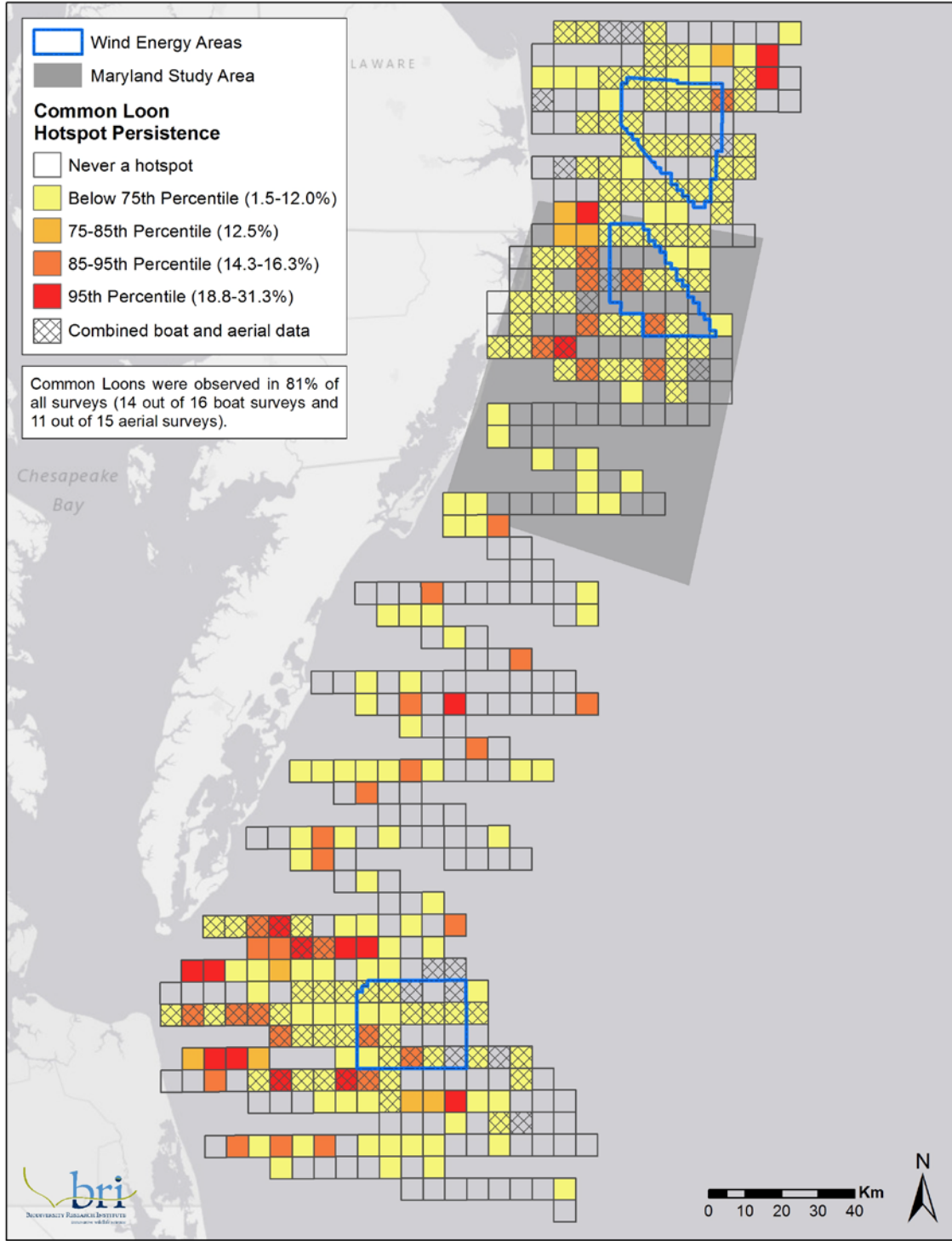


Figure 11-7. Classified persistent abundance hotspots for Common Loons (*Gavia immer*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

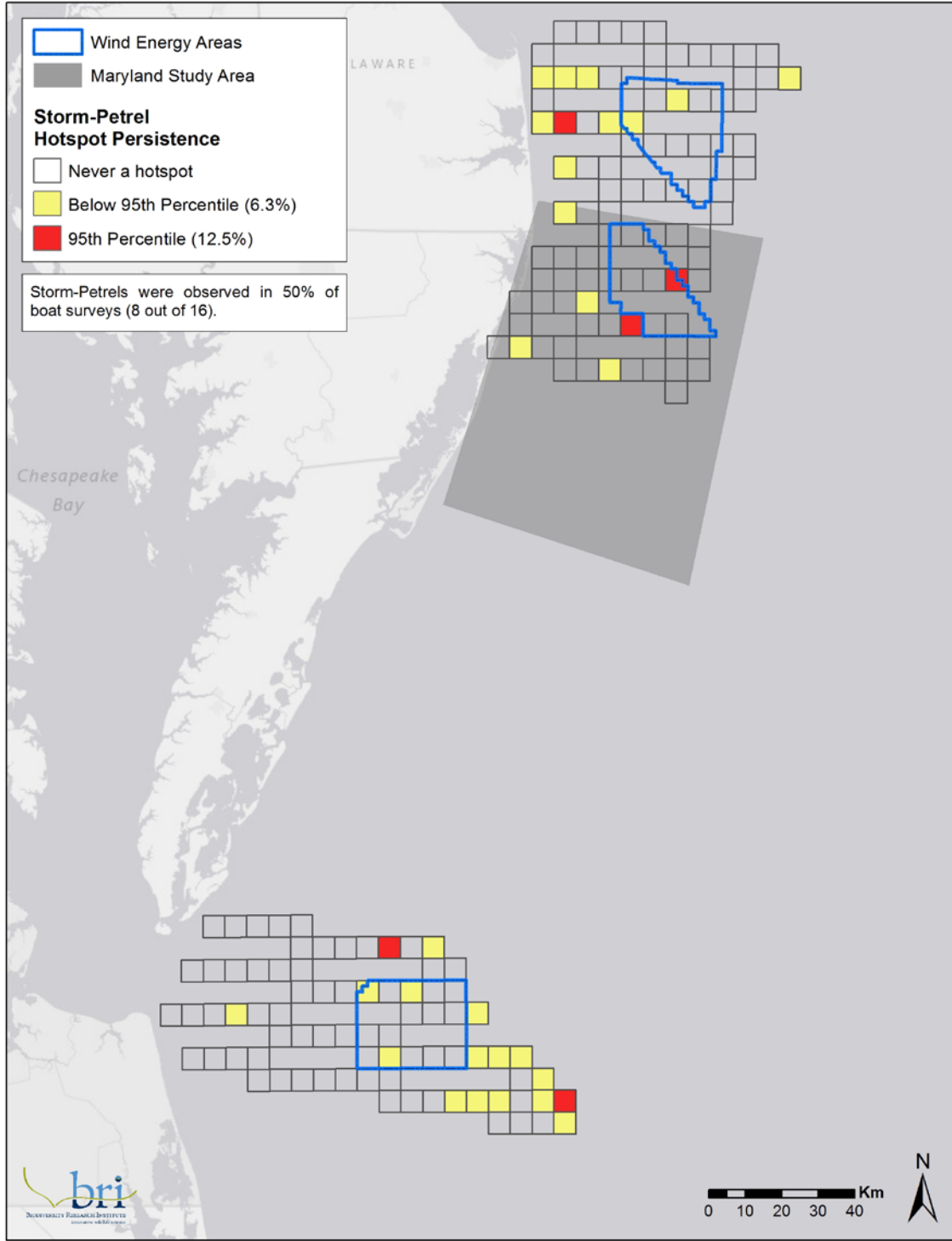


Figure 11-8. Classified persistent abundance hotspots for storm-petrels (*Hydrobatidae* spp.) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into two persistence classes as only two distinct persistence values were calculated (see text). Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

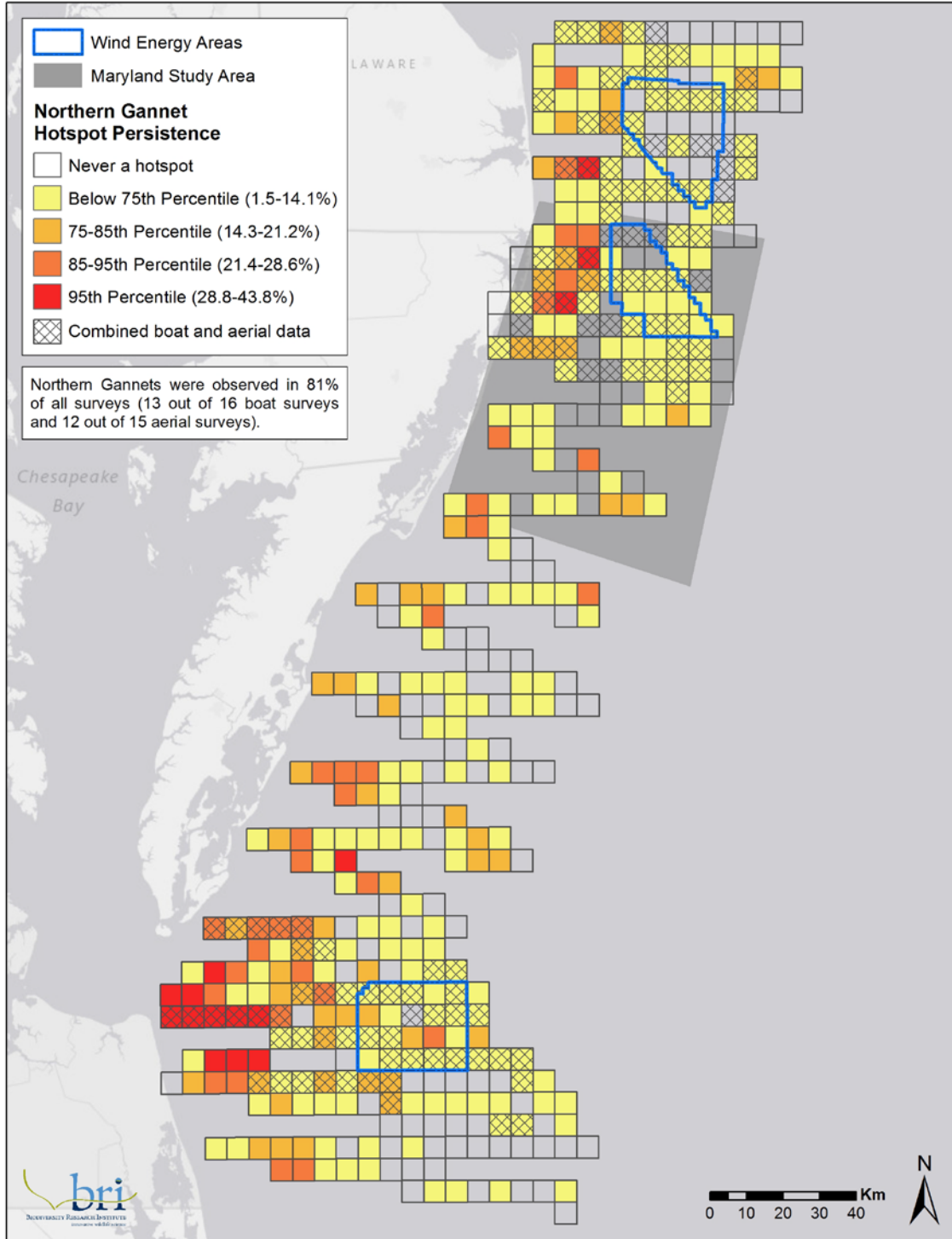


Figure 11-9. Classified persistent abundance hotspots for Northern Gannets (*Morus bassanus*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

