# Occurrence, Distribution, and Density of Protected Species in the Jacksonville, Florida, Atlantic Fleet Training and Testing (AFTT) Study Area

*Submitted to:*

Naval Facilities Engineering Command Atlantic under Contract No. N62470-15-D-8006, Task Order 015, issued to HDR, Inc.

*Prepared by*

Heather J. Foley[1], Charles G.M. Paxton[2], Erin W. Cummings[3], Ryan J. McAlarney[3], William A. McLellan[3], D. Ann Pabst[3], and Andrew J. Read[1]

[1] Nicholas School of the Environment, Duke University

[2] Center for Research into Ecological and Environmental Modeling, University of St. Andrews

[3] Department of Biology and Marine Biology, University of North Carolina Wilmington

*Submitted by:*

HDR

Virginia Beach, VA

May 2019

**Suggested Citation:**

Foley, Heather J., Charles G.M. Paxton, Erin W. Cummings, Ryan J. McAlarney, William A. McLellan, D. Ann Pabst, and Andrew J. Read. 2019. *Occurrence, Distribution, and Density of Protected Species in the Jacksonville, Florida, Atlantic Fleet Training and Testing (AFTT) Study Area.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command (NAVFAC) Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Orders 29 and 48, issued to HDR, Inc., Virginia Beach, Virginia. May 2019.

**This project is funded by U.S. Fleet Forces Command and managed by Naval Facilities Engineering Command Atlantic as part of the U.S. Navy's marine species monitoring program.**

# Table of Contents

## Figures

## Tables

This page intentionally left blank.

# 1. History of Monitoring Effort

Initial monitoring of potential sites for an Undersea Warfare Training Range (USWTR) began in 1998 when University of North Carolina Wilmington (UNCW) conducted aerial surveys for marine mammals and sea turtles off Wallops Island, Virginia and Onslow Bay, North Carolina. These surveys were conducted year-round in 1998 and 1999 and provided baseline data on the occurrence and distribution of marine mammals and sea turtles at these two sites.

In 2005 a consortium of academic institutions, including Duke University, UNCW, the Scripps Institution of Oceanography and the University of St. Andrews, was contracted to develop a monitoring program to assess the possible impact of U.S. Navy training and testing activities on marine mammals and sea turtles at a proposed USWTR site in Onslow Bay, North Carolina. Simulation models, parameterized using data from the earlier aerial surveys, indicated that it would be very difficult, if not impossible, to detect any effects of potentially harmful training activities on populations of marine mammals and sea turtles in Onslow Bay. Model results suggested that, in the absence of daily sampling, traditional surveys would provide insufficient statistical power to detect even the worst possible effects of training activities. Given the results of this simulation exercise, the consortium decided against implementing a Before-After-Control-Impact (BACI) assessment and, instead designed a monitoring program that would improve understanding of the occurrence, distribution and density of marine mammals and sea turtles in the area.

A multi-modal survey approach was developed, which included vessel and aerial line transect surveys as well as a passive acoustic monitoring program. Sightings data collected during vessel and aerial surveys were used to derive estimates of cetacean and sea turtle density, and photographs taken from both platforms confirmed species identity. Photographs taken during vessel surveys provided information on the residency and movement patterns of individual cetaceans. The vessel surveys employed a towed hydrophone array to obtain acoustic recordings of cetaceans, identified to the species level during visual encounters. High-frequency Acoustic Recording Packages (HARPs) provided year-round data on the occurrence of vocalizing cetaceans. This program was designed to ensure that even cryptic, deep-diving species, such as beaked whales, would be detected by at least one survey method.

Monthly surveys were initiated at the Onslow Bay, North Carolina site in June 2007 and continued, uninterrupted, for four years. These surveys were conducted along ten 74-km long transect lines (**Figure 1.1**) in a study area 46 x 37 km in spatial extent, including the proposed USWTR in its entirety. The surveys provided a rich picture of the seasonal occurrence, distribution and density of cetaceans and sea turtles in Onslow Bay (Read et al. 2014).

A similar multi-modal monitoring program at a second potential USWTR site off Jacksonville, Florida (JAX) was initiated in 2009. This effort duplicated the approach developed for Onslow Bay, with a similar set of survey track lines (**Figures 1.1 and 1.2**). Monitoring efforts continued at the Onslow Bay site, so concurrent monthly vessel and aerial line transect surveys were conducted at both sites through 2011. Two additional HARPs were deployed in JAX, with a total of four HARP site locations used in the survey area. Commencing in January of 2009, aerial surveys in JAX were synchronized with the intensive, seasonal aerial monitoring of North Atlantic right whale (*Eubalaena glacialis*) calving habitat in the southeast U.S.

In 2011, several important changes were made to the monitoring program. Vessel line transect surveys were discontinued in JAX and this effort was redirected to biopsy sampling and photo-identification efforts, which continue to the present. Aerial and vessel survey efforts in Onslow Bay were redirected to more northern monitoring sites off Cape Hatteras, NC and over Norfolk Canyon, off the coast of Virginia, to improve coverage in the Atlantic Fleet Training and Testing (AFTT) areas along the Mid-Atlantic coast. However, aerial surveys in JAX continued through 2017.

This report summarizes the aerial survey effort conducted at the JAX site from 2009 through 2017. The monitoring project was intended to provide information on the species composition, density, and spatial distribution of marine mammals and sea turtles present in Navy's JAX operating area (OPAREA), with particular focus on the intended site of the USWTR. These aerial surveys extended over nine years and yielded a very detailed seasonal picture of the occurrence, distribution and abundance of marine mammals and sea turtles in the region. This work also provides an important baseline against which future changes in the marine mammal and sea turtle fauna can be assessed.

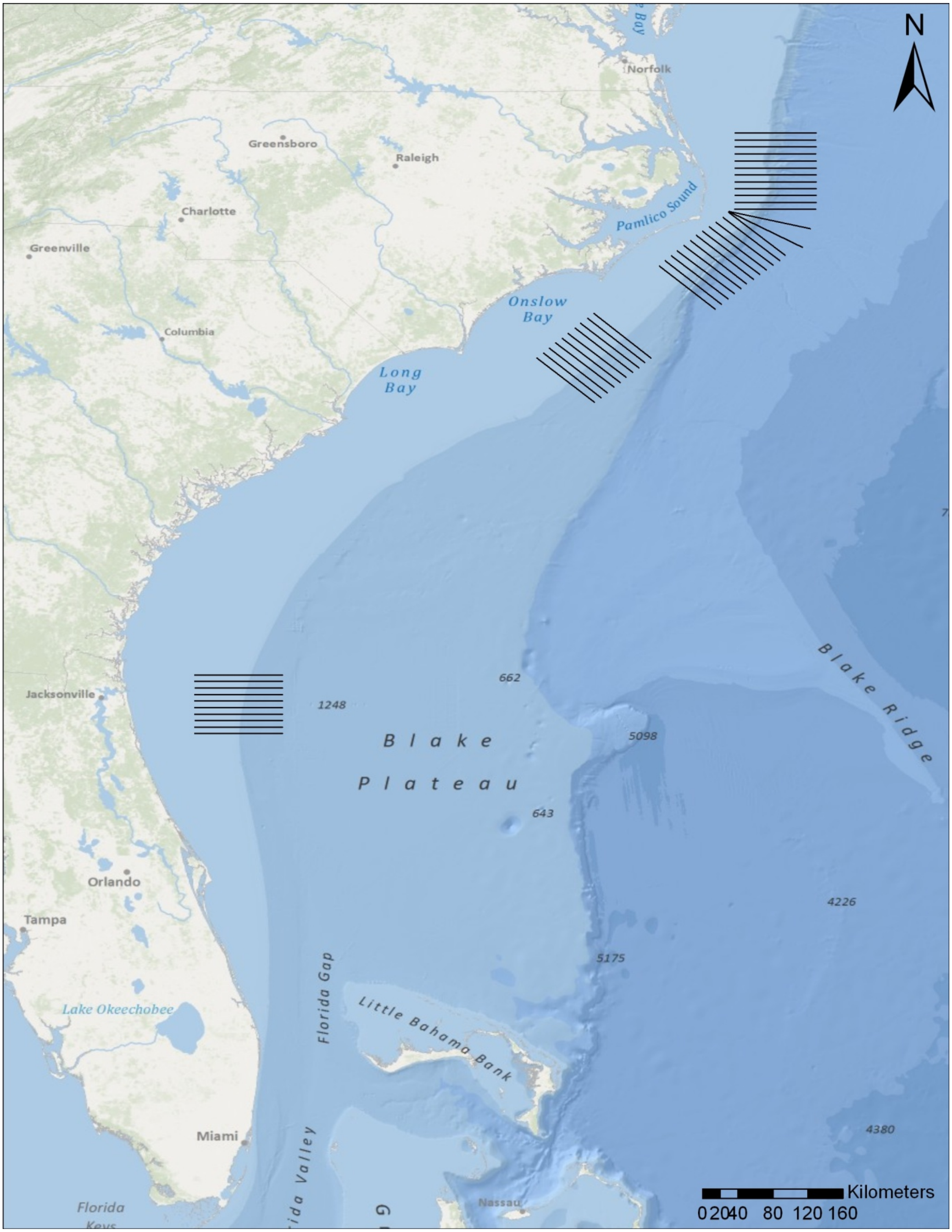


**Figure 1.1. Survey track lines in the Cape Hatteras, Onslow Bay, and Jacksonville study areas.**

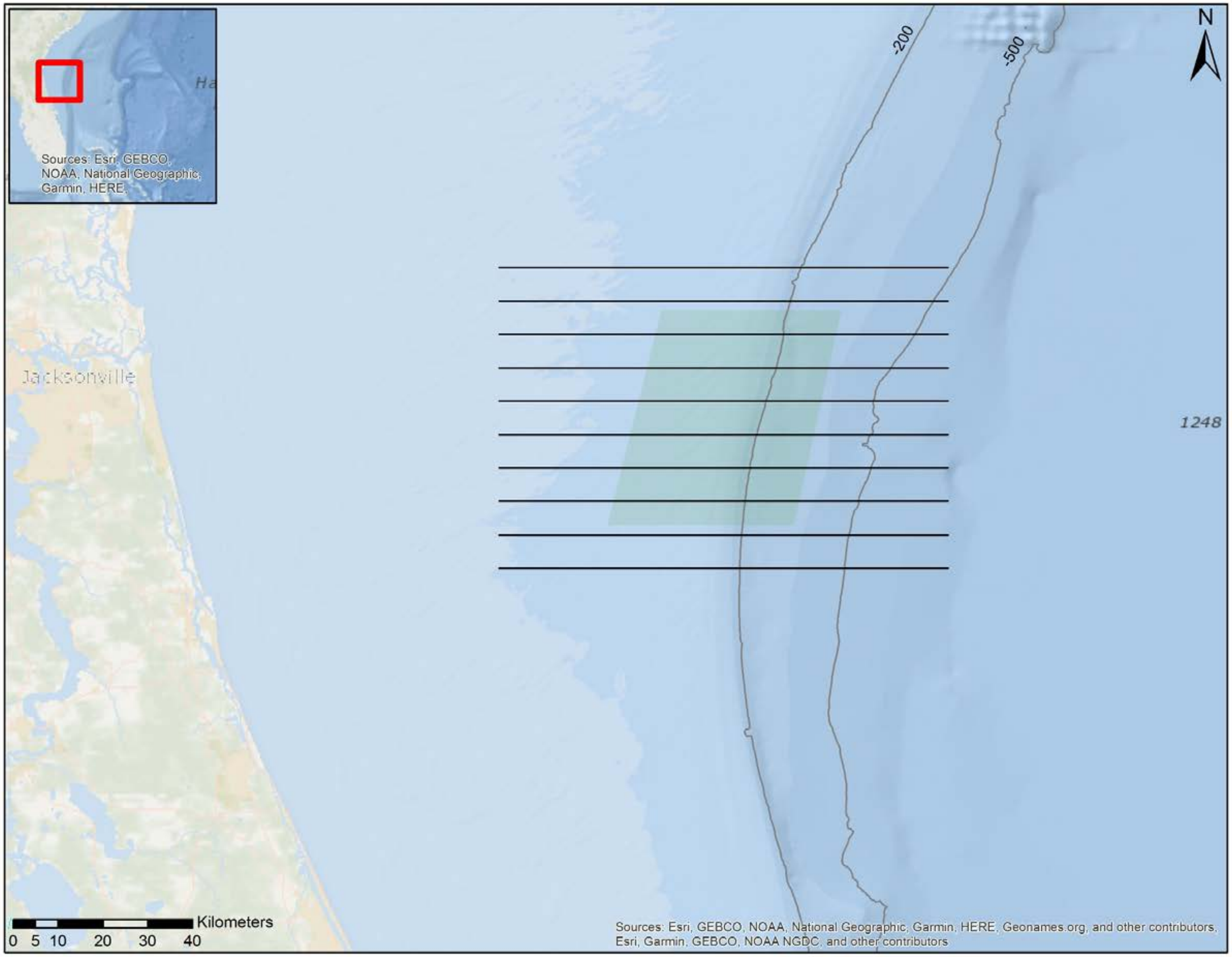


**Figure 1.2. Initial aerial survey tracklines in the Jacksonville study area, including the USWTR site (shaded area).**

# 2. Survey Effort

## 2.1 Methodology and Survey Design

The University of North Carolina Wilmington and Duke University provided aerial observers and contracted Orion Aviation (Siler City, North Carolina) to provide airplanes and certified pilots. Surveys were conducted using National Oceanic and Atmospheric Administration–Southeast Regional Minimum Aircraft and Crew Provisions Guidelines (2013), which require that aircraft are Code of Federal Regulations § 135 certified and that pilots have demonstrated experience working offshore below 305 meters in support of biological observational studies.

All surveys were flown in a Cessna 337 Skymaster, at 305m altitude and 185 km/hour speed, with one pilot, one co-pilot, and two observers. Each observer wore a Nomex® flight suit, Switlik® inflatable life jacket, a personal emergency position-indicating radio beacon, and additional safety equipment. An inflatable life raft, plane emergency position-indicating radio beacon, and satellite telephone were onboard at all times.

The original JAX study design consisted of ten 86-km tracklines, spaced 7.4 km apart, covering a survey area of 5,727 km$^2$ (**Figure 1.2**). As discussed at the 2015 Marine Species Monitoring Program Atlantic Technical Review Meeting (held from 30–31 March 2015 in Virginia Beach, Virginia), there was interest in better understanding the habitat usage of pelagic cetaceans beyond the eastern portion of the original JAX survey area. Thus, a series of additional lines were added in 2015 that extended 43.6 km from each of the eastern endpoints of the original transects, covering an additional 2,903 km$^2$ (**Figure 2.1**). Survey effort conducted on these additional offshore tracklines is included here.

The two observers (one on either side of the plane) searched for marine mammals and sea turtles and, when an animal was detected, they recorded vertical declination angle to the sighting, species and group size. When a cetacean was observed, search effort was suspended while the plane left the transect line to investigate the sighting and collect high quality images to confirm species, group size and behavior. The search effort was resumed along the transect line after leaving the sighting. Environmental conditions were recorded and analyzed as specific trackline units.

Estimates of perpendicular distance from the transect line to turtle sightings were obtained from the declination angle of the plane to the observed animals. Due to the configuration of the aircraft side windows, no animals could be detected within 149 m of either side of the transect line. For cetaceans, perpendicular distances were calculated by trigonometry using the position of the plane at first observation of the animals on the trackline and the subsequent location directly above the animals. If, however, this distance was estimated as less than 149m then it was adjusted to 149m.

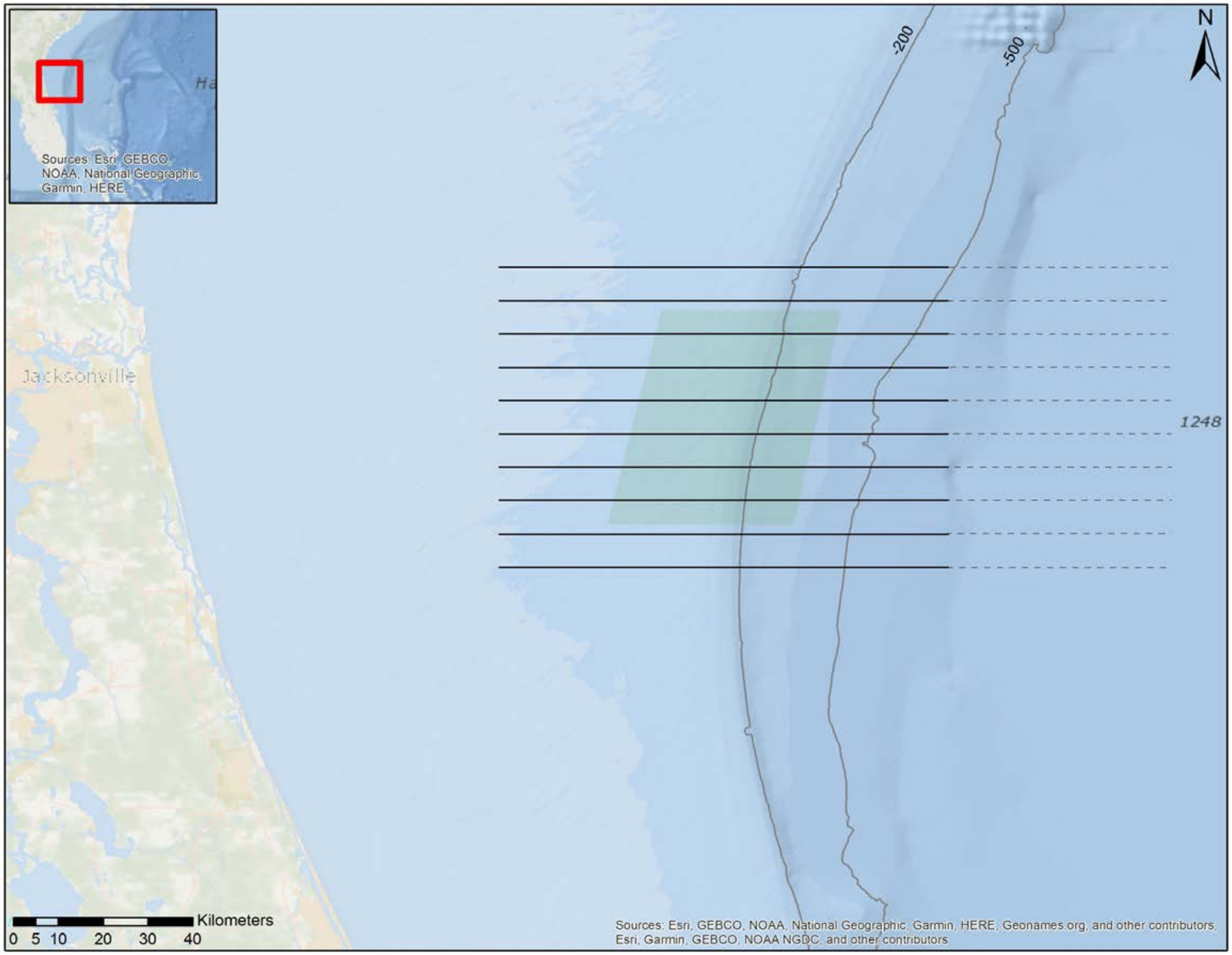
## 2.2 Aerial Survey Effort

Aerial surveys were conducted from January 2009 through November 2017, including 144 survey days (**Appendix 1**). Total survey effort encompassed 93,369 kilometers, 1,147 tracklines and 839 Hobbs hours (**Table 2.1**). The offshore tracklines were flown on eight survey days between April 2015 and November 2017.

During these surveys, Beaufort Sea State (BSS) ranged from 0-6, with a mean BSS of 2.44 (**Appendix 2**). A total of 968 on-effort sightings of cetaceans were recorded and, of these, 891 were identified to species, comprising 11,493 individuals, in addition to an additional 33 off-effort sightings. A total of 4,036 sea turtle sightings were recorded, 3,437 of which were identified to species (**Appendix 2**).

