Chapter 17: Integrating data across survey methods to identify spatial and temporal patterns in wildlife distributions

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Chapter 17 Highlights

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

Context[1]

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. This chapter uses both datasets to identify temporal and spatial patterns of species presence and relative abundance in the study area, 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. Predicted species identification of Red-throated Loons (*Gavia stellata*) and Common Loons (*G. immer*) presented in Chapter 16 were used in calculating persistent hotspots for these species. 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 study area (Chapters 15-16 and 18-19). In some instances, one survey method was used to predict abundance of specific taxa (e.g., Chapter 15), while in other cases, the two datasets could be combined using an integrated modeling framework (Chapter 19). Additional chapters in Part IV compare boat and aerial survey methodologies (Chapters 13-14), 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 a baseline study 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 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 study area during non-breeding (summer or winter), breeding, and migratory periods.

Introduction

The mid-Atlantic region is an extremely 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; Smith and Kemp 1995; Schofield et al. 2008). 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. We collected this data 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 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. This Mid-Atlantic Baseline Studies Project is the largest application of video aerial surveys in the U.S. to date. We also conducted boat-based surveys within the study area 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 (Chapters 13-14), 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 mid-Atlantic study area. 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 (OCS). 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 across the mid-Atlantic study area. Details on the study area and data collection methods can be found in Chapter 3 and Chapter 7. 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.

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) OCS lease blocks (a 23.0 km^2 grid, where each cell is 4.8 x 4.8 km) using ArcGIS version 10.2.2 (ESRI, Redlands, California). 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 areas. 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 map.

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. 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., alcids, Alcidae).

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 (km^2) 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 17-1).

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 (Chapters 1 and 14). 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 (km^2) 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:

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

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 (*Gavia immer*) or Red-throated Loons (*G. stellata*). We used the species identification model with environmental covariates developed in this study (Chapter 16) 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 (Chapter 16). For these four aerial surveys, we summed the predicted counts of Red-throated 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 Wind Energy Areas (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 14-15 and 18). 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 allowed for variation in the data presented while also controlling somewhat for variation in effort between periods (Chapters 5 and 8).

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 within a 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 17-1) and individual species (Table 17-3). 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 17-2). Though scoters were observed at all longitudes within the study area, 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 17-2). The persistent hotspots of scoter abundance identified in Figure 17-2 were some of the largest and most consistent of any species group examined. Surf Scoters (Figure 17-3) and Black Scoters (Figure 17-4) 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 Chapter 20.

Loons

Loons, including Common Loons and Red-throated Loons, were present in 90% of surveys, with greatest numbers present in the study area between November and May (Table 17-2, Table 17-4). 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; Chapter 16). Red-throated Loons showed highest hotspot persistence close to shore along the length of the study area (Figure 17-5). Common Loon hotspots were scattered across the width of the OCS, though many of the most persistent Common Loon hotspots were located offshore of the mouth of Chesapeake Bay (Figure 17-6). Additional information on Red-throated Loon movements and habitat use in the mid-Atlantic is presented in Chapter 21.

Storm-petrels

Storm-petrels were not identified frequently enough from the aerial data to justify 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 17-7. Storm-petrels were observed in 50% of boat surveys, and almost exclusively in summer (Table 17-2). Identified hotspots of relative abundance included both nearshore and offshore locations (Figure 17-7). 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 study area. The most persistent abundance hotspots for gannets contained large aggregations between 36% and 54% of the time that the species was present in the study area, but the majority of grid cells (70%) were identified as an abundance hotspot during at least one survey (Figure 17-8), indicating that Northern Gannet distribution and abundance patterns varied widely between surveys. The most persistent hotspots tended to be located within about 30-40 km of the shoreline, although abundance hotspots were also consistently observed in several offshore locations (Figure 17-8). 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 17-4). The two survey methods showed very similar temporal variance 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 Chapters 22 and 24.

Alcids

Family Alcidae, which in the mid-Atlantic generally includes Dovekies (*Alle alle*), Razorbills (*Alca torda*), Atlantic Puffins (*Fratercula arctica*), and both murres (*Uria* spp.), were not identified frequently enough from the aerial data to justify mapping persistent hotspots of abundance. Hotspots estimated from boat data for this taxon are presented in Figure 17-9. Alcids were present almost exclusively in winter (Table 17-2). Identified hotspots of relative abundance included both nearshore and offshore locations, but 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 17-9). 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 17-4). 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 study area, though the most persistent of these were located in the western half of the study area, and particularly in three locations: the mouth of Chesapeake Bay, the mouth of Delaware Bay, and the northern shore of Maryland (Figure 17-10). The same patterns for the most persistent hotspots are present in both the gull-specific (Figure 17-11) and tern-specific (Figure 17-12) maps. A comparison of Figure 17-10 to Figure 17-12, 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 study area, and were most persistent along the north shore of Maryland and at the mouth of the Chesapeake Bay (Figure 17-15; Figure 17-16). Laughing Gull hotspots were also most persistent in nearshore areas, primarily in the northern parts of the study area (Figure 17-14). In contrast, Bonaparte's Gulls were notably more persistently observed in large numbers in the southern half of the study area, and at a range of distances from shore (Figure 17-13).

Common Terns were the only tern species abundant enough to include in analysis, and were only observed in large numbers by boat (only one Common Tern was identified over the course of the study in digital video aerial surveys). Common Tern hotspots occurred across the OCS, but were most persistent near the mouth of Delaware Bay (Figure 17-17). 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 17-12). 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 17-4) that are mapped in aggregate in Figure 17-12.

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 17-2). They were not identified frequently enough from the boat data to justify mapping persistent hotspots of abundance, so only the aerial data are presented in Figure 17-18. 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 17-18). 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 17-2). They were also much more frequently observed in video aerial surveys than from the boat (Chapter 14), 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 justify mapping persistent hotspots of abundance, so only the video aerial data are presented in Figure 17-19. Sea turtle species were observed in 80% of video aerial surveys, and were more consistently located in large numbers in the southern half of the study area and farther from shore (Figure 17-19). Further examination of seasonal distribution patterns and possible environmental drivers for this taxon is presented in Chapter 15.

Dolphins and porpoises

Odontoceti, or toothed whales, were observed throughout the study period, with some summertime increases in observations (Table 17-2). 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 17-2; Chapter 14). Almost all identified observations were either Bottlenose Dolphins (*Tursiops truncatus*) or Common Dolphins (*Delphinus delphis*). Bottlenose Dolphins were observed primarily in warmer months, were observed across the study area, and made up a higher proportion of the aerial data than the boat data for most time periods (Table 17-4). 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 17-4), and were mostly observed in the eastern part of the study area. The persistent hotspots identified in Figure 17-20 reflect a combination of these species' distributions. Nearshore hotspots were likely driven by coastal Bottlenose Dolphin populations (Chapter 15), while hotspots located father 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 (Figure 17-21). Further examination of seasonal distribution patterns and possible environmental drivers for Bottlenose Dolphin distributions are presented in Chapter 15.

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 often observed in the western half of the study area, and were most persistently observed in highest densities in the nearshore regions of the study area, particularly off the coast of Delaware and Maryland (Figure 17-22). 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), particularly in northern Maryland, near the mouth of Chesapeake Bay and the North Shore of Virginia, and near the mouth of Delaware Bay (Figure 17-23). Hotspots of species richness were consistently located in similar areas (Figure 17-23). 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 17-2). 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 17-2). 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 17-4).

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 (3.2%), with a total of 2,035 individuals observed. 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. Nearly all were identified as Double-Crested Cormorants (*Phalacrocorax auritus*). Only 42 Double-Crested Cormorants were observed by video aerial surveys. Cormorants were observed across the study area, but the largest groups were mostly observed close to the mouths of Delaware Bay and Chesapeake Bay (Figure 17-24). Cormorants were most commonly observed by boat in the spring and fall (Table 17-2).

Passerines made up a small proportion of the aerial data, compared to boat data; 180 passerines were observed by boat and 17 were observed by video aerial survey methods (representing 22 unique identified species; Chapters 5 and 8), with peak numbers of passerines spring through the fall (Table 17-2). Songbirds were observed throughout the study area (Figure 17-25). Swallows (Hirundinidae) were the most frequently observed passerine, particularly in the coastal waters off of Virginia. Warblers (Parulidae) were most commonly observed in the Delaware and Maryland 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 17-4). Additional discussion of passerine migration (which largely occurs nocturnally) may be found in Chapters 26-27.

Shorebirds (Charadriiformes) were also observed primarily on boat-based surveys, with 587 observations of at least 15 species reported, as compared to 74 observations in the aerial data (Chapters 5 and 8). Shorebird observations were distributed broadly across the study area (Figure 17-26). 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 17-4). 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 8).

Observations of shearwaters and fulmars (Procellariidae) were more consistent across survey platforms, with 325 individuals of six species of observed by boat surveys, and 112 individuals from at least five species observed during video aerial surveys (Chapters 5 and 8). Great Shearwaters (*Puffinus gravis*) and Cory's Shearwaters (*Calonectris diomedea*) were most commonly observed, typically in the eastern part of the study area (Figure 17-27). Manx Shearwaters (*Puffinus puffinus*) were mostly observed on boat surveys, and a single Audubon's Shearwater (*P. lherminieri*) was also observed on boat surveys. Shearwaters were observed primarily in the spring and fall, while Northern Fulmars (*Fulmaris glacialis*) were observed primarily in winter (Table 17-4).

Fifty-one large whales were observed throughout the study area during surveys, of which 35 were identified to species or family (Figure 17-28). North Atlantic Right Whales (*Eubalaena glacialis*) were detected primarily by video aerial survey methods, with several sightings 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. Other whales, including Humpback Whales (*Megaptera novaeangliae*), Fin Whales (*Balaenoptera physalus*), and Minke Whales (*Balaenoptera acutorostrata*), were also observed throughout the study area (Figure 17-28). Thirty-one of the 51 large whale observations occurred during winter months (Chapters 5, 8, and 15).

Aerial and boat surveys both detected migratory movements of Eastern Red Bats (*Lasiurus borealis*) in the offshore environment in September of 2012 (Hatch et al. 2013) and September of 2013. Seventeen bats were observed altogether, including two during boat surveys and 15 in video aerial surveys. Bats were observed between approximately 16 and 70 km from shore (Figure 17-29), 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 project study area 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 OCS 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 father 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 within 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., 2008; 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 (Chapter 18 Appendix A; Ainley et al., 2009; Camphuysen and Webb, 1999).

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Figures and tables

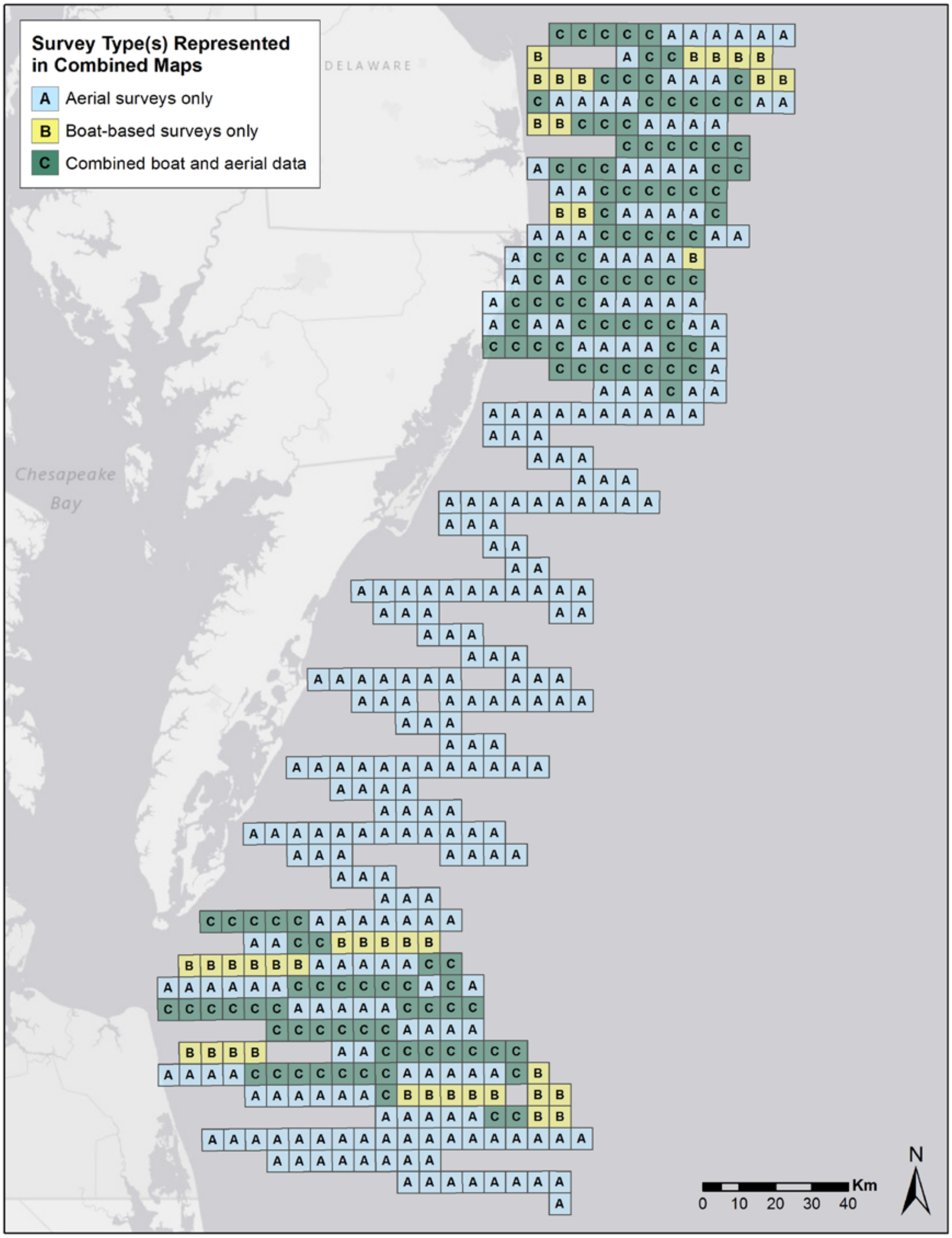

Figure 17-1. Survey method by grid cell. Sixteen boat-based and 15 video aerial surveys were conducted across the study area, resulting in a total of 450 surveyed grid cells: (A) 262 grid cells surveyed by video aerial surveys only, (B) 40 grid cells surveyed by boat-based surveys only, and (C) 128 grid cells surveyed by both methods.

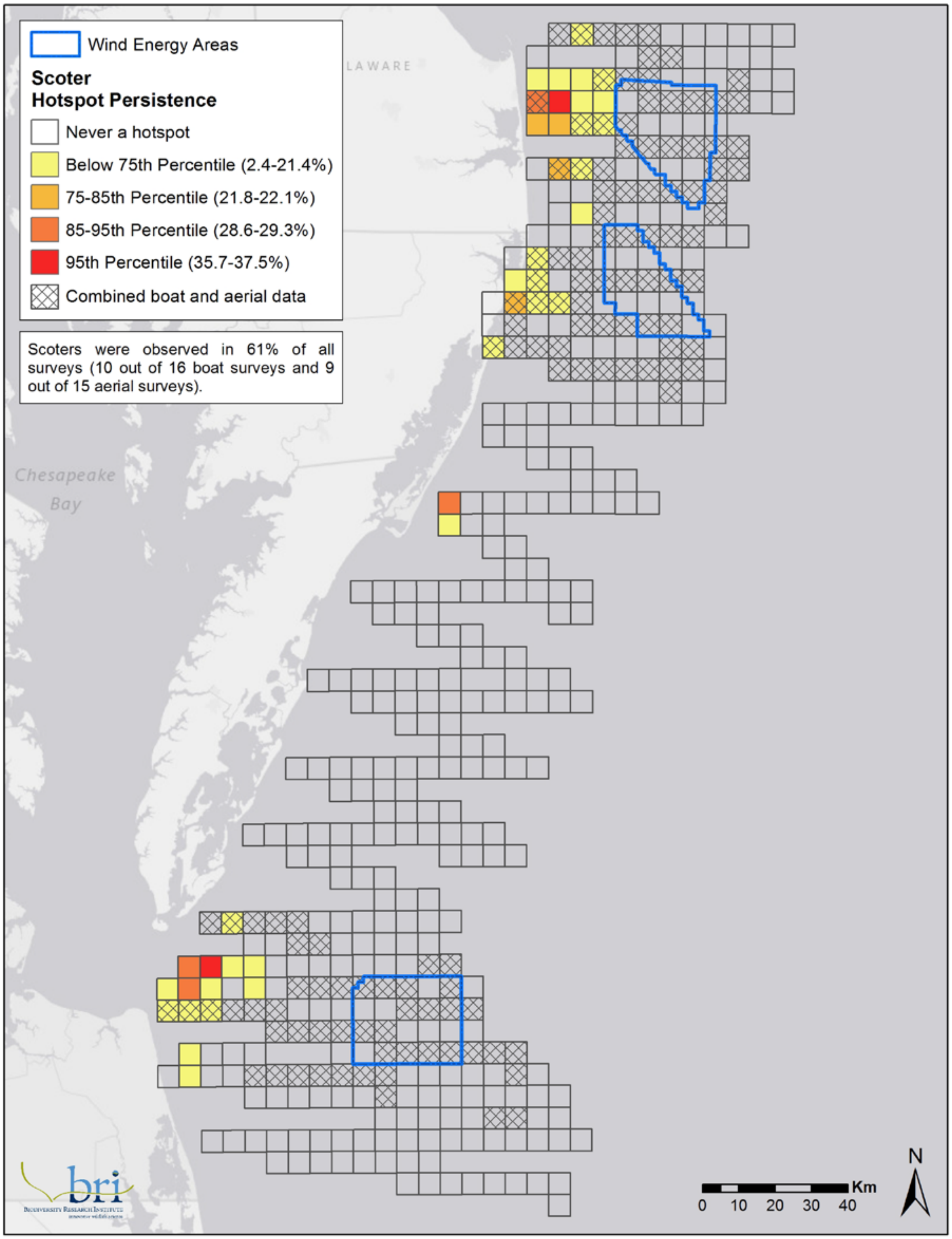

Figure 17-2. Classified persistent abundance hotspots for scoters (*Melanitta spp.*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods.