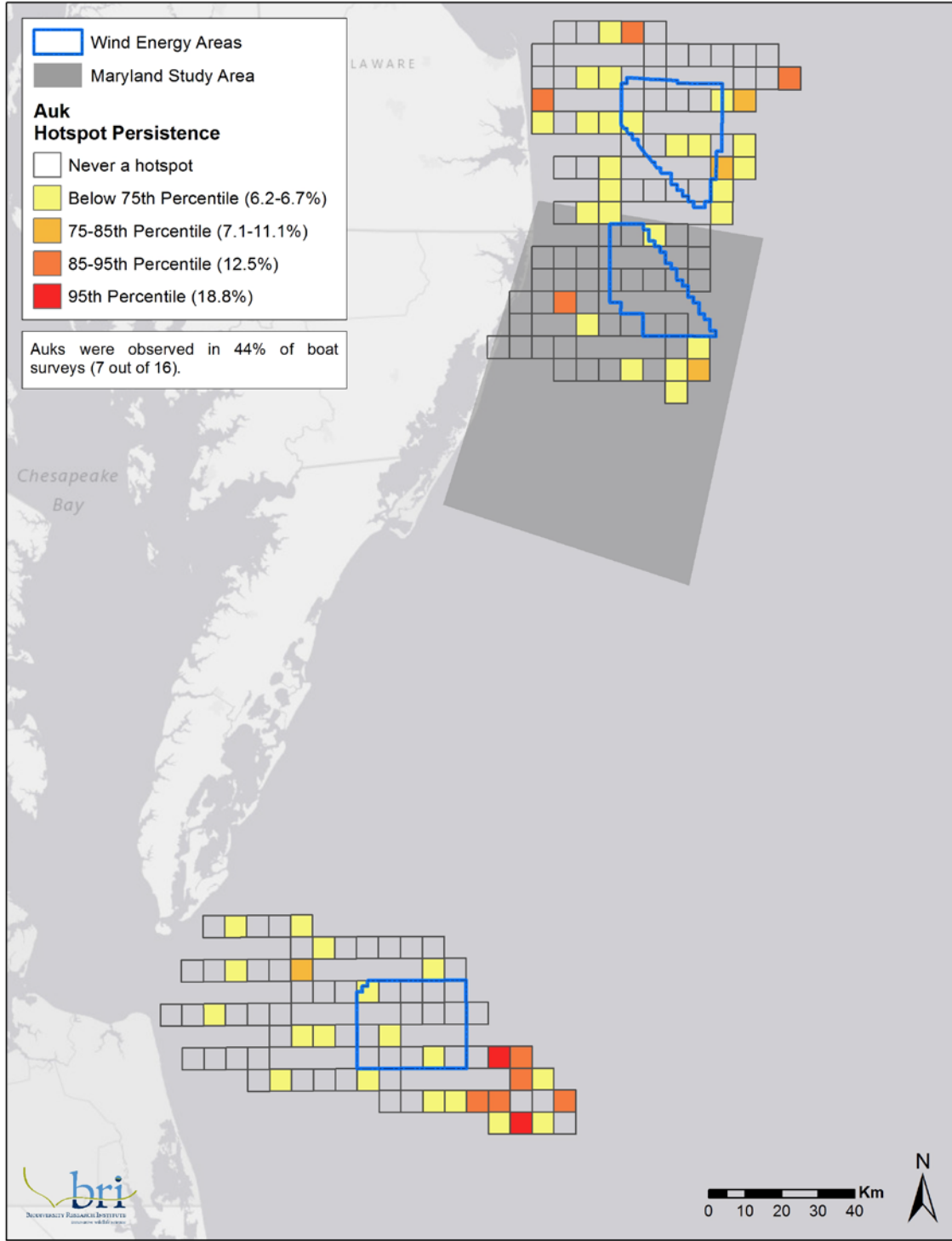


Figure 11-10. Classified persistent abundance hotspots for auks (*Alcidae* spp.) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

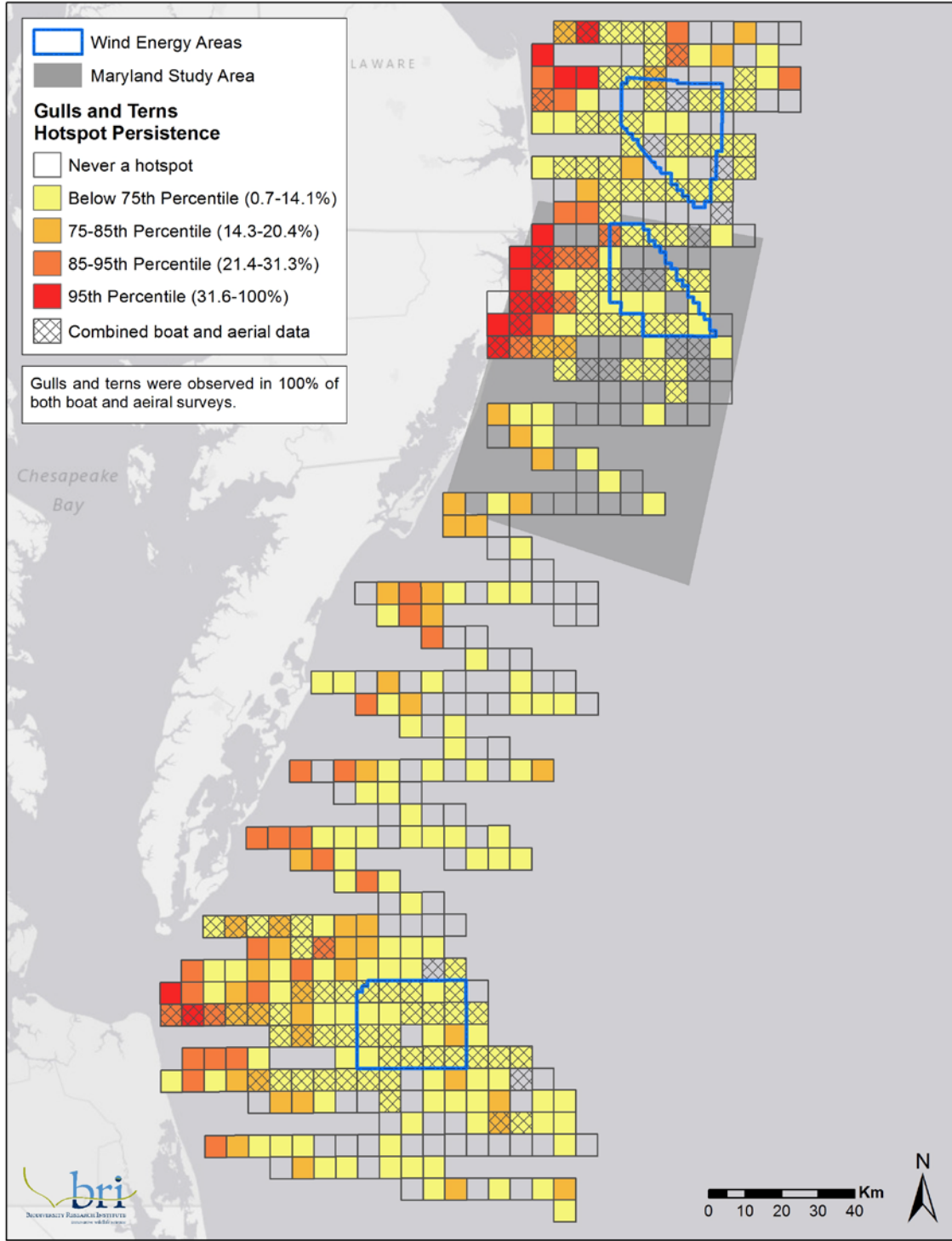


Figure 11-11. Classified persistent abundance hotspots for gulls and terns (*Laridae spp.*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

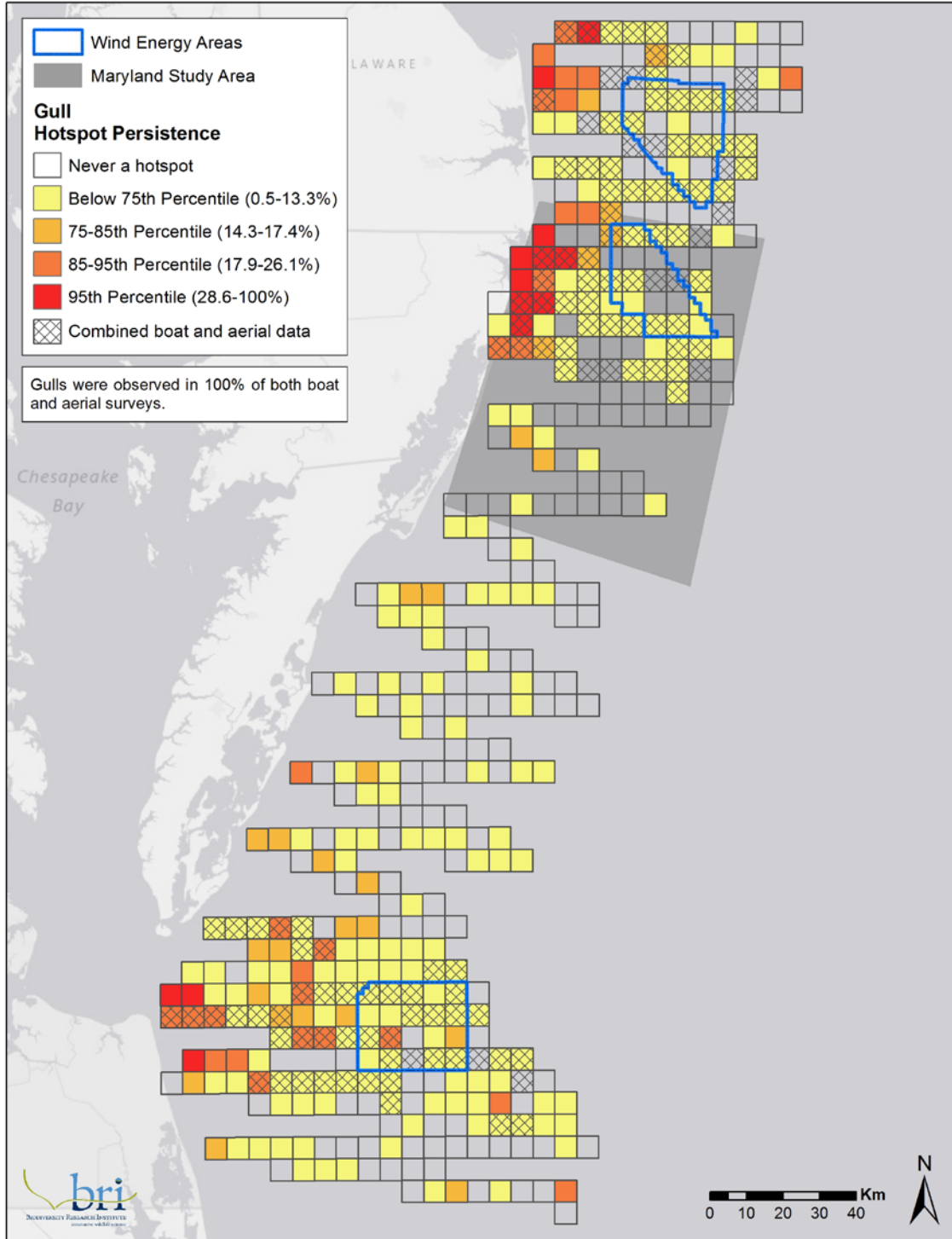


Figure 11-12. Classified persistent abundance hotspots for gulls (*Larinae* spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

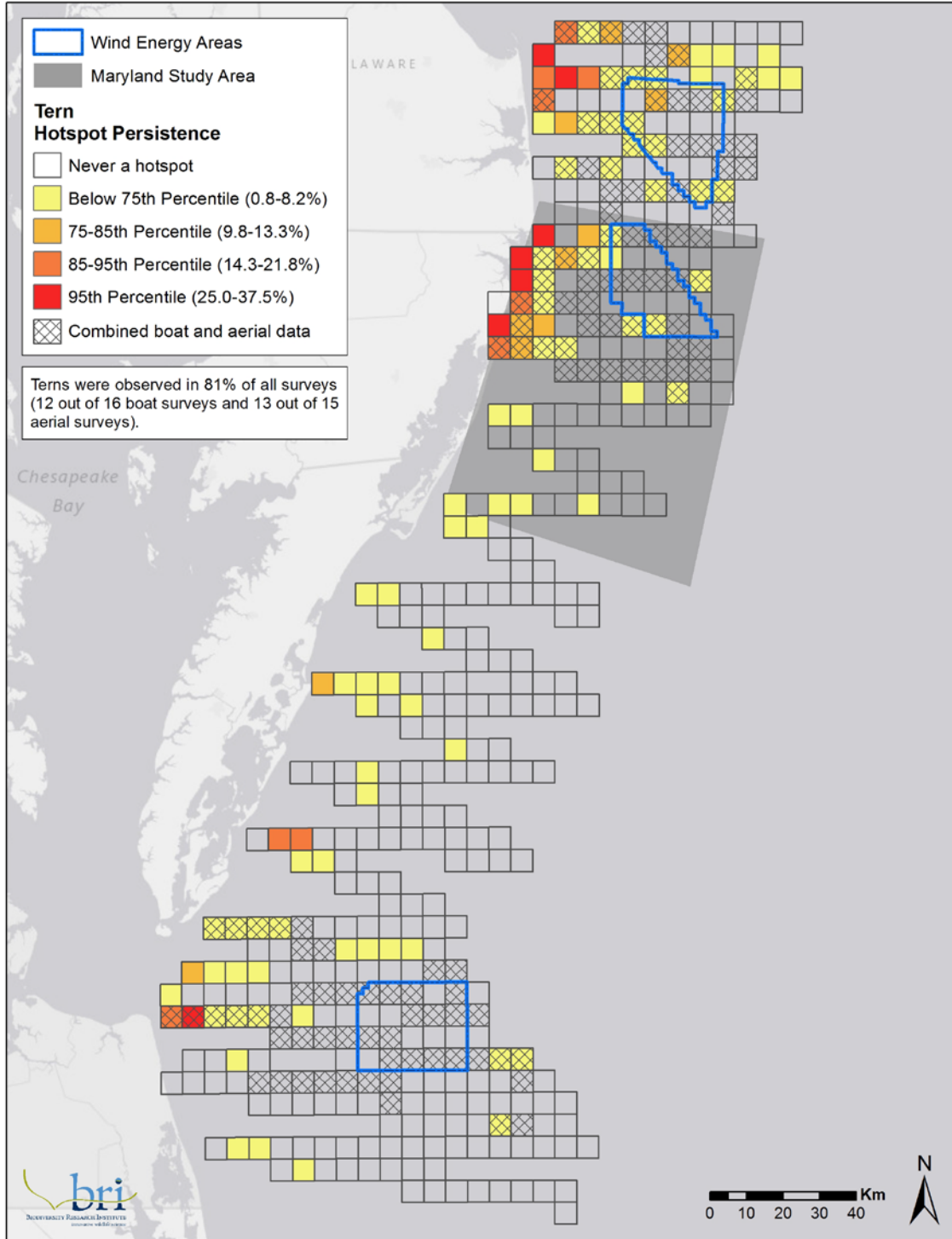


Figure 11-13. Classified persistent abundance hotspots for terns (*Sterninae* spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

