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Controlling for Survey Effort Is Worth the Effort: Comparing Bottlenose Dolphin (*Tursiops truncatus)* Habitat Use Between Standardized and Opportunistic Photographic-Identification Surveys

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Abstract

Although opportunistic data collected from wildlife ecotours can provide useful information on marine mammal distribution and behavior, concerns exist about whether resultant analyses have diminished accuracy due to spatial bias. To address these concerns, this study compared common bottlenose dolphin (*Tursiops truncatus*) habitat use results derived from standardized boat-based photographic-identification surveys and opportunistic photographic-identification surveys conducted during wildlife ecotours in Roanoke Sound, North Carolina. The main objectives of this study were to (1) identify areas of importance to dolphins, (2) identify activities (feed, mill, social, and travel) most often observed in these areas, and (3) determine the consistency of habitat use results between standardized and opportunistic surveys. Standardized survey hot spots for feeding and travel were located in southern Roanoke Sound according to the hot spot (Getis-Ord Gi*) spatial statistic. Conversely, opportunistic survey hot spots for feeding and travel were detected in central Roanoke Sound near the wildlife ecotour launch site. Opportunistic survey effort was concentrated around the ecotour launch site which introduced spatial bias by overestimating dolphin density in this area. These hot spot location differences between survey methods indicate that opportunistic survey results are affected by spatial bias which can lead to inaccurate conclusions about dolphin habitat use. Hot spot results of standardized data without survey effort supported the conclusion that spatial bias affected opportunistic habitat use results. This study provides a direct comparison of standardized and opportunistic datasets and demonstrates the importance of controlling for survey effort when examining marine mammal distribution and habitat use.

Key Words: habitat utilization, marine mammal distribution, platform of opportunity, presence-only data, spatial bias, cetacean, hot spot (Getis-Ord Gi*) spatial statistic

Introduction

Understanding common bottlenose dolphin (*Tursiops truncatus*) habitat use is fundamental to addressing the conservation needs of this species (Wilson et al., 1997). Bottlenose dolphin habitat use is variable and may be influenced by water depth, slope, distance to shore, presence of seagrass, and environmental variables such as water temperature and salinity (Würsig & Würsig, 1979; Shane, 1990; Wilson et al., 1997; Barros & Wells, 1998; Barco et al., 1999; Ingram & Rogan, 2002; Hastie et al., 2003, 2004; Miller & Baltz, 2009). Additionally, prey availability tends to influence dolphin distribution and behavior which can vary greatly across study sites (Barco et al., 1999; Wells & Scott, 1999; Miller & Baltz, 2009). Therefore, dolphin habitat use findings should not be generalized across sites and communities (Ingram & Rogan, 2002).

Standardized photographic-identification surveys (hereafter referred to as *standardized surveys*) consistently cover a particular area to assess cetacean distribution, habitat use, and site fidelity patterns. In general, they are expensive to conduct, require extensive labor and time, and have difficulty obtaining sufficient numbers of observations required for analyses (Aragones et al., 1997). Opportunistic surveys, however, can provide large quantities of data at little expense with less labor and time investment. Typically, such surveys use historical sighting data or collaborate with an established platform of opportunity to collect data (Hauser et al., 2006; Kiszka et al., 2007). Consequently, some researchers use opportunistic datasets obtained by either wildlife ecotours or commercial transportation services (Hauser et al., 2006; Kiszka et al., 2007; Moura et al., 2012).

Despite these potential advantages, there are limitations to using opportunistic survey data such as spatial and temporal bias (Hauser et al., 2006; Kiszka et al., 2007). For example, wildlife ecotours and commercial ferries often concentrate survey effort over specific areas and have fixed schedules. These factors can introduce bias into the dataset and potentially can lead to inaccurate conclusions about cetacean distribution and habitat use (MacLeod et al., 2008). If survey effort of a vessel is recorded, then spatial bias can potentially be controlled for during analyses. However, wildlife ecotour operators typically do not record survey effort in this way which may misrepresent distribution, home range size, and habitat use of a marine mammal community or population (Evans & Hammond, 2004; Rondinini et al., 2006). While the convenience of opportunistic sampling is advantageous, resultant data may not be suitable to address spatial questions if survey effort is not recorded and controlled for analytically.