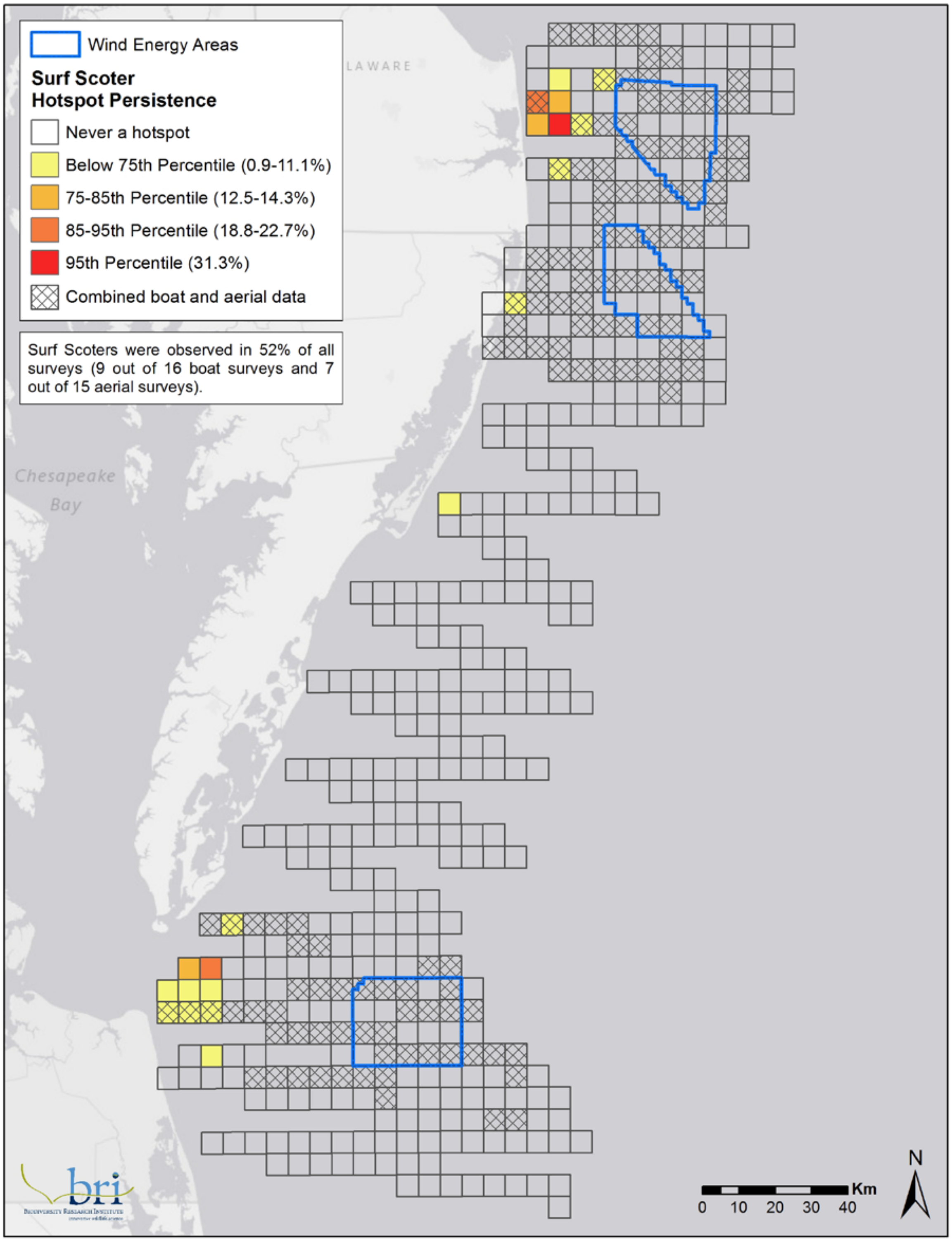

Figure 17-3. Classified persistent abundance hotspots for Surf Scoters (*Melanitta perspicillata*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown 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.

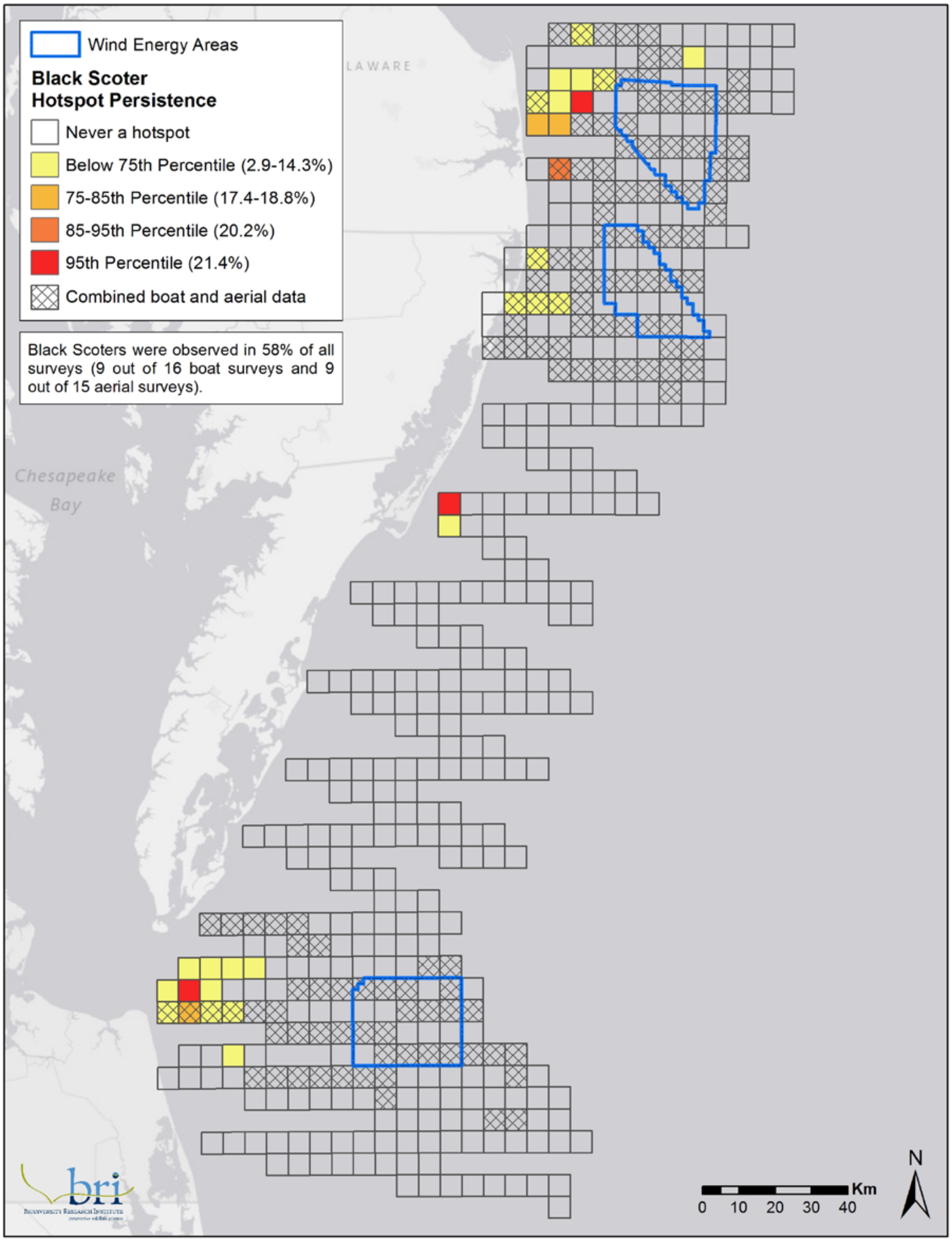

Figure 17-4. Classified persistent abundance hotspots for Black Scoters (*Melanitta americana*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown 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.

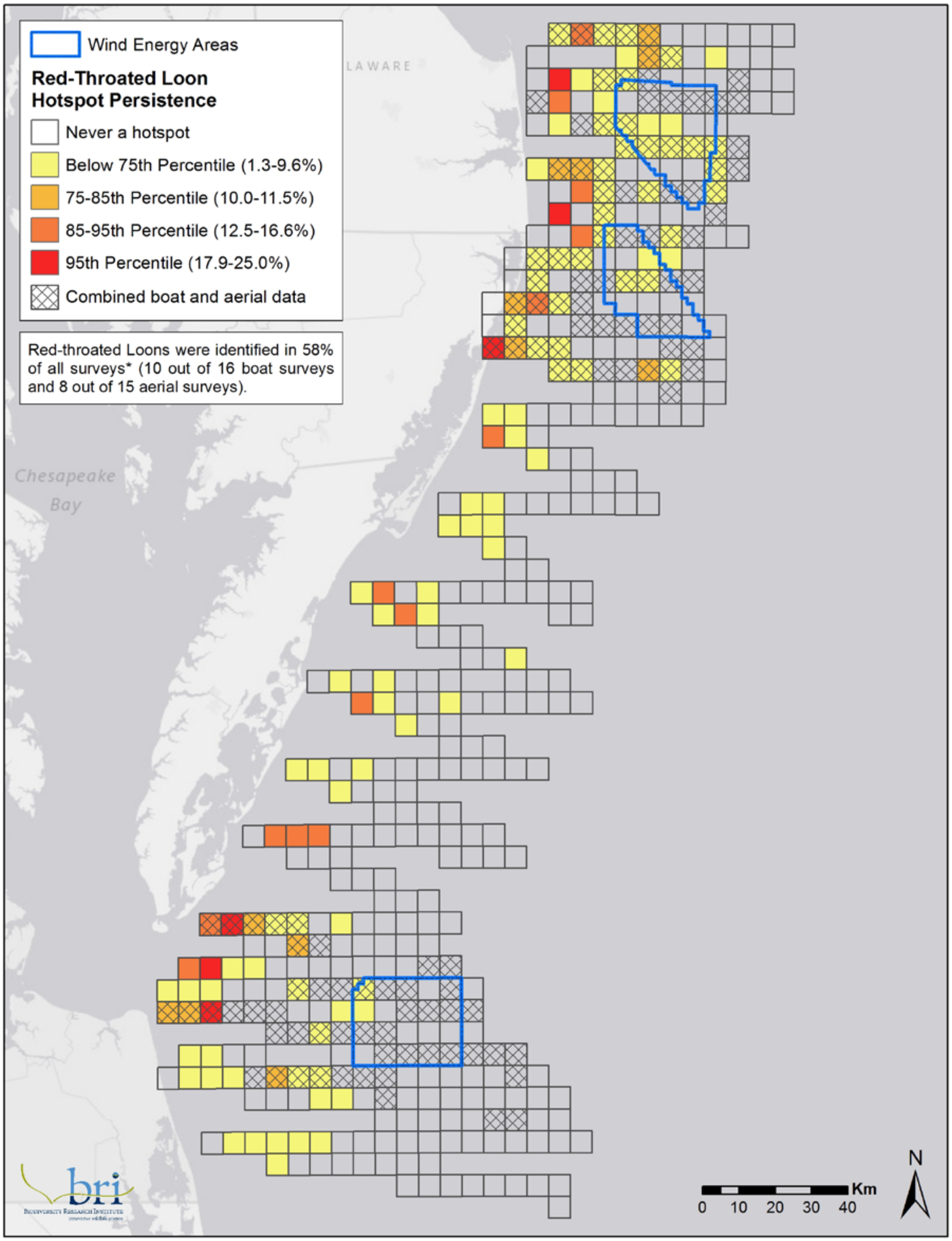

Figure 17-5. Classified persistent abundance hotspots for Red-throated Loons (*Gavia stellata*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown 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 (Chapter 17).

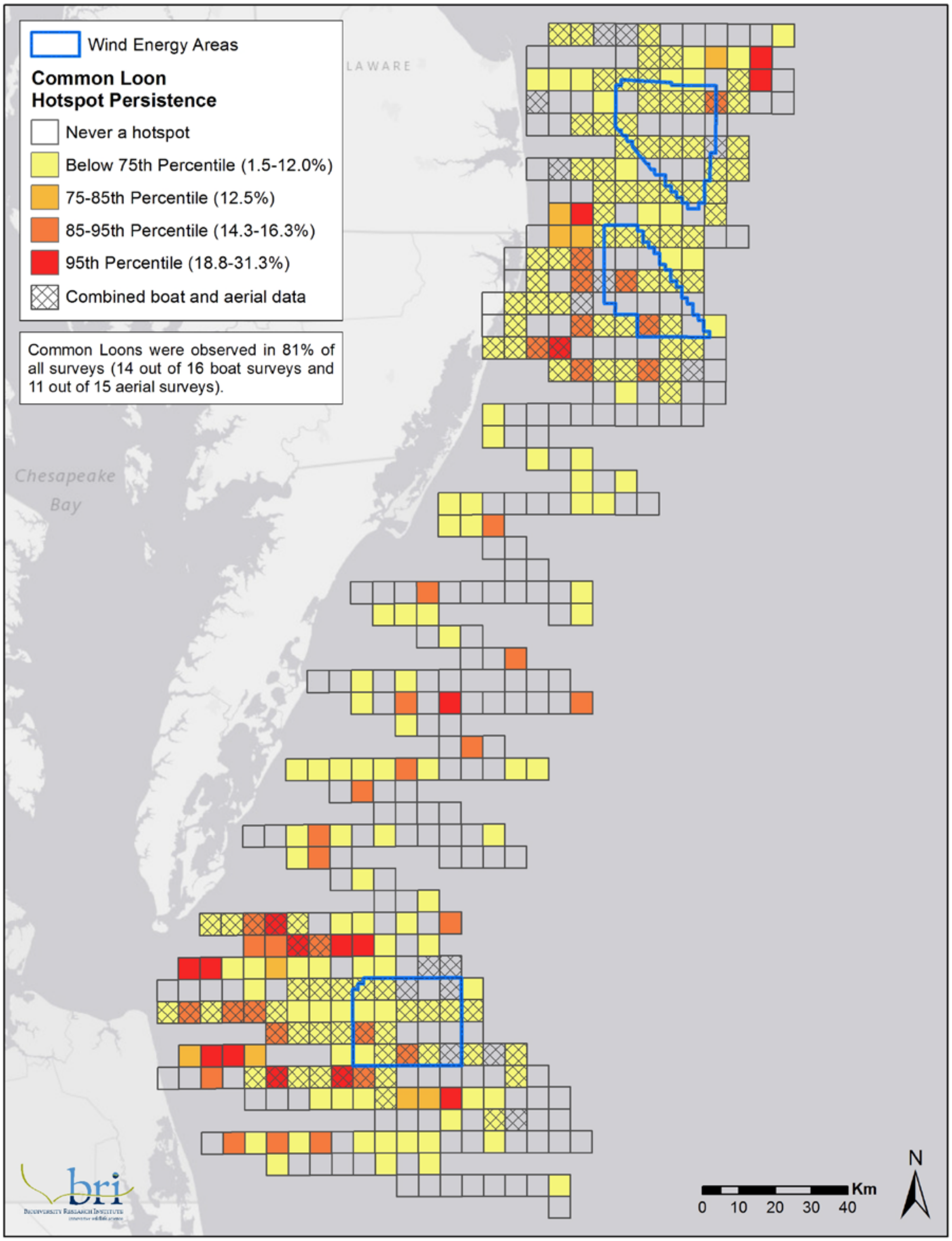

Figure 17-6. Classified persistent abundance hotspots for Common Loons (*Gavia immer*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods.

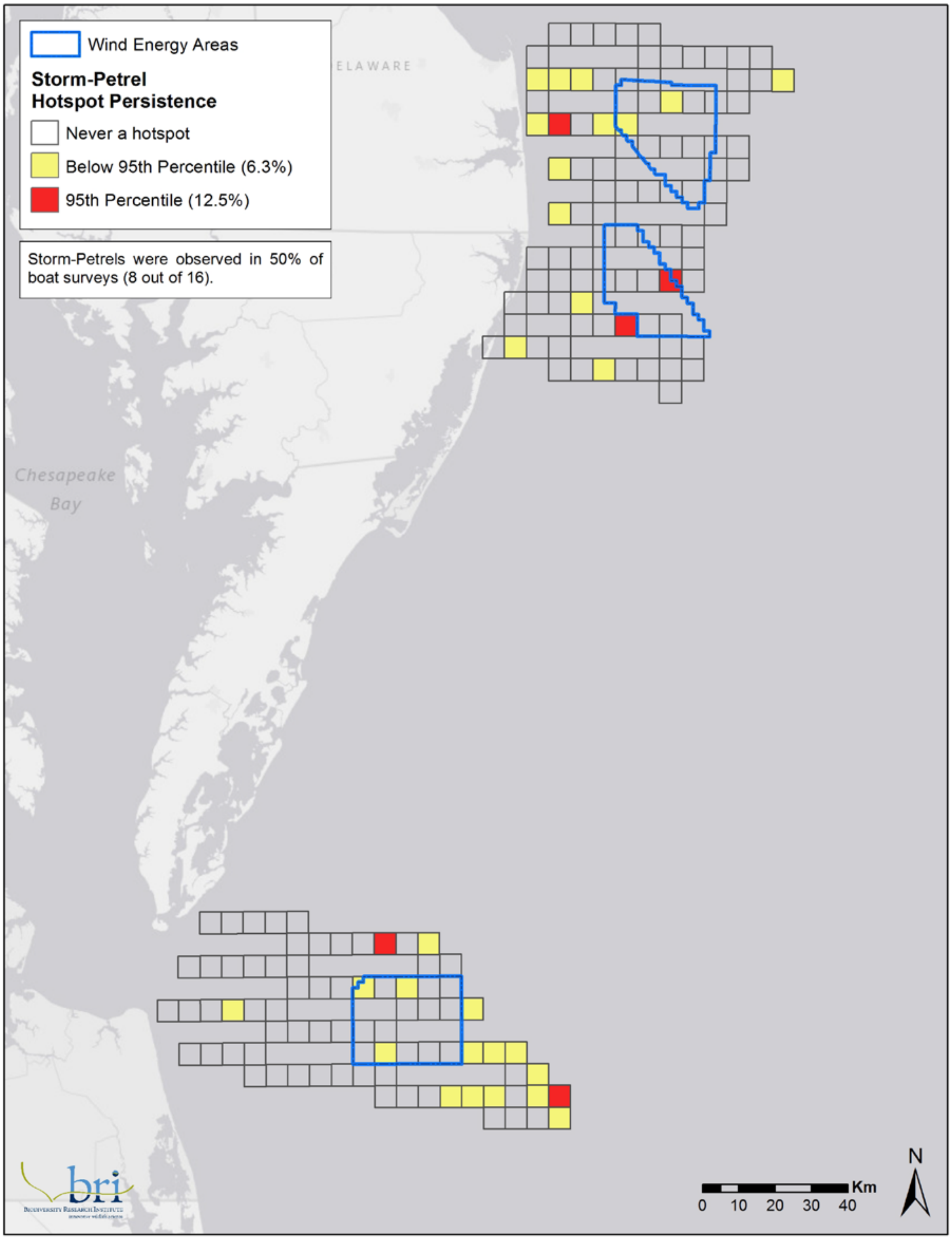

Figure 17-7. Classified persistent abundance hotspots for storm-petrels (Hydrobatidae spp.) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into only two persistence classes as only two distinct persistence values were calculated.