**Table 2.1. Aerial survey effort divided by season in the Jacksonville study area, January 2009 – November 2017.**

| Season | Winter (Dec – Feb) | Spring (Mar – May) | Summer (June – Aug) | Autumn (Sep – Nov) |
|---|---|---|---|---|
| Number of Surveys | 37 | 35 | 38 | 34 |
| Total Tracklines | 282 | 290 | 302 | 273 |
| Kilometers Flown | 23,401 | 22,793 | 24,560 | 22,615 |
| Hobbs Hours | 214 | 213 | 209 | 202 |



Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE

Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

**Figure 2.1. Aerial survey tracklines in the Jacksonville study area, including the USWTR site (shaded area), and extended offshore tracklines (dashed lines).**

# 3. Species Occurrence

Eleven species of cetaceans and three species of sea turtles were identified during these surveys (**Table 3.1**). Two species of delphinids comprised more than three-quarters of all cetacean sightings: the common bottlenose dolphin (*Tursiops truncatus*) and the Atlantic spotted dolphin (*Stenella frontalis*). Four species of large whales were detected, together with five species of pelagic odontocetes (**Table 3.1**). Loggerhead (*Caretta caretta)*, leatherback (*Dermochelys coriacea)*, and Kemp's Ridley (*Lepidochelys kempii)* sea turtles were all observed.

**Table 3.1. All cetacean sightings, including off-effort sightings (n=31), from aerial surveys in the Jacksonville study area, January 2009 – November 2017.**

| Scientific name | Common name | Sightings | Individuals |
|---|---|---|---|
| *Tursiops truncatus* | Bottlenose dolphin | 450 | 3,742 |
| *Stenella frontalis* | Atlantic spotted dolphin | 355 | 6,515 |
| *Grampus griseus* | Risso's dolphin | 54 | 815 |
| *Globicephala macrorhynchus* | Short-finned pilot whale | 26 | 326 |
| *Balaenoptera acutorostrata* | Minke whale | 11 | 16 |
| *Steno bredanensis* | Rough-toothed dolphin | 10 | 365 |
| *Eubalaena glacialis* | North Atlantic right whale | 6 | 9 |
| *Megaptera novaeangliae* | Humpback whale | 3 | 3 |
| *Physeter macrocephalus* | Sperm whale | 3 | 4 |
| *Kogia* sp. | Unidentified kogiid | 2 | 3 |
| *Stenella attenuata* | Pantropical spotted dolphin | 2 | 27 |
| Unidentified delphinid | Unidentified delphinid | 78 | 268 |
| Unidentified cetacean | Unidentified cetacean | 1 | 1 |
|  |  | **1,001** | **12,094** |

# 4. Distribution and Seasonality

The pattern of cetacean distribution was very consistent over the entire study period (**Figure 4.1**). Bottlenose dolphins were encountered throughout the entire study area (**Figure 4.2**), but the occurrence of Atlantic spotted dolphins was restricted to shallow, shelf waters (**Figure 4.3**). Pelagic odontocetes were observed only in deeper waters beyond the 200m shelf break, with the exception of rough-toothed dolphins (*Steno bredanensis*), which were observed routinely inshore of the 200m isobath (**Figure 4.4**). Large whales, with the exception of North Atlantic right whales, were observed only in deeper waters (**Figure 4.5**).

Baleen whales were observed only in winter and early spring (December to early April) (**Figure 4.6**), but there was no other obvious pattern of seasonality in the occurrence of cetaceans (**Figures 4.6 – 4.9**). Winter is defined in this study as December through February, while spring is March through May. Summer months include June through August, and autumn encompasses September through November. Bottlenose and Atlantic spotted dolphins were seen in every month. Risso’s dolphins were observed every month, except December. Rough-toothed dolphins were observed from January through November with no apparent seasonal pattern. Interestingly, short-finned pilot whales (*Globicephala macrorhynchus*) were seen only between April and October (**Figures 4.7 – 4.8**), despite not demonstrating seasonality in the Cape Hatteras survey area. Too few sightings of sperm whales (*Physeter macrocephalus*), pantropical spotted dolphins (*Stenella attenuata)*, and kogiids occurred to allow any conclusions to be drawn regarding their patterns of seasonality (**Figures 4.6 – 4.9**).