Several studies have compared marine mammal distributions using presence-only opportunistic datasets (Hauser et al., 2006; MacLeod et al., 2008; Moura et al., 2012). However, the effects of spatial bias on opportunistic data remain poorly understood. This study provides a direct comparison of how dolphin habitat use results can vary across survey methods and illustrates the extent to which spatial bias can alter conclusions about dolphin habitat use. The objectives of this study were to (1) identify areas of importance to bottlenose dolphins in Roanoke Sound, (2) identify activities (feed, mill, social, and travel) most often observed in those areas, and (3) compare habitat use results between standardized and presence-only opportunistic survey data.

Methods

Survey Area

Roanoke Sound is part of the Albemarle Estuary System, which is a drowned river valley located in the northern Outer Banks of North Carolina (Giese et al., 1985). The sound ranges from 5 to 11 km east to west and separates Roanoke Island from the Outer Banks barrier islands. Roanoke Sound drains through Oregon Inlet to the Atlantic Ocean. For this study, we divided the sound into northern, central, and southern regions (Figure 1).

Standardized Survey Data Collection

Standardized surveys began in spring of 2009. Initially, two standardized routes were used to survey the northern and southern regions. Surveys were attempted in each region at least once per month year-round. Route order was alternated each month to equalize coverage between regions in case both surveys were not completed each month. At the end of 2011, the northern and southern routes were combined. This combined route was also attempted at least once per month year-round, and vessel tracks were recorded using a GPS. In 2014, the route was modified by reducing the number of cross sections (east to west tracks) in the northern region to reduce survey time.

During standardized surveys, at least two researchers took photos of dolphins' dorsal fins for photographic-identification and recorded data. For each group, we recorded GPS coordinates for start and end locations, time, group size, number of calves, weather, water temperature, salinity, and any observed behavioral activity (Table 1).

Opportunistic Survey Data Collection

Opportunistic survey data were collected onboard the Nags Head Dolphin Watch vessel from 2009 to 2014. Wildlife ecotours occurred from May through early October and ranged from one to four ecotours per day. Each ecotour was 2 to 2.5 h long. Opportunistic surveys used standardized survey methods to record data. However, the ecotour vessel track was not recorded with a GPS; thus, opportunistic survey effort was not recorded. The ecotour vessel operators initially searched for dolphins in central Roanoke Sound near the ecotour launch site before moving either north or south. Typically, the southern region was searched more often.

Hot spot analyses are sensitive to outliers that can skew results (Getis & Ord, 1992). Therefore, we removed 5% of the farthest groups from both datasets to eliminate outlier bias and standardize the analyses across survey methods (Smith et al., 2013). We used the 'Near' tool in *ArcGIS 10.X* geospatial software (Redlands, CA, USA) to