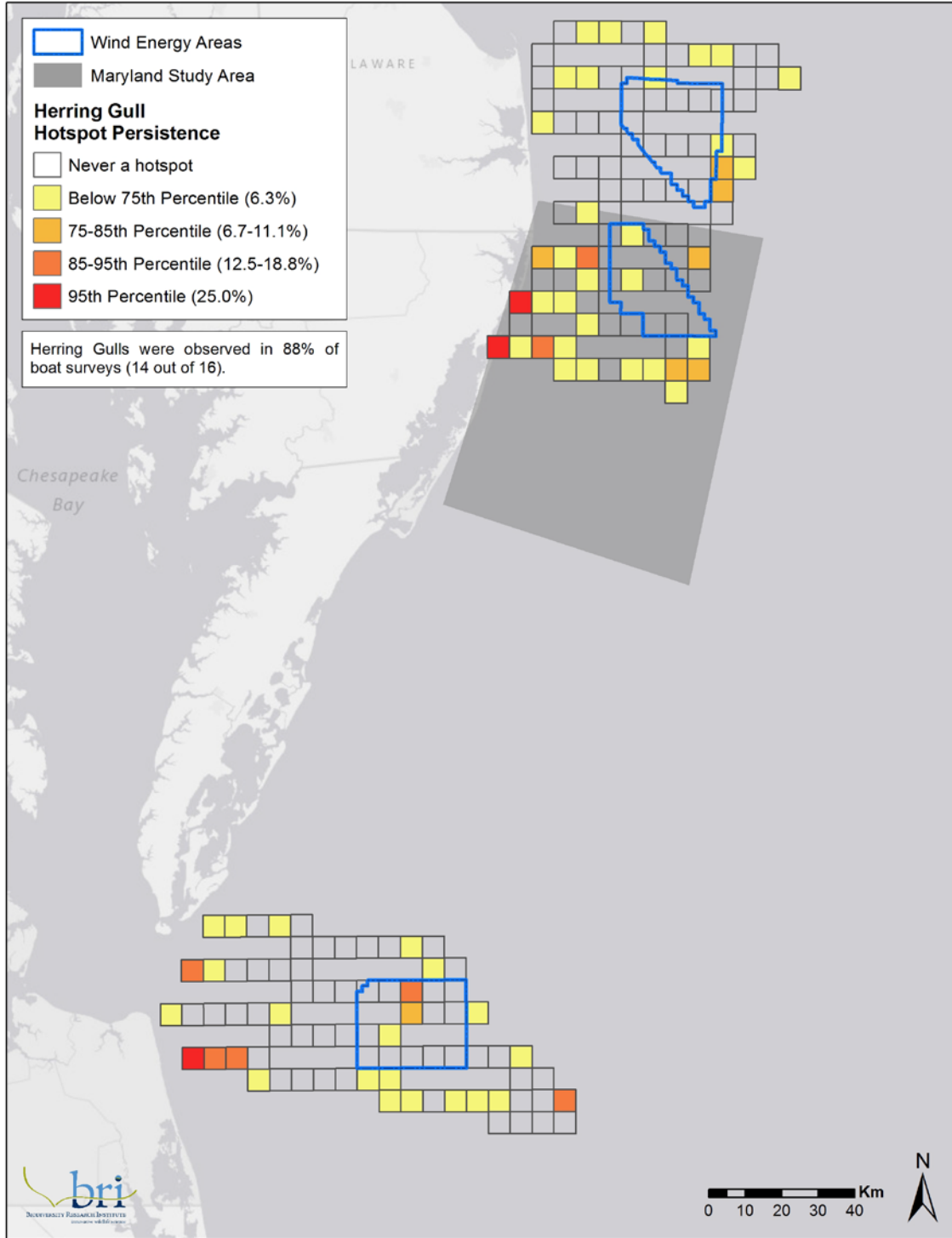


Figure 11-14. Classified persistent abundance hotspots for Herring Gulls (*Larus argentatus*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

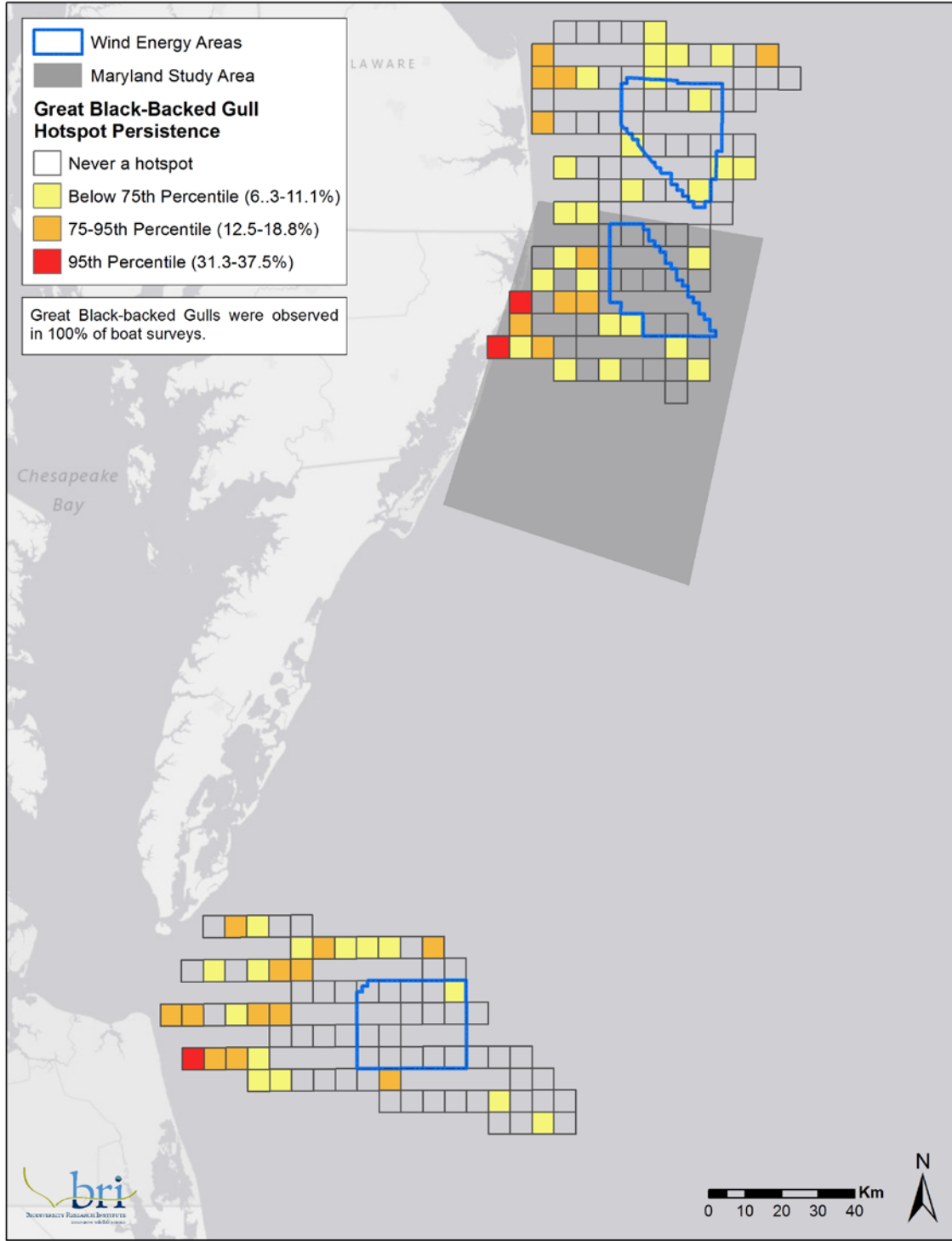


Figure 11-15. Classified persistent abundance hotspots for Great Black-backed Gulls (*Larus marinus*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into only three persistence classes as the 75th and 85th percentile of persistence fell at the same value (12.5%). Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

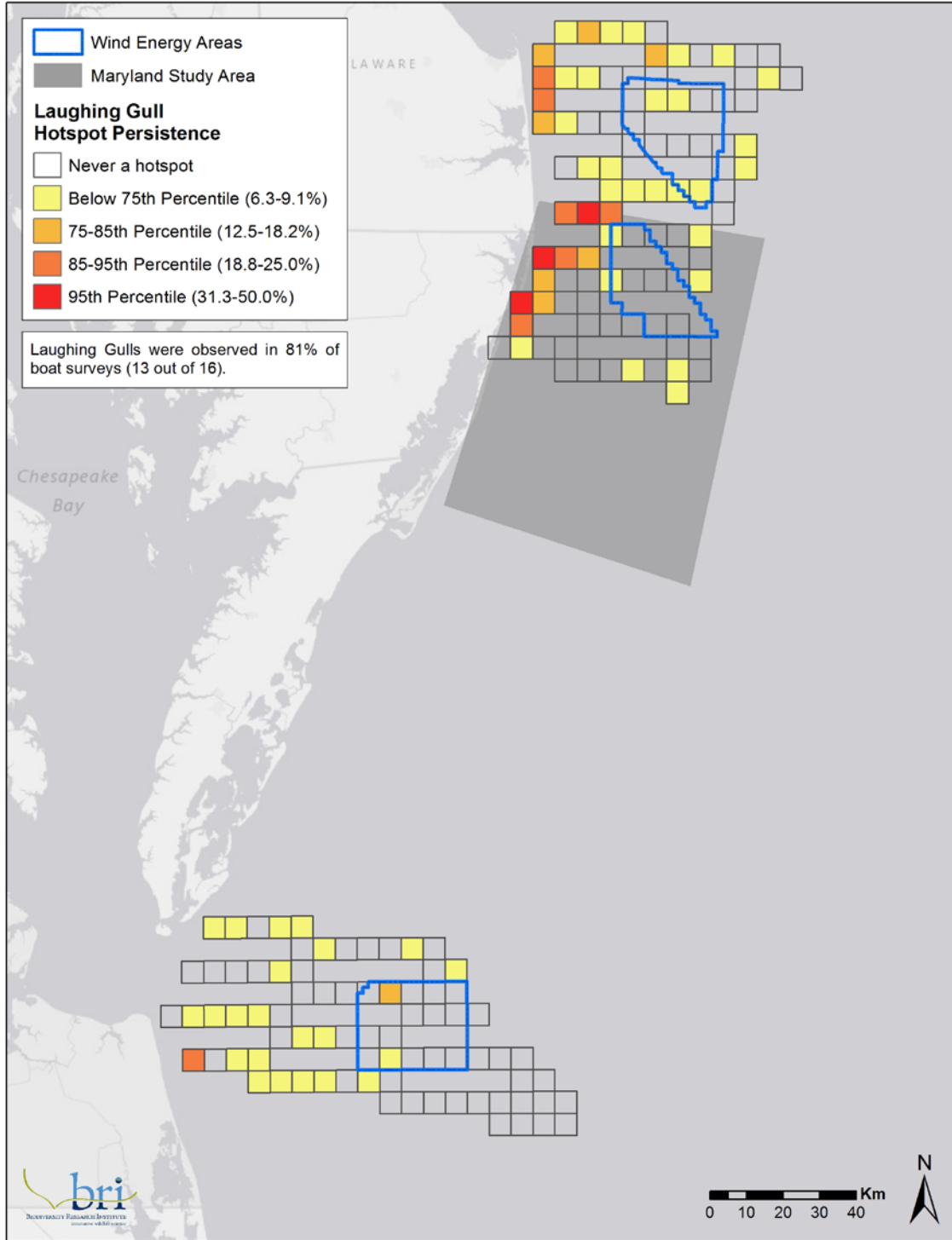


Figure 11-16. Classified persistent abundance hotspots for Laughing Gulls (*Leucophaeus atricilla*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