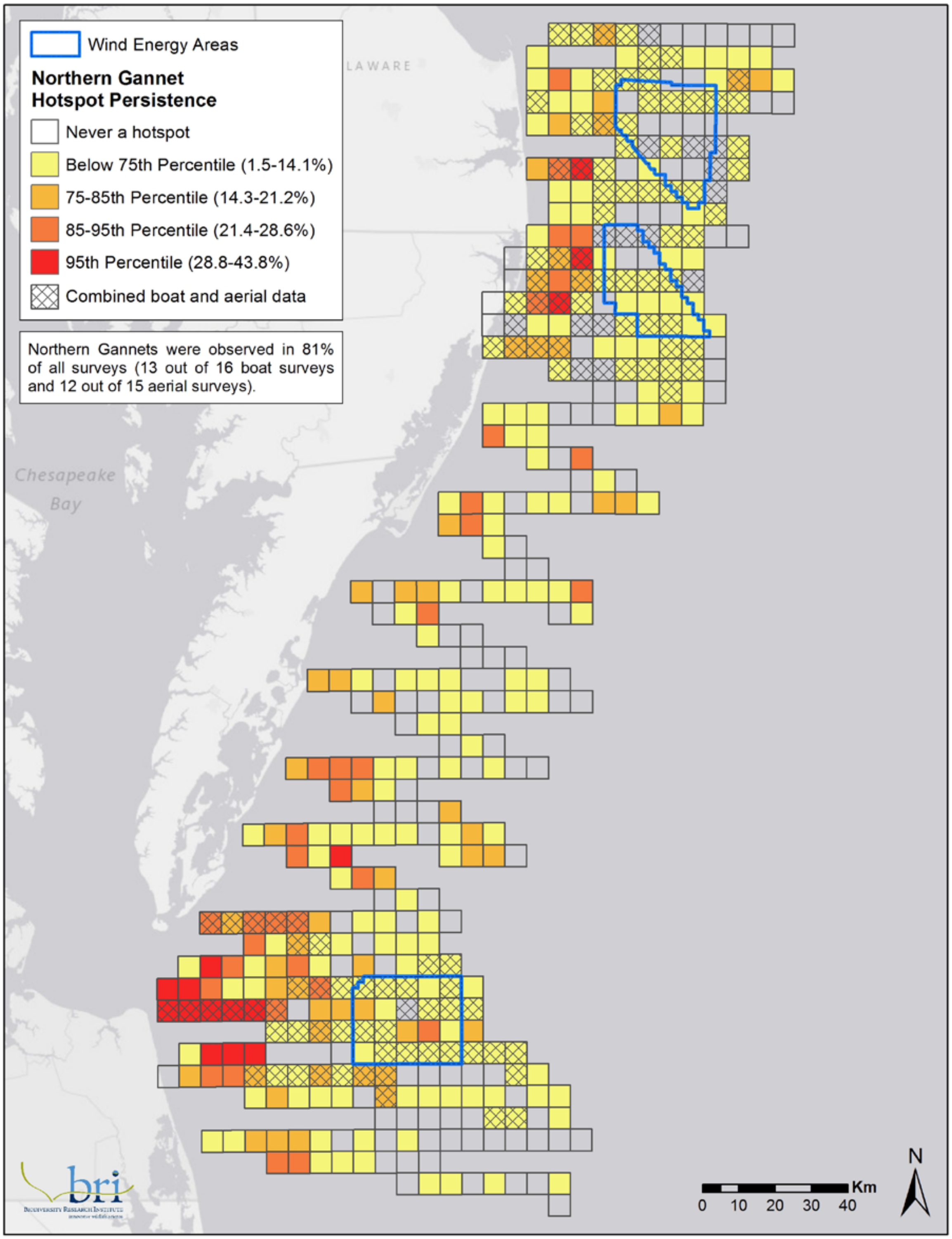

Figure 17-8. Classified persistent abundance hotspots for Northern Gannets (*Morus bassanus*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown 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.

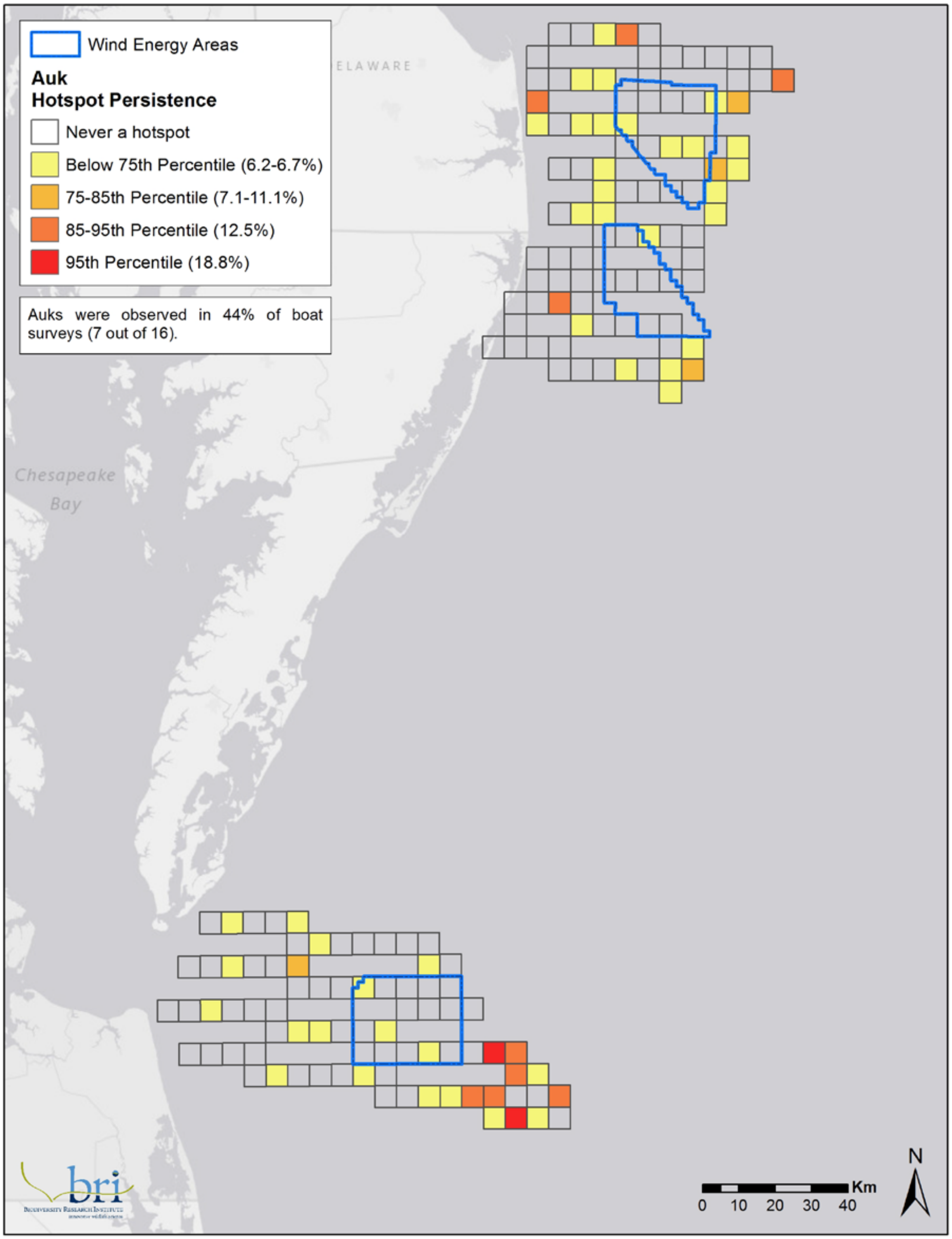

Figure 17-9. Classified persistent abundance hotspots for alcids (Alcidae spp.) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot.

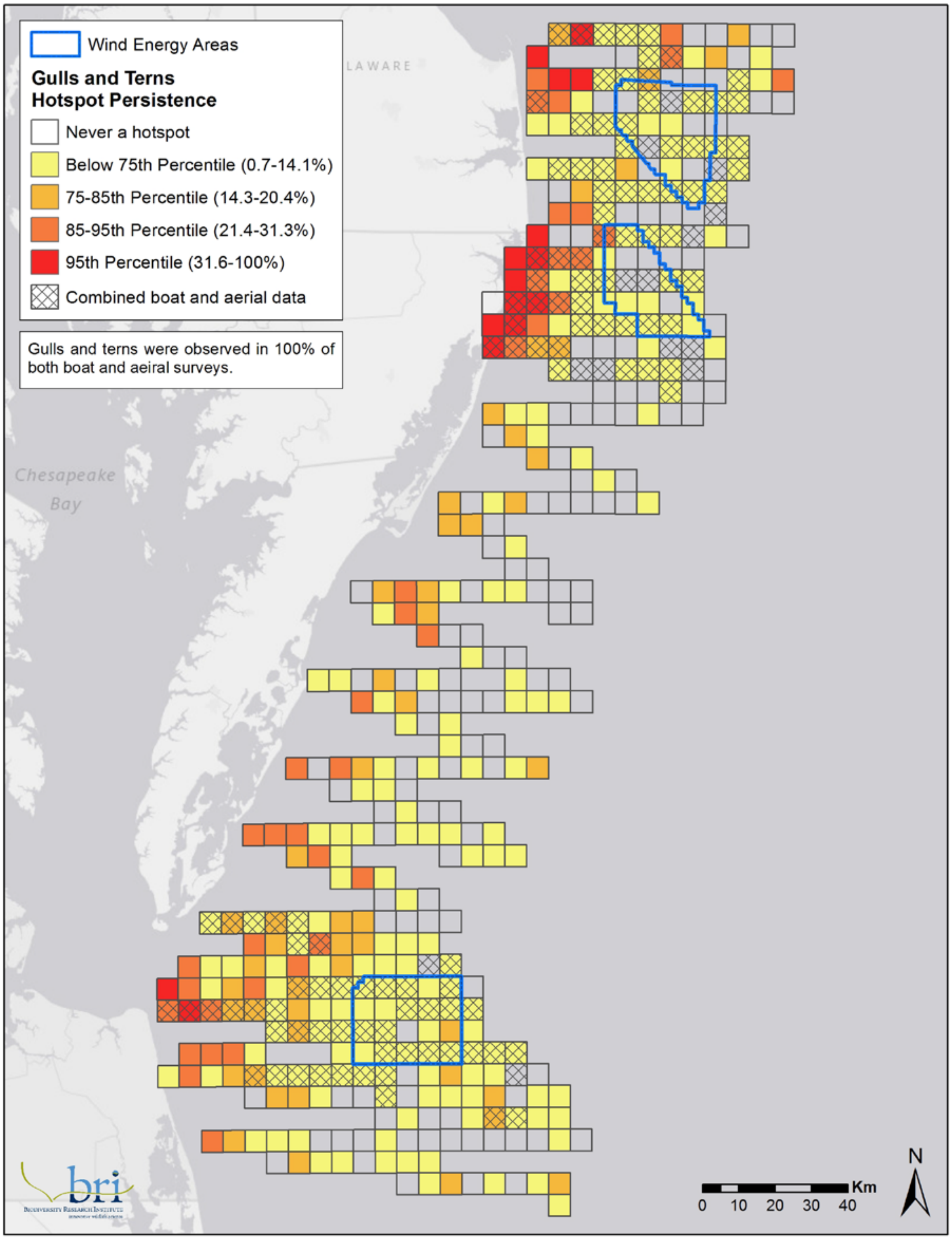

Figure 17-10. Classified persistent abundance hotspots for gulls and terns (Laridae spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods.

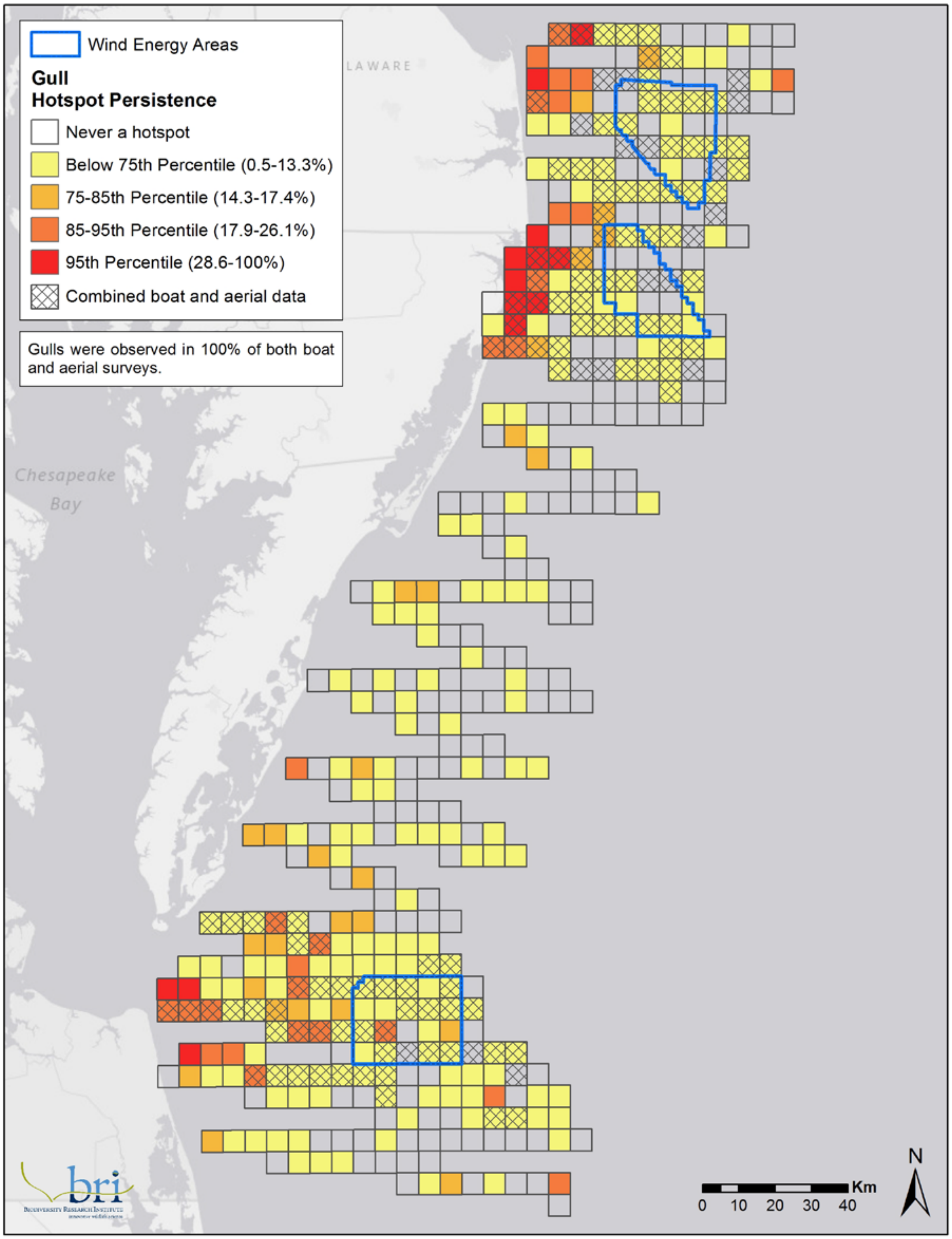

Figure 17-11. Classified persistent abundance hotspots for gulls (Larinae spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods.

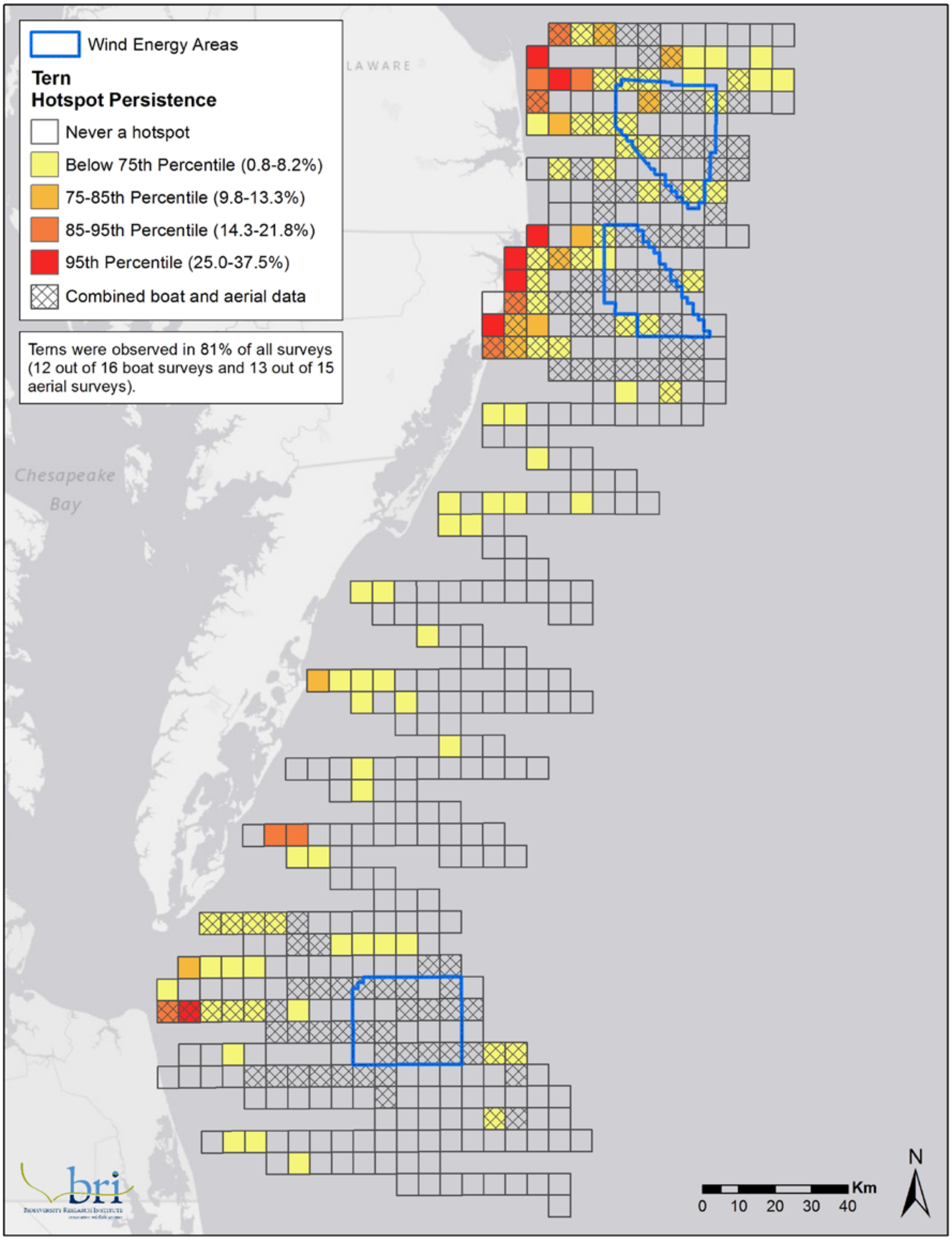

Figure 17-12. Classified persistent abundance hotspots for terns (Sterninae spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods.