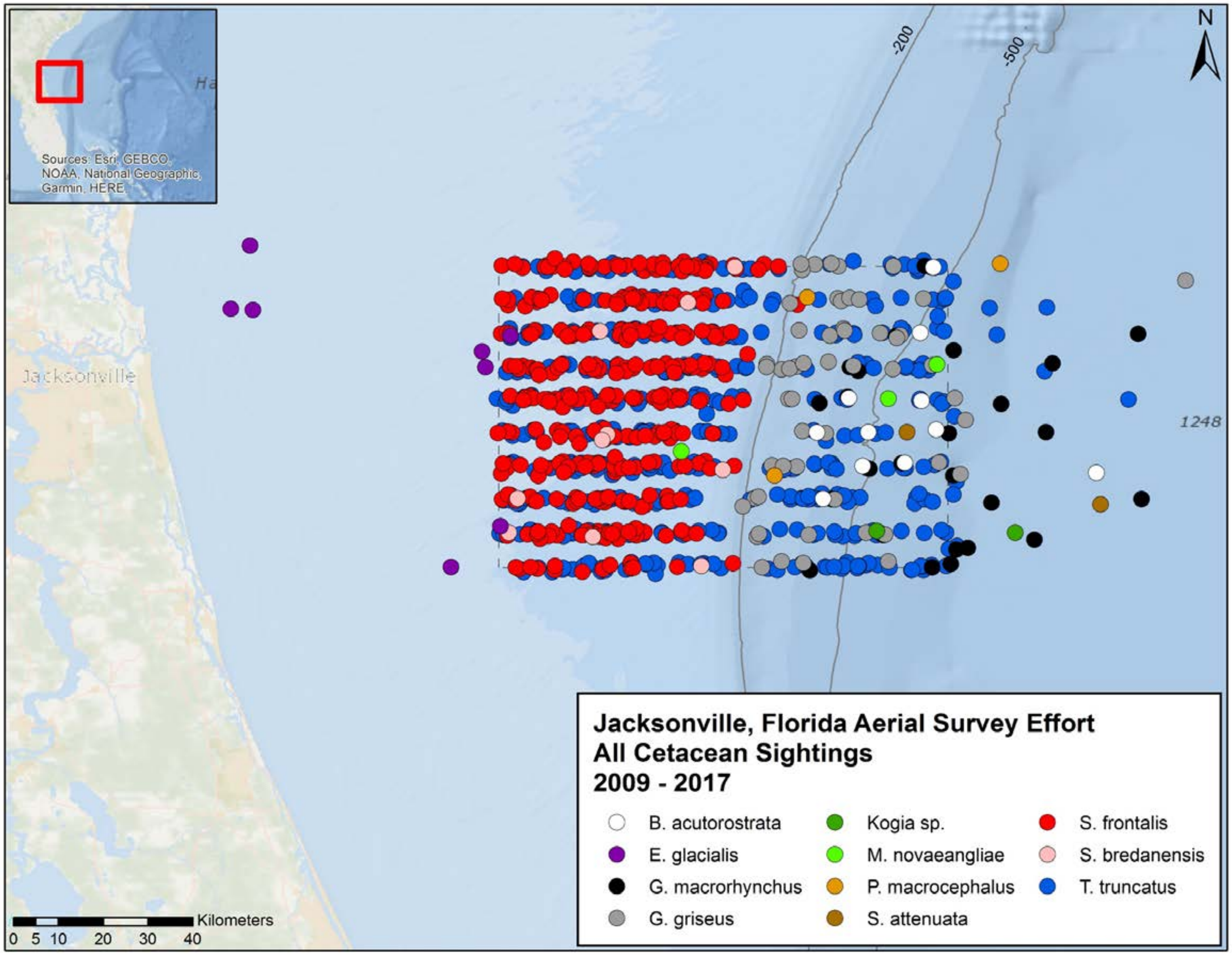


**Figure 4.1. All cetacean sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

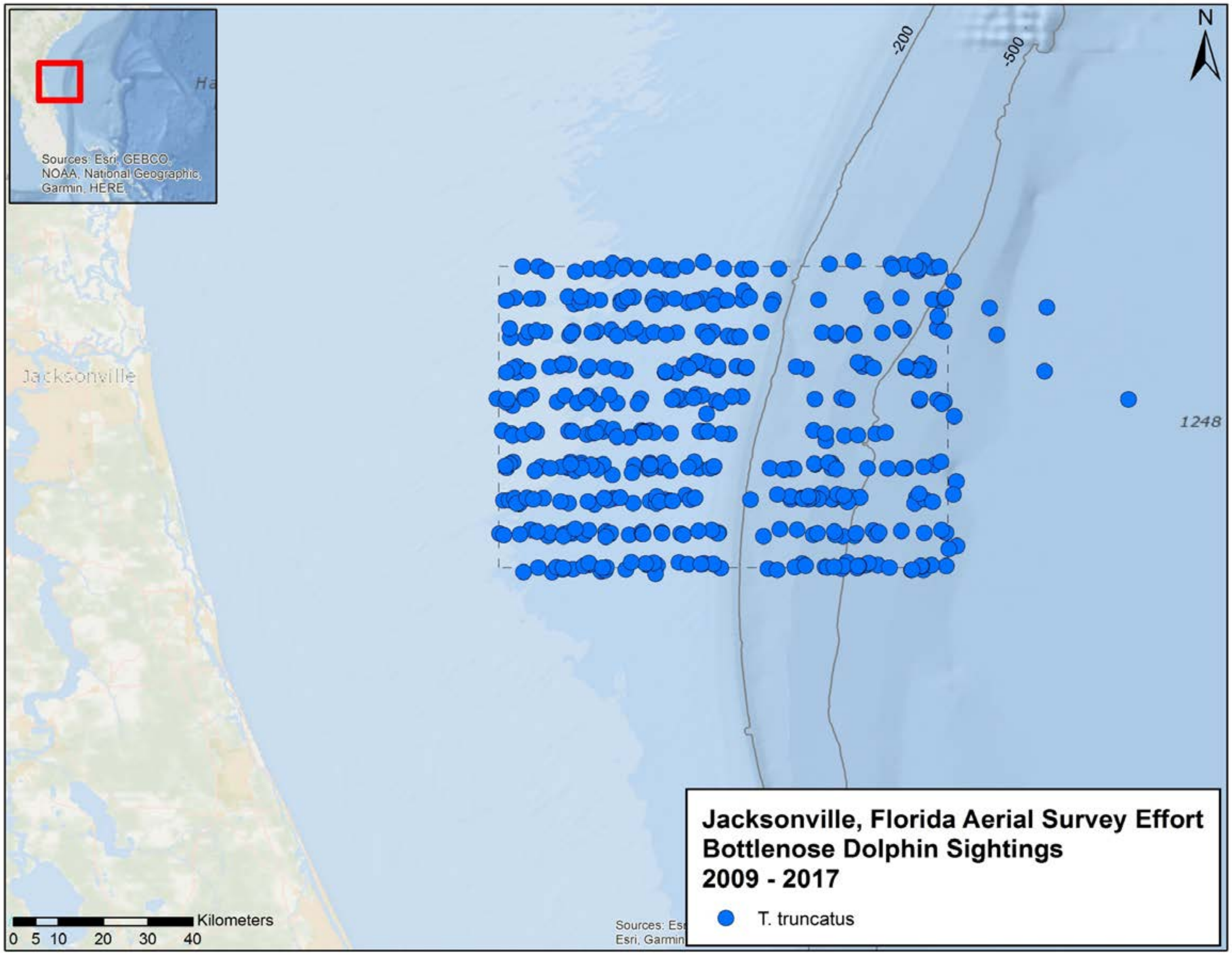


**Figure 4.2. Sightings of bottlenose dolphins from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

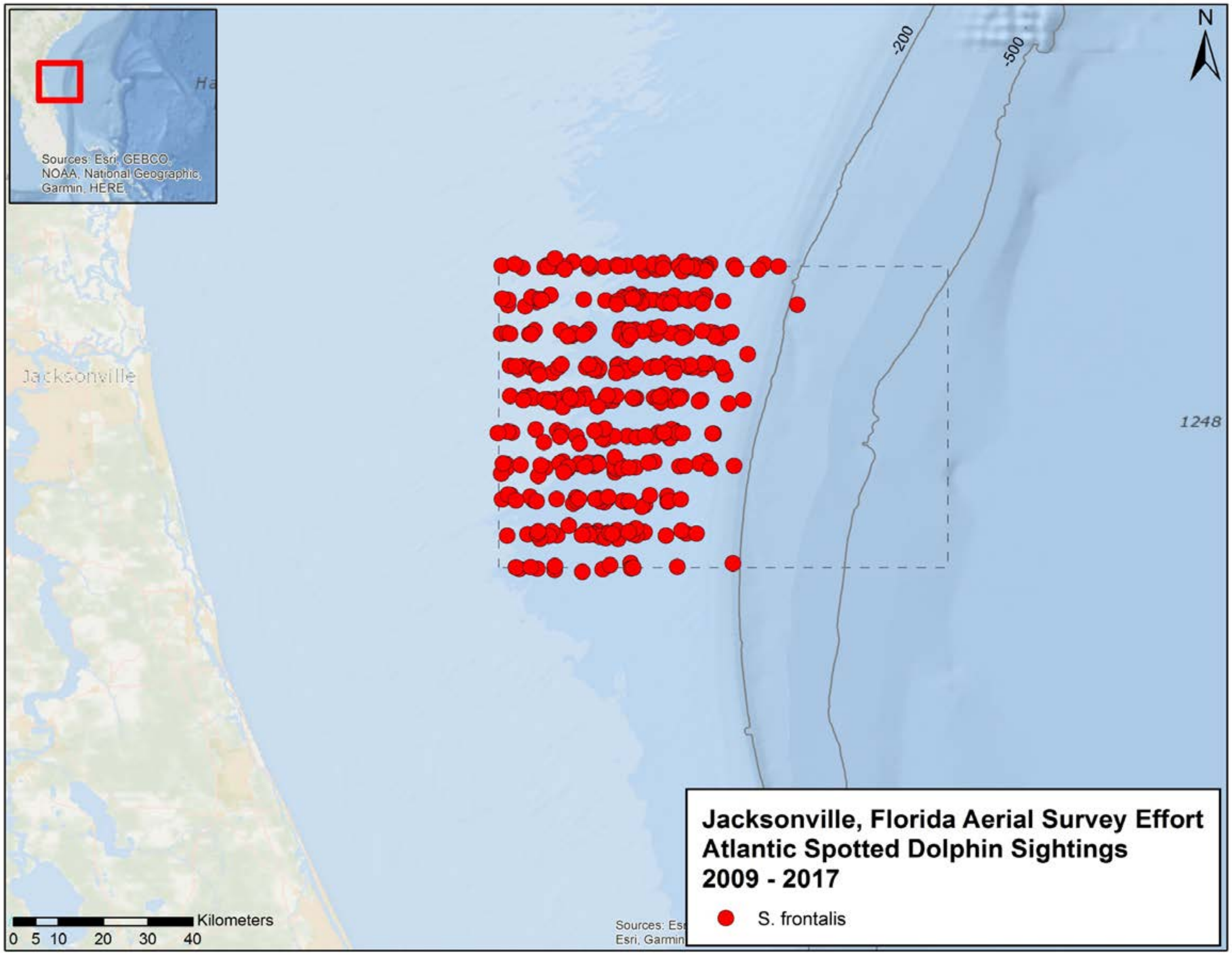


**Figure 4.3. Sightings of Atlantic spotted dolphins from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

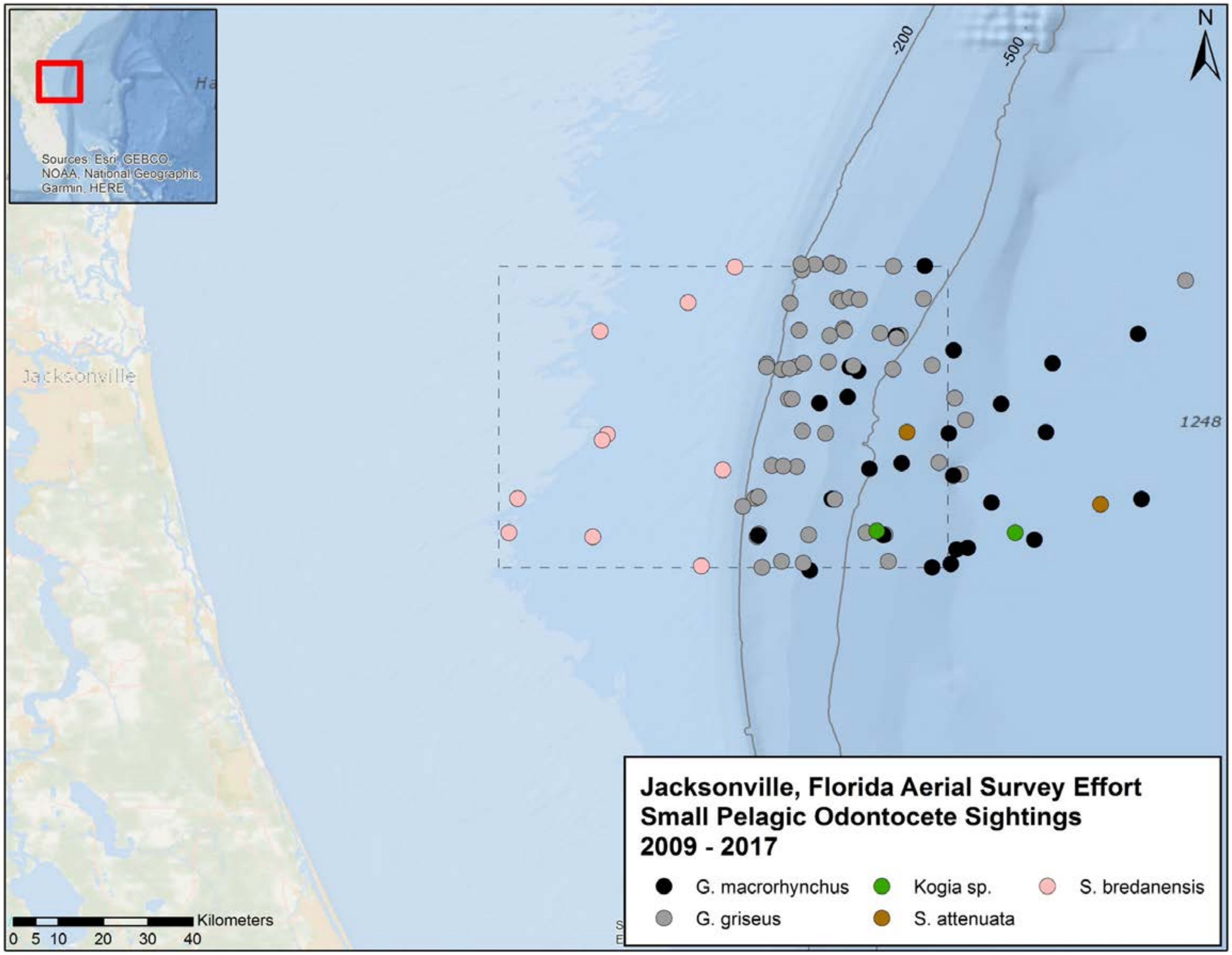


**Figure 4.4. Sightings of small pelagic odontocetes from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

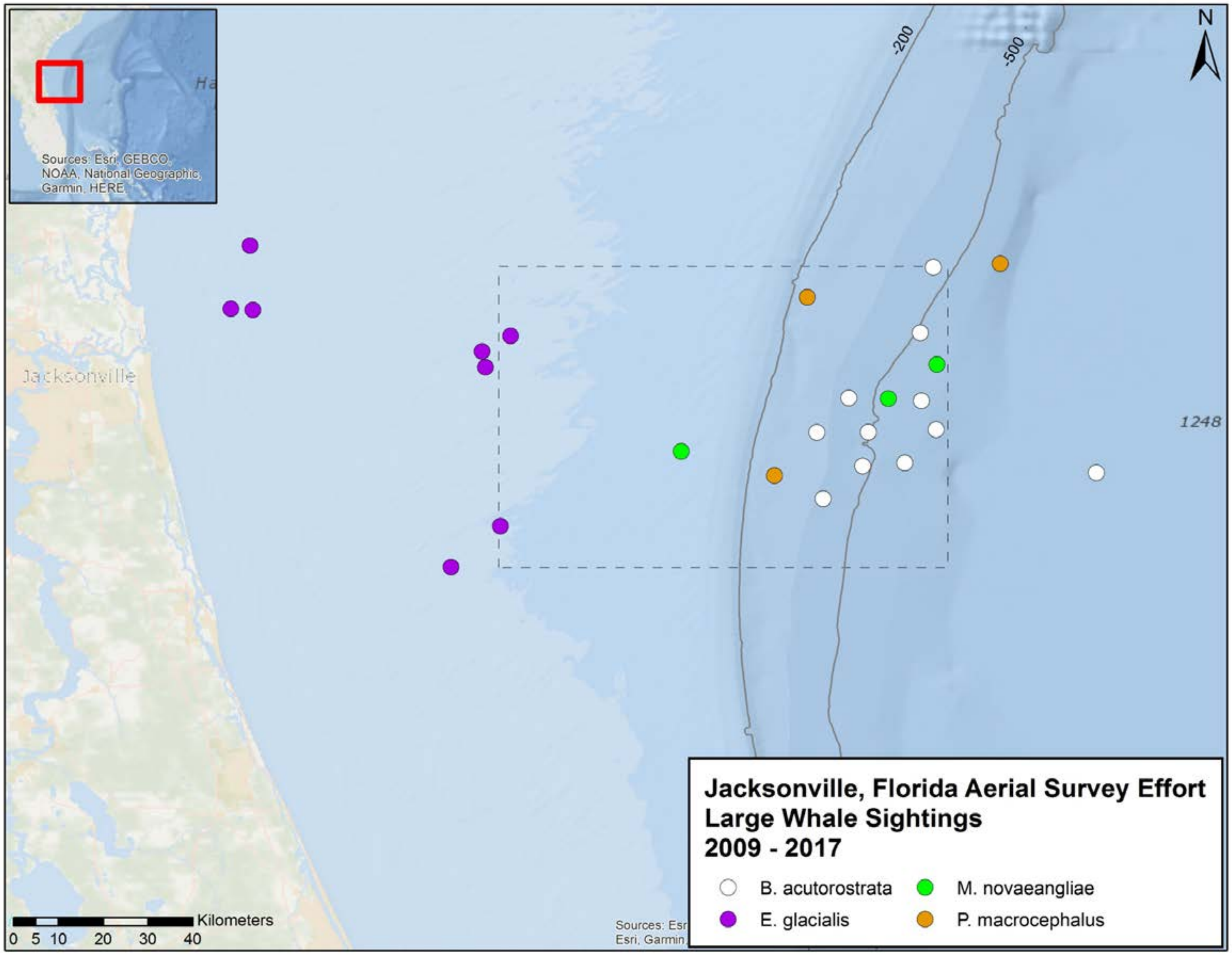


**Figure 4.5. Sightings of large whales from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

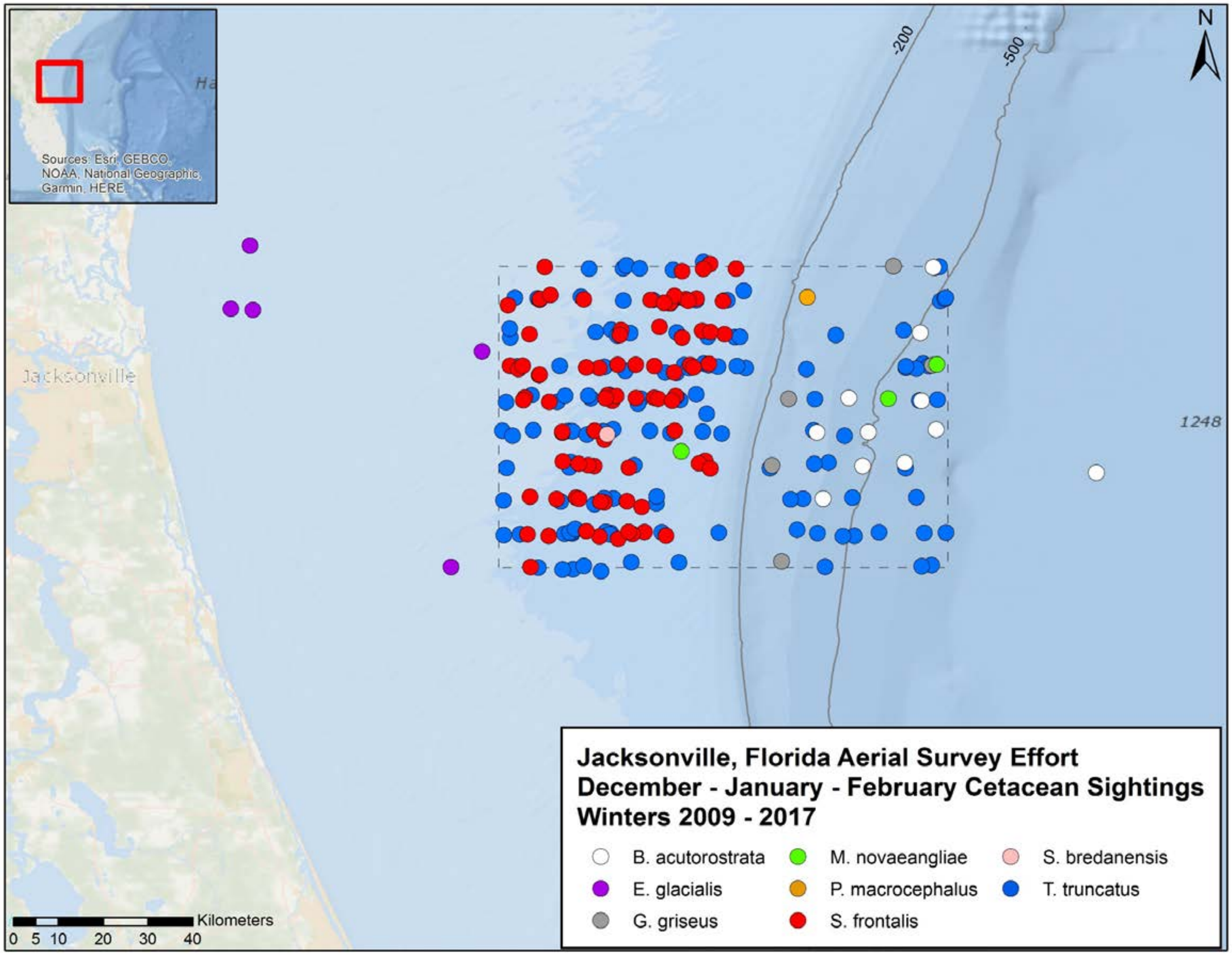


**Figure 4.6. Winter cetacean sightings from aerial survey conducted in the Jacksonville study area, January 2009 – November 2017.**

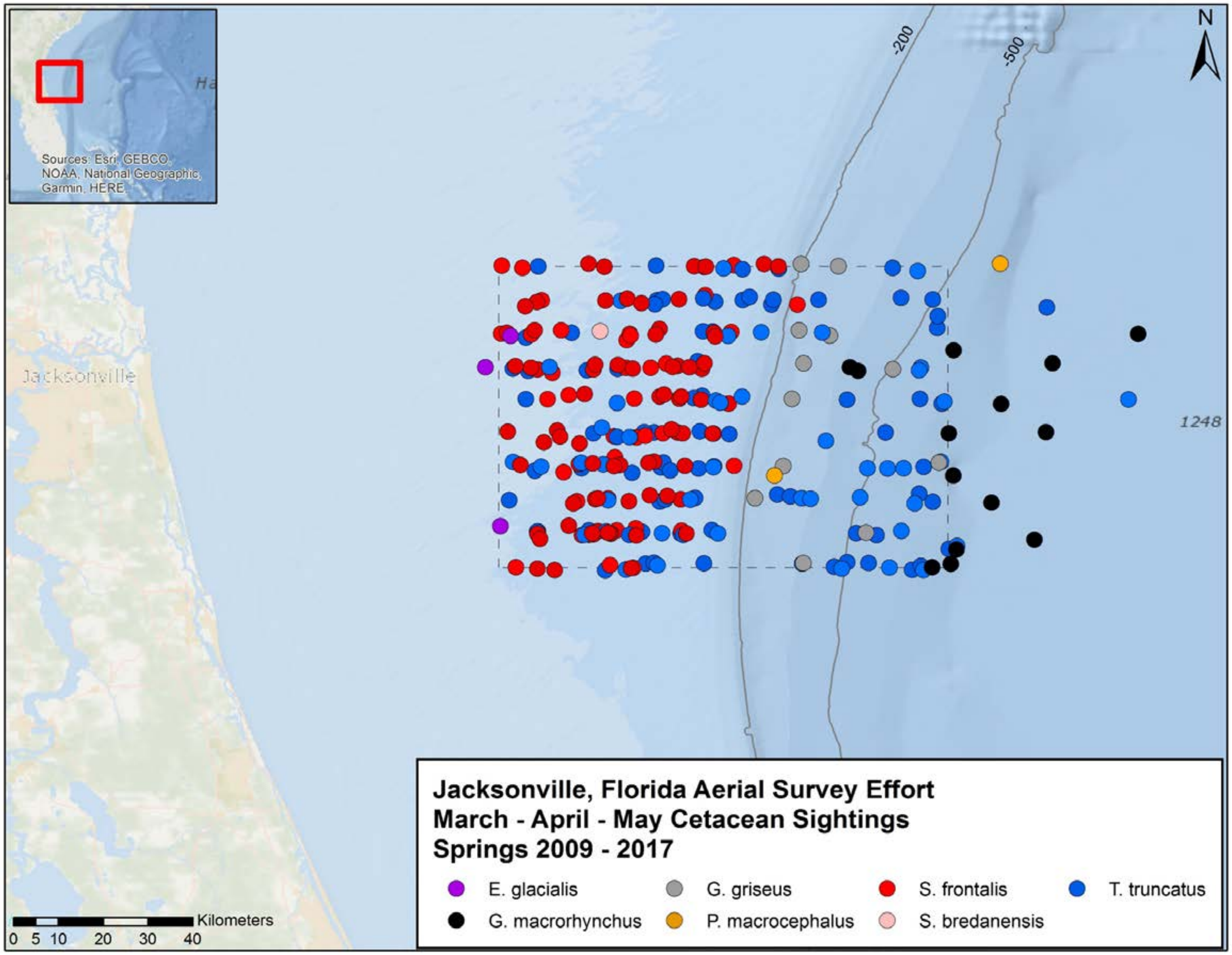


**Figure 4.7. Spring cetacean sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

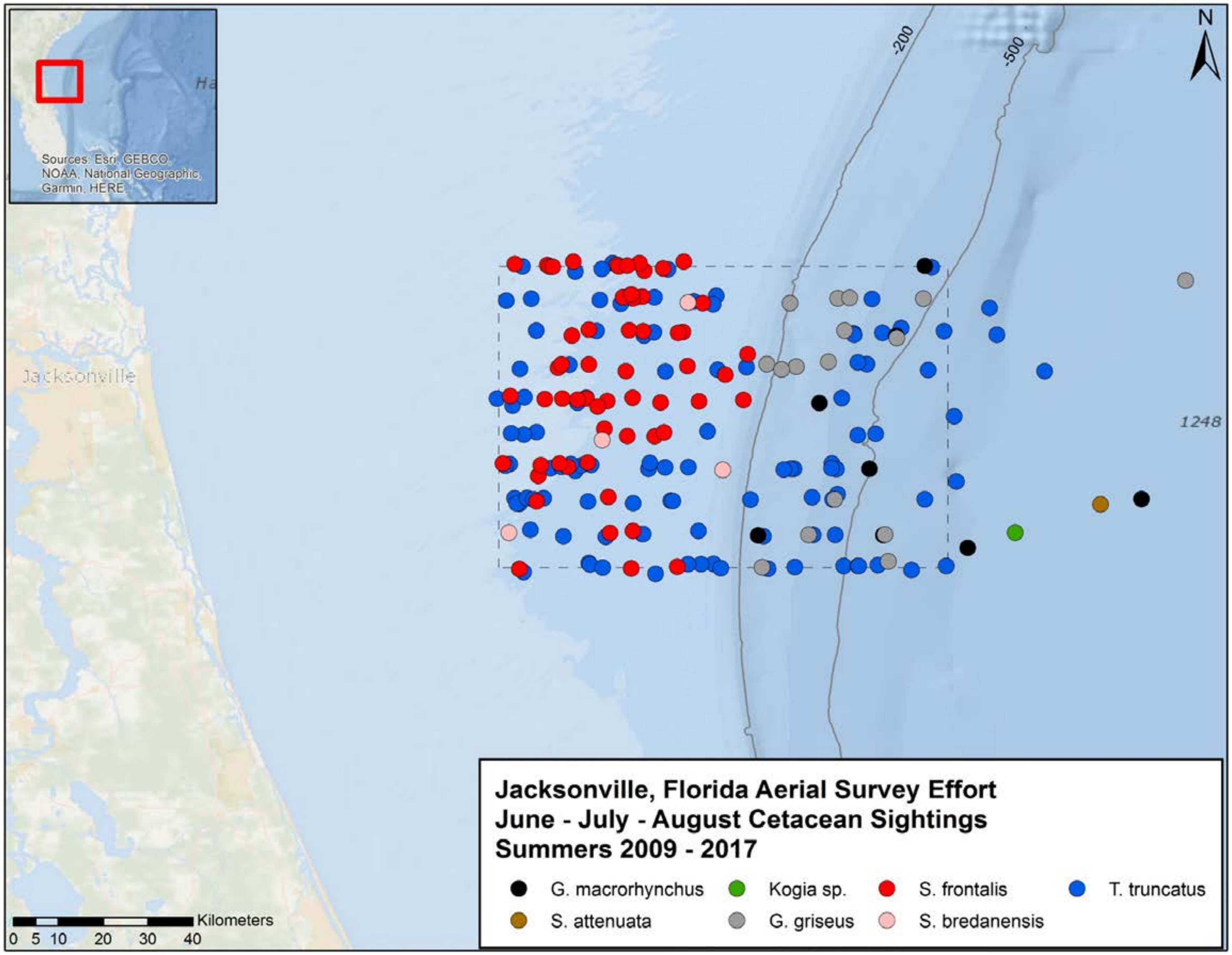


**Figure 4.8. Summer cetacean sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

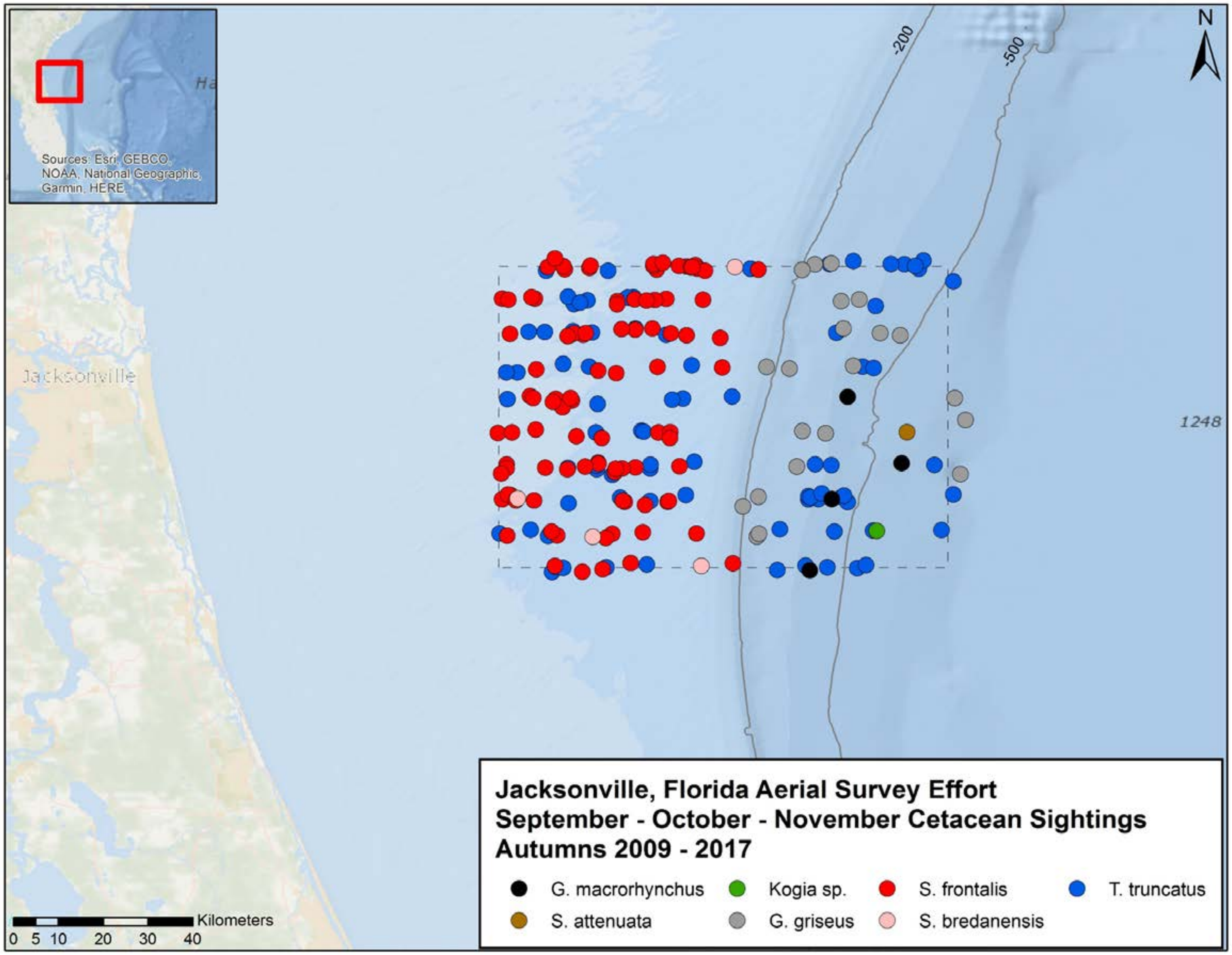


**Figure 4.9. Autumn cetacean sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

Several aspects of the occurrence and distribution of baleen whales in JAX are worth noting. First, little prior information exists on the winter distribution and calving grounds of minke whales (*Balaenoptera acutorostrata*) in the northwestern Atlantic. The observations reported here suggest that the waters beyond the continual shelf break along the southeastern U.S. coast may represent a breeding area for this species. Minke whale sightings were recorded in JAX from December through February, and consisted of single animals or pairs, including two mother-calf pairs.

The only known calving area for the western North Atlantic right whale is located in the shallow waters off the southeastern United States, with a concentration inshore of the JAX study area. For over 20 years, Early Warning System (EWS) surveys have been conducted seasonally in this area to monitor right whale distribution and calf production. Prior to the surveys reported here, only one right whale live birth had been observed during EWS surveys. On 20 March 2010, during an aerial survey of the JAX study area, a single right whale was observed 63km offshore of St. Augustine, FL. The whale was observed for approximately 24 minutes prior to descending from the surface. Four minutes later, following the appearance of two blood clouds in the water, a small calf surfaced next to the clouds. The neonate's flukes were limp with ventrally curled tips and fetal folds visible on its flanks. After a brief period alone at the surface, during which time the calf was breathing and swimming unassisted, the mother moved to within 10m and the pair swam together in a circular fashion. Three minutes later, after active bleeding ended, the first tactile interactions between the mother and calf were observed. Ten to 13 minutes after the birth, behaviors interpreted as attempted nursing were observed. The observation of the birth of a North Atlantic right whale offers important biological insights into the biology of this critically endangered whale. The location of the calving event, outside of all current management areas, underscores the importance of re-evaluating critical habitat and associated management plans vital to the continued recovery of this species. This important observation is described more fully in Foley *et al*. (2011).

Four other North Atlantic right whale sightings were made near the JAX study area. On 20 March 2010, the same day as the observed birth described above, a single adult male (EG# 2303) was observed later in the afternoon in the northwestern portion of the survey area. Additionally, a mother-calf pair (EGNO 3360 and calf) was observed while transiting to the area on 2 April 2010. Two adults were observed west of the southernmost trackline in January 2014. In February 2014, an entangled North Atlantic right whale (EG# 4057) was observed just to the west of the survey area, as a vessel was conducting a focal follow after deploying a DTag on the individual. Three additional off-effort sightings of right whales, comprising two singletons and a mother-calf pair, were made in 2010, well inshore of the study area, during transit to and from the survey area (**Figure 4.5**).