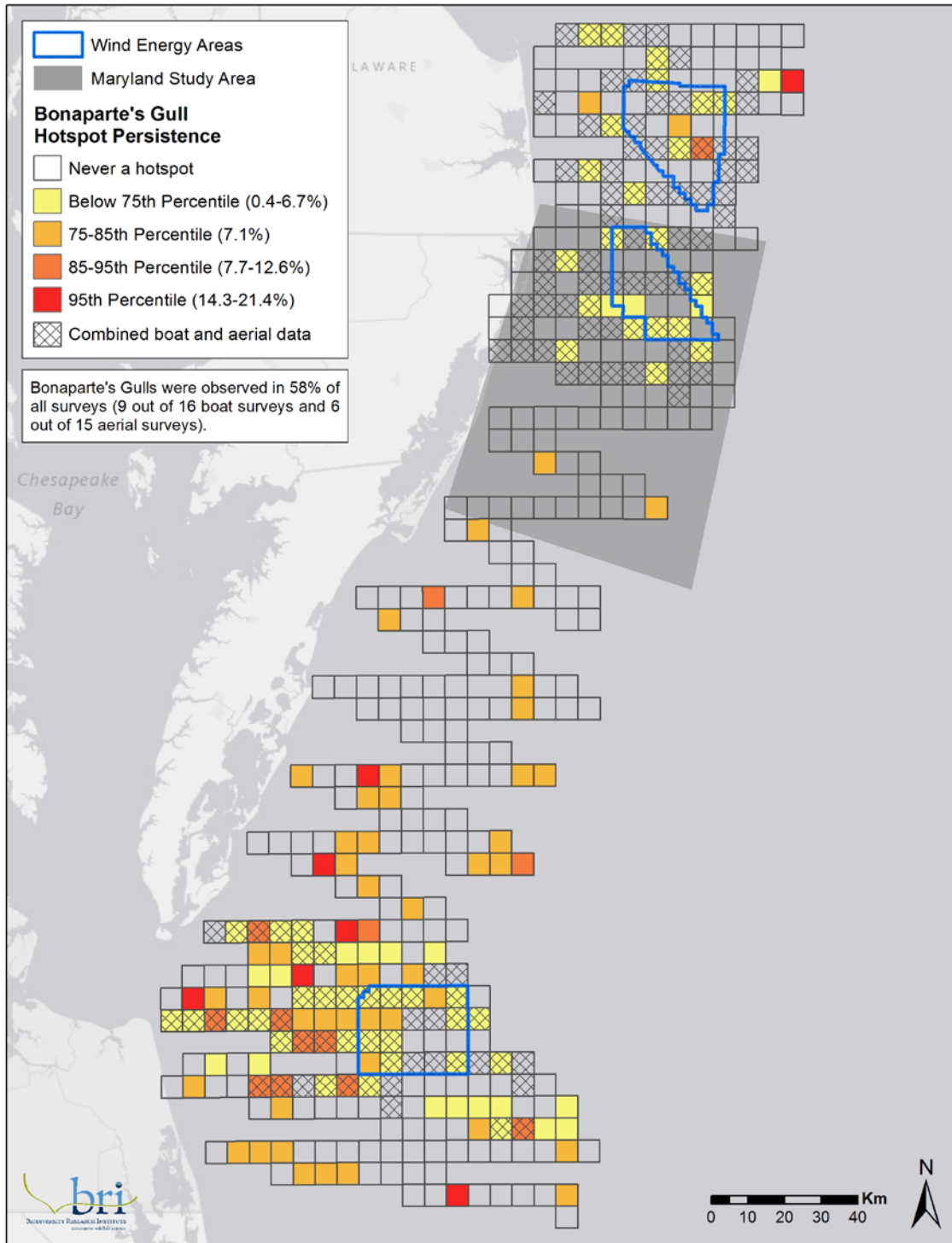


Figure 11-17. Classified persistent abundance hotspots for Bonaparte's Gulls (*Chroicocephalus philadelphia*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

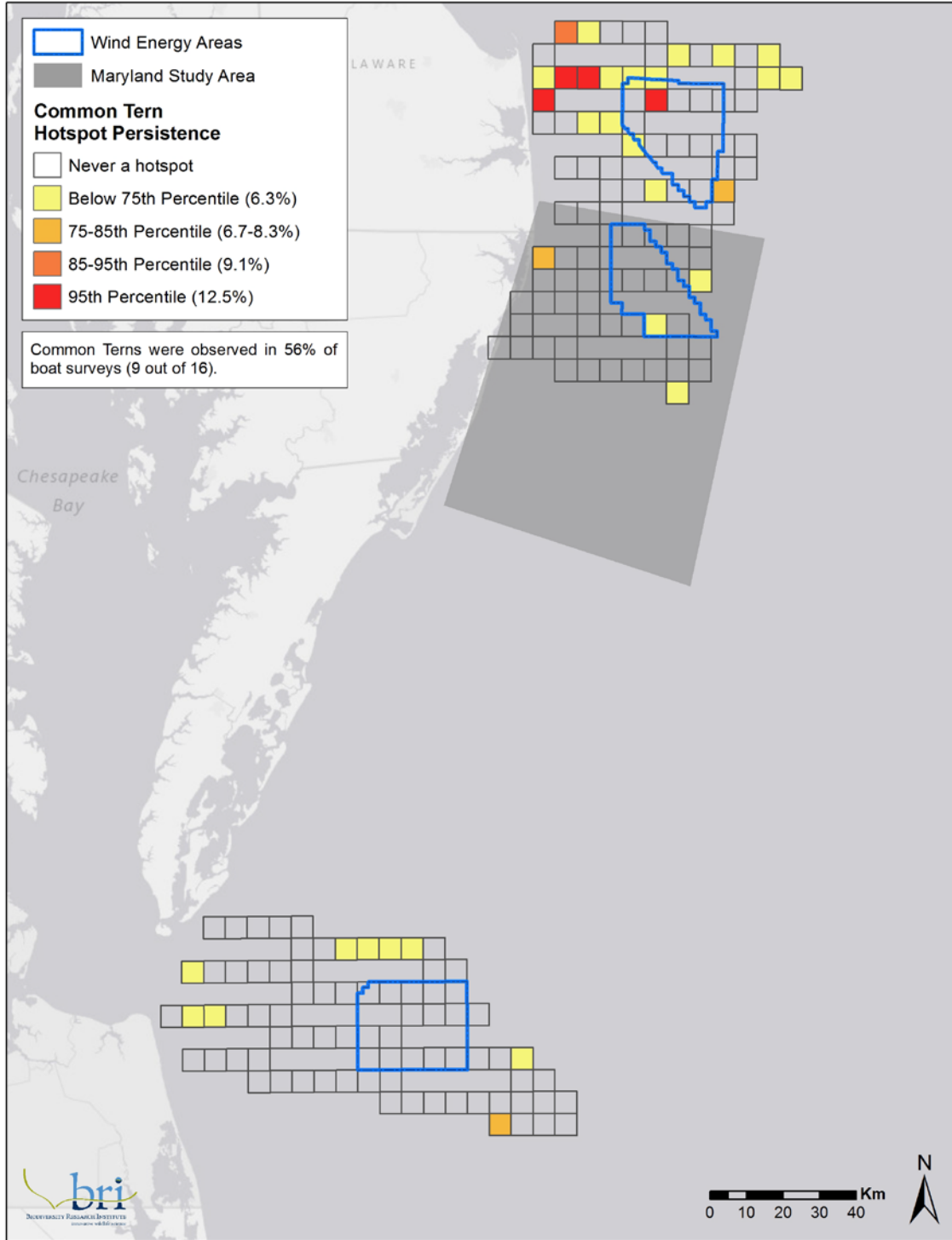


Figure 11-18. Classified persistent abundance hotspots for Common Terns (*Sterna hirundo*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

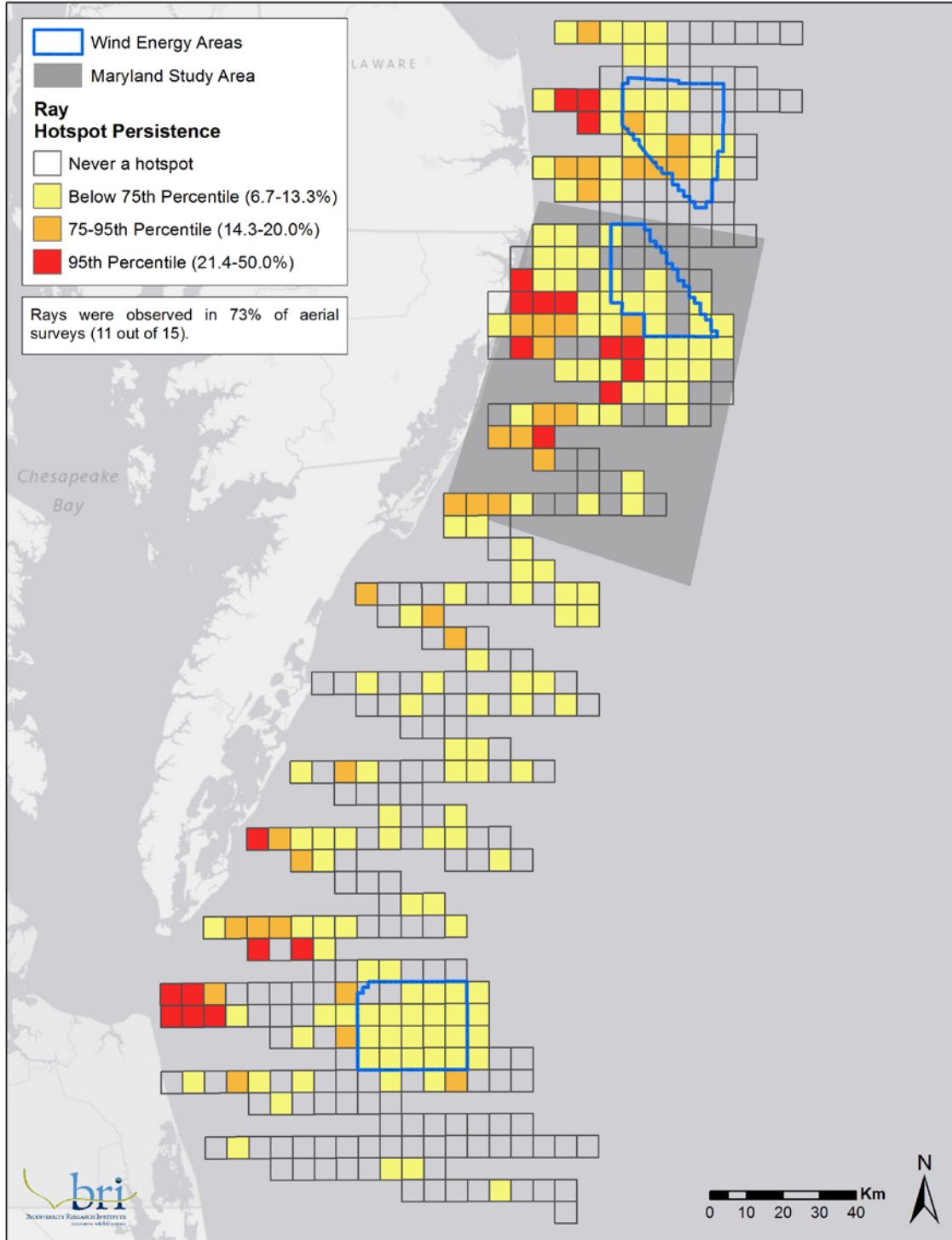


Figure 11-19. Classified persistent abundance hotspots for rays (*Batoidea* spp.) observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Data are split into only three persistence classes as the 75th and 85th percentile of persistence fell at the same value (14.3%). Blank cells never had high enough abundance to be considered a hotspot. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

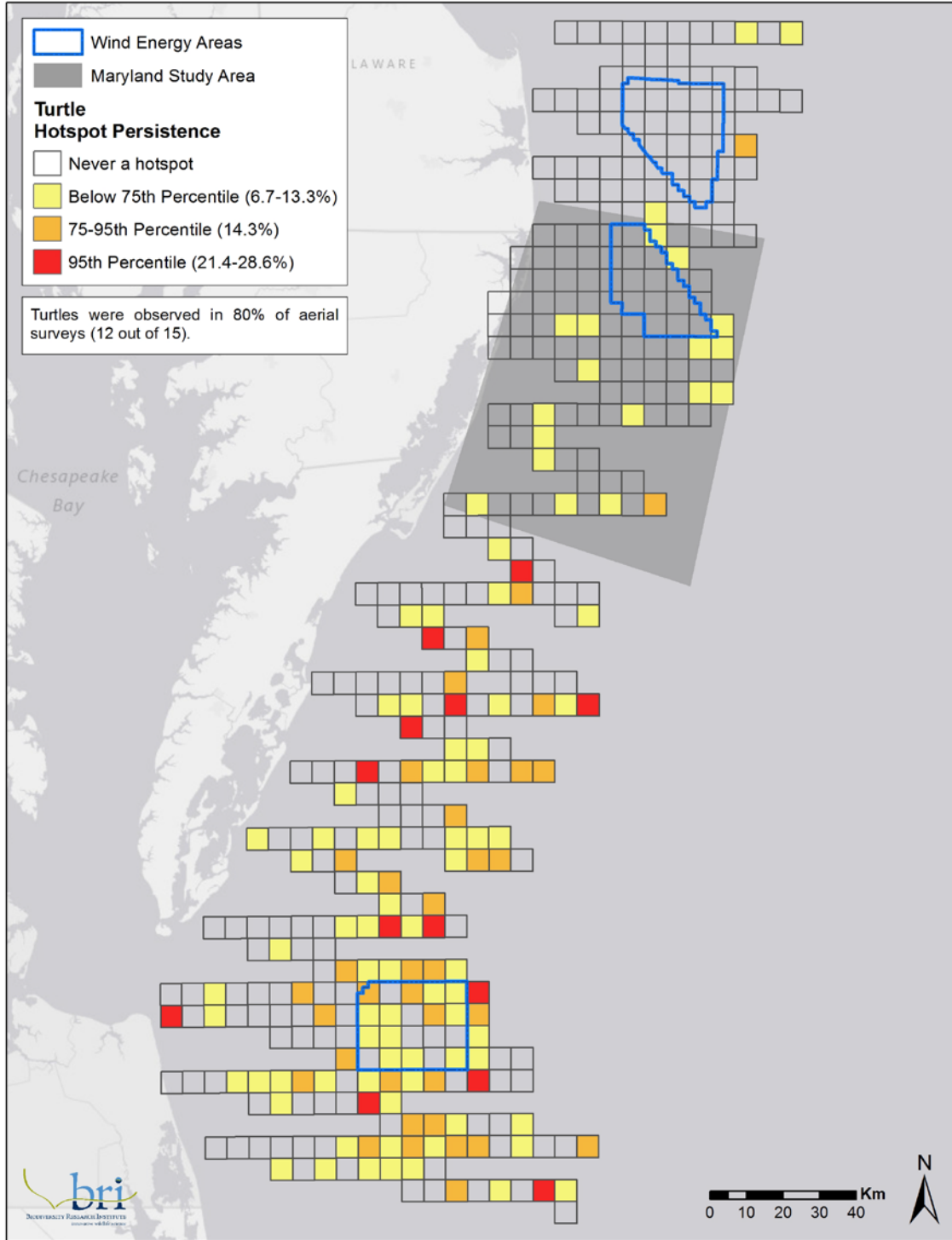


Figure 11-20. Classified persistent abundance hotspots for turtles (*Testudines* spp.) observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into only three persistence classes as the 75th and 85th percentile of persistence fell at the same value (14.3%). Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