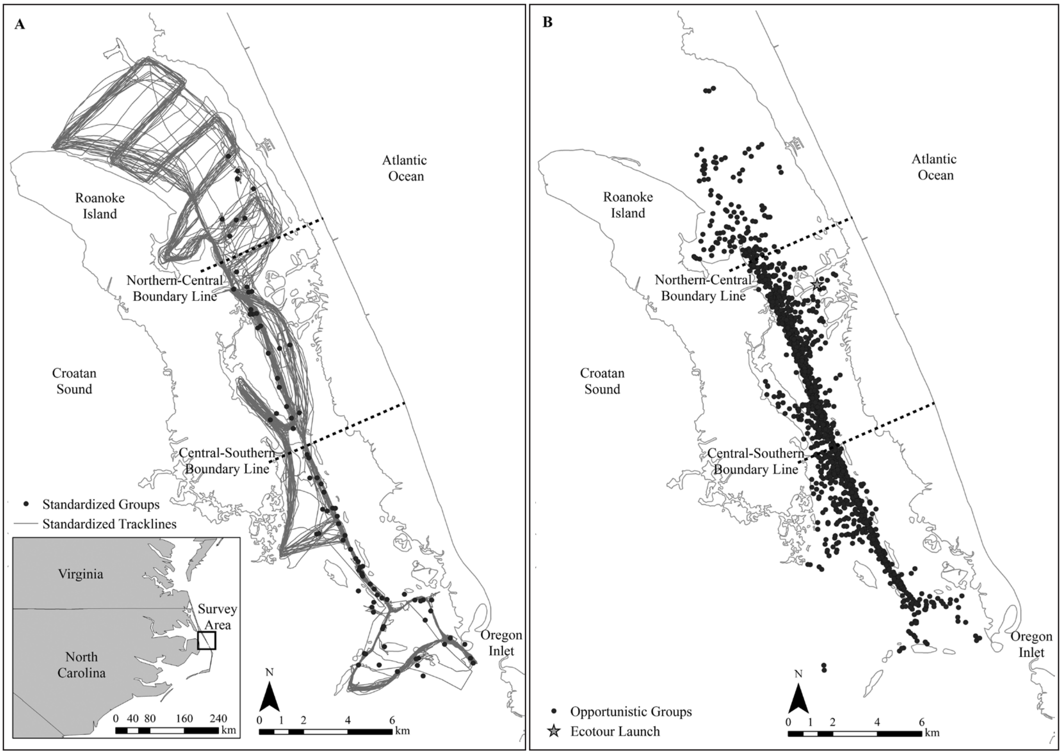

Figure 1. (A) Standardized survey groups and routes (87 groups; 37 surveys) and (B) opportunistic survey groups (1,406 groups; 607 surveys) in Roanoke Sound, North Carolina, from 2009 to 2014

Table 1. Behavioral activity definitions, adapted from Urian & Wells (1996)

Feed	Dolphin observed with a fish in its mouth
Probable feed	Fish chase, multiple fast surfacings, and tail-out/peduncle-out dives
Mill	Non-directional movement
Social	Active interactions with other individuals (e.g., tactile contact and chasing)
Travel	Directional movement with regular surfacings

determine distance between neighboring groups and removed groups with the largest neighbor distance.

Standardized Survey Hot Spot Analysis

Standardized southern routes from 2009 to 2011 were recreated from navigational waypoints. The northern surveys were excluded because navigational waypoints were not recorded from 2009 to 2011. All standardized survey routes, including the GPS vessel tracks from 2011 to 2014, were projected into spatial reference system WGS 1984 and WGS 1984 World Mercator.

A grid of 1 km × 1 km cells was created to cover the spatial extent of the surveyed area. This cell size was chosen because the average distance between the start and end coordinates of a group sighting was 1.08 km (SD = 0.79 km) which enabled spatial analysis of the data without losing any sighting data. A single location was calculated for each group using the centroid of the start and end coordinates of its sighting.

Standardized survey effort, which is the total vessel track distance (km), and the number of groups were calculated for each cell. Cells that contained at least 1.41 km of survey effort were exported for hot spot analyses; the 1.41 km minimum survey effort was chosen to remove potential outlier cells that were not surveyed often. The number of groups was divided by the amount of survey effort for each cell to obtain group density (groups/km) for each cell.

The hot spot (Getis-Ord Gi*) spatial statistic was used to identify clusters of high (hot spot) and low (cold spot) values of group density across the survey area. This spatial statistic calculated an observed local sum of group density for each cell, which is the sum of a cell and its neighboring cells. The observed local sum was compared to an expected local sum derived from the total number of groups and extent of the survey area (Getis & Ord, 1992). A z score and its associated p value were calculated for each cell based on the ratio of observed vs expected local sums to indicate the spatial distribution of hot and cold spots. A cluster of cells with high or low group density values was significant if it had an observed local sum that was very different than the expected local sum (Getis & Ord, 1992; ArcGIS Resource Center, 2012). Therefore, cells with high values of group density tended to be statistically significant hot spots only when they were surrounded by cells with high group density values.

For the hot spot analysis (adapted from Smith et al., 2013), the average distance between neighboring groups was used to detect peaks in spatial autocorrelation of group density values with the 'Incremental Spatial Autocorrelation' (ISA) tool. This tool ran a series of Global Moran's I statistics at various distances to detect whether similar values of group density clustered together across space. The first ISA peak was used as the distance threshold for the hot spot analysis. The analysis parameters for the hot spot (Getis-Ord Gi*) spatial statistic were provided in a spatial weights matrix file specifying the first ISA peak as the distance threshold for the hot spot analysis. A minimum of eight neighboring cells was also required to calculate the observed local sum for each cell (Getis & Ord, 1992). If eight neighboring cells were not within the first ISA distance threshold (i.e., perimeter cells), then the distance threshold was extended to include a minimum of eight neighboring cells.