# 5. Sea Turtles

As noted above, three species of sea turtles were observed in the study area. Loggerhead turtles dominated the sightings and appear to be particularly abundant in JAX, occurring primarily over shelf waters, but also extending beyond the shelf break (**Figure 5.1**).

Large numbers of leatherbacks were also observed in the study area (**Figure 5.1**), which lies just offshore of a major rookery for this species. Finally, a small number of Kemp's Ridley sea turtles were sighted in JAX. No other sea turtle species were observed during this monitoring work. The seasonality of sea turtle sightings is difficult to discern from a cursory examination of sightings alone (**Figures 5.2 – 5.5**), but the density work described in Section 6 provides additional information on this subject.

**Table 5.1. Sea turtle sightings from aerial surveys in the Jacksonville study area, January 2009 – November 2017.**

| Scientific name | Common name | Sightings |
|---|---|---|
| *Caretta caretta* | Loggerhead sea turtle | 3248 |
| *Dermochelys coriacea* | Leatherback sea turtle | 186 |
| *Lepidochelys kempii* | Kemp's Ridley sea turtle | 3 |
| Unidentified sea turtle | Unidentified sea turtle | 599 |

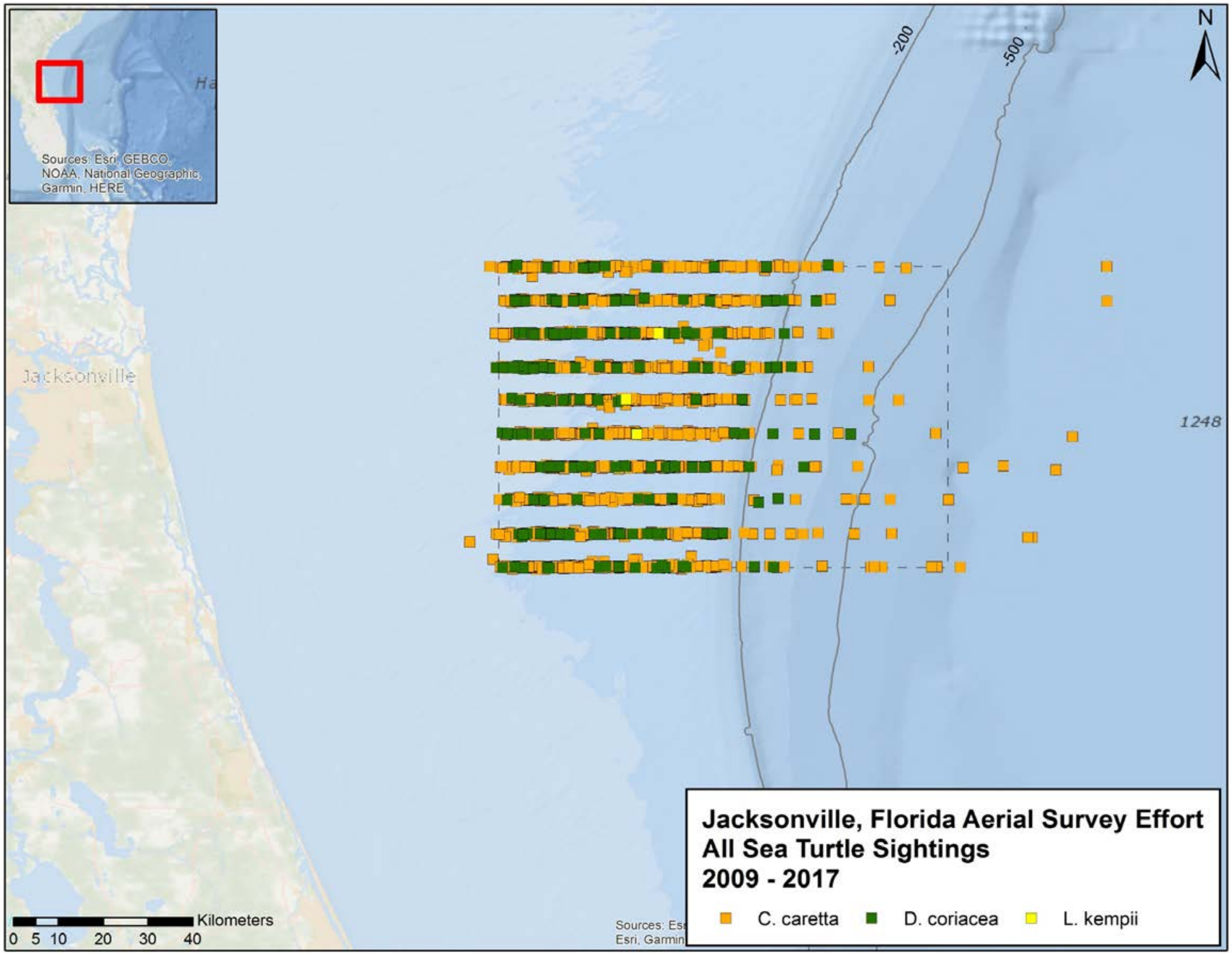


**Figure 5.1. All sea turtle sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

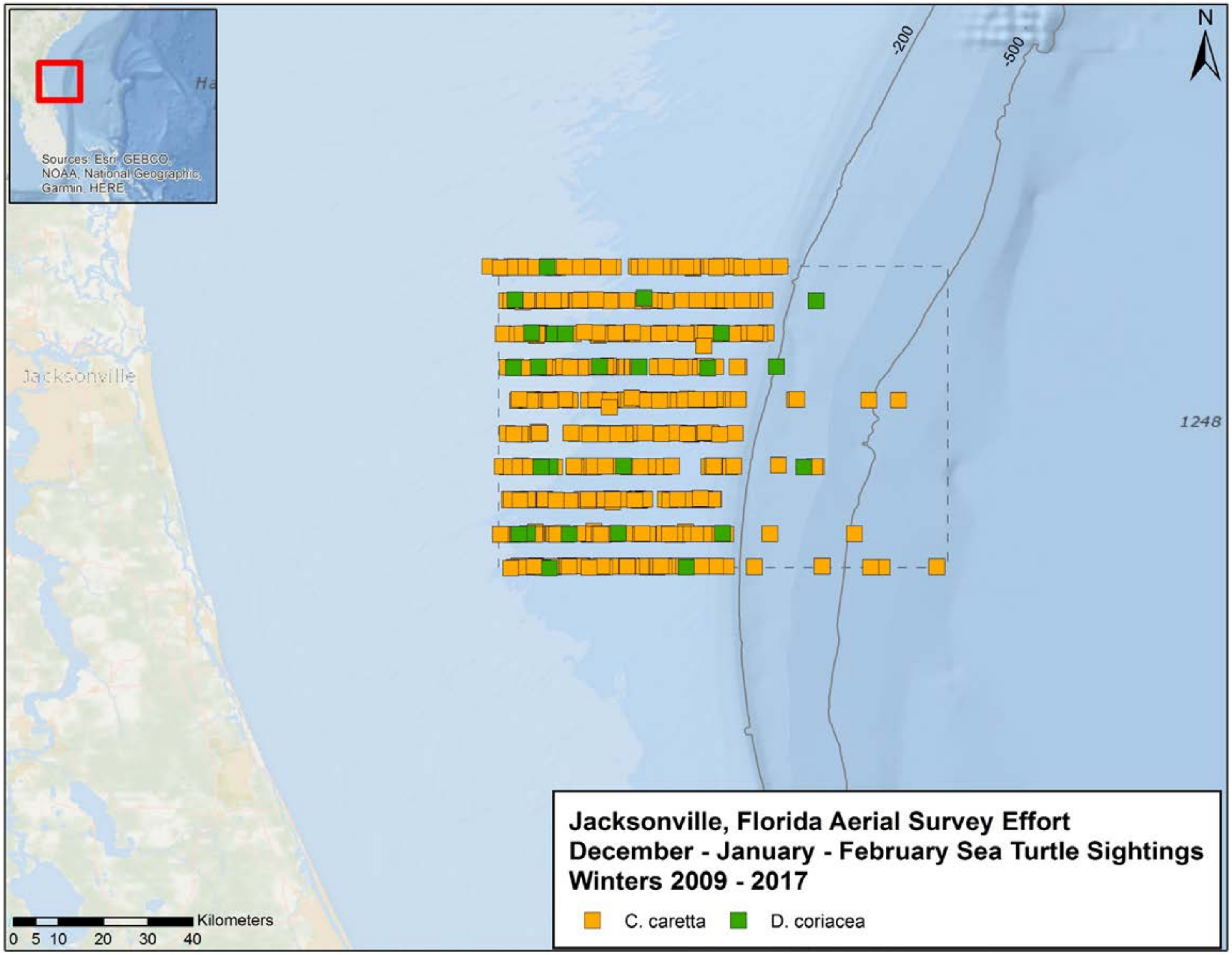


**Figure 5.2. Winter sea turtle sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

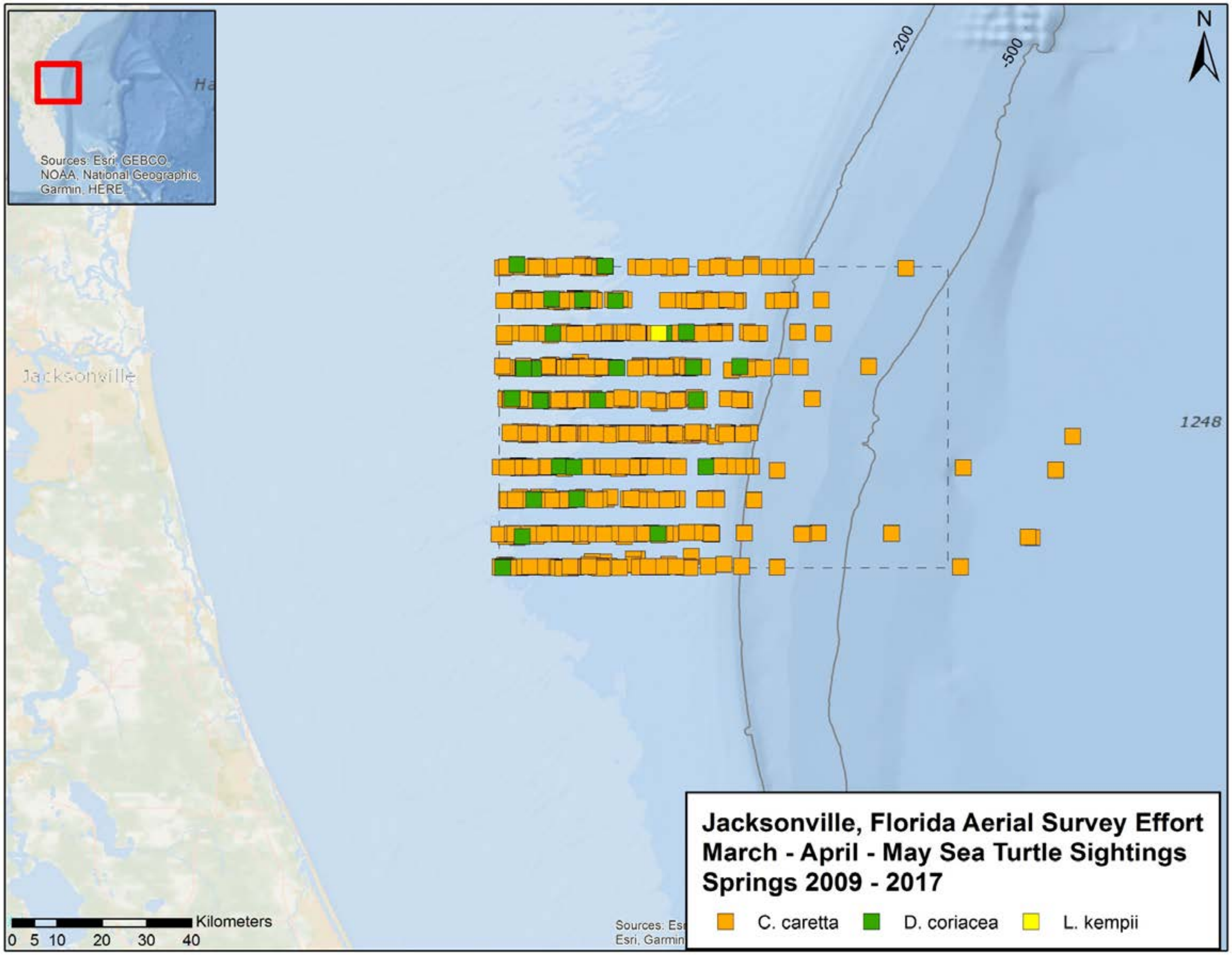


**Figure 5.3. Spring sea turtle sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

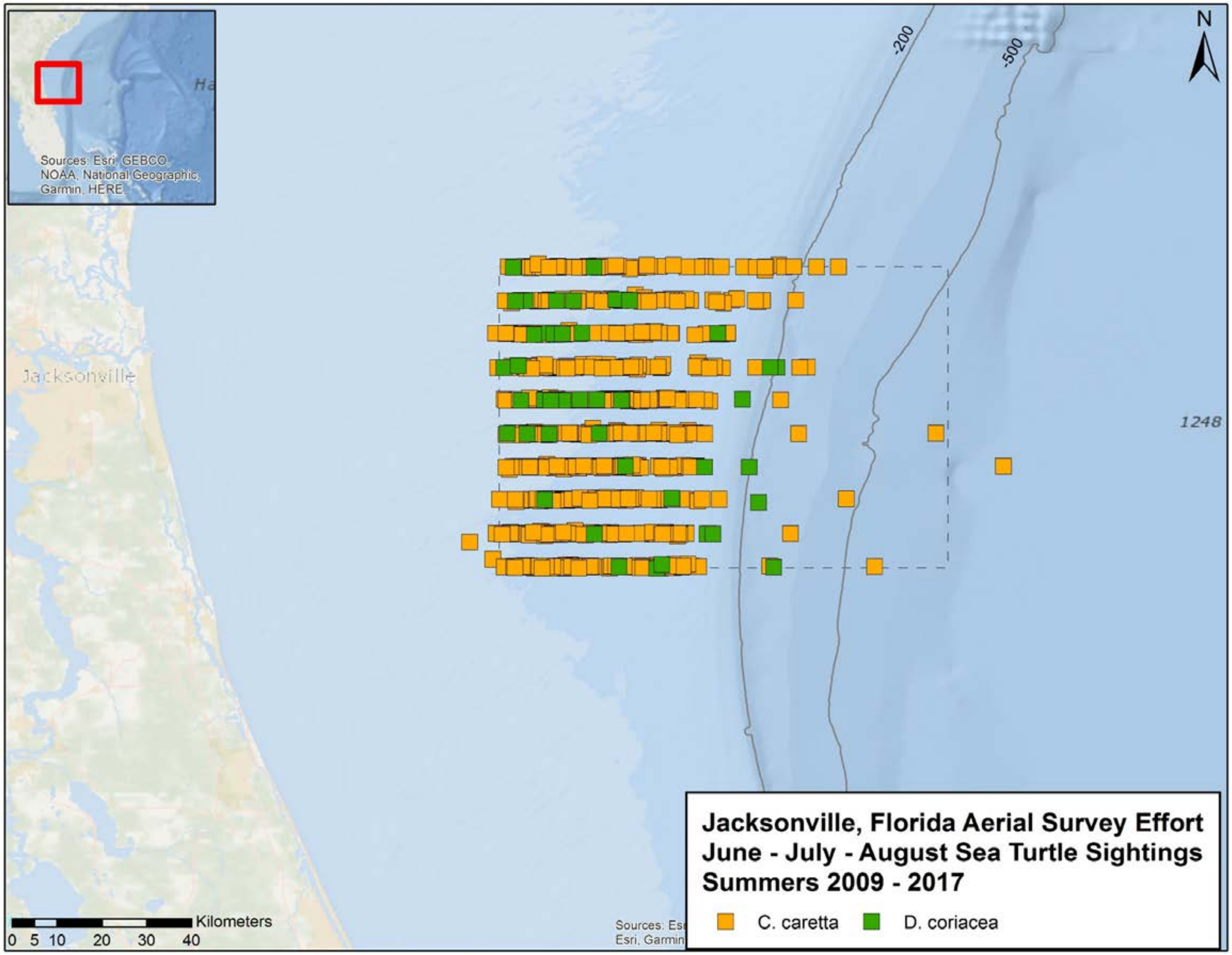


**Figure 5.4. Summer sea turtle sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

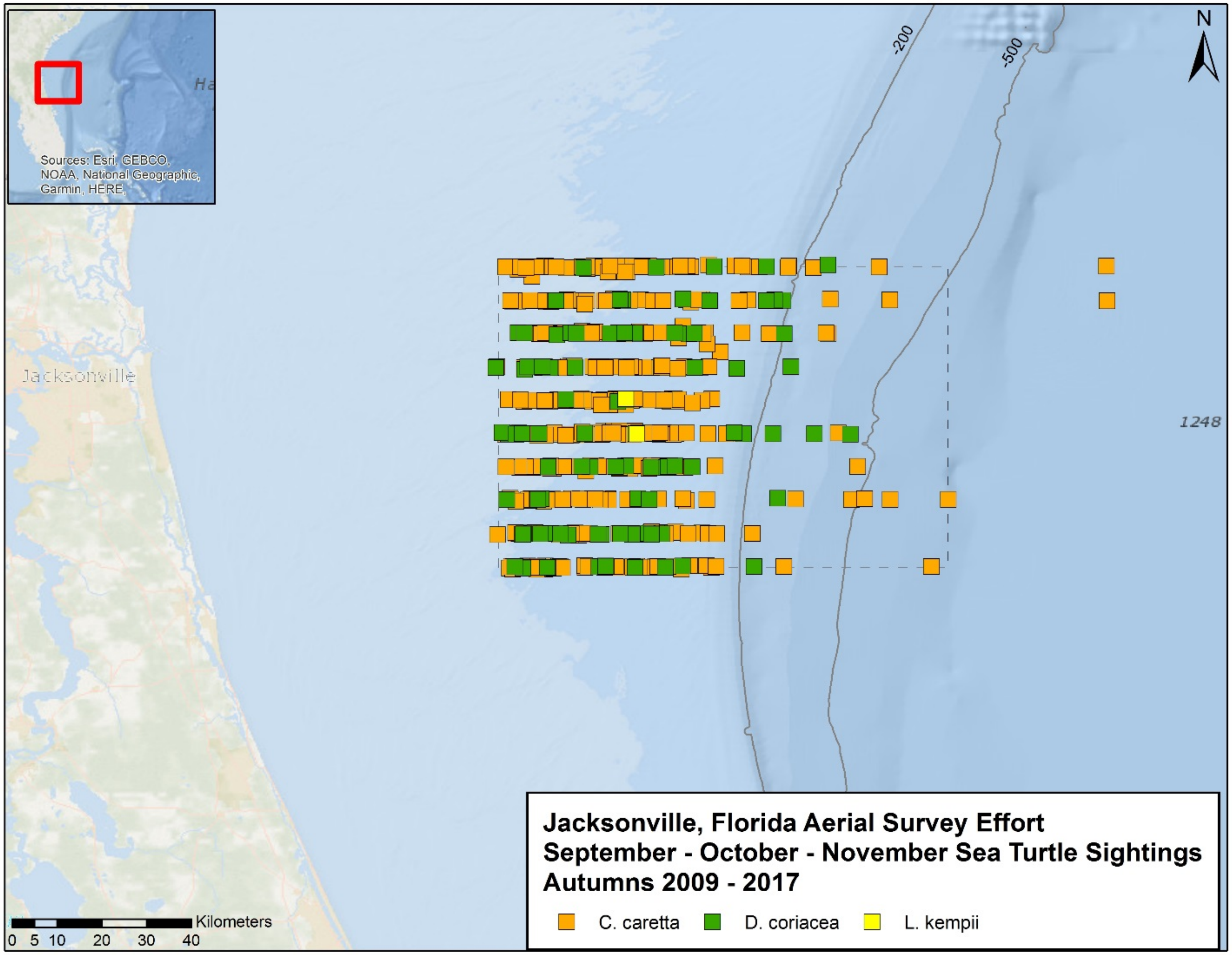


**Figure 5.5. Autumn sea turtle sightings from aerial surveys conducted in the Jacksonville study area, January 2009 – November 2017.**

# 6. Density

Data collected during these surveys were analyzed to estimate density and abundance of marine mammals and sea turtles in the JAX study area. This analysis also included data collected during shipboard surveys in JAX (see Paxton 2018 for details). Maps of estimated density were developed using density surface modeling techniques and abundances were obtained from these maps. These techniques allowed density to vary both spatially and temporally through the explanatory variables included in the models and, as data were collected throughout the year, the effects of seasonal abundance changes (if any) could be investigated. A full account of the density analysis is available in the associated report produced by Paxton (2018).