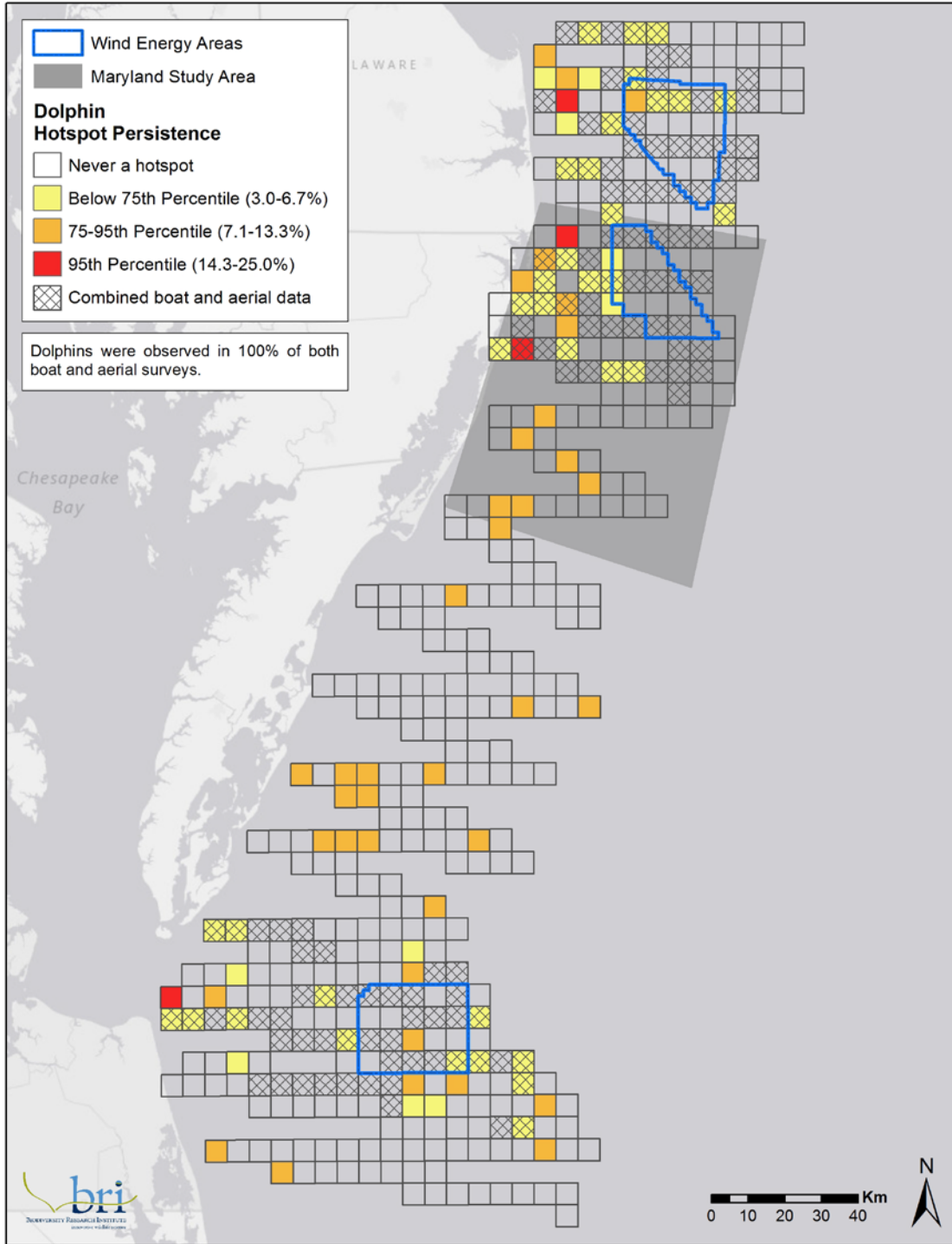


Figure 11-21. Classified persistent abundance hotspots for dolphin (*Odontoceti* spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Data are split into only three persistence classes as the 75th and 85th percentile of persistence values fell at the same value (7.1%). Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

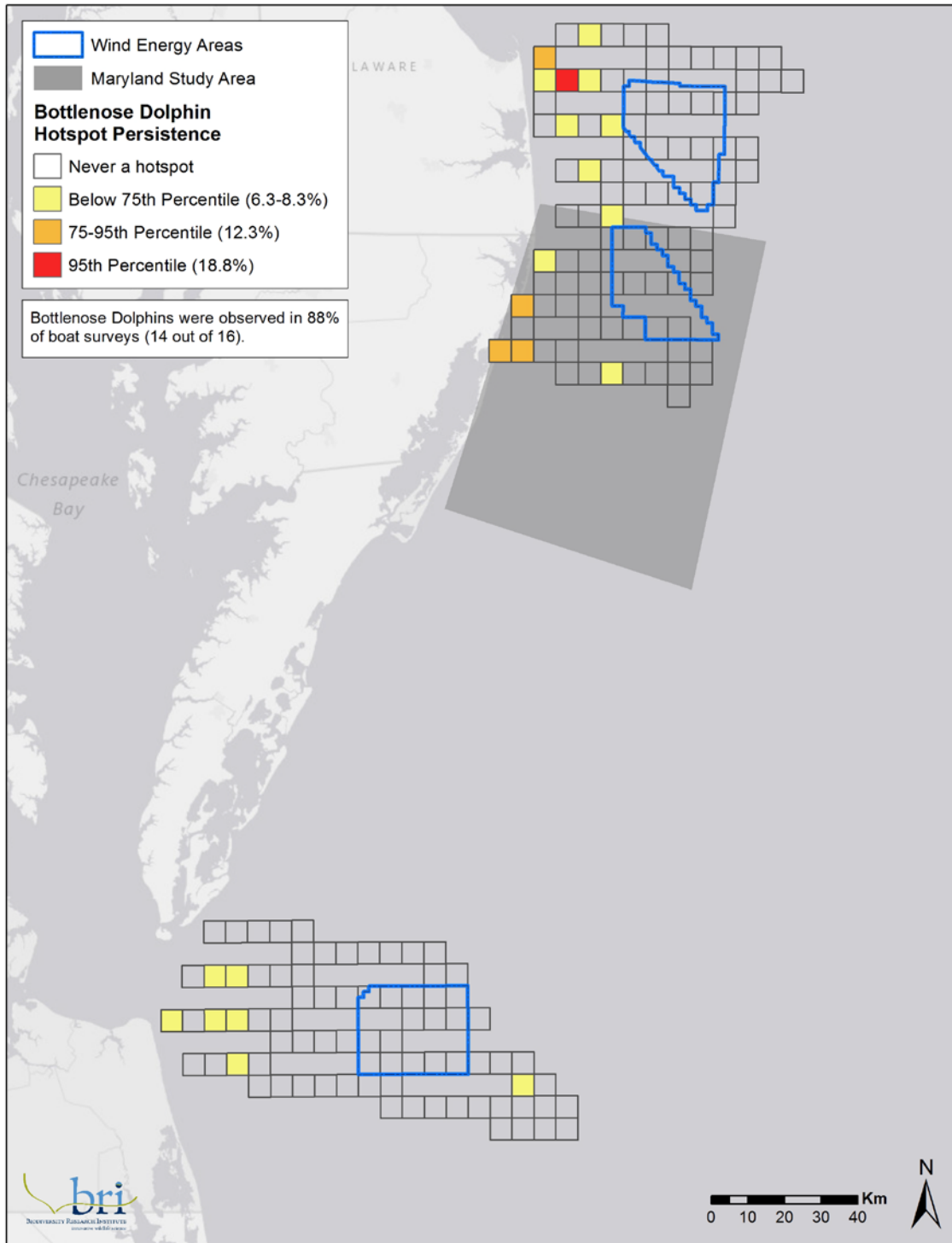


Figure 11-22. Classified persistent abundance hotspots for Bottlenose Dolphins (*Tursiops truncatus*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into only three persistence classes as the 75th and 85th percentile of persistence values fell at the same value (12.3%). Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

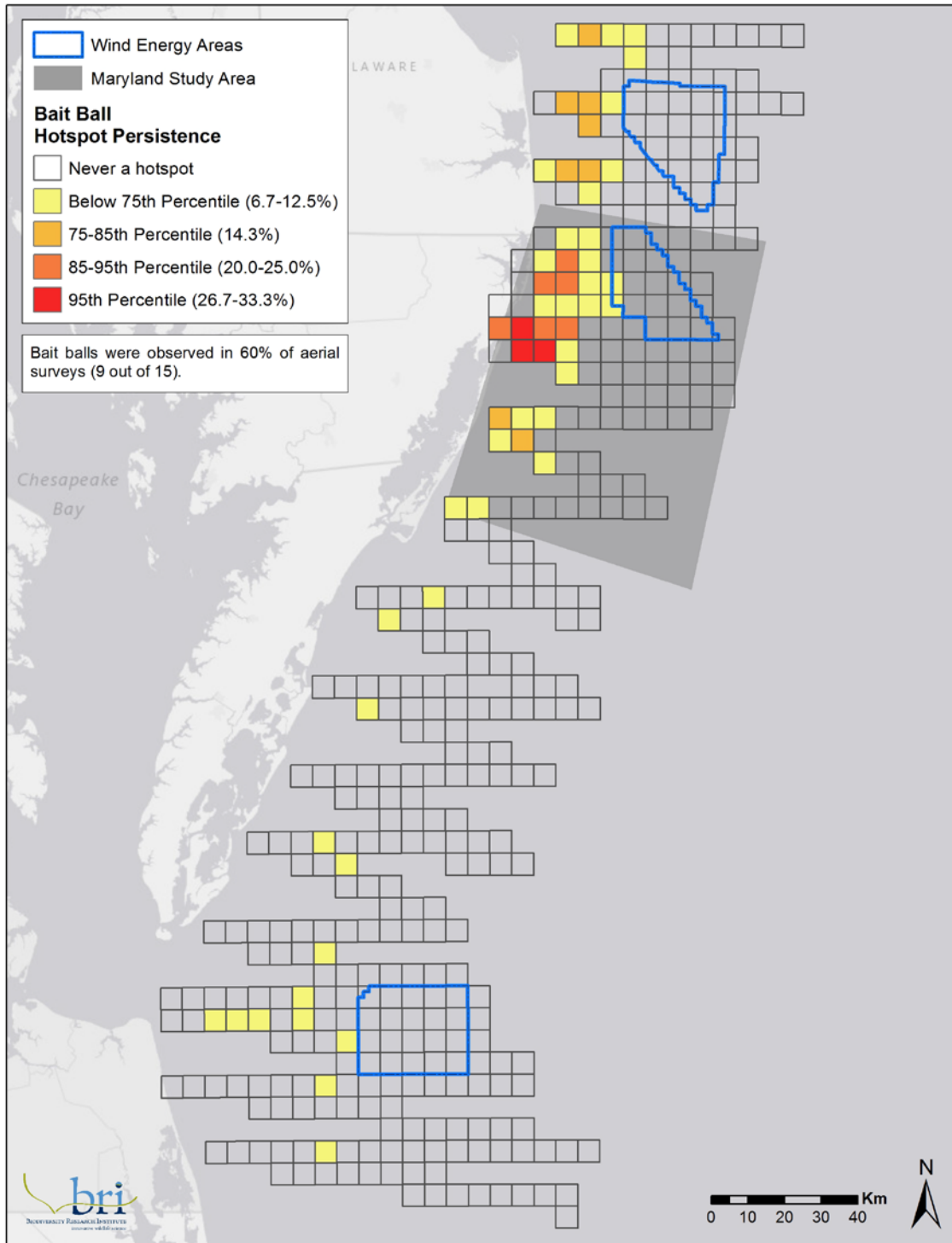


Figure 11-23. Classified persistent abundance hotspots for bait balls observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