Iteratively comparing each cell during the hot spot analysis may inflate Type I error or the false identification of a hot spot (Ord & Getis, 1995). A Bonferroni correction, which divides the overall significance level (alpha) by the number of comparisons, has been suggested to control for Type I error. However, this correction can be too conservative for large sample sizes (Getis & Ord, 1992; Ord & Getis, 1995). For example, a Bonferroni correction for these data would result in a highly conservative significance level of 0.000327 to identify significant hot spots. Therefore, the significance level was adjusted to 0.001 to equalize the interpretation of hot spot results across datasets and to balance the probability of Type I and Type II errors. Hereafter, all cells identified as *hot spots* had $p < 0.001$.

An additional hot spot analysis excluding survey effort was conducted on standardized data since survey effort was not available for opportunistic analyses. The number of groups per cell was analyzed to equalize analyses across survey methods.

Opportunistic Survey Hot Spot Analysis
A grid of 1 km × 1 km cells was created for the survey area that directly overlapped with the standardized survey grid to maintain spatial parity between standardized and opportunistic analyses. Because survey effort was not recorded, the number of groups was calculated for each cell (groups/cell) and analyzed as per the standardized survey data to identify hot spots.

Behavioral Hot Spot Analysis
A Pearson's chi-square was used to compare the frequencies of behavioral activities recorded on standardized and opportunistic surveys to determine whether behavioral activity differences existed between datasets. Feed and probable feed behaviors were combined. Each behavioral activity was analyzed separately, and the hot spot results were compared across survey methods.

Results

Standardized Survey Data
In total, 37 standardized surveys were completed from 2009 to 2014. Approximately 98% of surveys were conducted from April through November each year due to weather conditions. Five standardized surveys had a modified route due to deteriorating weather conditions. These surveys were retained for analyses because either the northern or southern region of the survey area was completely surveyed. In total, 92 groups were observed during standardized surveys. Five groups were excluded to remove potential outliers, leaving 87 groups for standardized hot spot analyses (Table 2).

Opportunistic Survey Data
A total of 607 opportunistic surveys were conducted seasonally (May through October) from 2009 to 2014. Of the 1,480 groups observed during ecotours, 74 groups were excluded to eliminate outliers. Therefore, 1,406 groups were analyzed for opportunistic hot spot analyses (Table 2).

Hot Spots Derived from Standardized and Opportunistic Surveys
Two hot spots were identified in southern Roanoke Sound near Oregon Inlet for standardized groups with survey effort (groups/km). Standardized survey hot spots changed when survey effort was

Table 2. Number of completed standardized and opportunistic surveys from 2009 to 2014

	2009	2010	2011	2012	2013	2014	Total
Standardized surveys	4	2	8	10	6	7	37
Opportunistic surveys	49	104	105	119	111	119	607
Standardized groups	10	3	10	31	15	18	87
Opportunistic groups	105	240	224	281	263	293	1,406