The abundance estimates presented below should be regarded as a minimum because they do not take into account perception bias on the trackline (*i.e.* not all animals may be detected by the observers) and availability bias (*i.e.* not all animals may be at the surface to be detected). In the case of turtles, the random allocation of unidentified turtles to species probably lessened the bias associated with the estimates, at the cost of making the models less precise.

The JAX USWTR core study area (the “inner” region) is shown in **Figure 6.1**, with the outer survey zone (referred to as “outer”) also shown. The area of the inner region is 1,707 km$^2$ and the area of the outer region (excluding inner) is 4,457 km$^2$. Abundance estimates were obtained for the whole region and for the inner and outer regions separately.

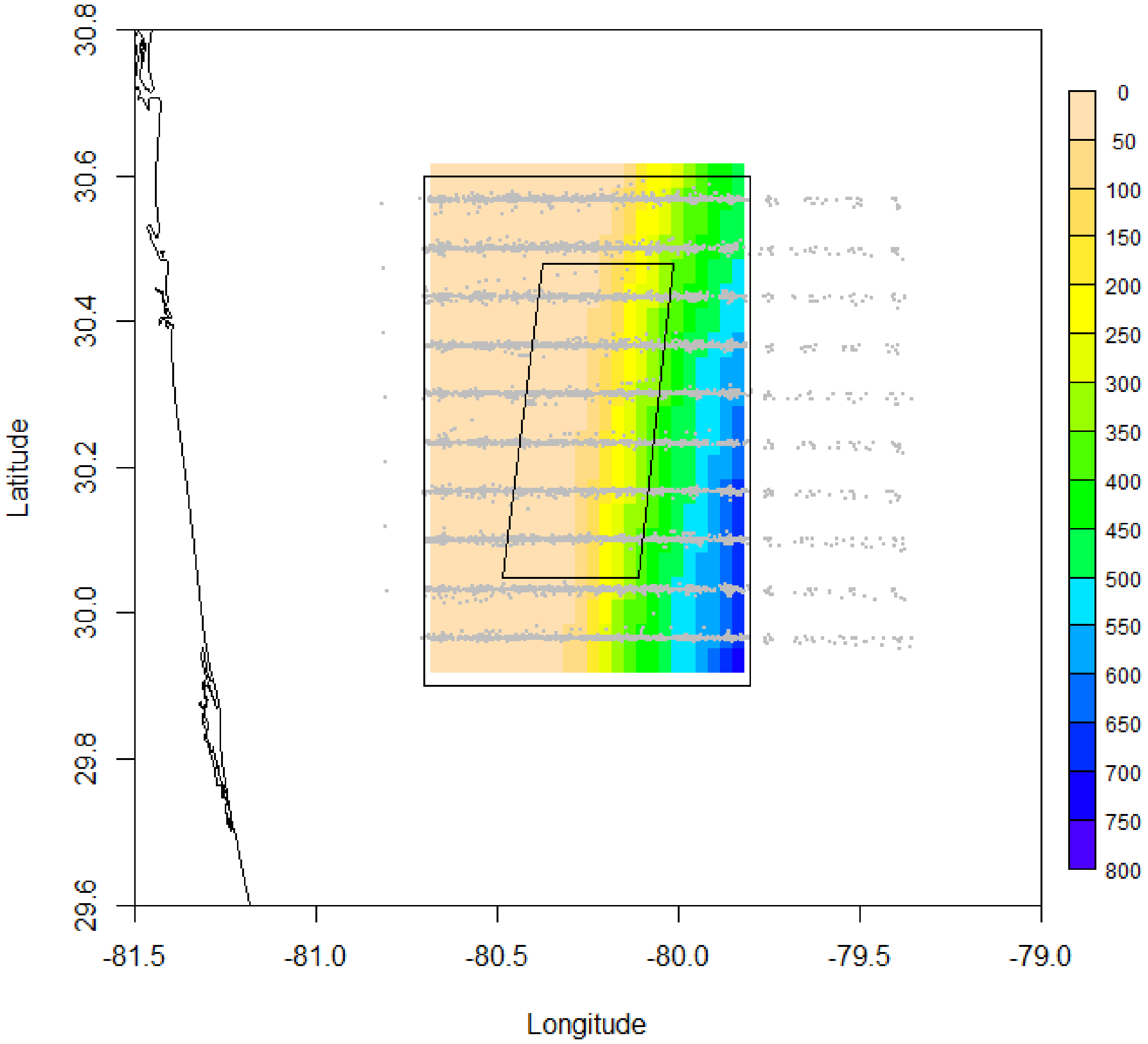


**Figure 6.1. Depiction of the JAX survey area used in analysis of density, with depth (m) indicated by color. Each grid cell is 1/30 degree of latitude and 1/30 of a degree of longitude. Grey dots indicate midpoint of effort segments from all surveys. The boundaries of the outer and inner regions of interest are shown by solid lines.**

## 6.1 Statistical Methods

The aim of the analysis was to estimate a density map for each species (or species group) using the count method of Hedley *et al*. (2004, 1999). However, the numbers of sightings of some species or groups were too few to be able to fit a model reliably to estimate a density surface. Thus, in these cases, a uniform surface was assumed (*i.e.* assuming no temporal or spatial variation) – equivalent to using a conventional line transect sampling estimator (Buckland *et al*. 2001).

For each species, the probability of detection associated with each sighting (assuming certain detection on the trackline) was estimated and this probability was then used to estimate abundance in small segments of the trackline. The estimated segment densities formed the response variable in one or more regression-type models with location, habitat and temporal variables used as potential explanatory variables. After model selection, the chosen models were used to estimate density for the region of interest and abundance was obtained by numerically integrating under the predicted density surface. Note that the resulting abundances are relative (rather than absolute) because they do not take into account imperfect detection on the transect line or the availability of animals at the surface.

In conventional line transect sampling (Buckland *et al*. 2001), the probability of detection depends only on the perpendicular distance of the sighting to the transect ($y$) and at zero perpendicular distance, the probability of detection is assumed to be one (denoted by $g(0)=1$). Both a hazard-rate ($1-\exp(-y/\sigma)^{-b}$) and a half-normal ($\exp(-y^2/2\sigma^2)$) form were considered as suitable forms for the detection functions (σ is a scale parameter) as the most appropriate form for the relevant data (Buckland *et al*. 2001). The effects of covariates, other than perpendicular distance, were incorporated into the detection function model by setting the scale parameter in the model to be an exponential function of the covariates (Marques 2001). Thus, the probability of detection becomes a multivariate function, $g(y,\boldsymbol{v})$, representing the probability of detection at perpendicular distance $y$ and covariates $\boldsymbol{v}$ ($\boldsymbol{v} = v_1,..,v_Q$ where $Q$ is the number of covariates). The scale term, σ, has the form:

$$\sigma = exp\left(\beta_0 + \sum_{q=1}^{Q}\left(\beta_q v_q\right)\right)$$

and $\beta_0$ and $\beta_q$ ($q$=1,…,$Q$) are parameters to be estimated. With this formulation, it is assumed that the covariates affect the rate at which detection probability decreases as a function of distance, but not the shape of the detection function. The covariates considered for inclusion into the aerial detection function were Beaufort sea state (BSS), group size, cloud cover, visibility, glare and species; all but species and group size were treated as continuous variables. Group size was considered both as a continuous and as a factor variable with group sizes above 3 binned into factor levels (1, 2, 3-5, 6-10, 11-20, 21-50, 51-100, 100+). A forward, stepwise selection procedure was used to decide which covariates to include in the model, with a minimum Akaike's Information Criterion (AIC) inclusion criterion. All model selection was performed using the *R* library mrds (v.2.1.14, Laake *et al*. 2013) within the statistical programming package *R 3.4.4.* (*R* Developmental Core Team 2018).

The aerial data from JAX were supplemented by additional aerial data from right whale surveys along the U.S. Mid-Atlantic coast from 2006-2007 conducted by UNCW to increase sample sizes to facilitate detection function fitting for larger whales. Despite this, there were few sightings of individual species and so data were amalgamated across species into groups with presumed similar detectabilities. For aerial detections, three groups were identified with sufficient numbers to allow abundance estimation; all dolphin species, medium-sized cetaceans (pilot whales and kogiids), large cetaceans (balaeanopterids and sperm whales) and sea turtles. For ship detections, two groups were identified for detection function fitting: dolphins and turtles.

Some animals could not be identified to species and were recorded as belonging to a species group (e.g. unidentified turtle). These unidentified animals/groups were assigned on a pro-rata basis to a relevant species.

### 6.1.1 Estimation of Density Surfaces

The ‘count model’ of Hedley *et al*. (2004) was implemented to model the trend in the spatial distribution of the different species. The response variable for this model is the estimated number of individuals in a small segment *i* of trackline, $\hat{N}_i$, calculated using an estimator similar to the Horvitz-Thompson estimator (Horvitz and Thompson 1952), as follows:

$$\hat{N}_i = \sum_{j=1}^{n_i} \frac{s_{ij}}{\int_o^w \hat{g}(y, v_{ij})\pi(y)dy}, \qquad i = 1, \ldots, T,$$

where for segment *i*, $\int_0^w \hat{g}(y, v_{ij})\pi(y)dy$ is the estimated probability of detection of the *j*th detected group, $n_i$ is the number of detected groups in the segment and $s_{ij}$ is the size of the *j*th group. The total number of transect segments is denoted by *T*. By assumption, $\pi(y)$, the probability density function of actual (not necessarily observed) perpendicular distances is uniform up to the truncation distance; this is satisfied by locating transects randomly or with a random start point.

Having obtained the estimated number of individuals in each segment, the density in segment *i*, $\hat{D}_i$, was estimated from $\hat{N}_i / a_i$ where $a_i$ is the area of segment *i*. Given that each segment density estimate is spatio-temporally linked to a variety of covariates, the density can be considered as a dependent variable in a regression type model. Segment area (also used as a weight) was calculated as the length of the segment multiplied by twice the truncation distance (which was decided when modeling the detection function). The realized transect lines were divided into distinct segments, based on when the observers had gone on- or off-effort and when environmental conditions changed. A target segment length of 10 km for the aerial survey was chosen as an appropriate compromise between maximizing the ratio of the number of segments containing sightings to the number of segments not containing sightings, maintaining environmental resolution and giving some measure of spatial independence. However, some segments were much smaller if there was a break in effort or change in environmental conditions. Due to the different sizes of each segment, the segment area was included as a weight in the subsequent model.

Generalized estimating questions (GEEs, Hardin and Hilbe 2002) were used as a way of dealing with the auto-correlated variation in the residuals from the models. Generalized estimating equations provide some advantages over generalized additive equations in that residual autocorrelation and to an extent, zero-inflation are dealt with although they are a little more difficult to implement and models that can be fitted are generally simpler. Their treatment of the autocorrelation makes them more appropriate for explanatory models and in this analysis allows consideration of all the densities in the explanatory models rather than just presences.

The environmental covariates considered for inclusion in the regression models as predictors were the same as in previous years: longitude (*Lon*) and latitude (*Lat*) (suitably transformed to *Eastings* and *Northings*), depth (*Depth*) and sea surface temperature (*SST*), day of the year (*Dayofyear*) and year (*Year*). Depths were obtained from the ETOPO1 one minute resolution relief data available from NOAA (http://www.ngdc.noaa.gov/mgg/global/global.html). Depths were associated with effort segments by finding the closest point in the bathymetry data to the midpoint of the effort segments using great circle distances. *SST* was obtained from NOAA Optimum Interpolation 1/4 Degree Daily Sea Surface Temperature data obtained from the Advanced Very High Resolution Radiometer (AVHRR) available from ftp://eclipse.ncdc.noaa.gov/pub/OI-daily-v2/NetCDF/ as described in part in Reynolds *et al*. 2002. *SST* was allocated to the appropriate segment by great circle distance and appropriate date.

All non-factor covariates were considered for inclusion in the model as one dimensional (1D) b-spline smooths (using the *Splines library* in *R*, Bates and Venables 2016) of the covariate values. *Easting* and *Northing* were also considered as a smooth interaction. Taking into account the low percentage of segments containing sightings, a maximum of 4 degrees of freedom was initially allowed in the selection of 1D smooths and 4 degrees of freedom was allowed in the case of the smooth interaction (i.e 4 for *Easting* and *Northing* each), thus allowing moderate flexibility but reducing the possibility of fitting unrealistically complicated functions. In the case of *Year,* the maximum allowed degrees of freedom was 3 because of the small range of years.

There were two modeling aims: (1) understanding habitat associations; and (2) predicting density, so two types of regression models were built. Unsurprisingly, *SST* was strongly correlated with *Dayofyear* (**Figure 6.2**)*; Easting* was also correlated with *Depth*. Thus, the inclusion of only one of these correlated variables in the final models should not be interpreted as necessarily precluding the influence of others. In the case of *SST* and *Dayofyear,* only one of these terms was allowed in the final models. Model selection was backward (i.e. starting with explanatory variables in the model and removing variables one at a time) using a P<0.05 inclusion probability. Selection proceeded as follows: first, all explanatory variables were fitted (*Survey, SST* or *Dayofyear*, *Depth* and *Year);* a decision was made to include *Dayofyear* or *SST* based on the variable with the lowest probability. Backwards selection then followed until an explanatory model was found. *Easting* and *Northing* were then added to the model initially as two 3-way interactions with *Year* and *Dayofyear* or *SST*. Then there was selection on the smooth interaction followed by backwards selection on the remaining 1D smooth variables to produce the final predicative model.

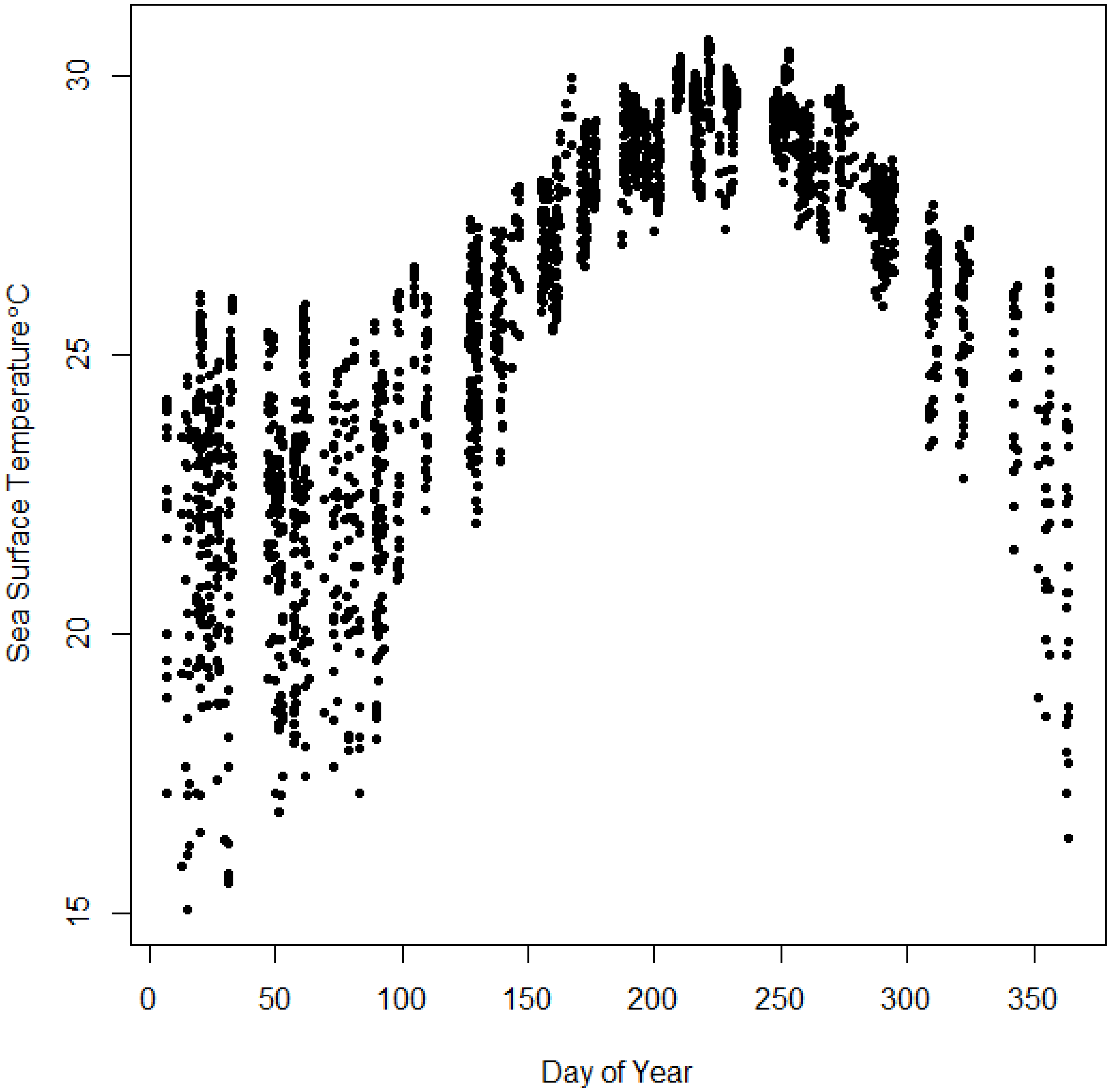


**Figure 6.2. Relationship between day of year and AVHRR-derived sea surface temperature (°C) for each segment of survey effort.**

### 6.1.2 Prediction

The selected models were used to predict the density of marine mammals and sea turtles in the total region, and in the inner and outer regions separately, using a two-minute resolution prediction grid. Animal abundance was estimated by numerically integrating under this predicted density surface. If survey platform was included in the model, abundance was predicted setting the variable *Survey* equal to “aerial” as this was the most recent survey technique; no vessel survey has been undertaken since 2011.

### 6.1.3 Estimation of Uncertainty

Variance for the uniform models was estimated by repeating (500 times) the entire abundance estimation process on samples drawn from the data to obtain a distribution of abundance estimates. Samples were obtained by sampling transects (and associated sightings), at random and with replacement, such that the selected effort reflected the effort in the original sample. For species with complex spatial models, uncertainty estimation was as above, with the addition of parametric bootstraps based on the spatial model by adding variation to the covariance matrix of the GEE model to obtain a new set of model coefficients to deal with the spatial correlation in the data. Confidence intervals were obtained from this resampling-derived distribution using the 2.5% and 97.5% percentiles to obtain the lower and upper limits, respectively, thus excluding extreme values. In the case of loggerhead turtles a small number of pathological bootstraps with unrealistically high predicted densities were also removed.

## 6.2 Results

### 6.2.1 Summary of Survey Effort and Sightings

The aerial surveys yielded 93,305 km of search effort (99,915 segments) and the vessel surveys realized 2,413 km of search effort in 600 segments. The breakdown of effort by month is given in **Table 6.1**.