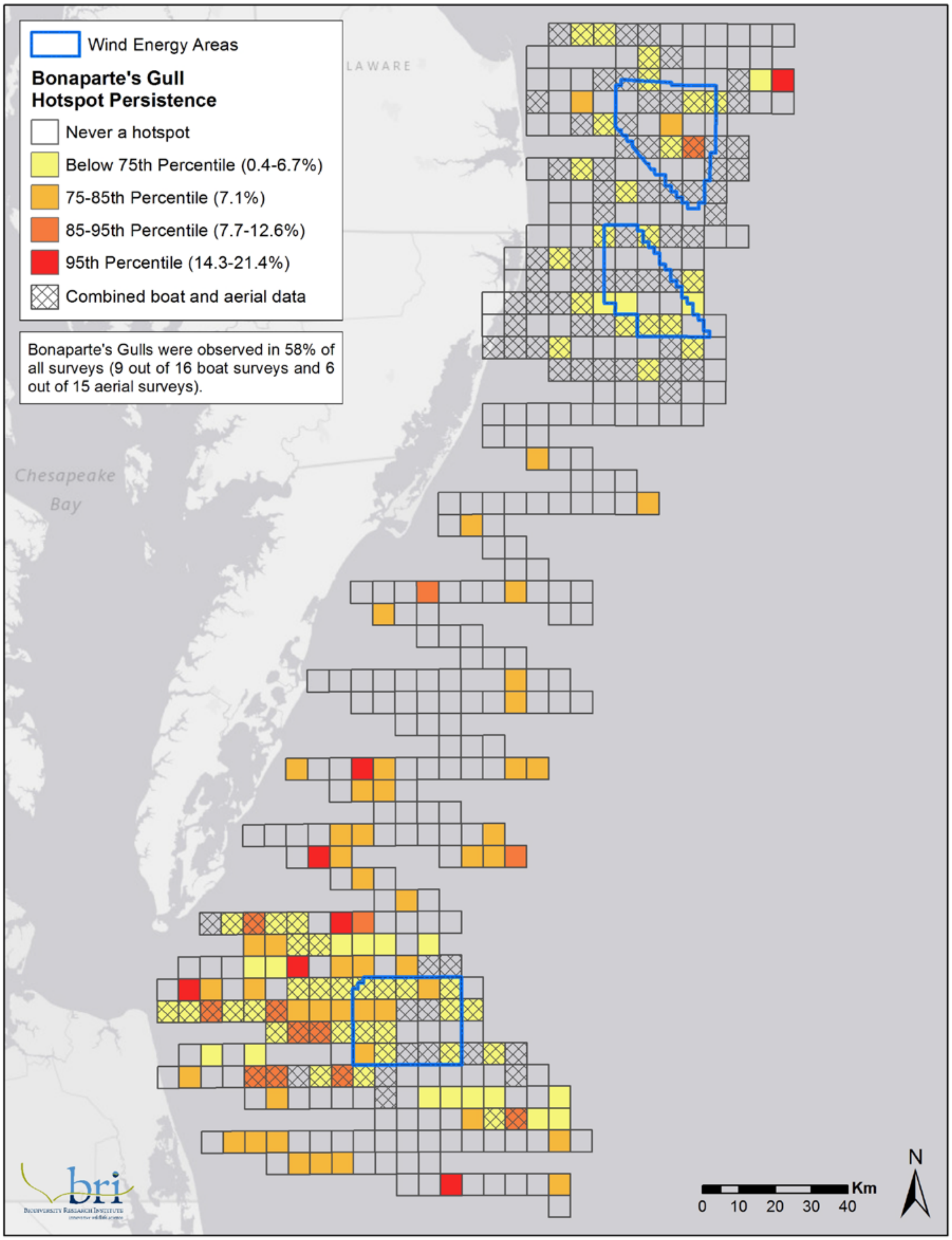

Figure 17-13. Classified persistent abundance hotspots for Bonaparte's Gulls (*Chroicocephalus philadelphia*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) 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.

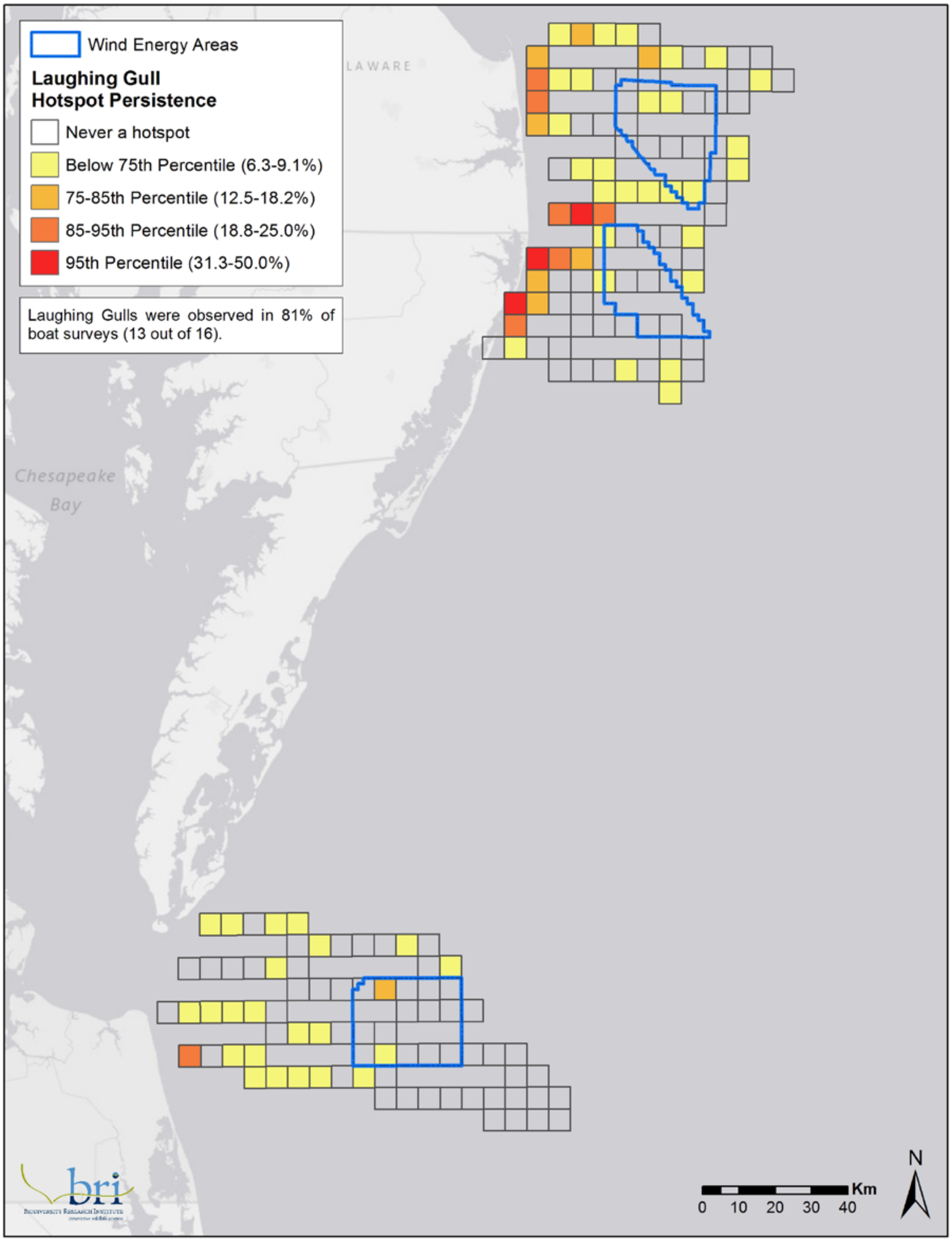

Figure 17-14. Classified persistent abundance hotspots for Laughing Gulls (*Leucophaeus atricilla*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot.

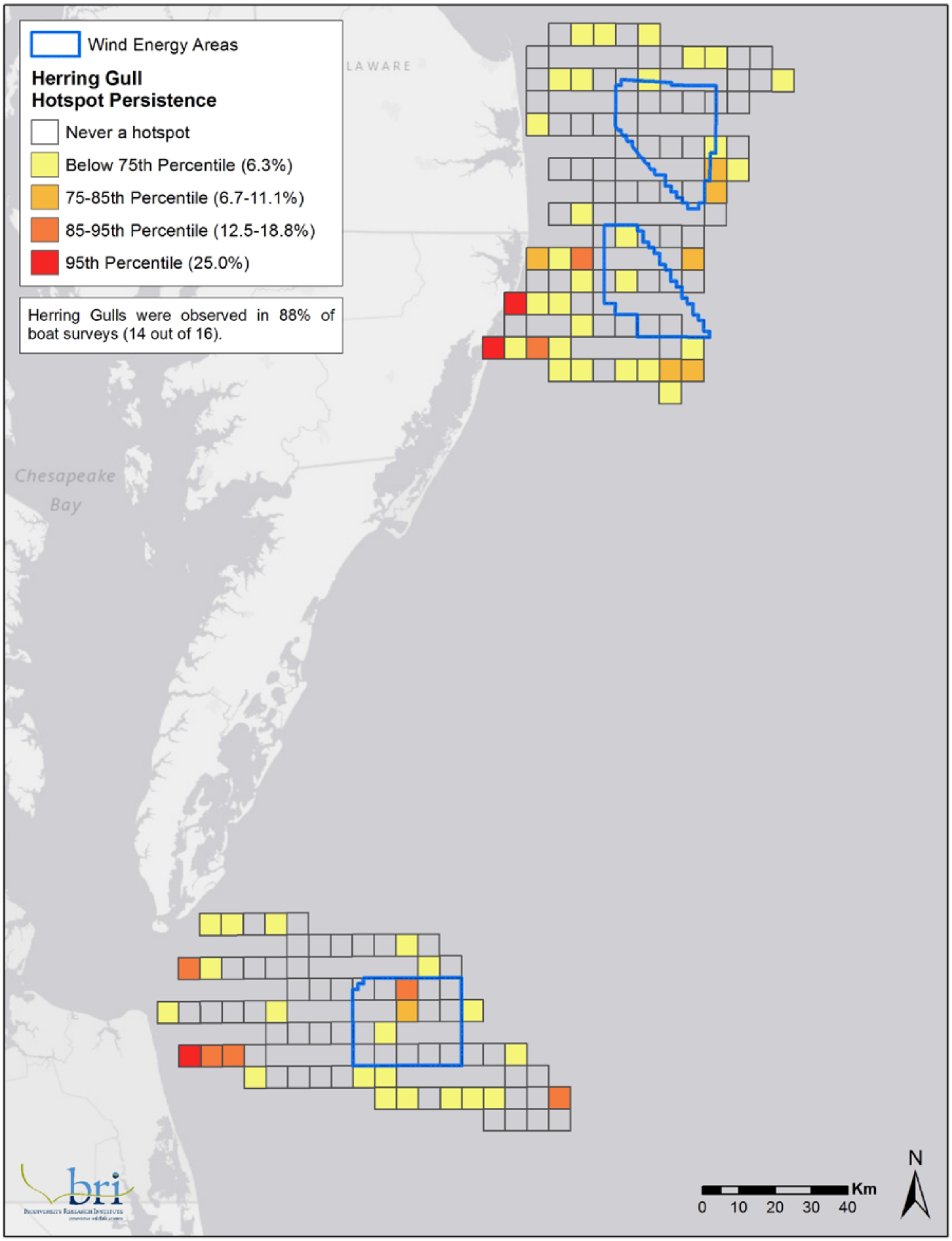

Figure 17-15. Classified persistent abundance hotspots for Herring Gulls (*Larus argentatus*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot.

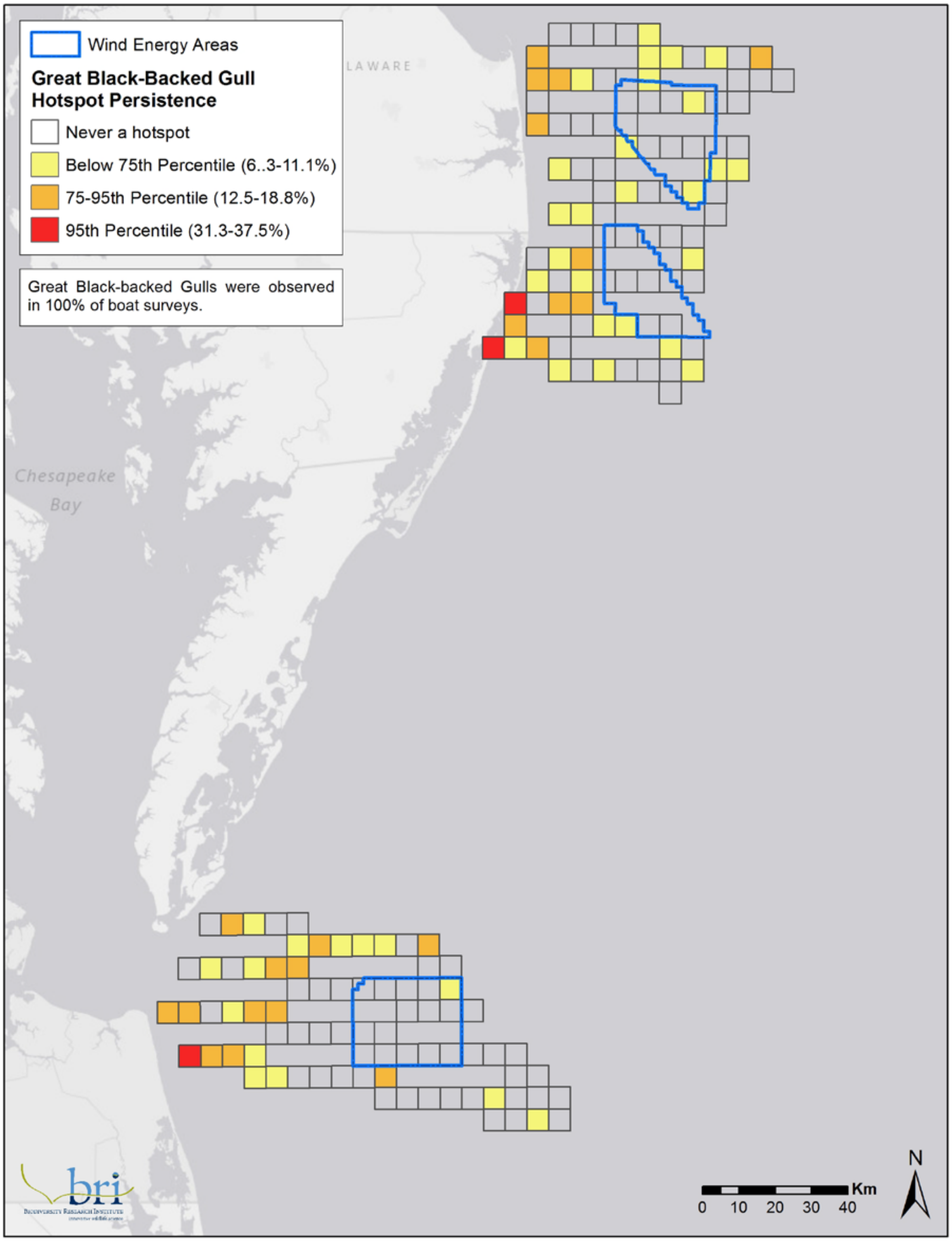

Figure 17-16. Classified persistent abundance hotspots for Great Black-backed Gulls (*Larus marinus*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. 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%).

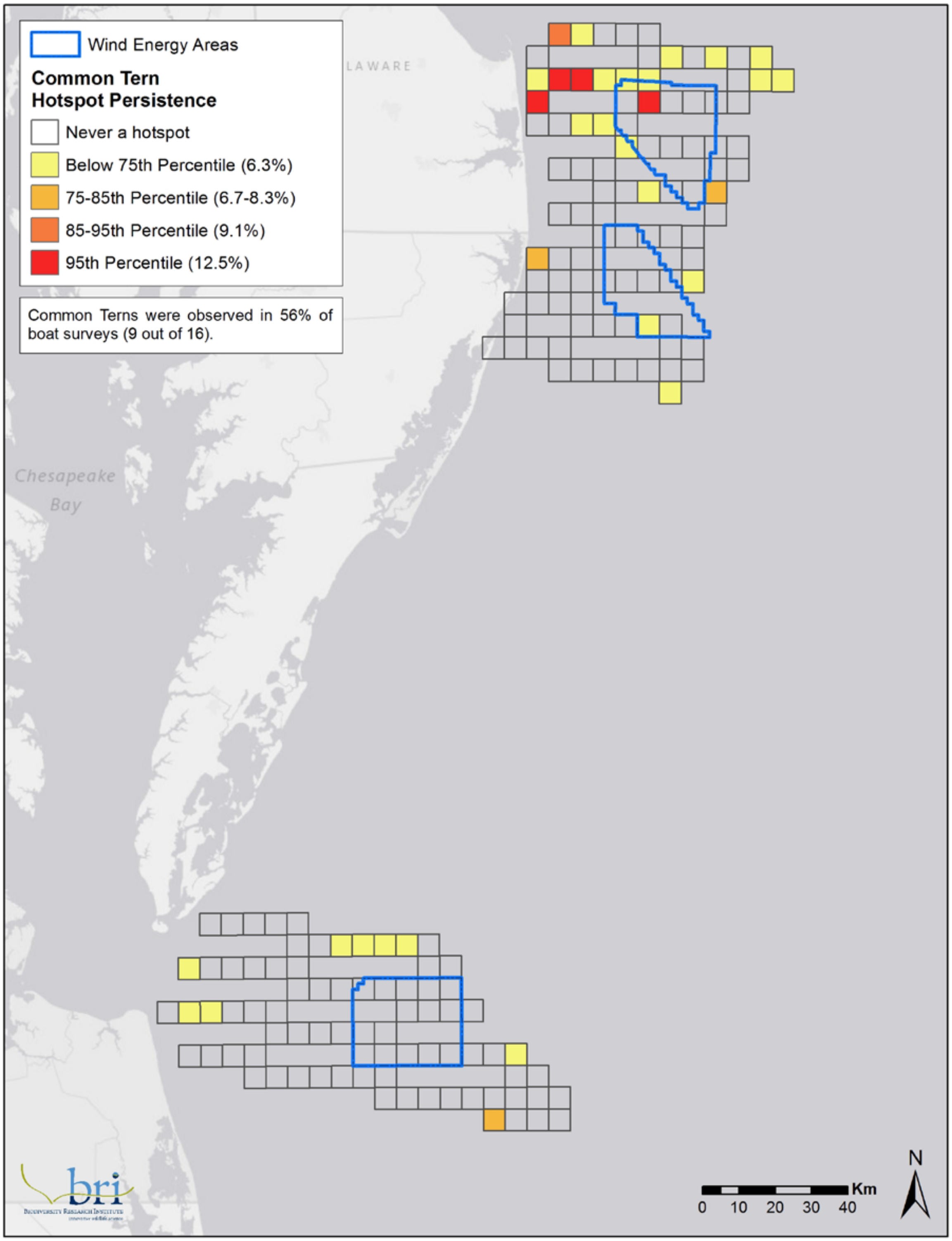

Figure 17-17. Classified persistent abundance hotspots for Common Terns (*Sterna hirundo*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot.

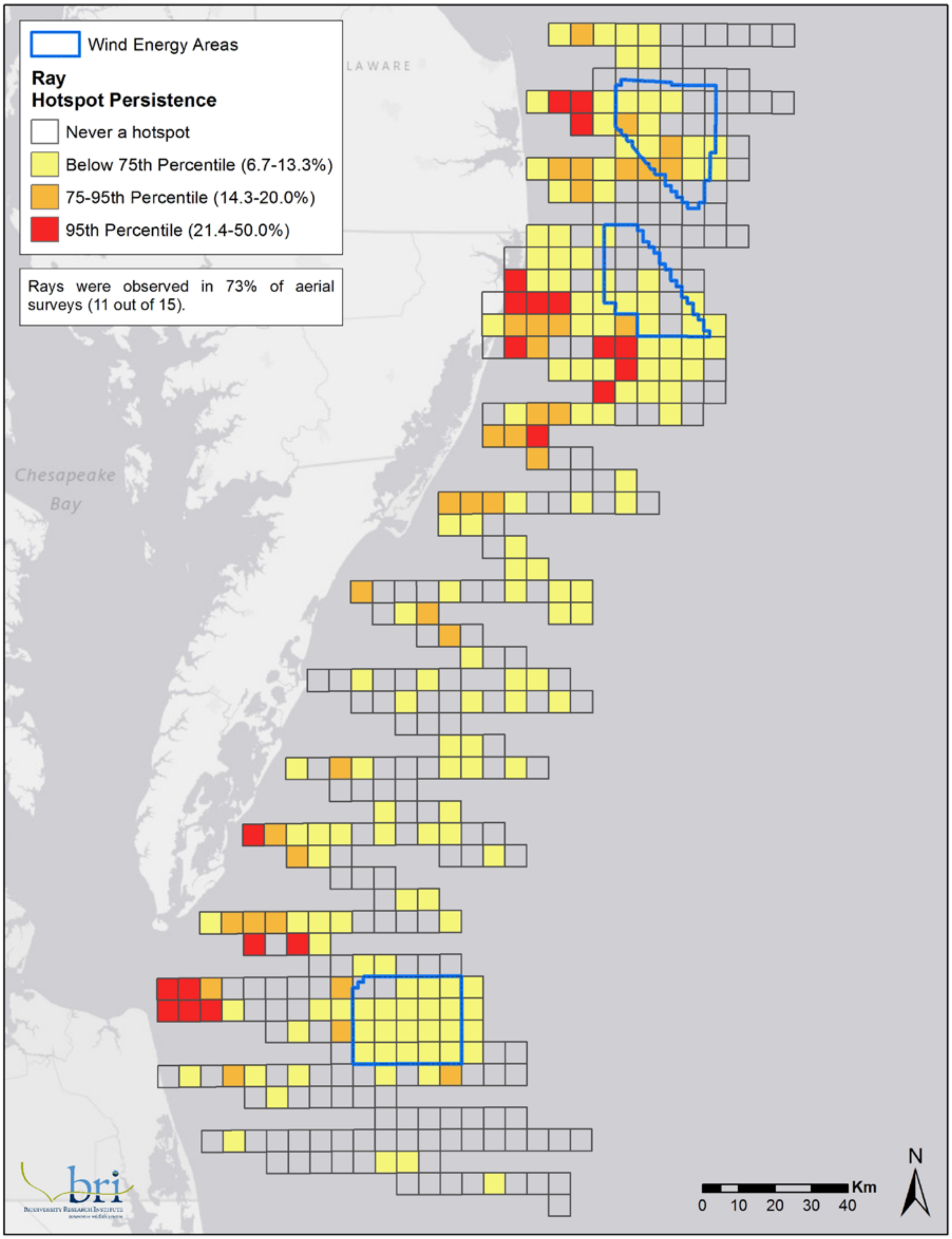

Figure 17-18. Classified persistent abundance hotspots for rays (Batoidea spp.) observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank 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%).