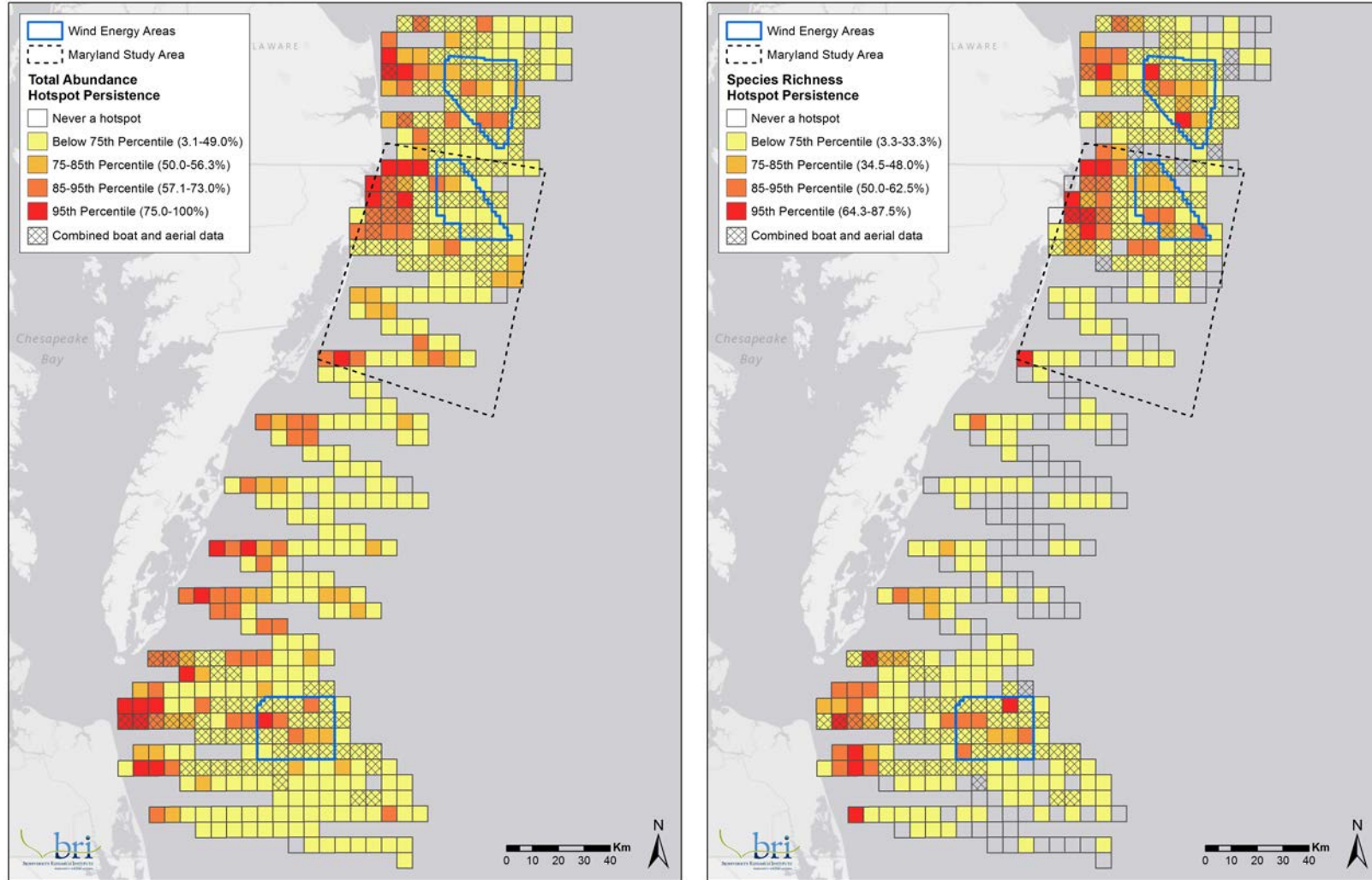


Figure 11-24. Persistent abundance hotspots identified across all taxa (left) and persistent species richness hotspots (right). These maps highlight areas where the greatest numbers of individuals across all taxa (left) and the greatest numbers of species (right) were consistently observed over the course of the study. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance or high enough species counts to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution.

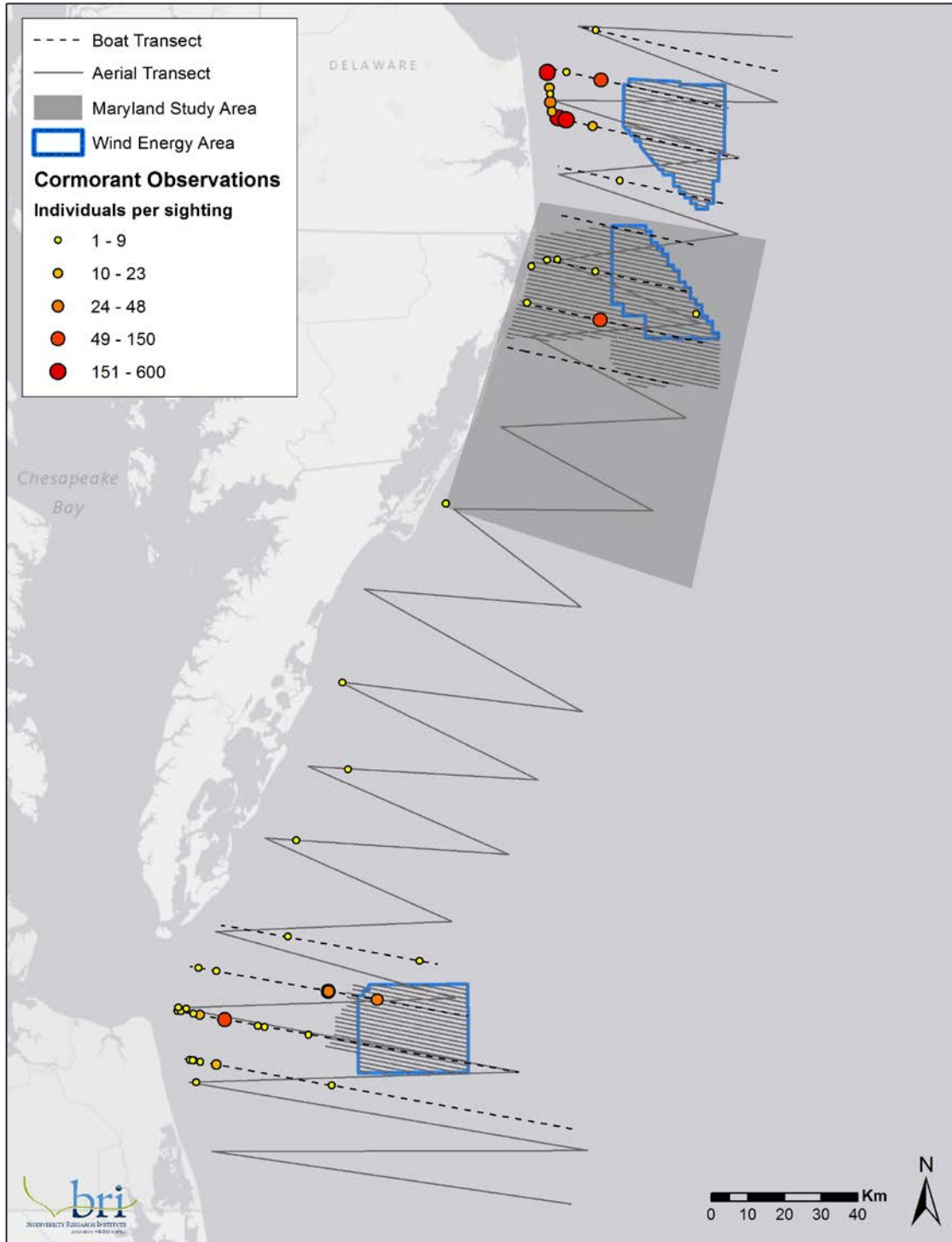


Figure 11-25. Cormorants (*Phalacrocoracidae*) observed by boat and video aerial surveys. A total of 2,077 cormorants were observed (2,035 by boat; 42 by aerial) over the course of the study, March 2012 – May 2014. Over half of these individuals were observed in three sightings by boat surveys near the mouth of Delaware Bay.

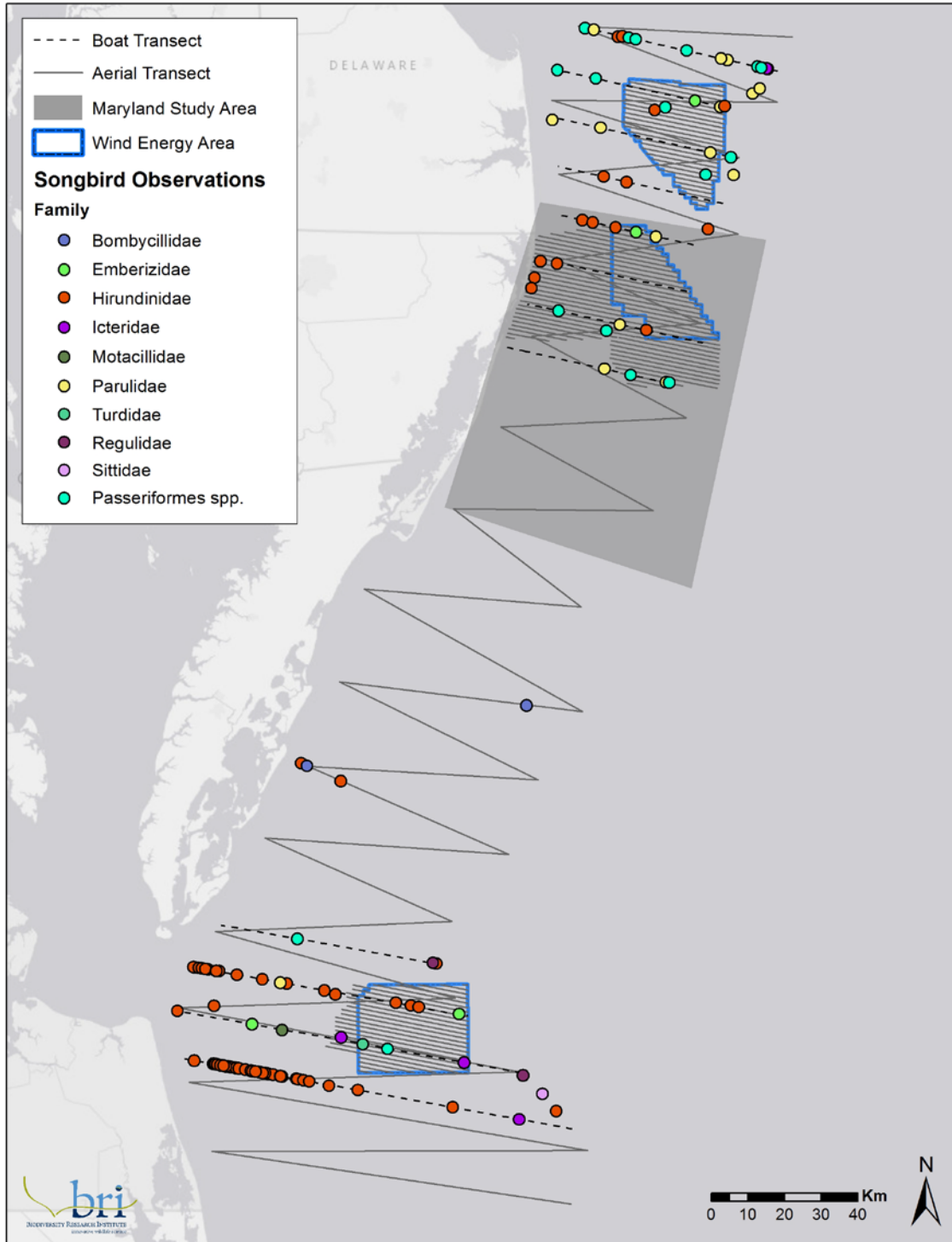


Figure 11-26. Songbirds observed in the boat and video aerial surveys displayed by family. Families include waxwings (Bombycillidae), sparrows (Emberizidae), swallows (Hirundinidae), blackbirds and cowbirds (Icteridae), pipits (Motacillidae), warblers (Parulidae), kinglets (Regulidae), nuthatches (Sittidae), robins (Turdidae), and unidentified passerines (Passeriformes).