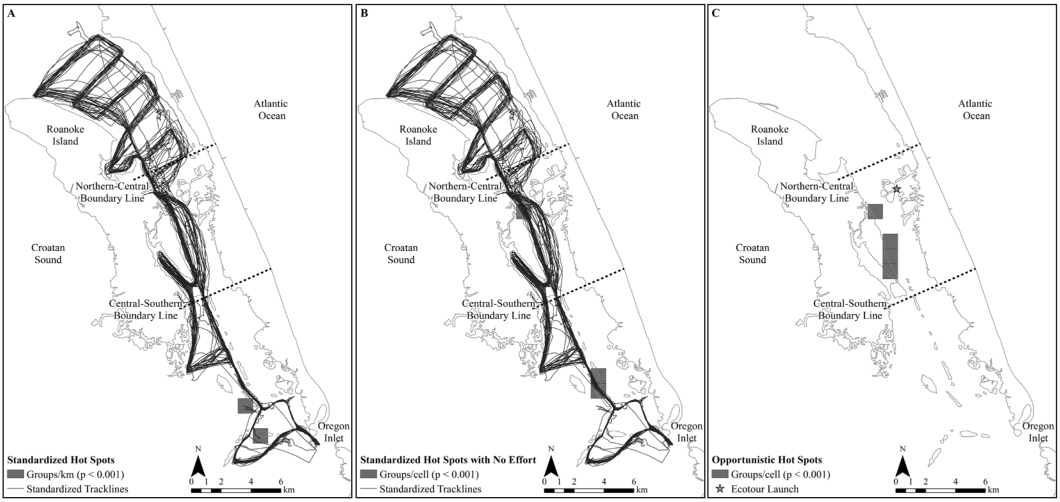

Figure 2. (A) Hot spots for all standardized groups analyzed with survey effort as groups/km, (B) standardized groups analyzed without survey effort as groups/cell, and (C) opportunistic groups analyzed as groups/cell using the Getis-Ord Gi* spatial statistic

removed. Instead, three hot spots were detected in central and southern Roanoke Sound for standardized groups without survey effort (groups/cell). Standardized hot spots were also spatially distinct from the opportunistic hot spots. Four opportunistic hot spots were identified in central Roanoke Sound near the ecotour launch site (Figure 2).

Behavioral Hot Spots

Travel and feed behaviors were observed more often than other behaviors across both standardized and opportunistic surveys (Table 3). Sample sizes for mill and social behaviors of standardized groups were very small and prohibited hot spot analyses of these behaviors across both datasets. A Pearson's chi-square analysis showed there were no significant differences in the frequencies of feed, mill, social, and travel behaviors recorded between survey methods ($\chi^2 = 4.676$, $df = 3$, $p = 0.197$).

Three feed hot spots were detected in southern Roanoke Sound for standardized groups which shows that dolphins often used the southern region for feeding. Standardized feed hot spots were spatially distinct from opportunistic feed hot spots. Three feed hot spots were identified in central Roanoke Sound near the ecotour launch for opportunistic groups. In contrast to standardized results, opportunistic feed hot spots indicate that central Roanoke Sound was often used by dolphins for feeding (Figure 3).

One standardized travel hot spot was identified in southern Roanoke Sound near Oregon Inlet which shows that dolphins often used the southern region for travel. Four opportunistic travel hot spots were detected in central Roanoke Sound near the ecotour launch site. Contrary to standardized results, opportunistic travel hot spots suggest that central Roanoke Sound was often used by dolphins for travel (Figure 4).

Discussion

Standardized survey hot spots located in southern Roanoke Sound suggest this region is often used by dolphins for feeding and travel. The presence of feed hot spots in the southern region aligns with the preferred environmental conditions of

Table 3. Groups and percentages of groups observed for each behavioral activity across standardized and opportunistic surveys (Percentage = behavior groups/total groups × 100)

	Standardized (n = 87)	Percentage	Opportunistic (n = 1,406)	Percentage
Feed	45	51.7	731	52.0
Mill	5	5.7	110	7.8
Social	20	23.0	398	28.3
Travel	73	83.9	993	70.6