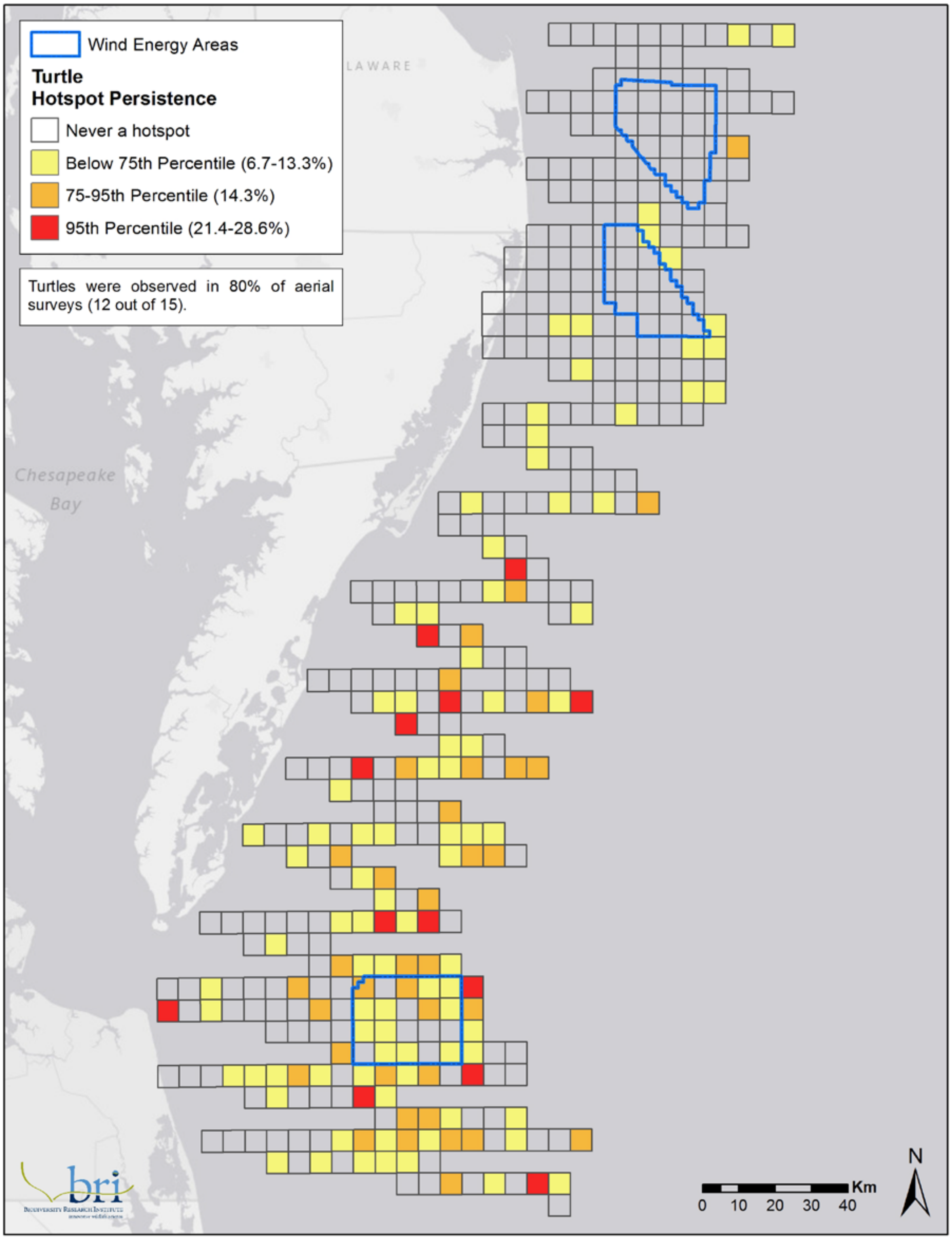

Figure 17-19. Classified persistent abundance hotspots for turtles (Testudines spp.) observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank 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%).

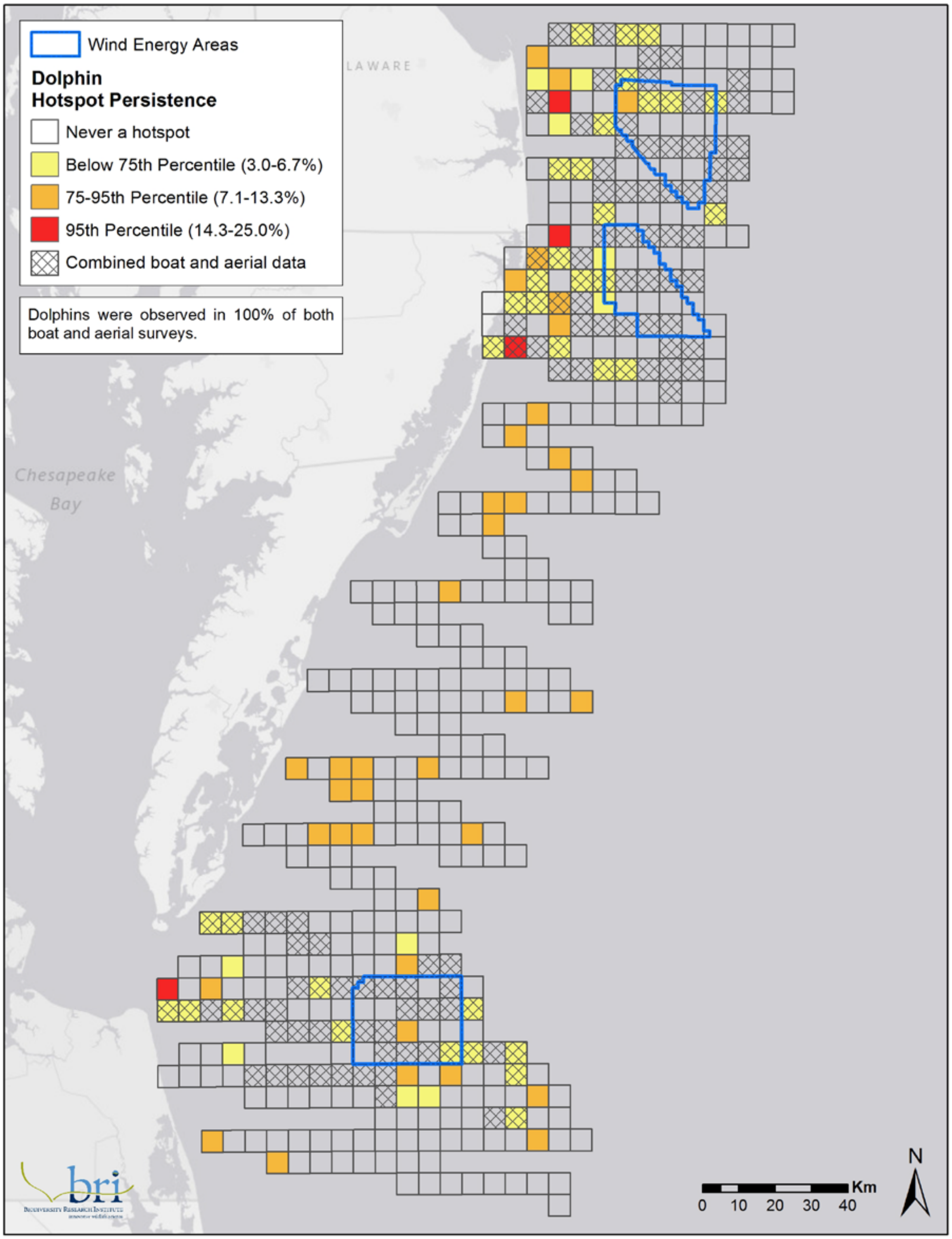

Figure 17-20. Classified persistent abundance hotspots for dolphin (Odontoceti spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. 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 is split into only three persistence classes as the 75th and 85th percentile of persistence values fell at the same value (7.1%).

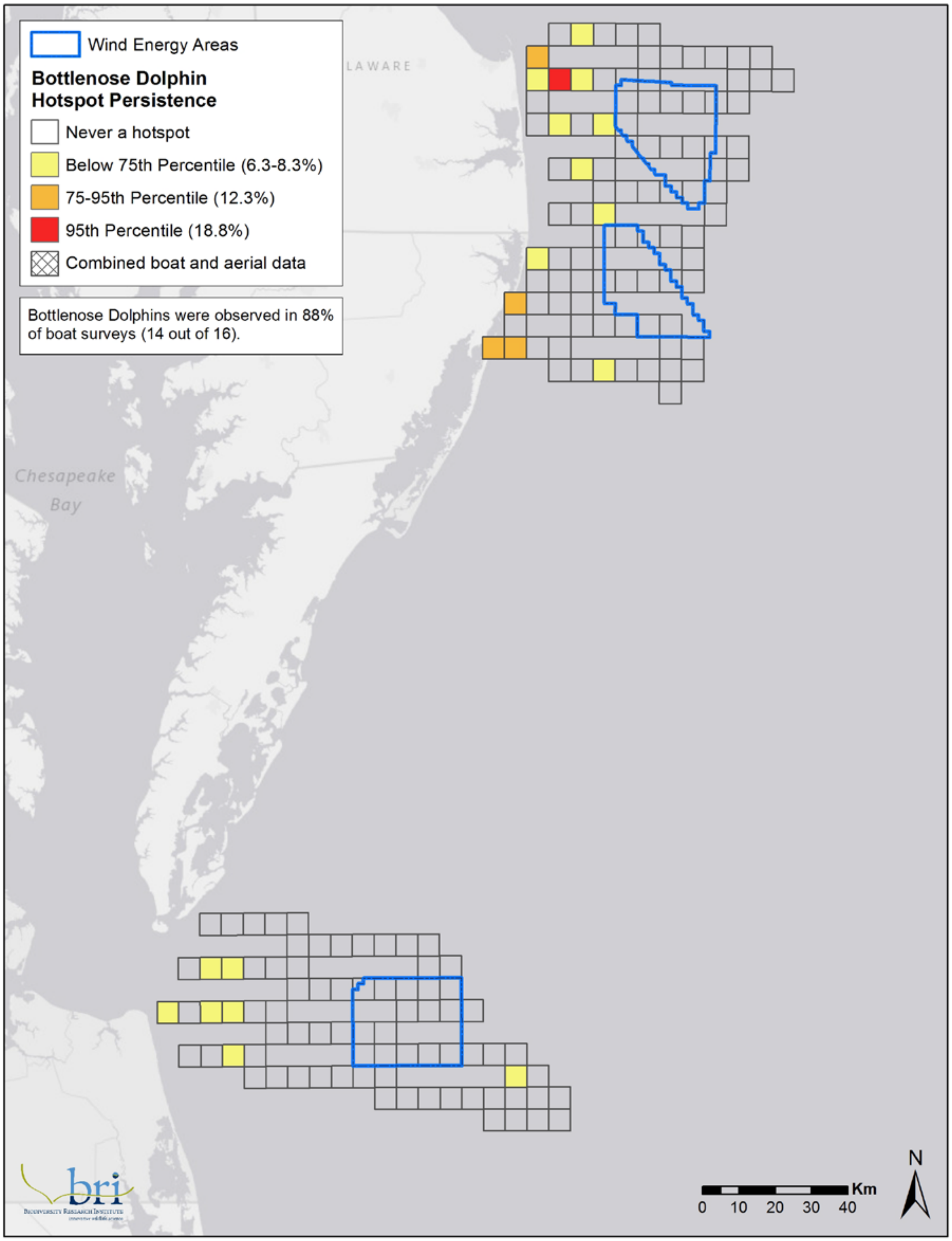

Figure 17-21. Classified persistent abundance hotspots for Bottlenose Dolphins (*Tursiops truncates*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data is split into only three persistence classes as the 75th and 85th percentile of persistence values fell at the same value (12.3%).

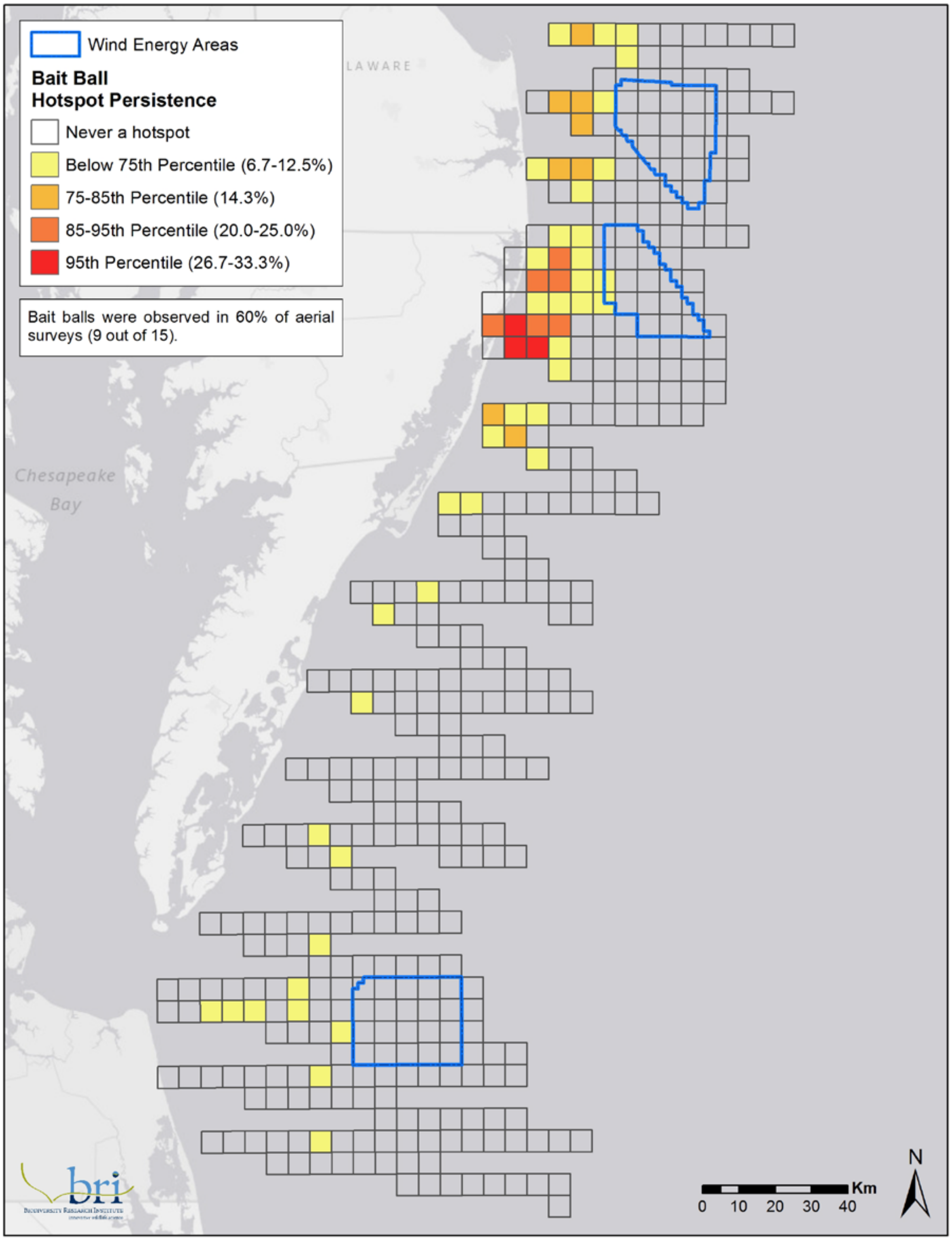

Figure 17-22. Classified persistent abundance hotspots for bait balls observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot.

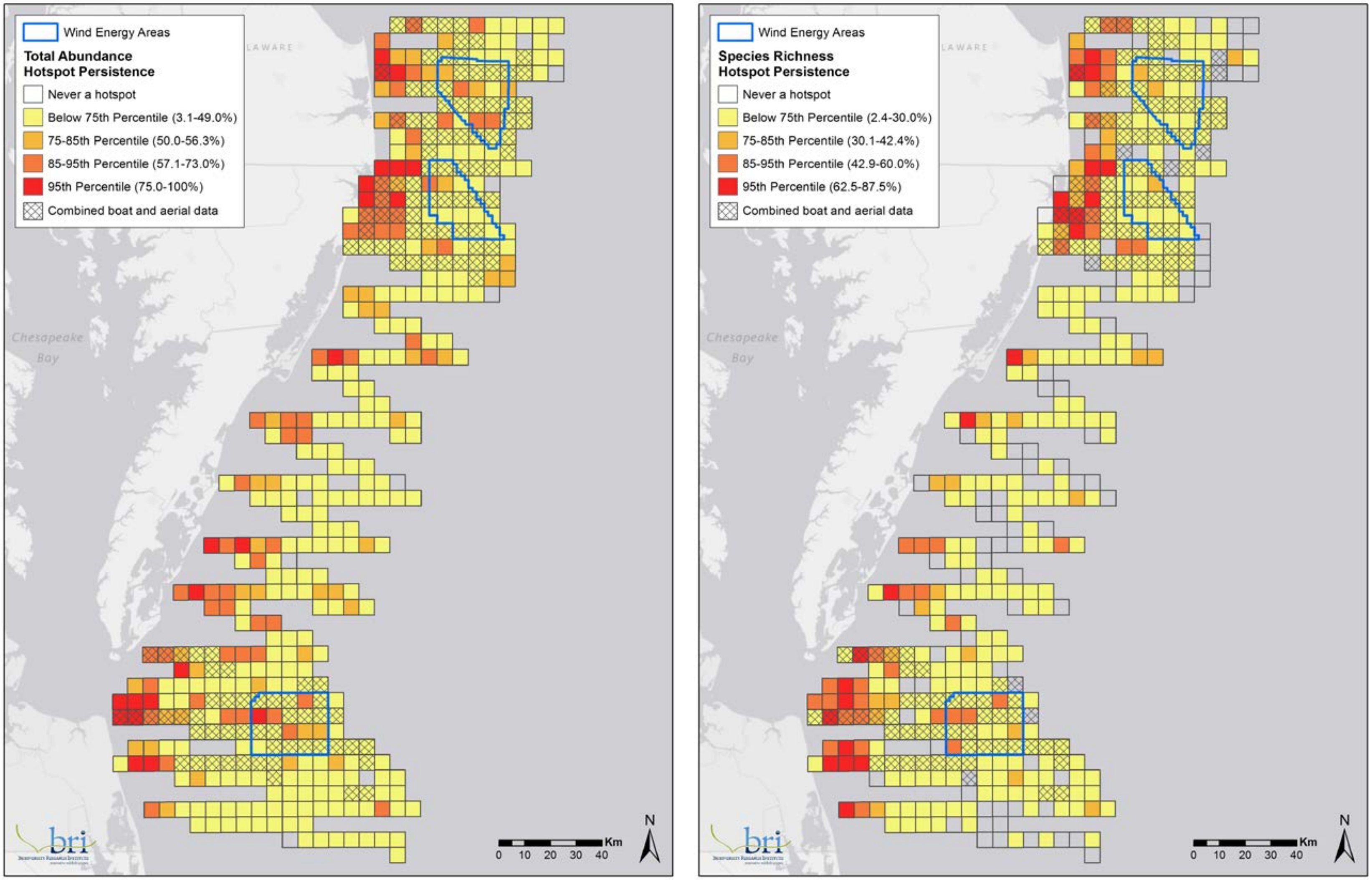

Figure 17-23. Persistent abundance hotspots identified across all taxa (left) and persistent species richness hotspots (right). These maps highlight areas where the greatest numbers of individuals across all taxa (left) and the greatest numbers of species (right) were consistently observed over the course 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.