**Table 6.1. Realized monthly effort (km) in the Jacksonville survey area. No line-transect vessel surveys were conducted after 2011.**

| Month | 2009 | | 2010 | | 2011 | | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Aerial | Boat | Aerial | Boat | Aerial | Boat | Aerial | Aerial | Aerial | Aerial | Aerial | Aerial |
| January | 888 | 0 | 3881 | 207 | 1692 | 138 | 1658 | 0 | 1009 | 0 | 838 | 0 |
| February | 1706 | 0 | 2536 | 0 | 1268 | 0 | 0 | 0 | 2159 | 0 | 859 | 1291 |
| March | 431 | 0 | 1680 | 139 | 0 | 205 | 559 | 863 | 1681 | 887 | 1295 | 0 |
| April | 0 | 0 | 2047 | 0 | 1541 | 0 | 1710 | 0 | 0 | 602 | 0 | 0 |
| May | 0 | 0 | 811 | 145 | 1330 | 0 | 1606 | 1635 | 1701 | 0 | 1121 | 1306 |
| June | 1683 | 0 | 3011 | 309 | 1029 | 0 | 0 | 890 | 1325 | 0 | 0 | 0 |
| July | 1708 | 166 | 1024 | 225 | 1690 | 0 | 1692 | 0 | 1458 | 0 | 0 | 1286 |
| August | 1696 | 256 | 1696 | 36 | 1680 | 0 | 0 | 0 | 1370 | 1280 | 0 | 0 |
| September | 3309 | 210 | 1643 | 0 | 1363 | 0 | 1279 | 1873 | 1682 | 0 | 0 | 0 |
| October | 822 | 137 | 1534 | 171 | 847 | 0 | 0 | 651 | 1155 | 1713 | 0 | 0 |
| November | 1688 | 0 | 860 | 0 | 0 | 0 | 1334 | 0 | 0 | 0 | 0 | 772 |
| December | 1816 | 0 | 1846 | 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Sightings in each species or species group from the aerial surveys used for detection purposes are summarized in **Table 6.2**. Sixty-eight sightings of unidentified delphinids within the truncation distance were allocated on a pro-rated basis to identified species. Most (81%) dolphin sightings were of animals in groups of fewer than 20, however, a group of 100 spotted dolphins was detected in January 2009. This random allocation was considered in the bootstrap.

Kemp’s Ridley turtles were represented by only three sightings. An additional 451 groups of turtles were detected but could not be identified to species (these were randomly assigned to identified species on a pro-rata basis). Species was considered as a covariate but with only a few sightings of Kemp’s Ridley turtle within the truncation distance estimating coefficient values reliably proved difficult, so Kemp’s Ridley sightings (real Kemp’s Ridley and allocated ones) were omitted from the data prior to detection function fitting. Again the uncertainty in the allocation of unknown sightings to known species was incorporated into the bootstrap.

Sixty-one groups of dolphins were detected during vessel surveys within the truncation distance, comprised by spotted (36), bottlenose (24) and one group of unidentified delphinids. Most dolphins observed during vessel surveys were in groups of between one and ten animals. The maximum group size was 55 spotted dolphins recorded in October 2010. No medium-sized cetaceans or large whales were detected during the ship surveys.

Sixty-six groups of turtles were detected during vessel surveys within the truncation distance, made up of loggerhead (56) and leatherback (10) turtles. One group of two loggerhead turtles was detected otherwise all other sightings of turtles were of single animals.

**Table 6.2. Summary of detection function models; number of detected groups (n) within the given truncation distances, detection function (DF) form (half normal HN or hazard rate HR), covariates added in addition to perpendicular distance and detection probability within the truncation distance.**

| Species | Survey | *n* | Truncation distance (m)* | DF form | Additional Covariates | Detection probability (se) |
|---|---|---|---|---|---|---|
| Dolphin | Aerial | 851 | 1200 | HR | Visibility + BSS | 0.320 (0.028) |
| | Ship | 61 | 250 | HR | BSS + Weather | 0.287 (0.039) |
| Turtles | Aerial | 3095 | 888 | HR | Group Size + Visibility | 0.310 0.006) |
| | Ship | 66 | 80 | HN | Weather | 0.486 (0.115) |
| Medium cetaceans | Aerial | 23 | 1000 | HN | Not considered | 0.526 (0.091) |
| | Ship | 0 | Assumed 250 | - | - | - |
| Big cetaceans | Aerial | 17 | 1000 | HN | Not considered | 0.594 (0.129) |
| | Ship | 0 | Assumed 250 | - | - | - |

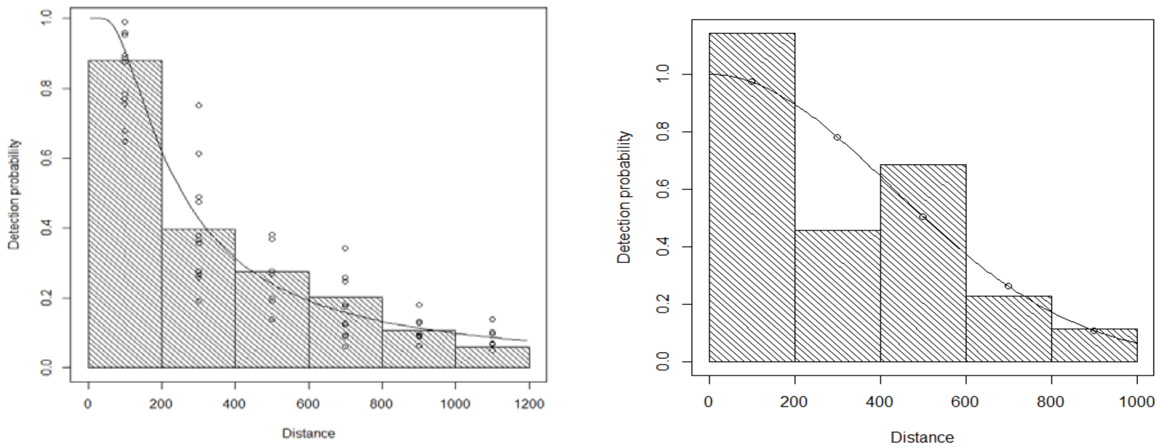
## 6.2.2 Detection Functions

The scaled histograms of perpendicular distances (after truncation) and the fitted detection functions are shown in **Figures 6.3** and **6.4** with details provided in **Table 6.2**. Perpendicular distances were binned into intervals for model fitting and to avoid a long tail in the detection function (Buckland *et al*. 2001); typically, between 5 -10% of the longest distances were truncated.

Of particular note was that aerial perpendicular distances for all species were left truncated at 149m. This was because, at the flying height of 305m, a strip of width 149m away from the trackline could not be seen and so any sightings within this distance must have been misestimated.

*a. dolphins*

*b. medium-sized cetaceans*



*c. large whales*

*d. turtles*

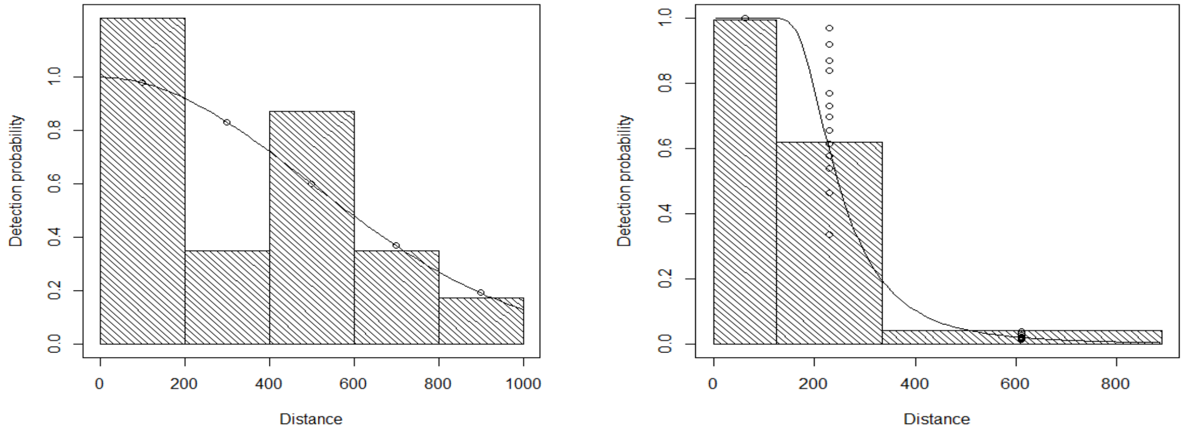


**Figure 6.3. Aerial survey detections:fitted detection functions overlaid onto scaled perpendicular distance distributions (data binned into 200m distance intervals for cetaceans); a. dolphins, b. medium-sized cetaceans, c. large whales and d. turtles. The points are individual detections and do not lie on the fitted curve when there are additional covariates.**

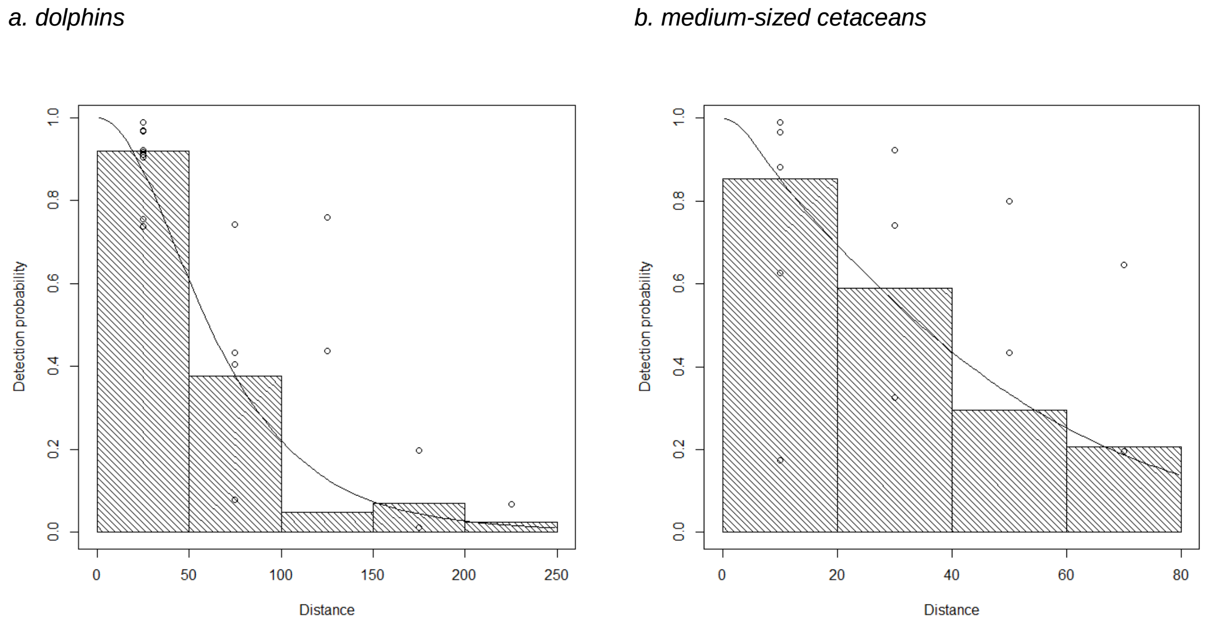


**Figure 6.4. Vessel survey detections: fitted detection functions overlaid onto scaled perpendicular distance distributions; a. dolphins (data binned into 50m sections), b. turtles (data binned into 20m sections).**

**Table 6.3. Adjusted detection probability corrected observed aerial densities $\hat{D}$ assuming no spatio-temporal change. 95% confidence intervals are given in parentheses. % non-zero segments is the number of segments containing detections.**

| Species | Predicted densities | Inner region uniform abundance | Outer region uniform abundance | % non-zero segments |
|---|---|---|---|---|
| Bottlenose dolphin | 0.050<br>(0.040 – 0.065) | 85 (70 – 110) | 220 (180 – 290) | 4 |
| Spotted dolphin | 0.084<br>(0.067 – 0.109) | 140 (120 – 190) | 370 (300 – 490) | 4 |
| Large whales | 0.0002<br>(0 – 0.0003) | <1 | <1 | 0.1 |
| Pilot whales | 0.003<br>(0.001 – 0.004) | 4 (2 – 7) | 12 (4 – 19) | 0.2 |
| Loggerhead turtles | 0.073<br>(0.066 – 0.081) | 120 (110 – 140) | 330 (300 – 360) | 18.1 |
| Leatherback turtles | 0.004<br>(0.004 – 0.005) | 8 (6 – 9) | 20 (16 – 24) | 2.0 |

### 6.2.3 Density Surface Models

The aerial search effort was divided into 9,915 segments with a mean length 9.41 km (maximum length 15 km). The ship effort was divided into 600 segments with a mean length of 4.02 km (maximum length 14.1 km). Estimates of abundance are given in **Table 6.3** and summaries of the fitted predictive models are given in **Tables 6.4** and **6.5**.

**Table 6.4. Summary of explanatory density surface models: selected model (where bs(variable) indicates a smooth function of variable) and percentage of deviance explained by the model. The total number of segments was 10,515 and % non-zero segments are calculated the same as in the previous table.**

| Species | Model | Natarajan et al.'s (2007) "coefficient of determination" |
|---|---|---|
| Bottlenose dolphins | Survey + s(Dayofyear, df=4) | <1% |
| *Stenella* sp. | Survey2+ s(Depth,df=4) + s(Year,df=3) + s(Dayofyear,df=4) | 3% |
| Loggerhead turtles | Survey2 + Year + s(Dayofyear, df=3)+s(Depth,df=4) | 7% |

**Table 6.5. Summary of density surface models used for abundance estimation: selected model (where s(var) indicates a smooth function of var) and percentage of deviance explained by the model.**

| Species | Model | Natarajan et al.'s (2007) "coefficient of determination" |
|---|---|---|
| Bottlenose dolphins | Survey + bs(Northing,df=4) * bs(Easting, df=4) *s(Dayofyear,df=4) | 1% |
| *Stenella* sp. | Survey + bs(Northing,df=3) * bs(Easting, df=4) + s(Dayofyear,df=4)+bs(Year, df=3) +bs(Depth, df=4) | 11.8% |
| Loggerhead turtles | Survey+s(Northing, df = 3)* bs(Easting, df=3)+ s(Depth,df=4) + bs(Easting, df=3)* bs(Dayofyear,df=3) + Year | 11% |

#### 6.2.3.1 BOTTLENOSE DOLPHINS

Only *Survey* and *Dayofyear* were included in the explanatory model (**Table 6.4**) and when assuming an aerial survey the predicted surface abundance was sufficiently low that no significantly different months were discernible. There is great uncertainty in the January and December figures caused by the low survey effort during these months, as suitable weather windows were rare (**Figure 6.5**).

A spatio-temporal model for the data could be fit, although it explained little of the variation so it is plausible that the animals are simply uniformly distributed over the survey area (**Figure 6.6**). Visual inspection of the data suggests no pattern in the sightings and it may well be that bottlenose dolphin do not have strong habitat preferences in this region.

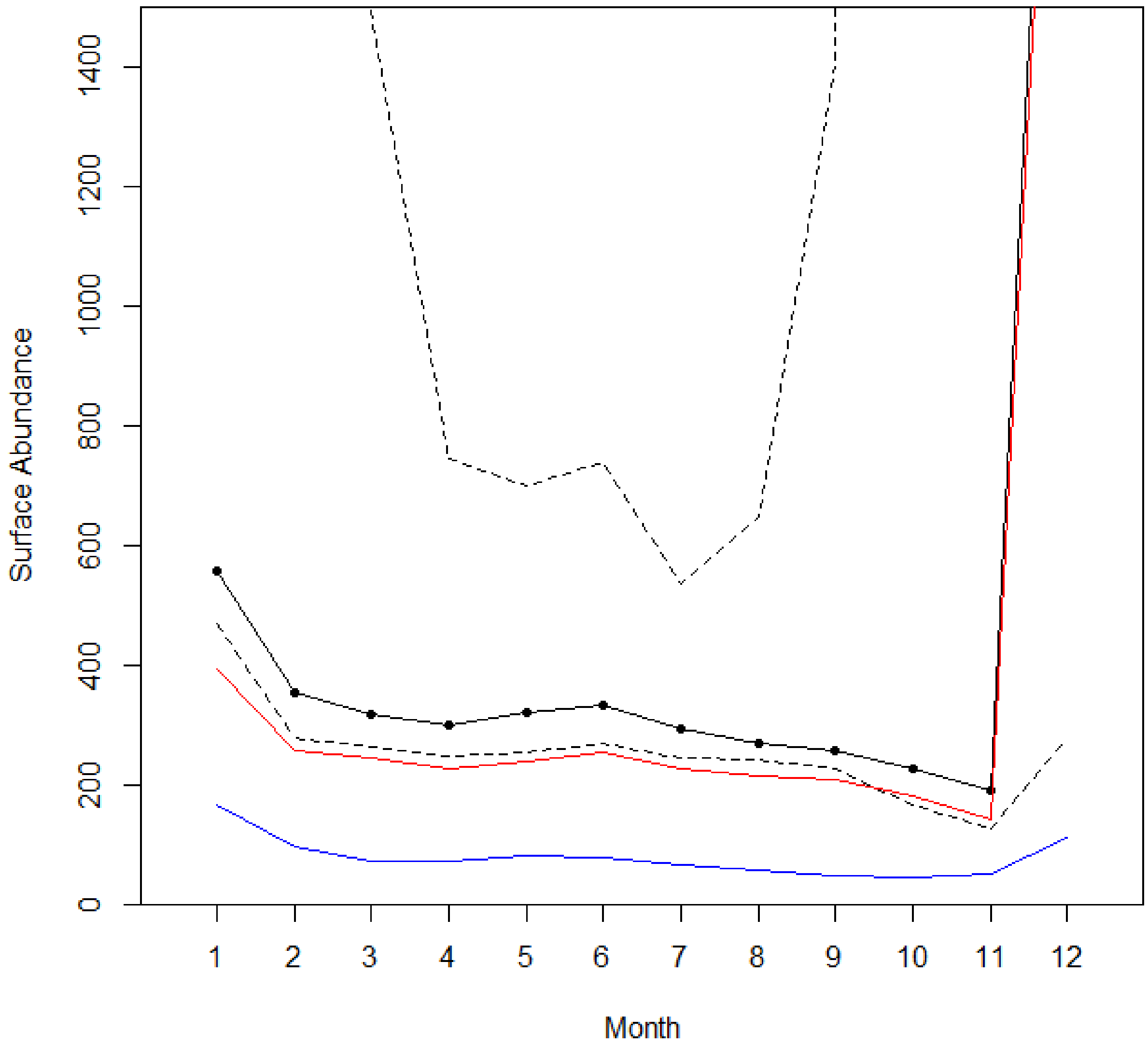


**Figure 6.5. Predicted surface abundance of bottlenose dolphins. Black indicates abundance estimates for the whole region and red and blue represents the abundance estimates for the outer and inner areas, respectively. Dashed lines represent the upper and lower 95% confidence bounds for the abundance estimates for the whole region.**

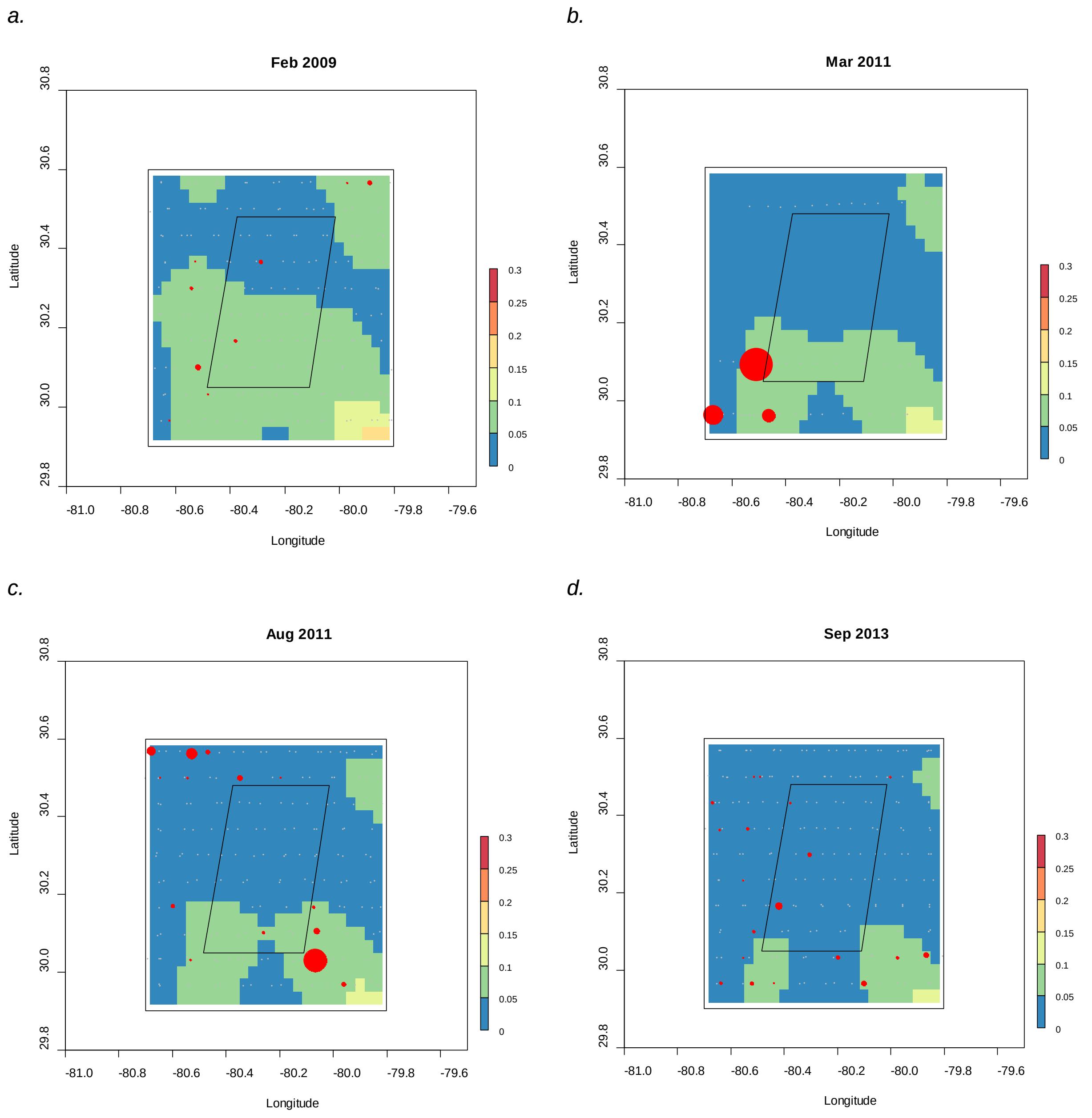


**Figure 6.6. Predicted surface density of bottlenose dolphins with representative months for each quarter. Colors indicate the density of surface animals per km$^2$. Grey points indicate the midpoints of effort segments for that month. The red circles indicate observed animals in the month seen (given for example for 2009, 2011 & 2013). The area of the circle is proportionate to the adjusted observed density.**

### 6.2.3.2 SPOTTED DOLPHINS

Explanatory model selection retained *Depth* (**Figure 6.7**), *Dayofyear* and *Year* (**Figure 6.8**). As noted above, spotted dolphins avoid the deeper waters offshore of the shelf break (**Figures 6.7** and **6.9**). The increased uncertainty in the response to *Depth* in deeper waters is caused by a paucity of data. Seasonality is very obvious in this data set (**Figure 6.9**) with increases in spotted dolphins in spring and autumn. From the predictive model, the minimum estimate over the entire area was 187 (50 – 380) in December 2015 (an unsurveyed month) and the maximum was 1,500 (800 – 2,380) in March 2017 (an unsurveyed month).