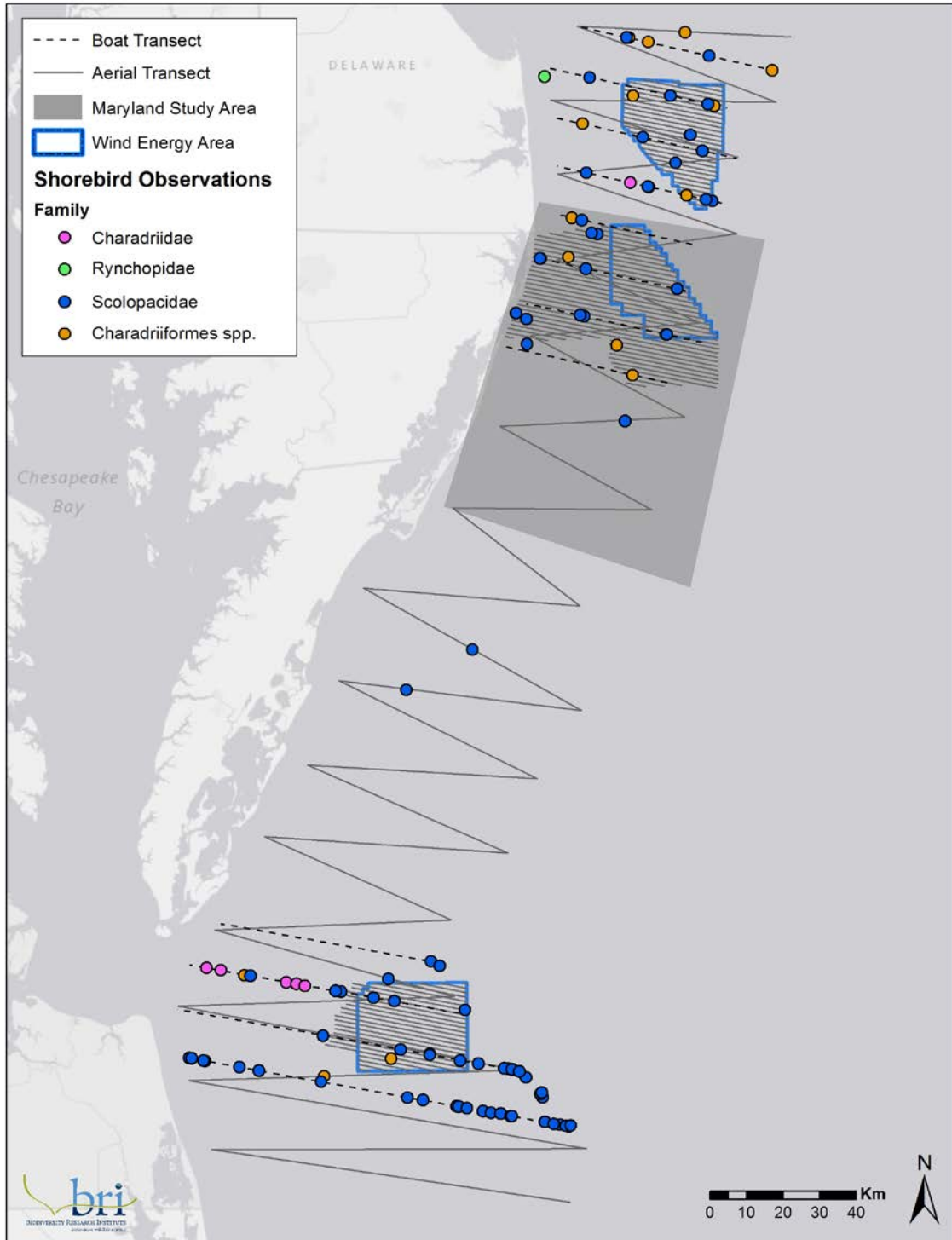


Figure 11-27. Shorebirds observed in the boat and video aerial surveys, displayed by family. Families include plovers (Charadriidae); skimmers (Rynchopidae); sandpipers, phalaropes, and other shorebirds (Scolopacidae); and unidentified shorebirds (Charadriiformes).

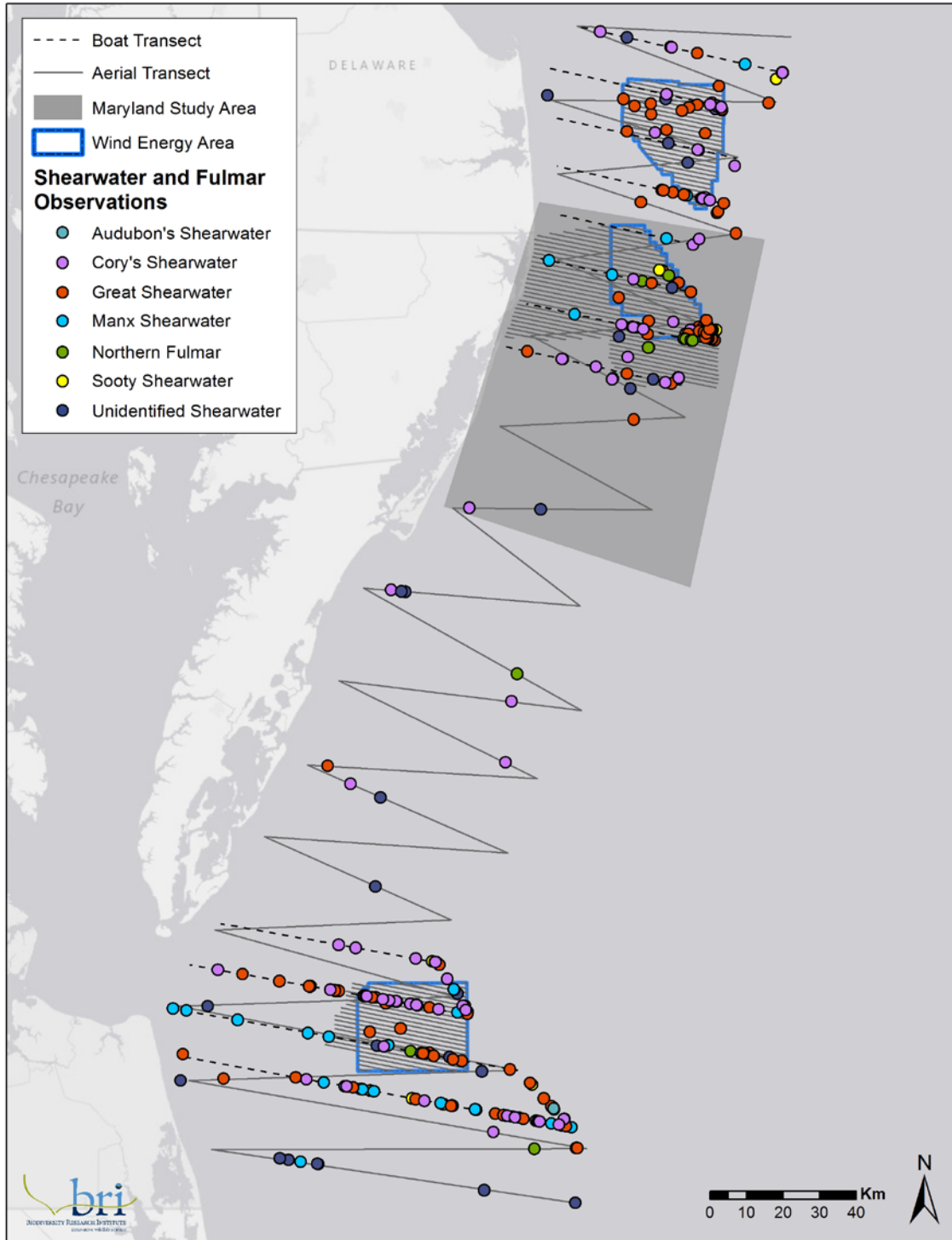


Figure 11-28. Shearwaters and fulmars (Procellariidae) observed on boat and video aerial surveys (March 2012-May 2014).

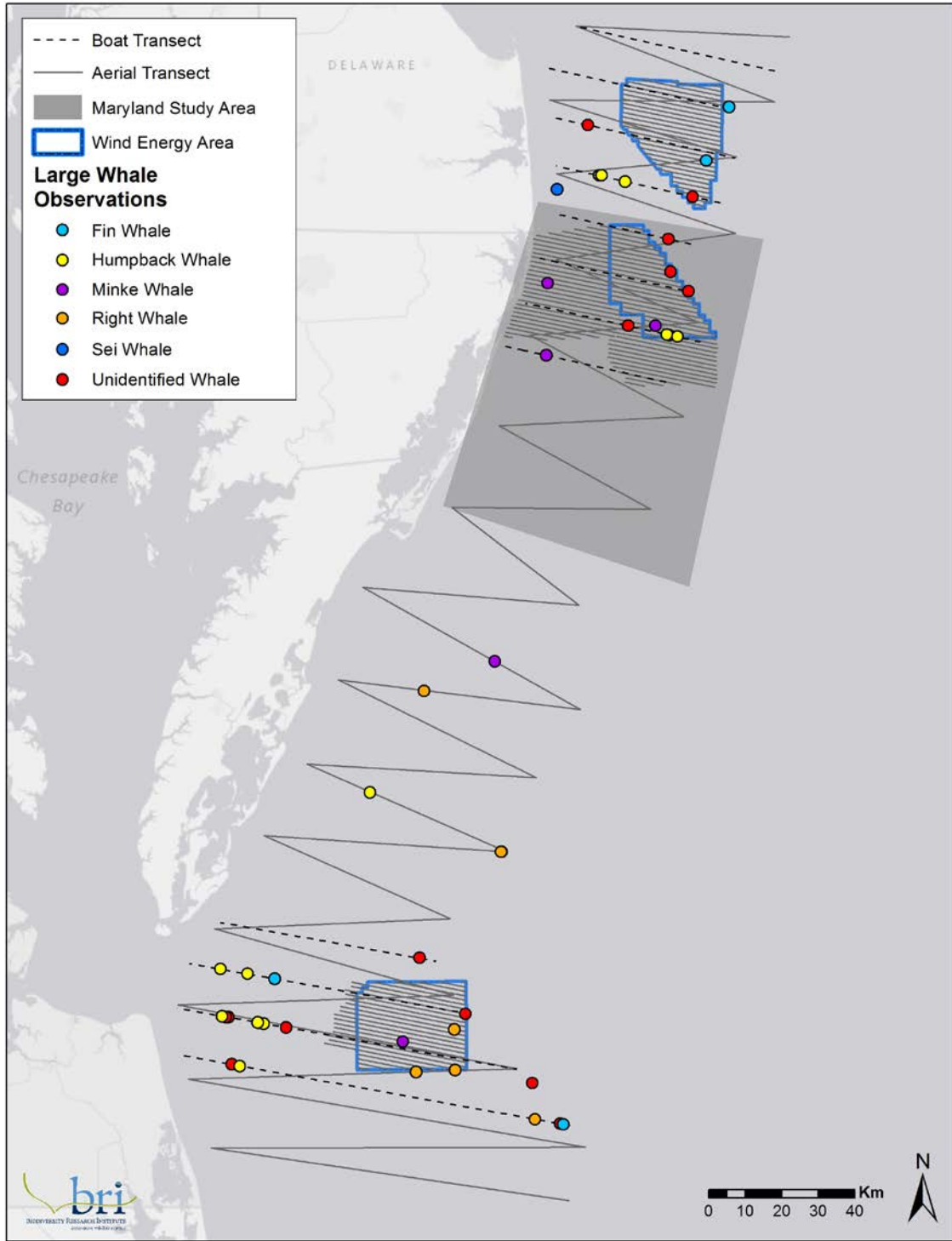


Figure 11-29. Large whale observations (Mysticeti) from boat and video aerial surveys (March 2012-May 2014).

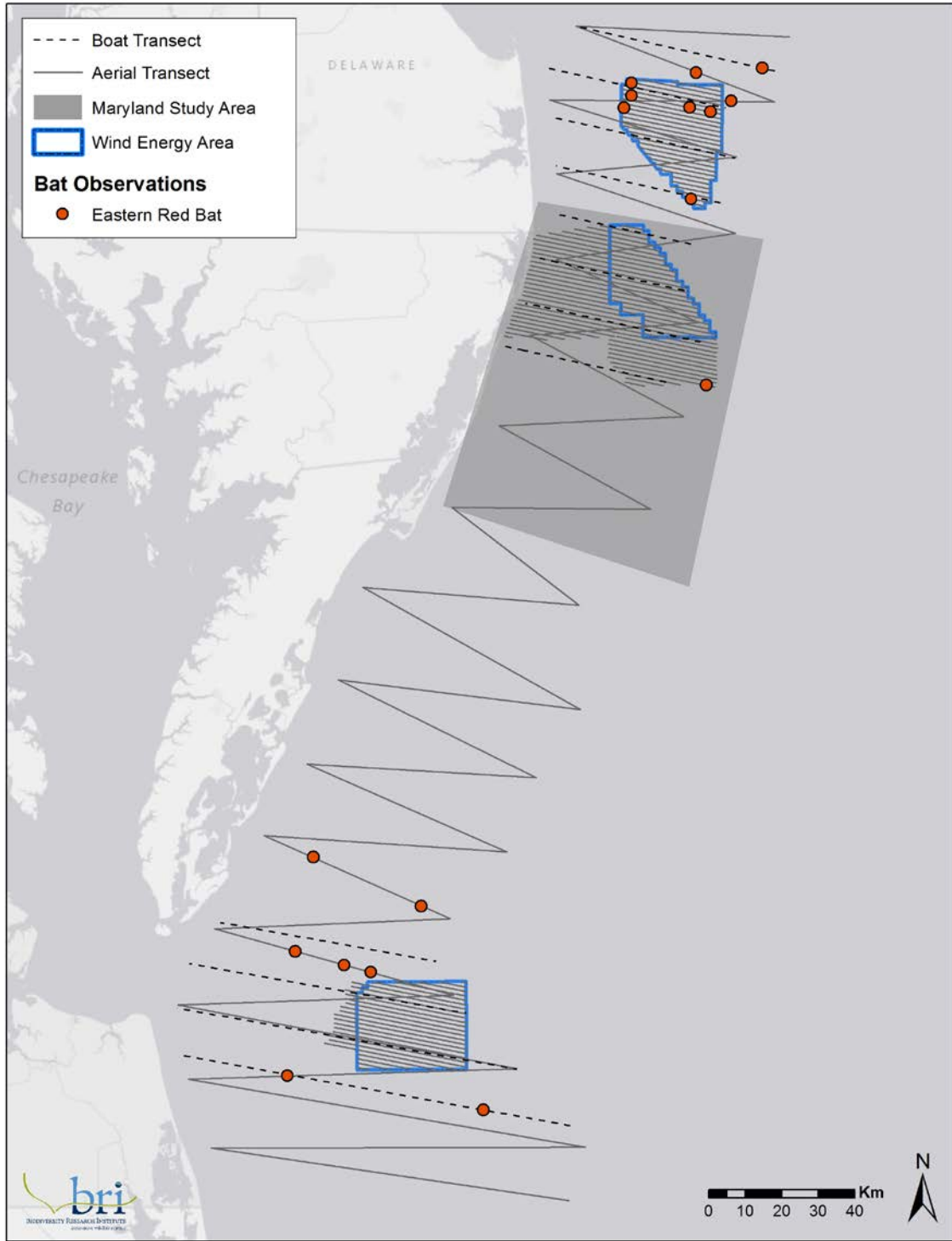


Figure 11-30. Red bat observations from boat and video aerial surveys (September 2012 and September 2013).