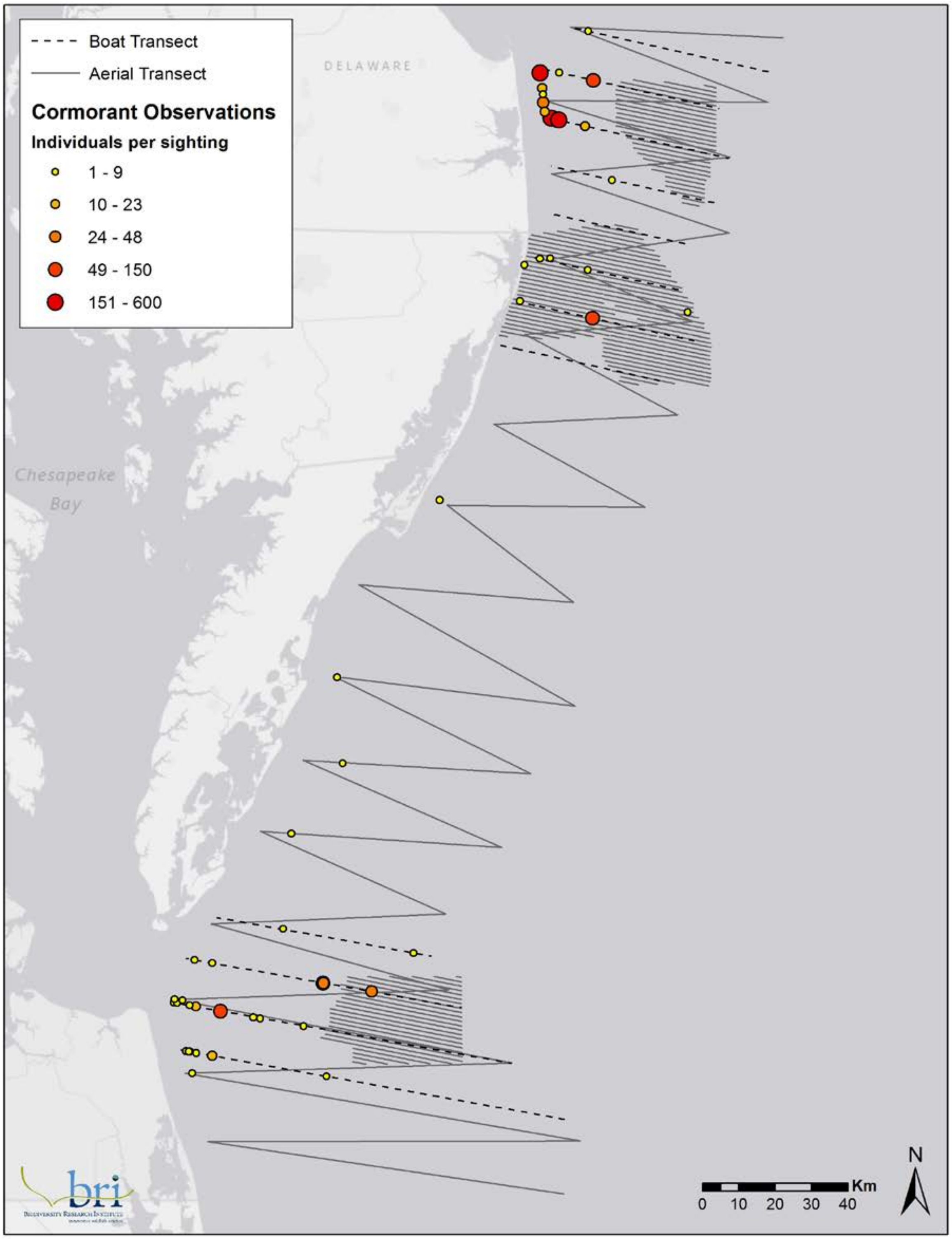

Figure 17-24. Cormorants (Phalacrocoracidae) observed by boat and video aerial surveys. A total of 2,077 cormorants were observed (2,035 by boat; 42 by aerial) over the course of the study, March 2012 – May 2014. Over half of these individuals were observed in three sightings by boat surveys at the northern end of the study area.

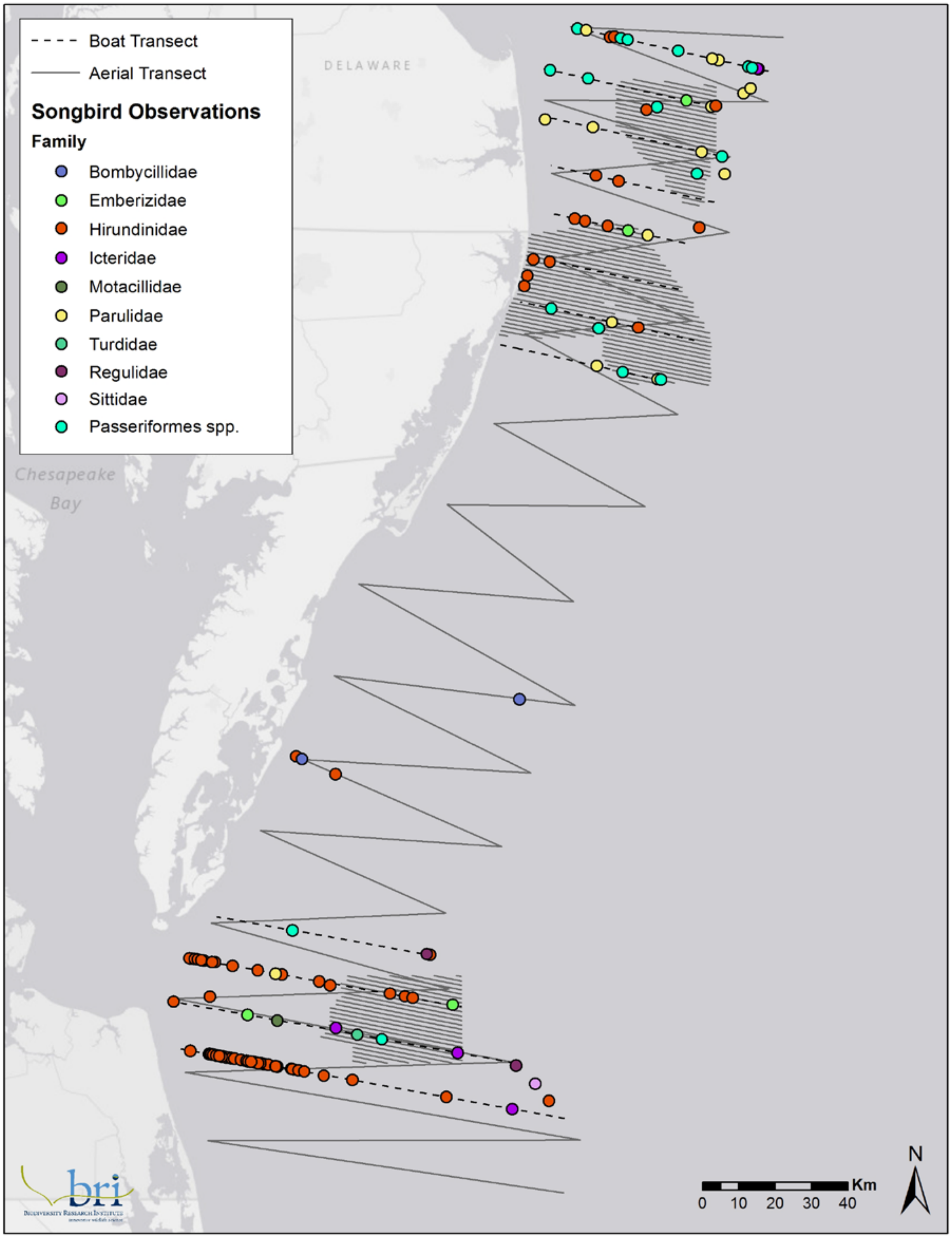

Figure 17-25. Songbirds observed in the boat and video aerial surveys displayed by family. Families include waxwings (Bombycilldae), sparrows (Emberizidae), swallows (Hirundinidae), blackbirds and cowbirds (Icteridae), pipits (Motacillidae), warblers (Parulidae), kinglets (Regulidae), nuthatches (Sittidae), robins (Turdidae), and unidentified passerines (Passeriformes).

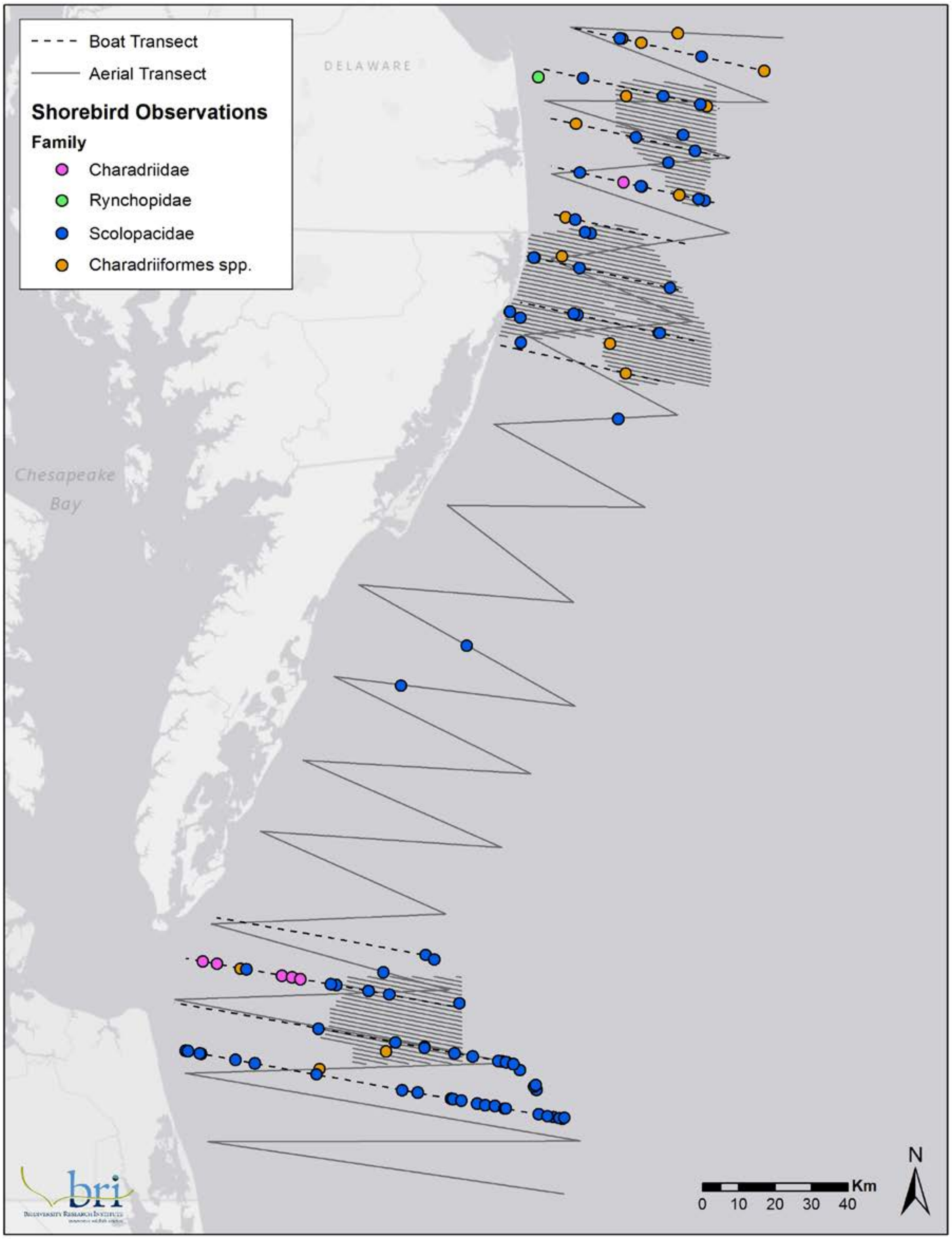

Figure 17-26. Shorebirds observed in the boat and video aerial surveys, displayed by family. Families include plovers (Charadriidae); skimmers (Rynochopidae); sandpipers, phalaropes, and other shorebirds (Scolopacidae); and unidentified shorebirds (Charadriiformes).

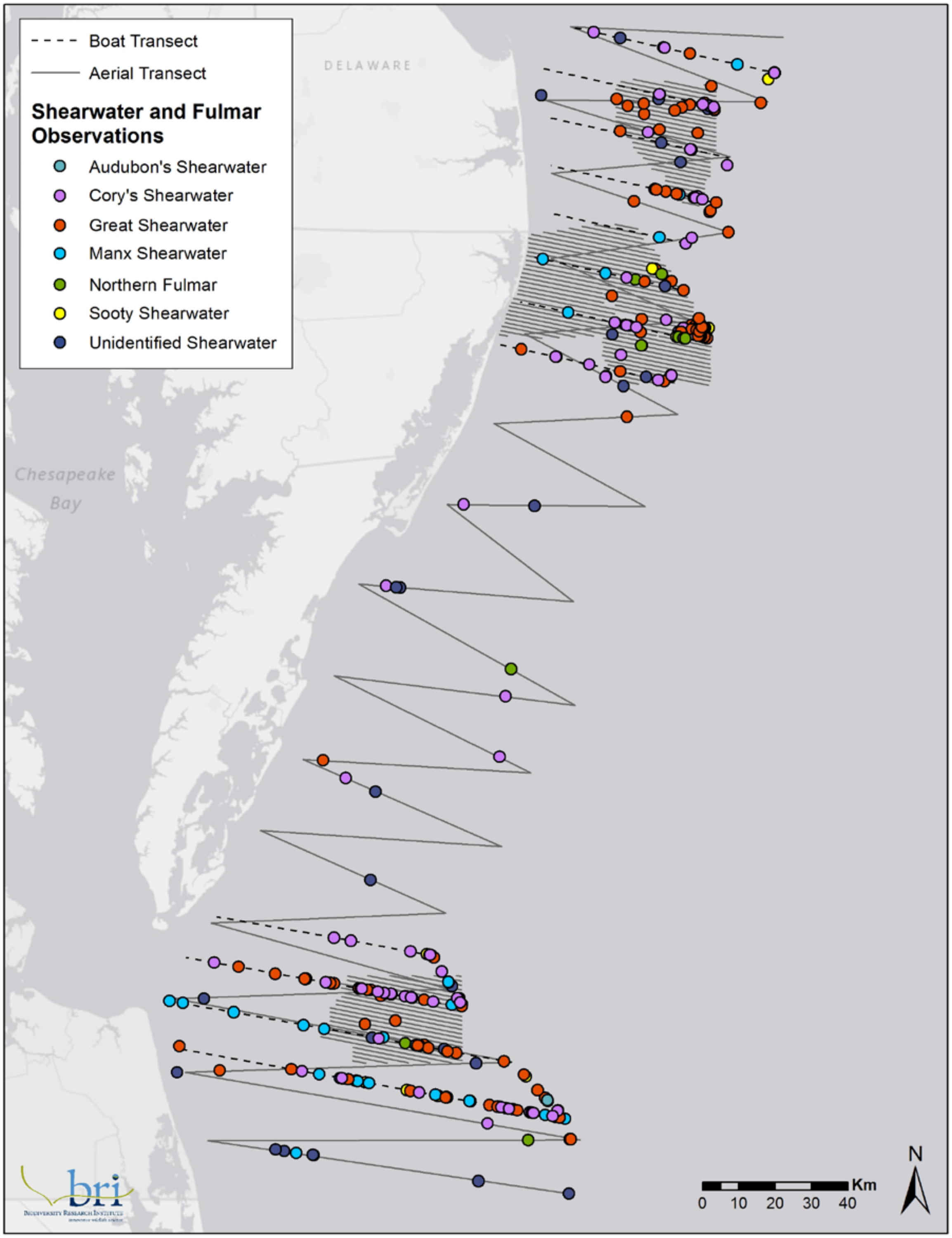

Figure 17-27. Shearwaters and fulmars (Procellariidae) observed on boat and video aerial surveys (March 2012-May 2014).