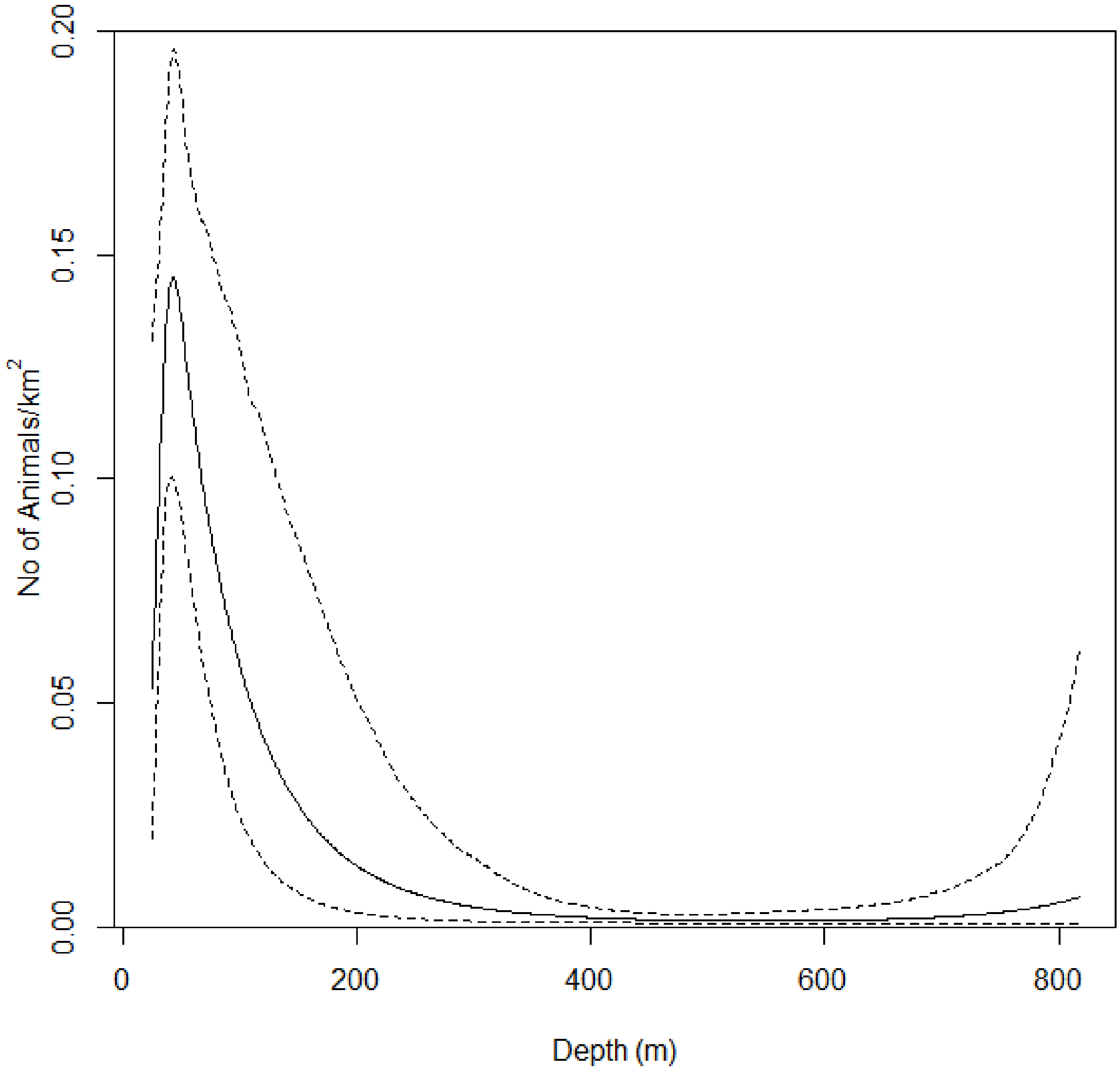


**Figure 6.7. Spotted dolphin density in response to *Depth* (assuming the 1$^{st}$ June 2012).**

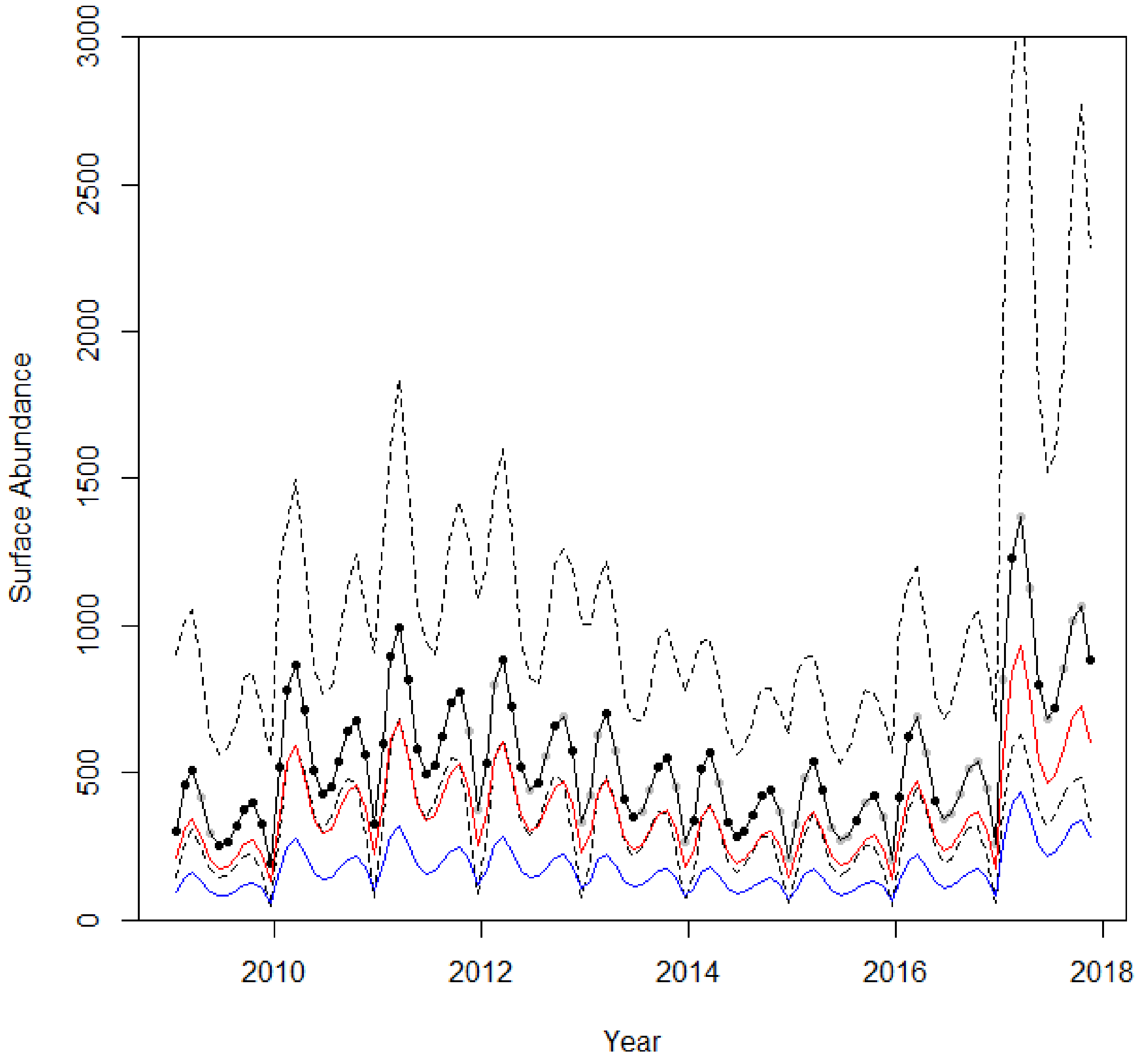


**Figure 6.8. Predicted surface abundance of spotted dolphins. Black indicates abundance estimates for the whole region and red and blue represents the abundance estimates for the outer and inner areas, respectively. Dashed lines represent the upper and lower 95% confidence bounds for the abundance estimates for the whole region. Black points indicate when there was effort as opposed to grey points indicating where there was no effort.**

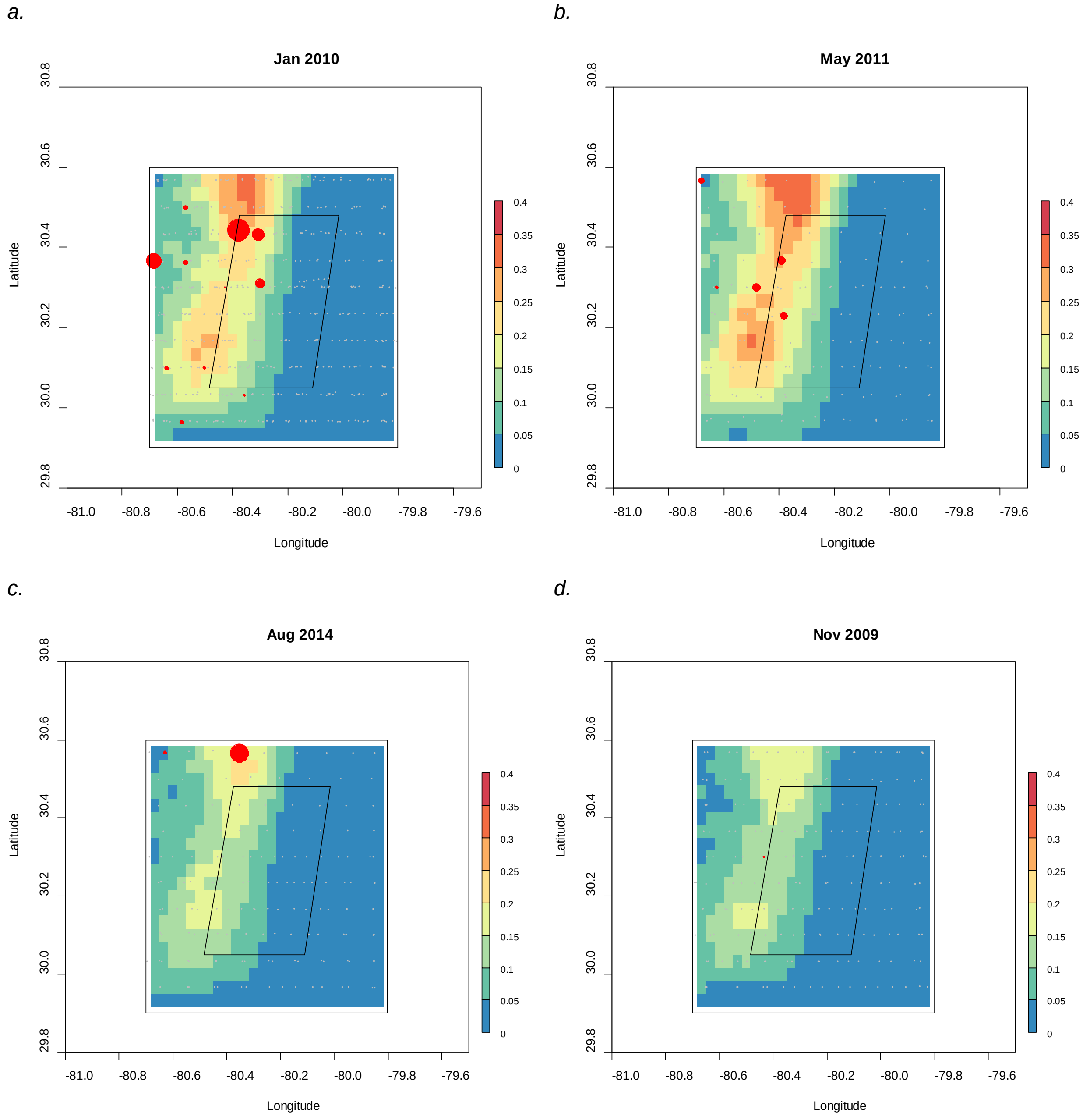


**Figure 6.9. Predicted surface density of spotted dolphins with representative months of each quarter. Colors indicate the density of surface animals per km$^2$. Grey points indicate the midpoints of effort segments for that month.**

### 6.2.3.3 MEDIUM-SIZED CETACEANS

Medium-sized cetacean groups were only detected in a few segments (**Table 6.3**) and so no model was fitted except for a *Survey* effect.

### 6.2.3.4 LARGE WHALES

With so few detections over nine years of surveys, it can be concluded with some assurance that the abundance of large whales in JAX is very low (**Table 6.3**).

### 6.2.3.5 LOGGERHEAD TURTLES

The best explanatory model can be seen in **Table 6.4** and the response of *Depth* can be seen in **Figure 6.10**. A clear preference for shallower water is apparent for this species. Model selection retained *Dayofyear* (as a spline with 3 df), so to obtain a clear picture of the seasonal/ temperature effects a further model was fitted with *SST* rather than *Dayofyear* (**Figure 6.11**).

Loggerhead turtles were found in a relatively large proportion of effort segments compared to the other species of turtles and indeed cetaceans. There is an observed decline in numbers over the last few years. The lowest predicted minimum abundance over the whole region was in December 2016 (an unsurveyed month) and the highest was in May 2009 (an unsurveyed month). However, November 2017 (a surveyed month) had a predicted density almost equal to that of December 2016. Loggerhead turtles exhibit a moderately consistent seasonality with very few seen in December (**Figure 6.12**). High abundances were never predicted for the deeper part of the survey region (**Figure 6.13**).

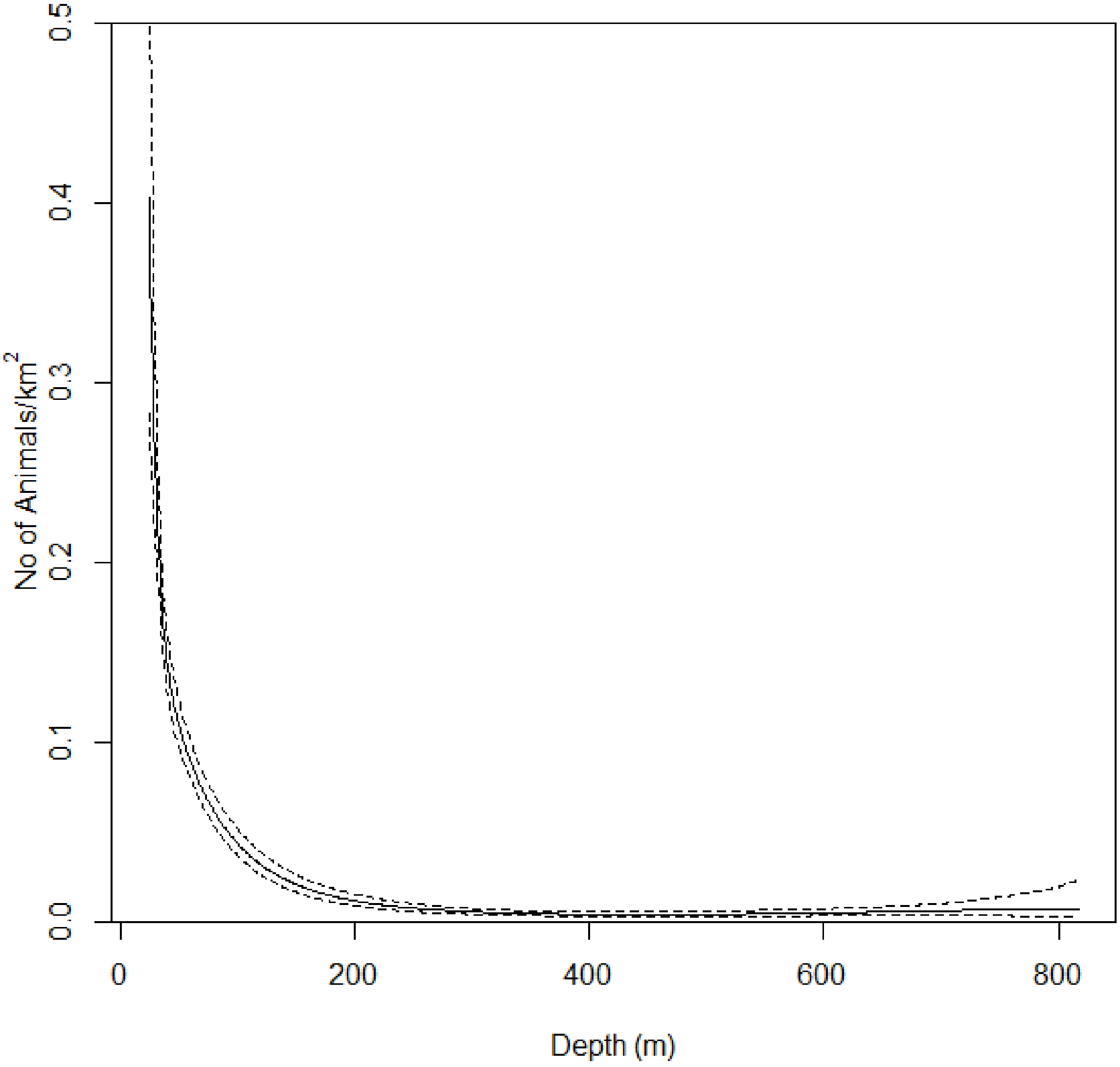


**Figure 6.10. Loggerhead turtle estimated density in response to *Depth* (assuming a survey in 2012, 25.7°C, and day 183) and SST (assuming a survey in 2012, 212m and day 183).**