Table 17-1. Figure legend for grouped species temporal charts. Darker and larger bars show time periods when a species or group was more commonly observed in surveys. Effort-corrected counts that correspond with percentile values are shown in kilometers.

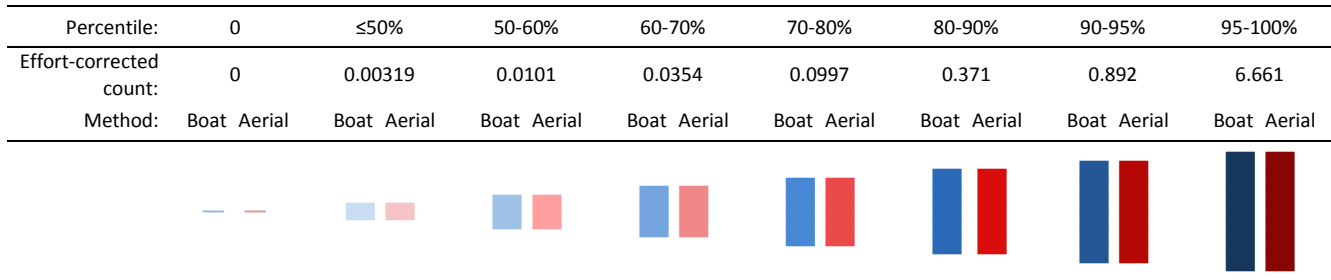
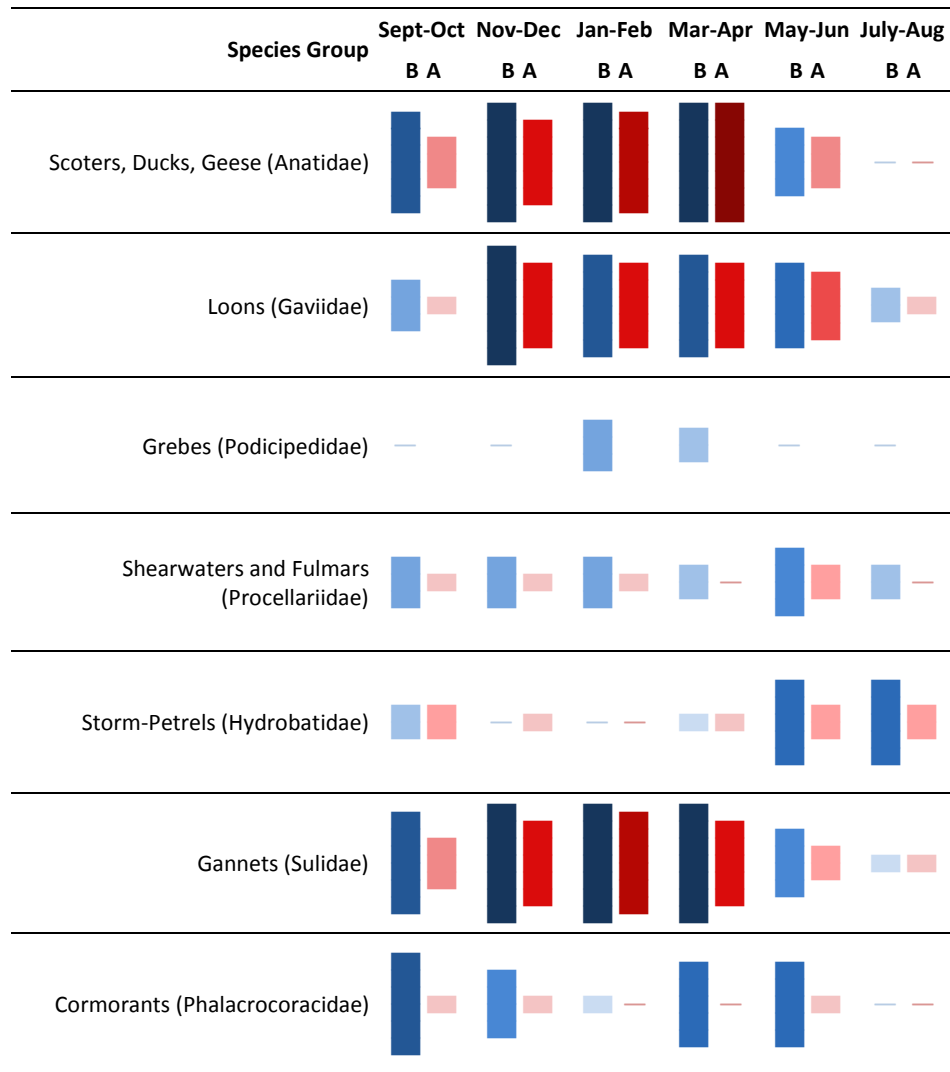
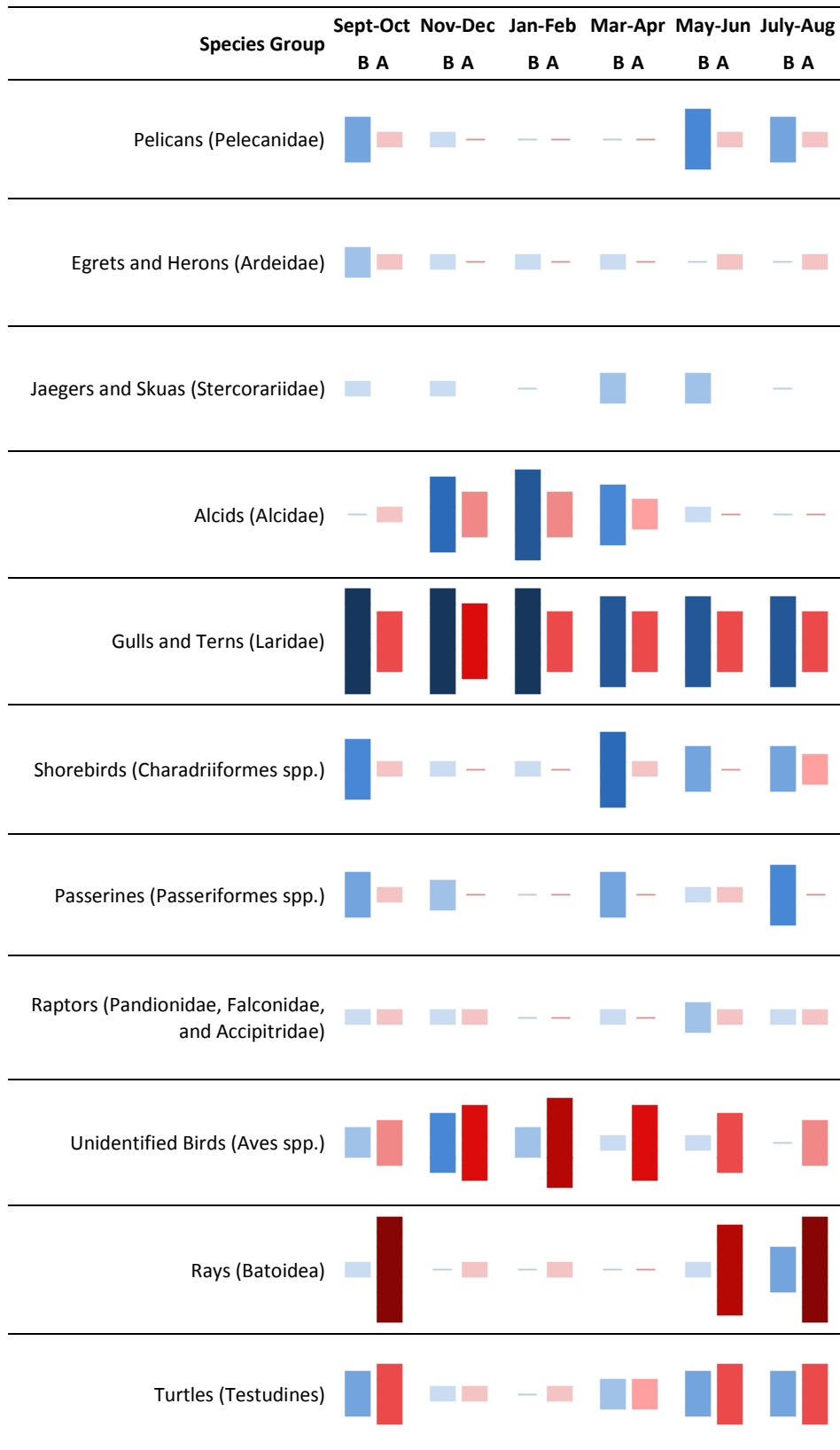


Table 17-2. Temporal bar charts for all taxonomic groups with more than 10 observations in the boat (B) and video aerial (A) surveys. When fewer than ten animals were observed in one survey type they were left blank for that survey type (e.g. bats in the boat survey). Avian and non-avian animals are presented in taxonomic order.





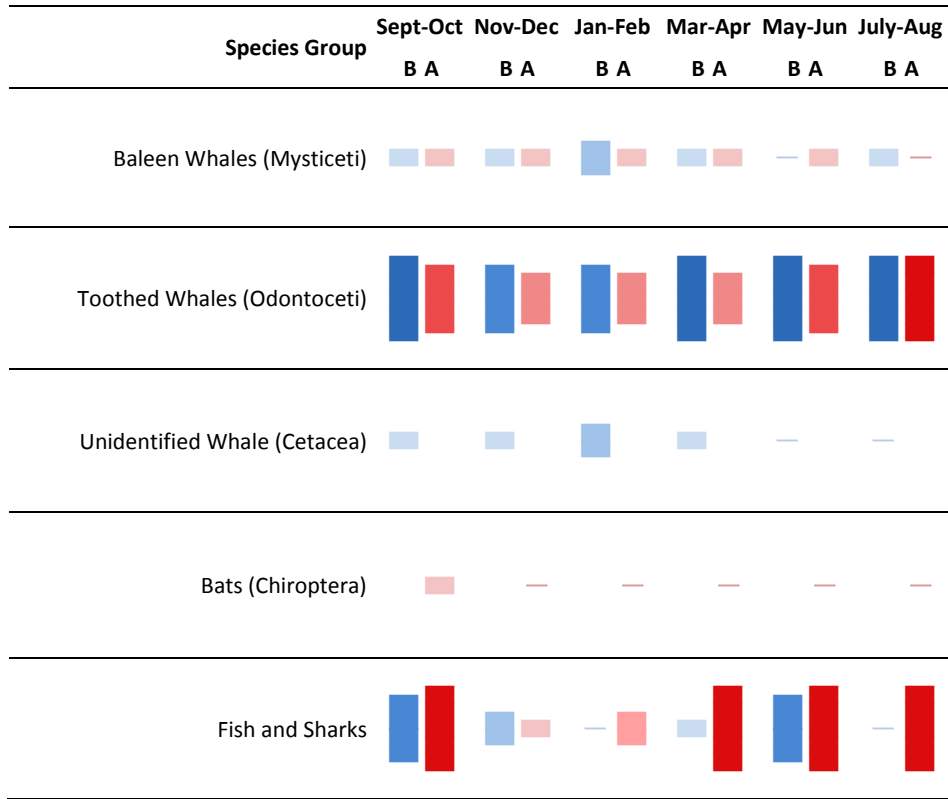


Table 17-3. Figure legend for individual species temporal charts. Darker and larger bars show time periods when a species or group was more commonly observed in surveys. Effort-corrected counts that correspond with percentile values are shown in kilometers.

Percentile:	0	≤50%	50-60%	60-70%	70-80%	80-90%	90-95%	95-100%
Effort-corrected count:	0	0.000543	0.00153	0.00490	0.0178	0.118	0.309	3.902
Method:	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial

Table 17-4. Temporal bar charts for all individual species with more than 10 observations in the boat (B) and video aerial (A) surveys. When fewer than ten animals were observed in one survey type they were not calculated for that survey type (e.g. Brants in the video aerial survey). Avian and non-avian animals are presented in taxonomic order.

Common Name	Sep-Oct		Nov-Dec		Jan-Feb		Mar-Apr		May-Jun		Jul-Aug	
	B	A	B	A	B	A	B	A	B	A	B	A
Brant	—	—	B	—	B	—	B	—	—	—	—	—
Canada Goose	—	—	B	—	—	—	B	—	B	—	—	—
Mallard	B	—	—	—	—	—	—	—	—	—	—	—
Green-winged Teal	B	—	—	—	—	—	—	—	—	—	—	—
Surf Scoter	B	A	B	A	B	A	B	A	—	—	—	—
White-winged Scoter	B	A	B	A	B	—	B	A	B	—	—	—
Black Scoter	B	A	B	A	B	—	B	A	B	A	—	—