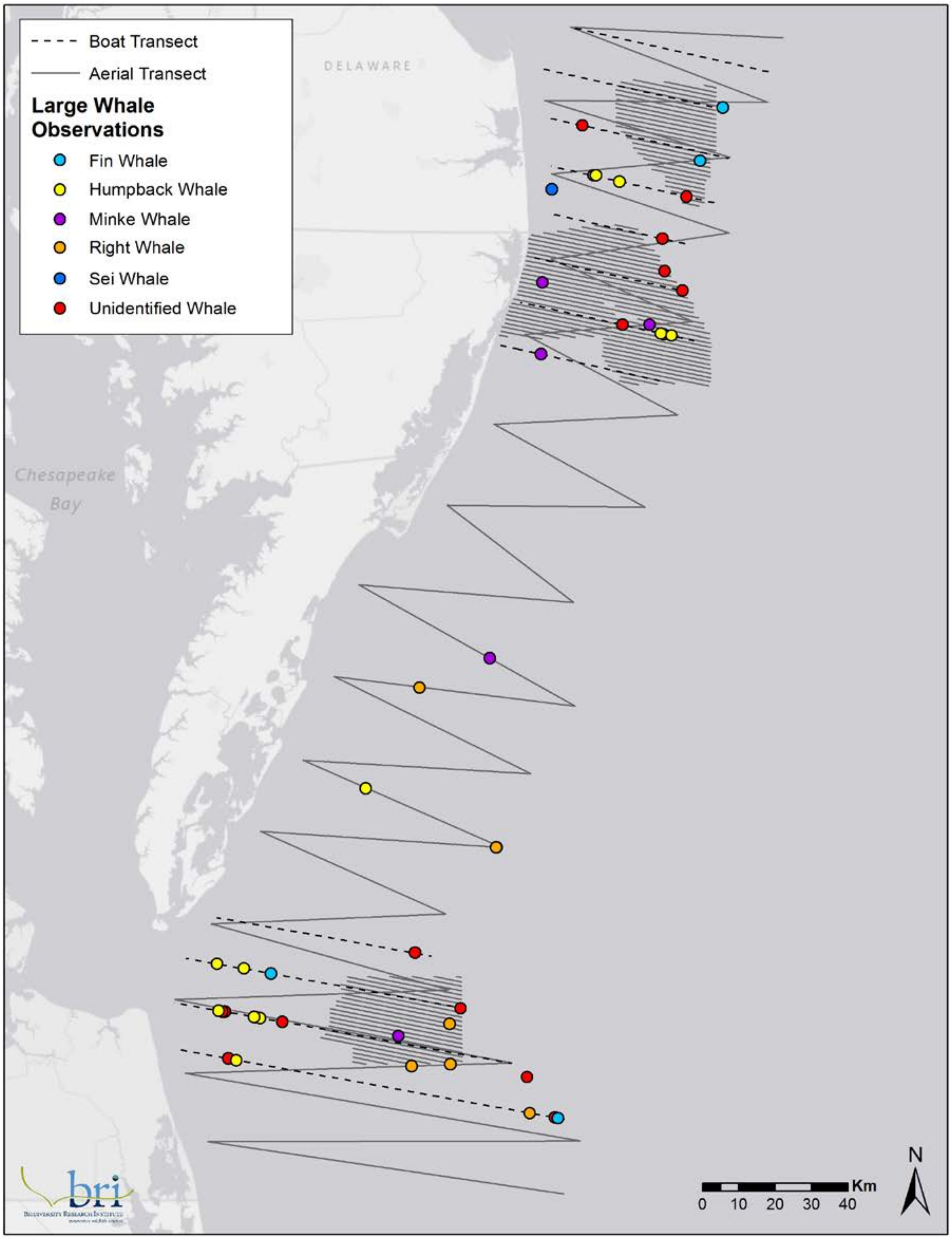

Figure 17-28. Large whale observations (Mysticeti) from boat and video aerial surveys (March 2012-May 2014).

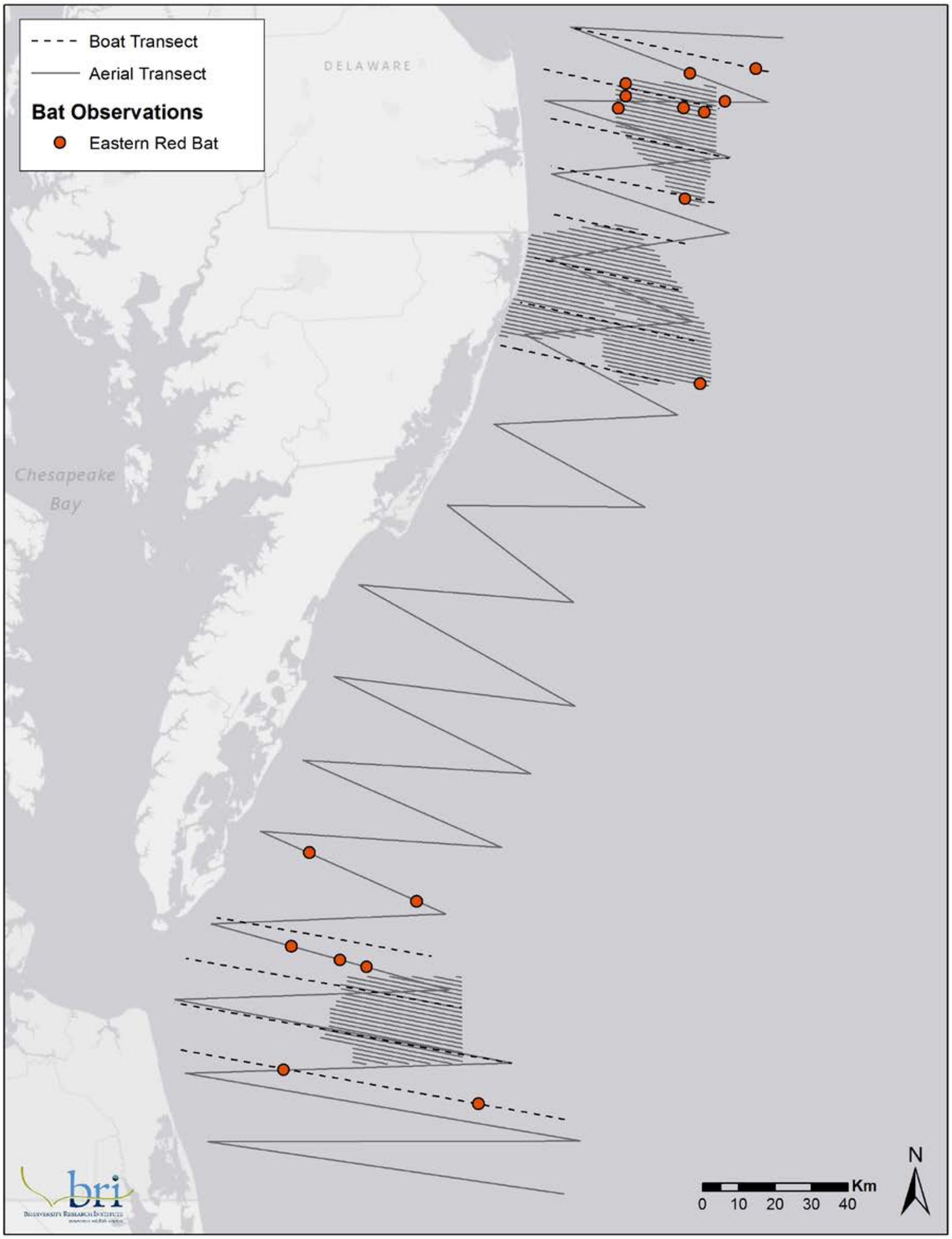

Figure 17-29. Red bat observations from boat and video aerial surveys (September 2012 and September 2013).

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.

Percentile:	0	≤50%	50-60%	60-70%	70-80%	80-90%	90-95%	95-100%
Effort-corrected count:	0	0.00319	0.0101	0.0354	0.0997	0.371	0.892	6.661
Method:	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial

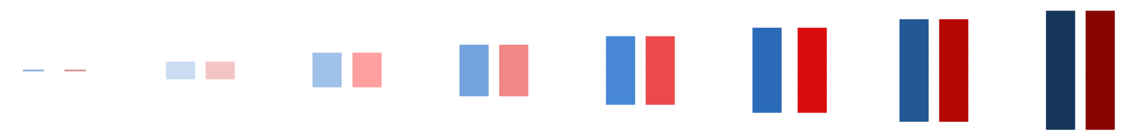

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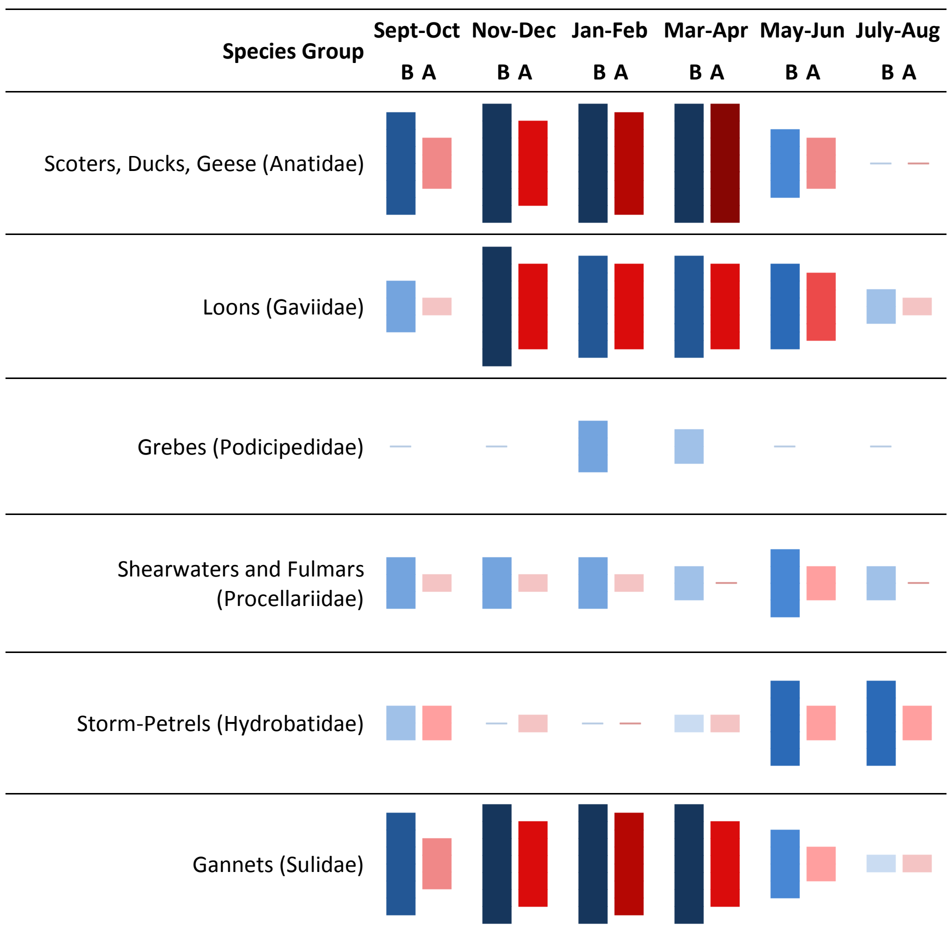
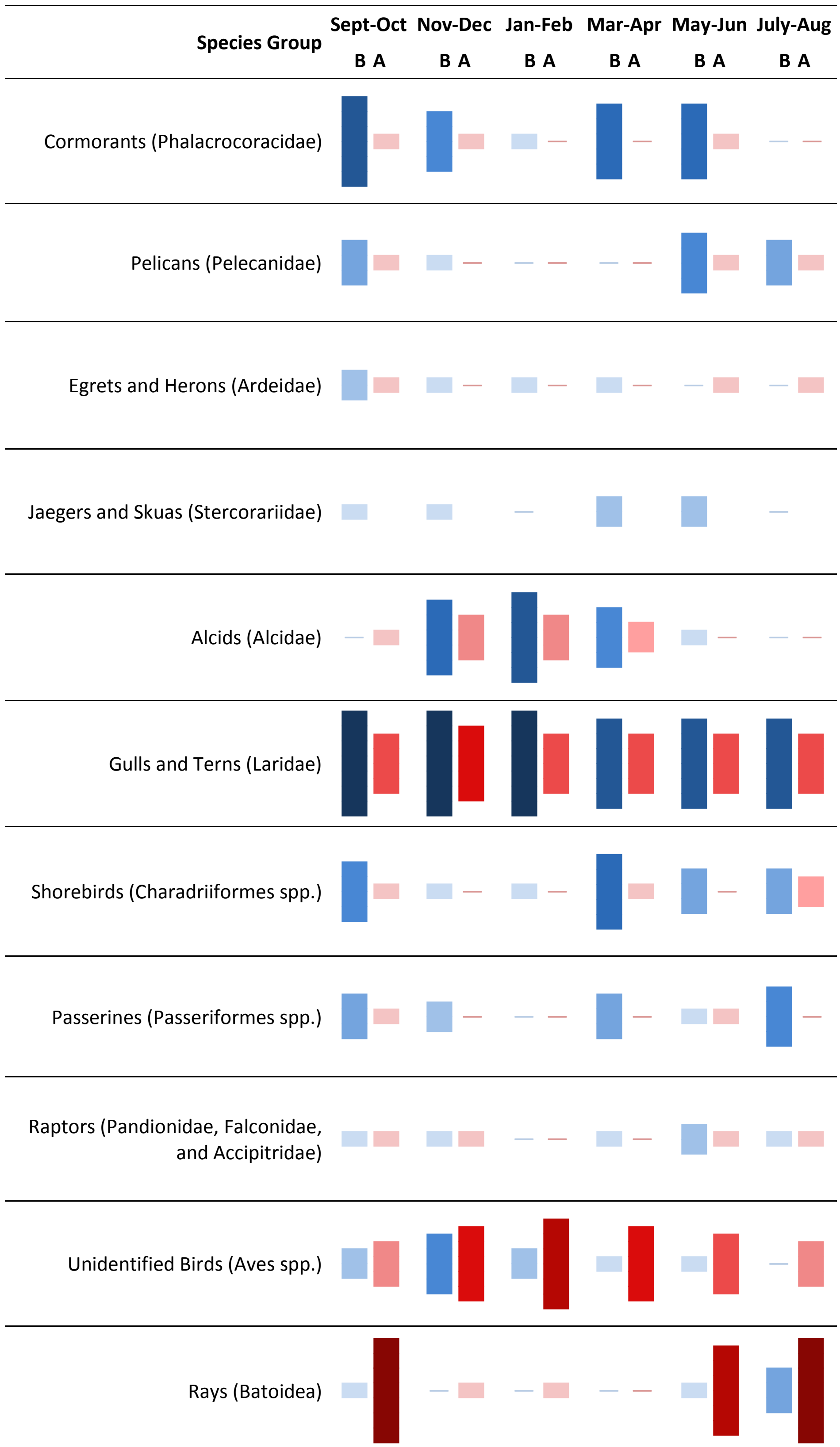
Table 17-2. Temporal bar charts for all taxonomic groups with more than 10 observations in the boat (B) and video aerial (A) surveys. When fewer than ten animals were observed in one survey type they were left blank for that survey type (e.g. bats in the boat survey). Avian and non-avian animals are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




Species Group
Sept-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
July-Aug
B A
B A
B A
B A
B A
B A
Cormorants (Phalacrocoracidae)
Pelicans (Pelecanidae)
Egrets and Herons (Ardeidae)
Jaegers and Skuas (Stercorariidae)
Alcids (Alcidae)
Gulls and Terns (Laridae)
Shorebirds (Charadriiformes spp.)
Passerines (Passeriformes spp.)
Raptors (Pandionidae, Falconidae, and Accipitridae)
Unidentified Birds (Aves spp.)
Rays (Batoidea)

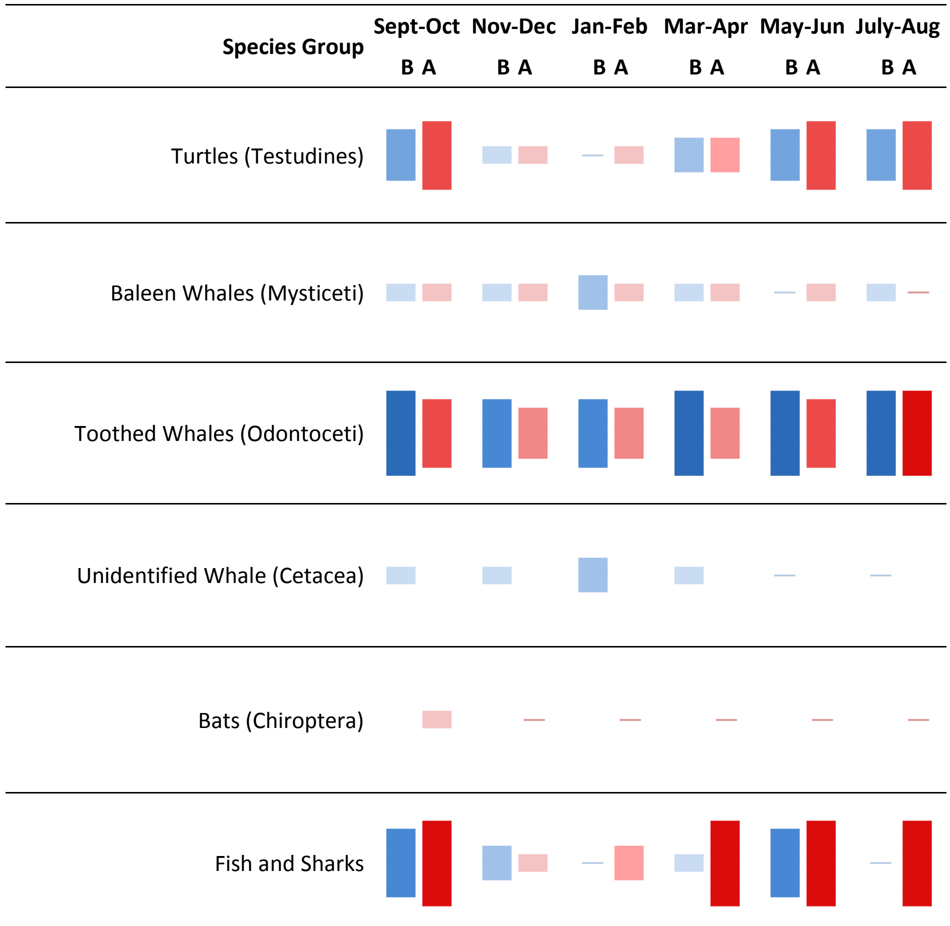

Species Group
Sept-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
July-Aug
B A
B A
B A
B A
B A
B A
Turtles (Testudines)
Baleen Whales (Mysticeti)
Toothed Whales (Odontoceti)
Unidentified Whale (Cetacea)
Bats (Chiroptera)
Fish and Sharks