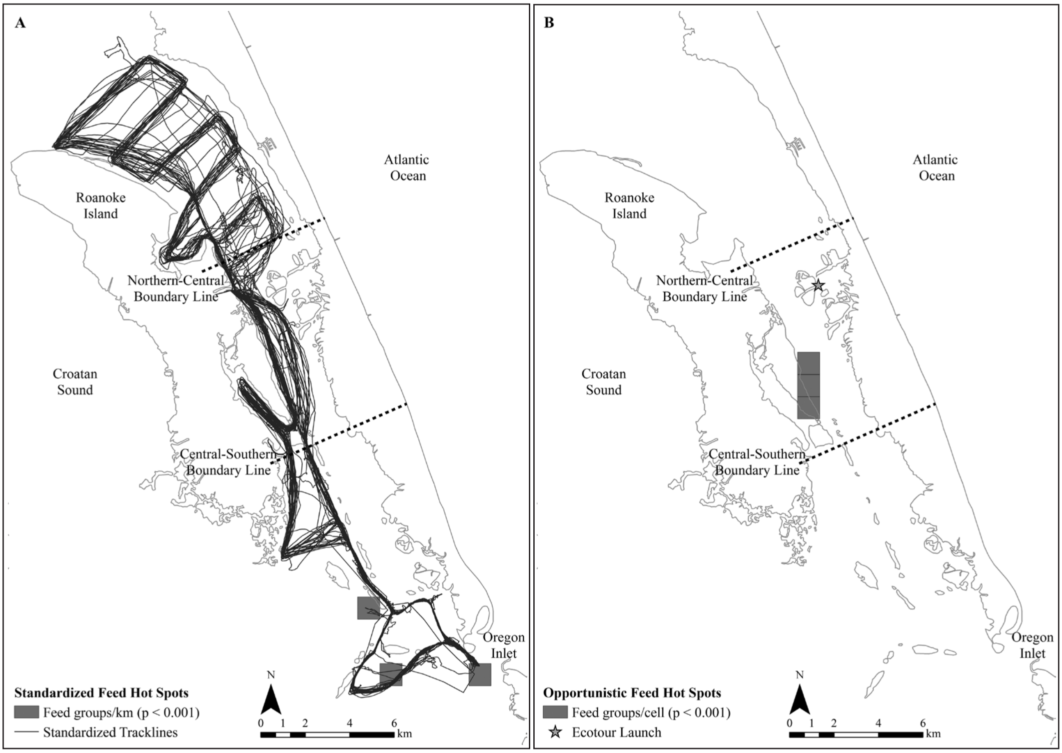

Figure 3. (A) Feed hot spots for standardized groups analyzed with survey effort as feed groups/km (45 groups; 37 surveys) and (B) opportunistic groups analyzed as feed groups/cell (731 groups; 607 surveys) using the Getis-Ord Gi* spatial statistic

their prey, including low salinity and high productivity (Haven, 1959; Phillips et al., 1989; Gannon & Waples, 2004). Submerged aquatic vegetation is distributed throughout the southern region (Albermarle-Pamlico National Estuary Partnership, 2008), which also creates suitable habitat for prey fish species. Additionally, estuary mouths, like those in the southern sound, are widely associated with dolphin foraging (Acevedo, 1991; Ballance, 1992; Hanson & Defran, 1993; Harzen, 1998). It is also plausible that dolphins are using the southern region of Roanoke Sound as a migratory corridor since it is close to Oregon Inlet which provides access between the inshore estuaries and the Atlantic Ocean. Dolphins that inhabit Roanoke Sound belong to the Northern North Carolina Estuarine System Stock, and these animals exhibit seasonal movements to inshore estuaries in late spring and coastal waters in early fall (Waring et al., 2014). In conclusion, the presence of both feed and travel hot spots suggests that the southern region of Roanoke Sound is an important area for the Roanoke Sound dolphin community which can be useful information for conservation and population management.

As opposed to standardized survey results, opportunistic hot spots in central Roanoke Sound indicate this region is often used for feeding and