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

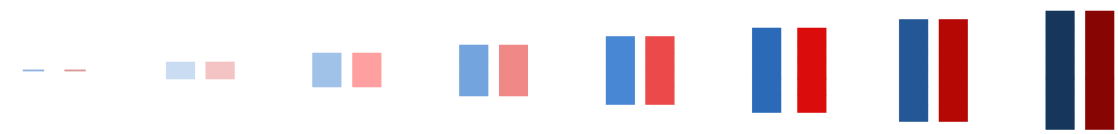
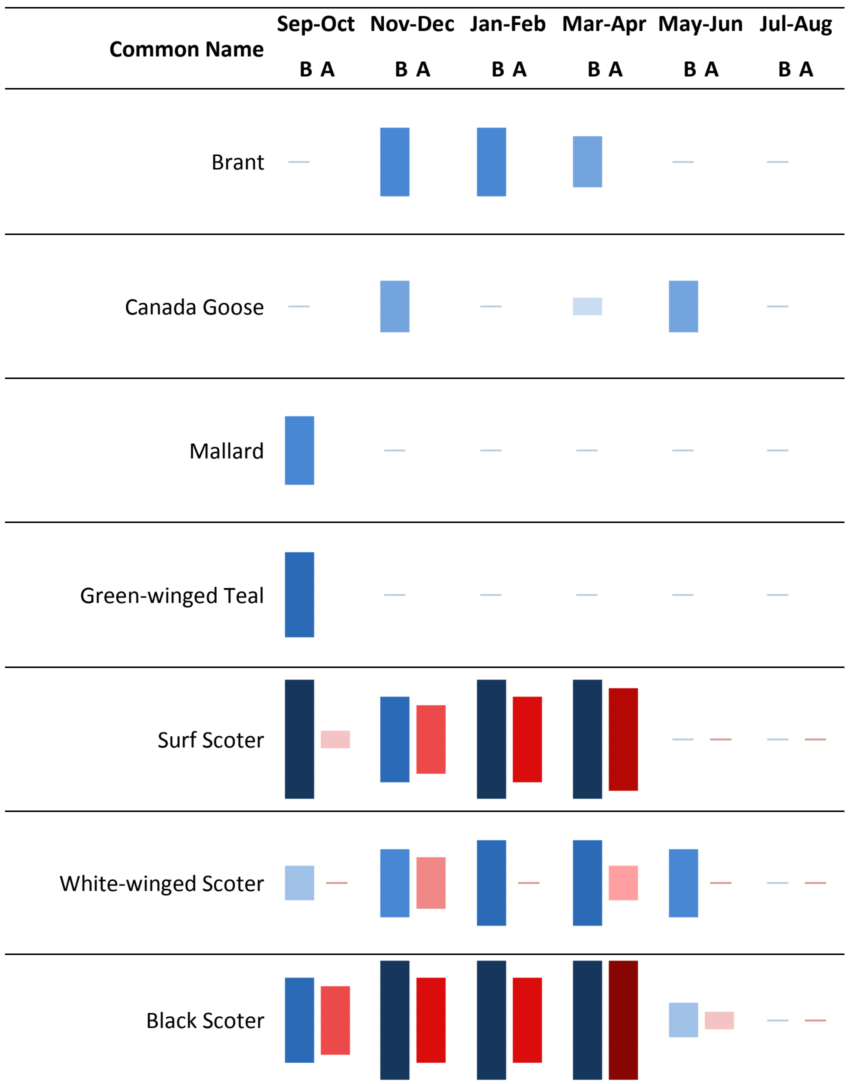
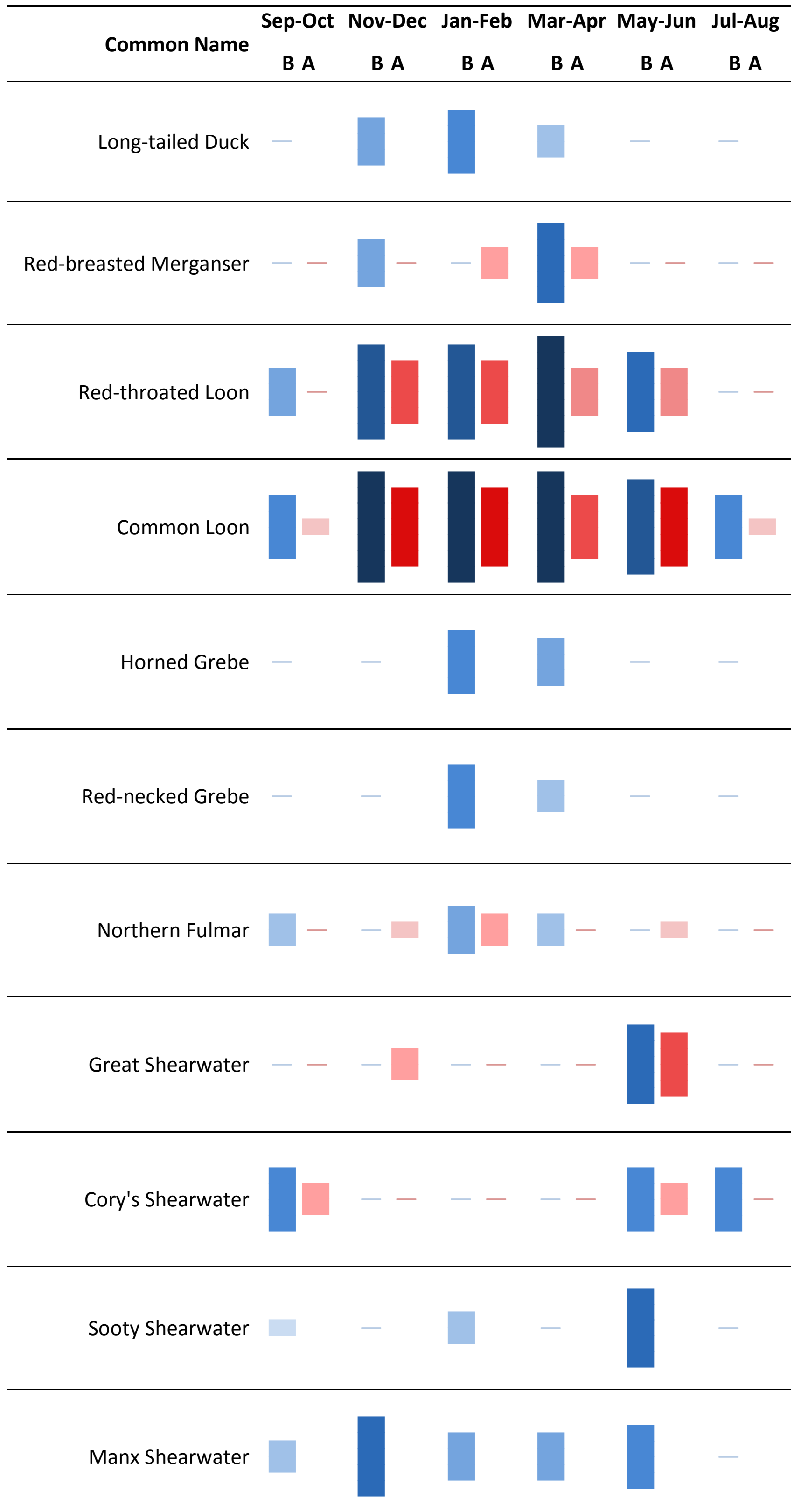
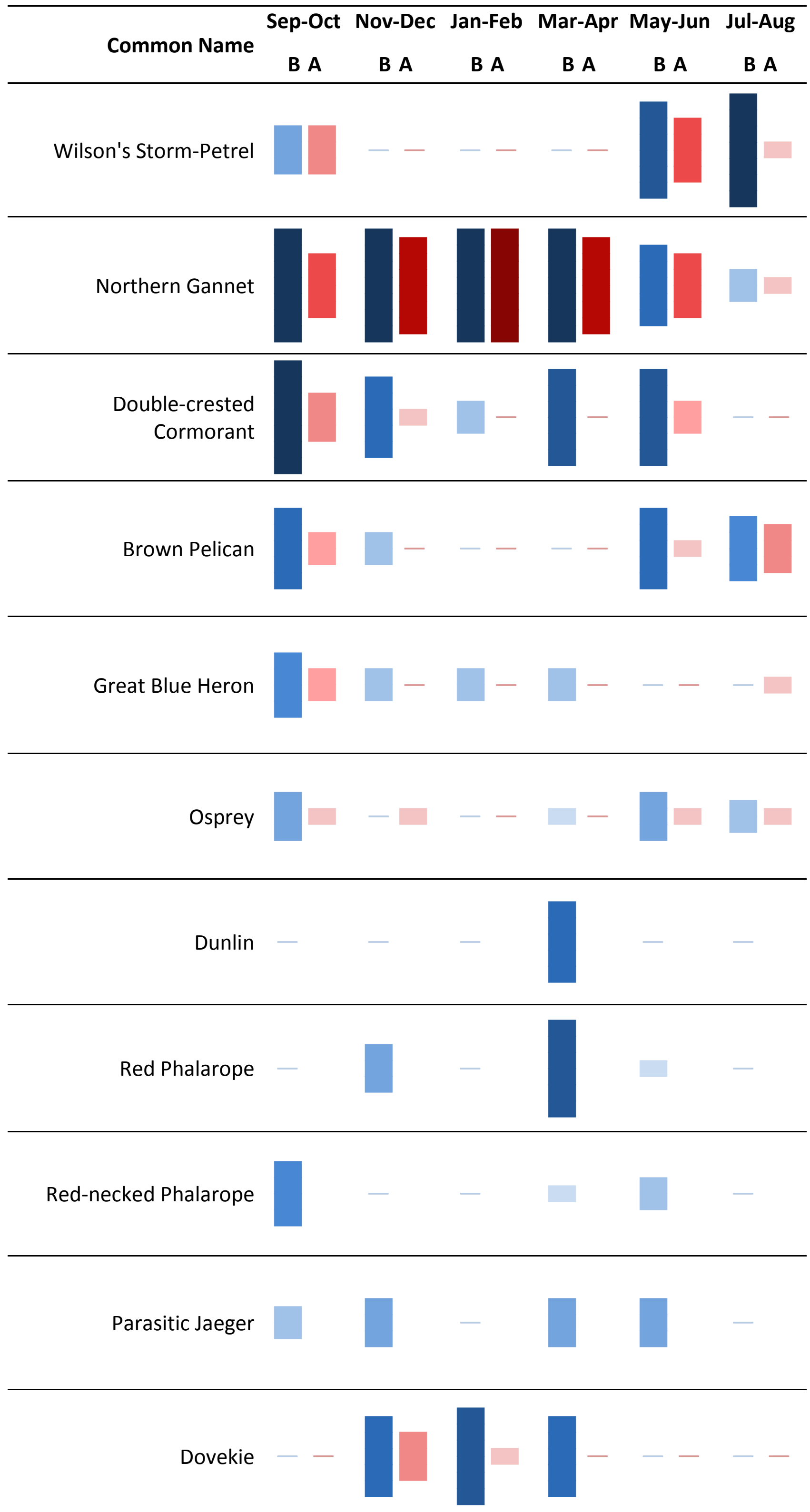
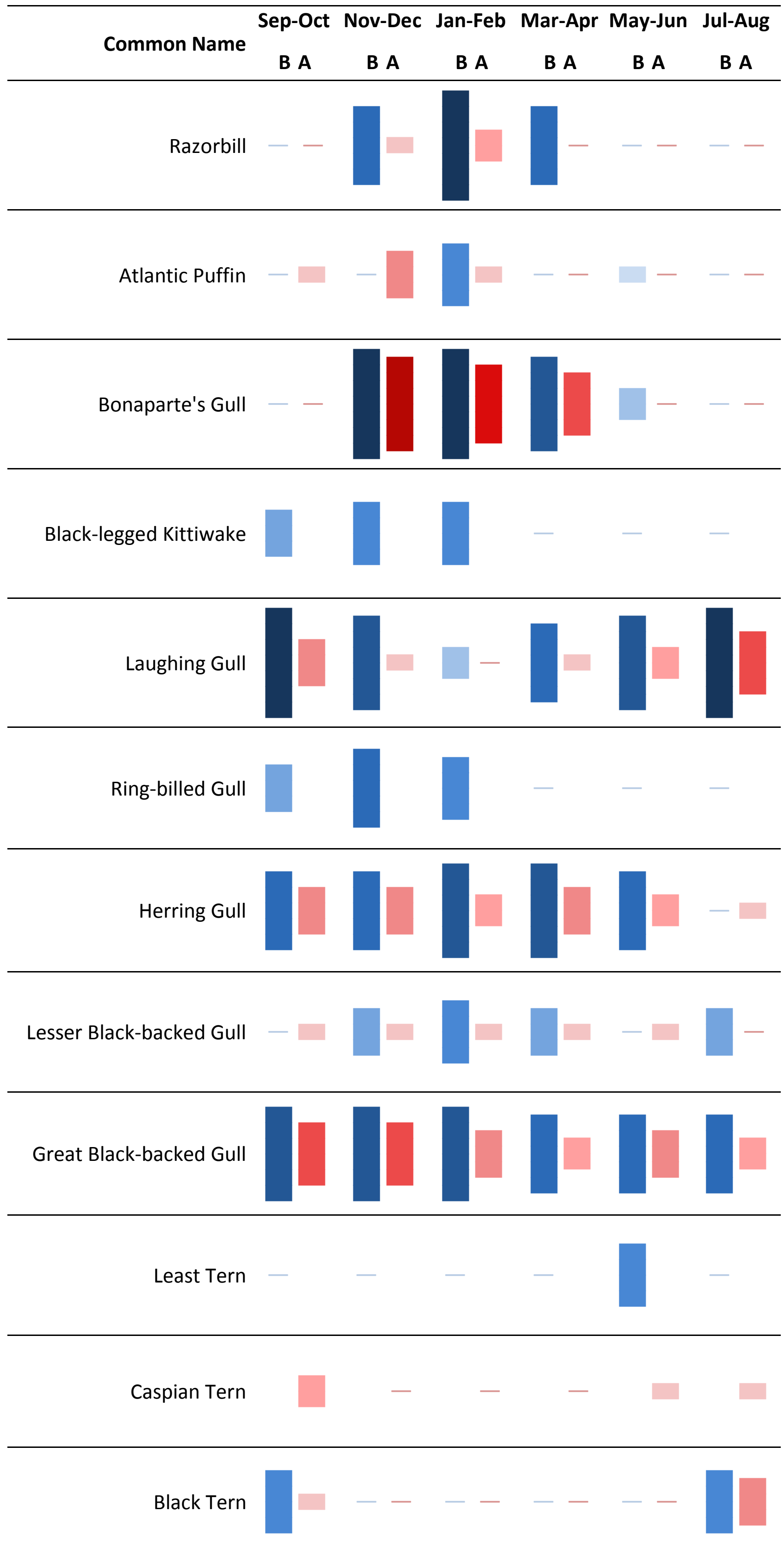


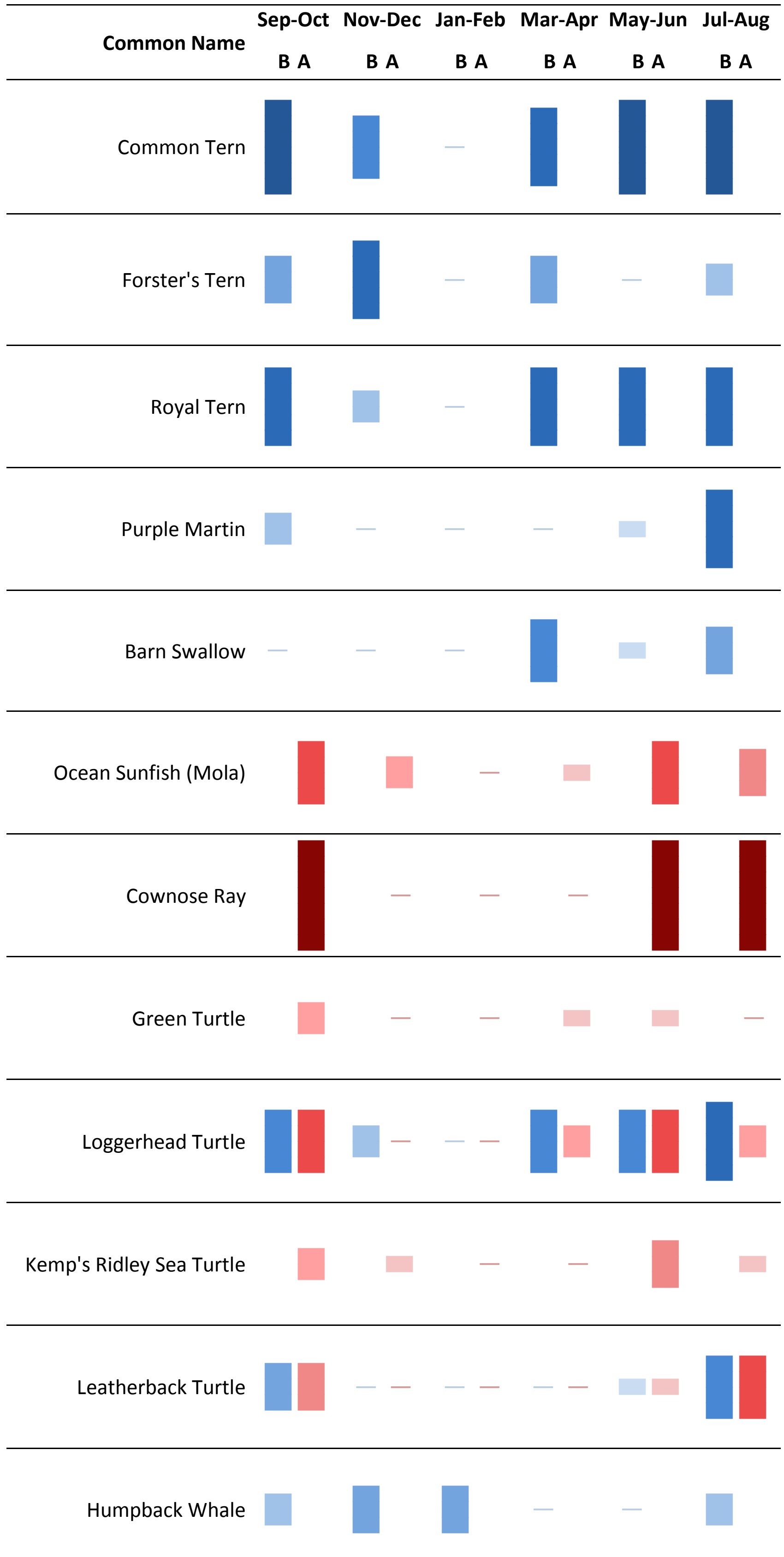
Table 17-4. Temporal bar charts for all individual species with more than 10 observations in the boat (B) and video aerial (A) surveys. When fewer than ten animals were observed in one survey type they were not calculated for that survey type (e.g. Brants in the video aerial survey). Avian and non-avian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

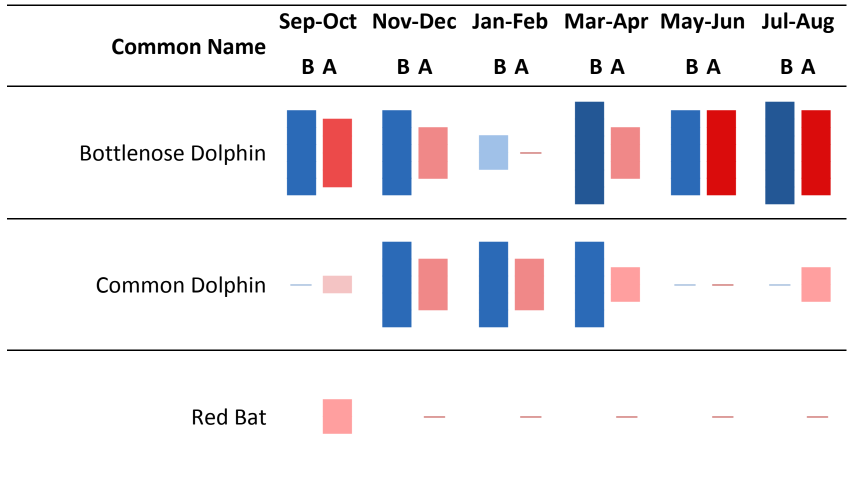



Common Name
Sep-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
Jul-Aug
B A
B A
B A
B A
B A
B A
Long-tailed Duck
Red-breasted Merganser
Red-throated Loon
Common Loon
Horned Grebe
Red-necked Grebe
Northern Fulmar
Great Shearwater
Cory's Shearwater
Sooty Shearwater
Manx Shearwater


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
Wilson's Storm-Petrel
Northern Gannet
Double-crested Cormorant
Brown Pelican
Great Blue Heron
Osprey
Dunlin
Red Phalarope
Red-necked Phalarope
Parasitic Jaeger
Dovekie


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
Razorbill
Atlantic Puffin
Bonaparte's Gull
Black-legged Kittiwake
Laughing Gull
Ring-billed Gull
Herring Gull
Lesser Black-backed Gull
Great Black-backed Gull
Least Tern
Caspian Tern
Black Tern


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
Common Tern
Forster's Tern
Royal Tern
Purple Martin
Barn Swallow
Ocean Sunfish (Mola)
Cownose Ray
Green Turtle
Loggerhead Turtle
Kemp's Ridley Sea Turtle
Leatherback Turtle
Humpback Whale


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
Bottlenose Dolphin
Common Dolphin
Red Bat