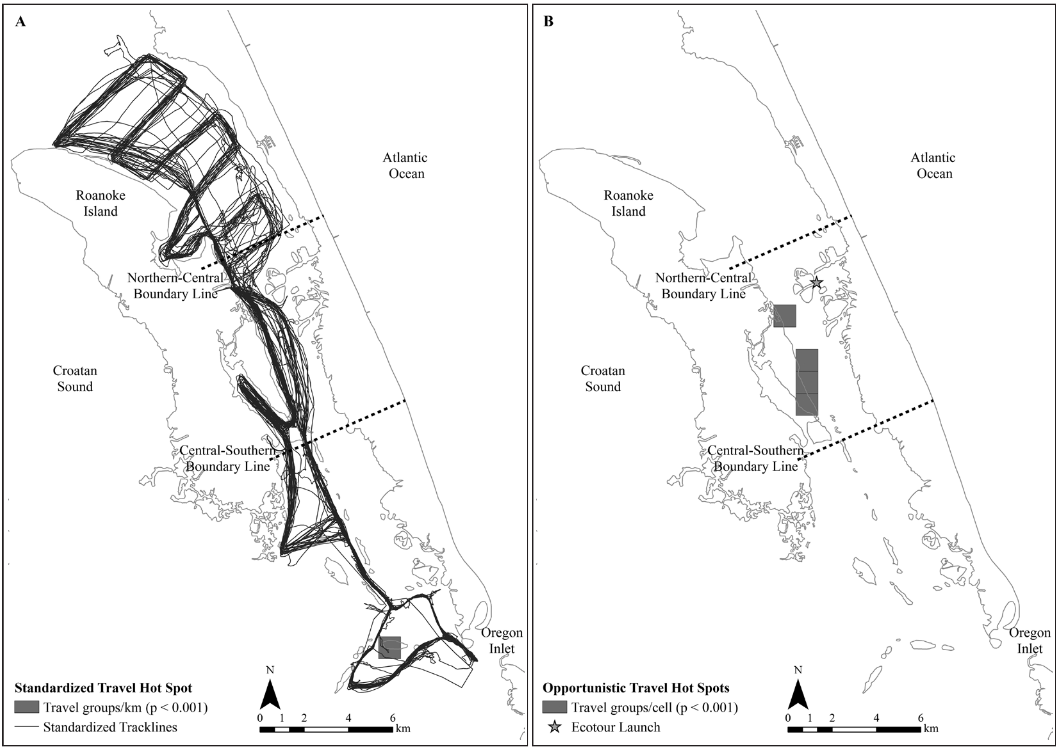

Figure 4. (A) Travel hot spots for standardized groups analyzed with survey effort as travel groups/km (73 groups; 37 surveys) and (B) opportunistic groups analyzed as travel groups/cell (993 groups; 607 surveys) using the Getis-Ord Gi* spatial statistic

travel. Potential explanations for these differences include disparities in sample size, data collection period, and survey effort. These spatial results did not differ when the opportunistic dataset was subsampled to match the standardized dataset; therefore, it is unlikely that sample size affected these results (McBride, 2016). Also, differences in data collection period are not likely to explain the difference in habitat use results because approximately 89.2% of standardized surveys ($n = 33$ surveys) and 94.3% of standardized groups ($n = 82$ groups) occurred during the same months in which opportunistic data were collected. Therefore, the only factor that remains to explain the difference between habitat use results is the difference in survey effort.

Opportunistic hot spots in central Roanoke Sound are likely influenced by spatially biased survey effort. Spatial bias can be introduced by focusing survey effort in easily accessible areas, which, in turn, influences animal distribution data (Davis et al., 1990; Rondinini et al., 2006). Opportunistic group density was likely overestimated in central Roanoke Sound due to spatially biased survey effort and, consequently, hot spots were identified in this region. This point was demonstrated by analyzing the standardized dataset for hot spots with and without controlling for survey effort. The later results showed hot spots in both central and southern regions (Figure 2B). These hot spots contained the most standardized groups, but they also had a high amount of survey effort (range = 149 to 181 km) compared to the average 73.40 km per cell (SD = 54.79 km). Such cells likely had high group counts because of increased survey effort. The difference between results using the same dataset suggests that spatially biased survey effort can result in the detection of false hot spots where survey effort is concentrated. Based on this evidence, it is more likely that the opportunistic hot spots are artifacts of spatial bias rather than authentic habitat use results.

Despite these inherent biases, opportunistic datasets can provide valuable information on marine mammals such as behavior, association, and residency patterns. Further, opportunistic datasets can be used to address questions about marine mammal distribution and habitat use if survey effort is recorded. A comparative analysis of standardized and opportunistic surveys with recorded vessel tracks would be helpful in determining whether all effects of spatial bias could be resolved. Since opportunistic survey effort is typically localized, we recommend that conclusions about marine mammal distribution and habitat use not extend beyond the surveyed area.

Our results suggest that recording and controlling for survey effort is necessary for accurate spatial analyses of marine mammal distribution and habitat use. Spatial bias in presence-only opportunistic data can lead to inaccurate conclusions about marine mammal distribution and their habitat use compared to standardized surveys. This finding can have implications for conservation and management because spatial bias can misdirect efforts and resources to areas that are not effectively supporting the population (Rondinini et al., 2006). Therefore, future research should focus on the development of statistical methods to account for spatial bias in existing presence-only datasets to greatly expand the number of datasets available to support the conservation of marine mammals.

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