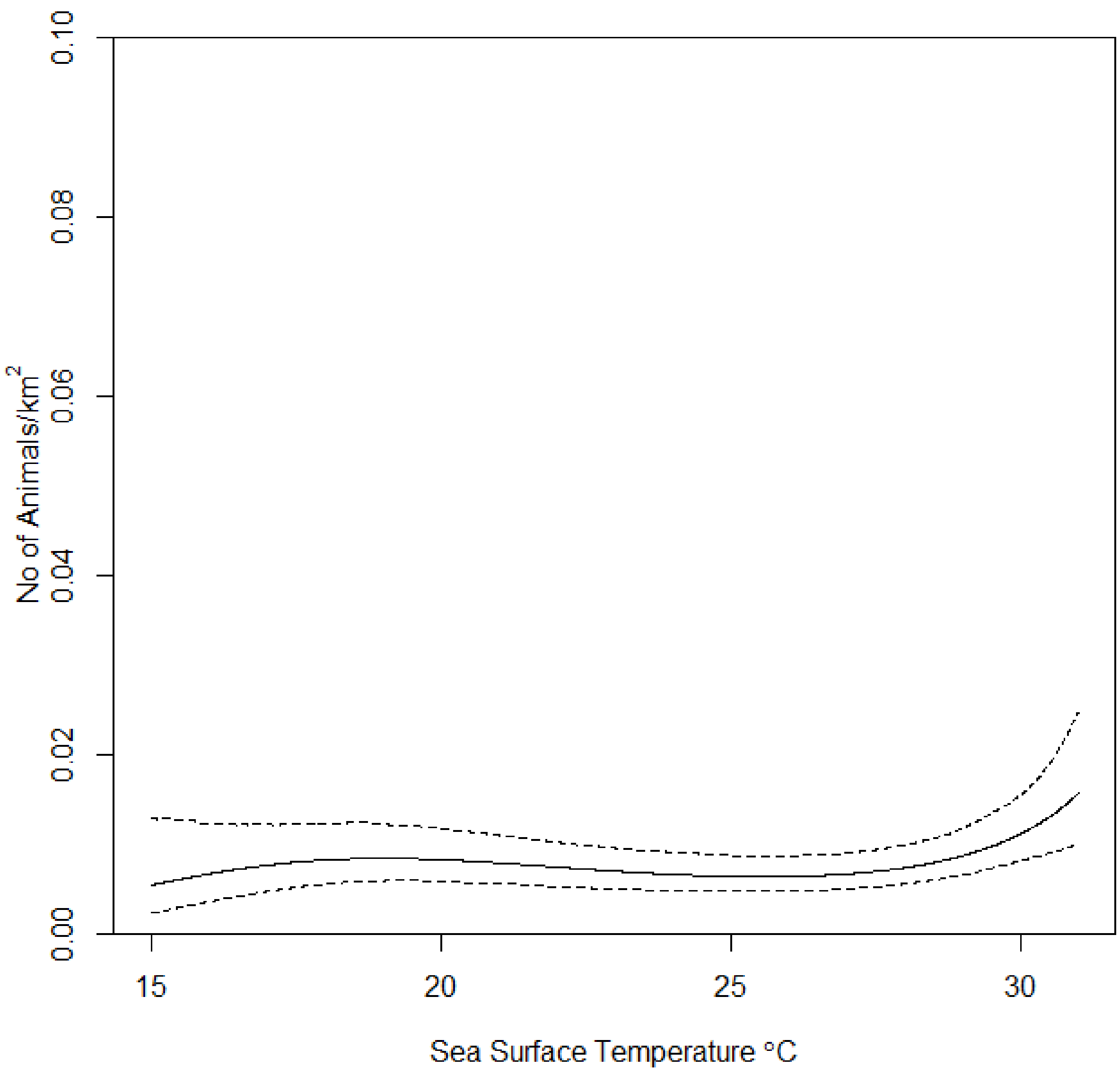


**Figure 6.11. Loggerhead turtle estimated density in response to SST assuming a survey in 2012 in water of 100m.**

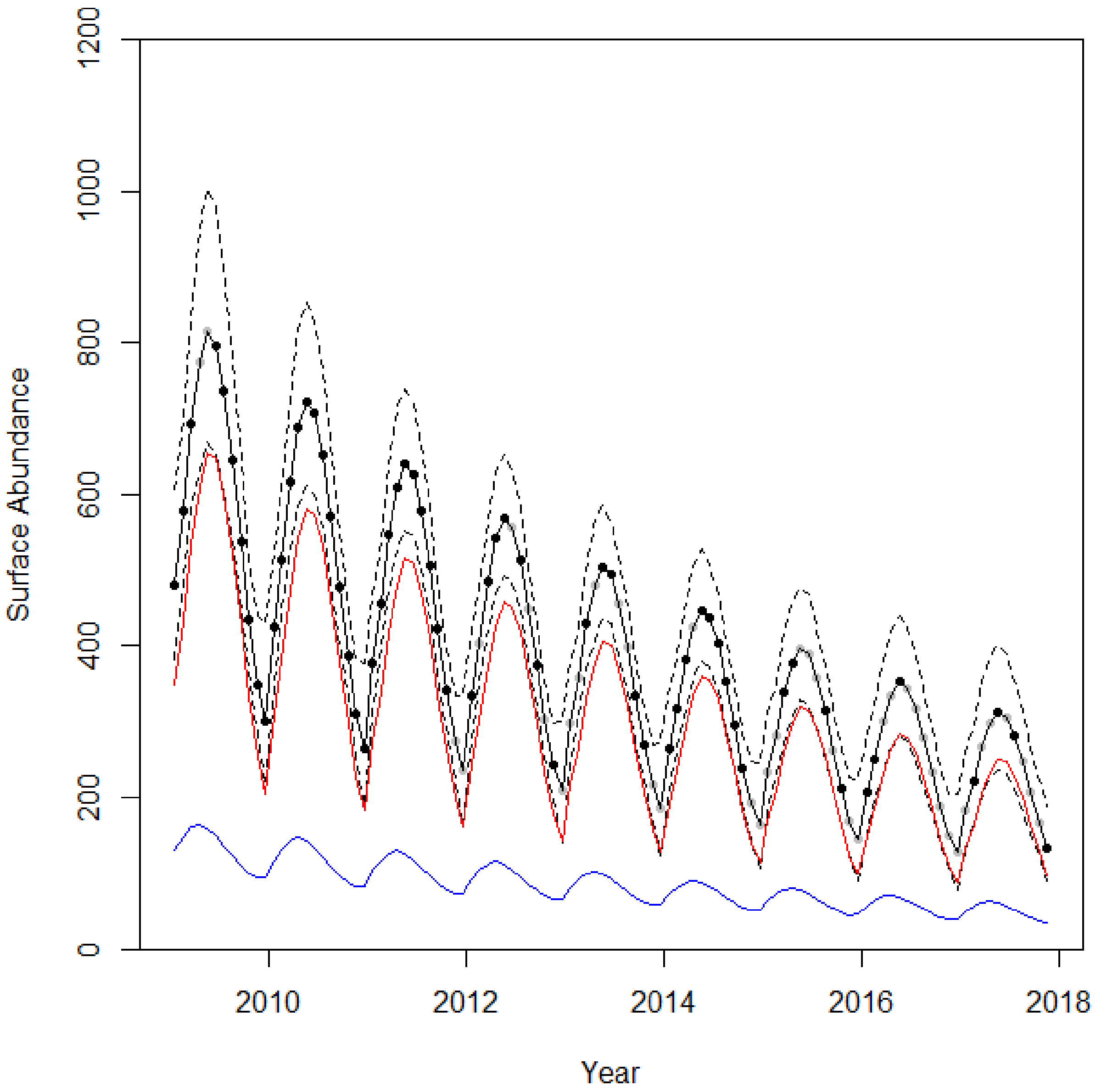


**Figure 6.12. Predicted surface abundance of loggerhead turtles. Black indicates abundance estimates for the whole region and red and blue represent the abundance estimates for the inner and outer areas, respectively. Dashed line is the 95% confidence interval for the total region. Black points indicate when there was effort as opposed to grey points indicating where there was no effort.**

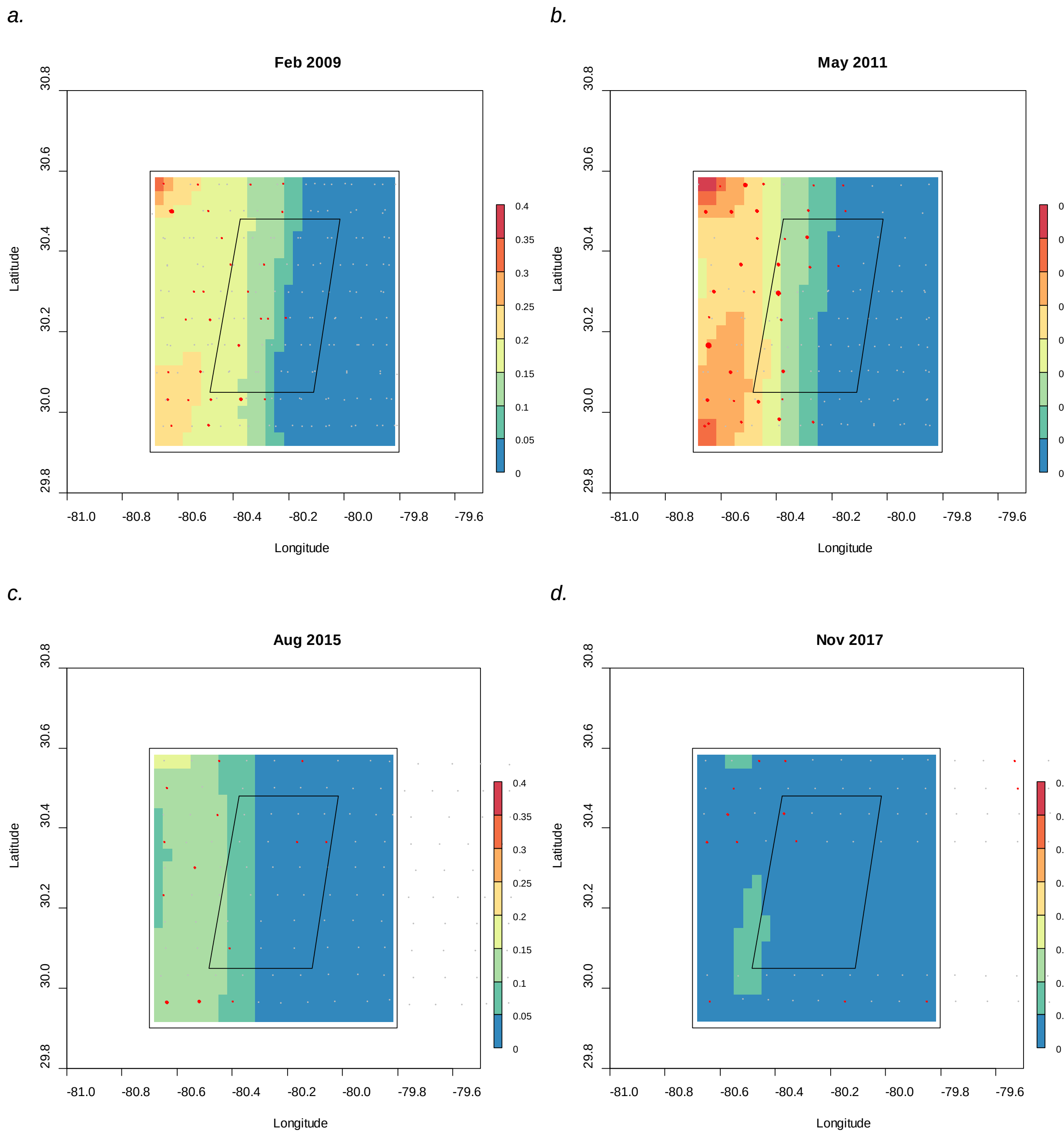


**Figure 6.13. Predicted surface abundance of loggerhead turtles. Colours indicate the density of surface animals per km$^2$. Grey points indicate the midpoints of effort segments and the area of the red circles is proportional to the adjusted density of observed animals per km$^2$.**

# 7. Data Contributions to OBIS-SEAMAP

During the course of this project, large volumes of geo-referenced data on survey effort and sightings were generated and submitted to OBIS-SEAMAP (http://seamap.env.duke.edu), a spatially referenced online database, hosted by Duke University, that aggregates marine mammal, seabird and sea turtle observation data from across the globe. At the outset of the project all consortium participants made a full commitment to make all data available to the public, to ensure transparency and allow oversight by all interested stakeholders. All aerial survey data sets published by UNCW and all vessel data credited to Duke University have been uploaded into OBIS-SEAMAP, forming the second largest contribution of geo-referenced data to this online data portal.

# 8. Publications and Presentations

Cummings E., R. McAlarney, W. McLellan, and D.A. Pabst. 2018. Protected Species Monitoring in the Jacksonville OPAREA, Jacksonville, Florida, January 2017–December 2017 Report. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-10-D-3011, Task Orders 14, 38, 49, 58 and 05, issued to HDR, Inc., Virginia Beach, Virginia. 1 February 2018.

Cummings E., R. McAlarney, W. McLellan, and D.A. Pabst. 2017. Protected Species Monitoring in the Jacksonville OPAREA, Jacksonville, Florida, January 2016–December 2016. *Draft Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-10-D-3011, Task Orders 14, 38, 49, 58, and 05, issued to HDR, Inc., Virginia Beach, Virginia. 1 February 2017.

Cummings E., R. McAlarney, W. McLellan, and D.A. Pabst. 2015. Protected Species Monitoring in the Jacksonville OPAREA, Jacksonville, Florida, January 2015–December 2015. *Draft Report.* Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-10-D-3011, Task Orders 14, 38, 49, 58 and 05, issued to HDR, Inc., Virginia Beach, Virginia. 12 February 2016.

Cummings, E.W., McAlarney, R.J., Nilsson, P.B., Foley, H.J., Hardee, R.E., Holt, R.C., Pabst, D.A., and McLellan, W.A. 2012. Jacksonville Aerial Surveys – Annual Report to the US Navy. Report submitted to the Department of the Navy, Norfolk, VA.

Foley, H.J., R.J. McAlarney, Z.T. Swaim, E.W. Cummings, L.W. Hodge, R.C. Holt, P.B. Nilsson, R.E. Hardee, W.A. McLellan, D.A. Pabst, and A.J. Read. 2013. Protected Species Monitoring in the Proposed Undersea Warfare Training Range offshore of Jacksonville, FL. Abstracts, Southeast and Mid-Atlantic Marine Mammals Symposium, 22-24 March 2013. Jacksonville, Florida. Oral presentation.

Foley, H. J., R. C. Holt, R. E. Hardee, P. B. Nilsson, K. A. Jackson, A. J. Read, D. A. Pabst, and W. A. McLellan. 2011. Observations of a western North Atlantic right whale (*Eubalaena glacialis*) birth offshore of the protected southeast U.S. critical habitat. *Marine Mammal Science* 27(3): E234-E240.

Foley, H. J., P. B. Nilsson, R. E. Hardee, R. C. Holt, W. A. McLellan, D. A. Pabst, and A. J. Read. 2011. Occurrence and distribution of marine mammals in a proposed Undersea Warfare Training Range off Jacksonville, FL. Abstracts, Nineteenth Biennial Conference on the Biology of Marine Mammals. 27 November-3 December 2011. Tampa, Florida.

Foley, H. J., R. C. Holt, R. E. Hardee, P. B. Nilsson, K. A. Jackson, A. J. Read, D. A. Pabst, and W. A. McLellan. 2010. Observations of a western North Atlantic right whale (*Eubalaena glacialis*) birth offshore of the protected Southeast U.S. critical habitat. Presentation, North Atlantic Right Whale Consortium Annual Meeting. 3-4 November 2010. New Bedford, Massachusetts.

Foley, H.J., Holt, R.C., Hardee, R.E., Nilsson, P.B., Jackson, K.A., Read, A.J., Pabst, D.A. and W.A. McLellan. Observations of a North Atlantic right whale (*Eubalaena glacialis*) birth offshore

of the protected Southeast U.S. critical habitat. Abstracts, Southeast Implementation Team Meeting, October 2010. Jacksonville, Florida.

Hodge, L.E.W., S. Baumann-Pickering, J.A. Hildebrand, J.T. Bell, E.W. Cummings, H.J. Foley, R.J. McAlarney, W.A. McLellan, D.A. Pabst, Z.T. Swaim, D.M. Waples, and A.J. Read. 2018. Heard but not seen: Occurrence of *Kogia* spp. along the western North Atlantic shelf break. Marine Mammal Science.

Holt, R. C., P. B. Nilsson, H. J. Foley, R. E. Hardee, R. J. McAlarney, E. W. Cummings, D. W. Johnston, M. S. Soldevilla, W. A. McLellan, D. A. Pabst, and A. J. Read. 2011. Protected species monitoring in the proposed Undersea Warfare Training Range offshore of Jacksonville, FL: January – December 2010. Abstracts, SEAMAMMS (Southeast and Mid-Atlantic Marine Mammal Symposium). 1-3 April 2011. Conway, South Carolina.

McAlarney, R., E. Cummings, H. Foley, R. Hardee, L. Hodge, R. Holt, P. Nilsson, W. McLellan, D.A. Pabst, and A. Read. 2013. Winter occurrence of minke whales (*Balaenoptera acutorostrata*) in the South Atlantic Bight. Abstracts, Southeast and Mid-Atlantic Marine Mammal Symposium, 22-24 March 2013. Jacksonville, Florida. Poster presentation.

McAlarney, R.J., E.W. Cummings, D.A. Pabst, and W.A. McLellan. 2015. Protected Species Monitoring in the Jacksonville OPAREA Jacksonville, Florida, January 2014 - December 2014. In: *Annual Report 2014*. Submitted to The Department of the Navy, Norfolk, Virginia.

McAlarney, R.J., E.W. Cummings, D.A. Pabst, and W.A. McLellan. 2014. Protected Species Monitoring in the Jacksonville OPAREA Jacksonville, Florida, January 2013 - December 2013. In: *Annual Report 2013*. Submitted to The Department of the Navy, Norfolk, Virginia.

McAlarney, R.J., Cummings, E.E., Pabst, D.A., McLellan, W.A., Aerial Surveys of the proposed Undersea Warfare Training Range (USWTR) in Jacksonville, Florida, July 2010 to December 2011. Submitted to The Department of the Navy Norfolk, VA. March 20, 2012.

McLellan, W., Foley, H., McAlarney, R., Cummings, E., Swaim, Z., Hodge, L., Stanistreet, J., Urian, K., Waples, D., Paxton, C., Pabst, D., Bell, J., and Read, A. Patterns of cetacean species occurrence, distribution and density at three sites along the continental shelf break of the U.S. Atlantic coast. Abstracts, Southeast and Mid-Atlantic Marine Mammal Symposium. March 28-30, 2014. Wilmington, NC. Poster presentation.

McLellan, W., Foley, H., McAlarney, R., Cummings, E., Swaim, Z., Hodge, L., Stanistreet, J., Urian, K., Waples, D., Paxton, C., Pabst, D., Bell, J., and Read, A. Patterns of cetacean species occurrence, distribution and density at three sites along the continental shelf break of the U.S. Atlantic coast. Abstracts, 20th Biennial Conference on the Biology of Marine Mammals. 9-13 December 2013. Otago University, Dunedin, New Zealand. Poster presentation.

Nilsson, P., E. Cummings, H. Foley, R. Hardee, R. Holt, R. McAlarney, W. A. McLellan, D. A. Pabst, and A. J. Read. 2011. Recent winter sightings of minke whales (*Balaenoptera acutorostrata*) in the South Atlantic Bight. Abstracts, Nineteenth Biennial Conference on the Biology of Marine Mammals. 27 November-3 December 2011. Tampa, Florida.

Nilsson, P. B., H. J. Foley, R. E. Hardee, R. C. Holt, R. J. McAlarney, E. W. Cummings, D. W. Johnston, W. A. McLellan, D. A. Pabst, and A. J. Read. 2010. Protected species monitoring in the proposed Under Sea Warfare Training Range Offshore of Jacksonville, FL: January - December 2009. Abstracts, SEAMAMMS (Southeast and Mid Atlantic Marine Mammal Symposium). 26-28 March 2010. Virginia Beach, Virginia.

Nilsson, P. B., Foley, H. J., Hardee, R. E., Holt, R. C., Cummings, E. W., McAlarney, R. J., Pabst, D. A. and McLellan, W. A. 2010. Aerial surveys of the proposed Under Sea Warfare Training Range (USWTR) off Jacksonville, Florida, January 2009 to June 2010. Report submitted to the Department of the Navy, Norfolk, VA.

# 9. Acknowledgements

We thank Ed Coffman, owner and operator of Orion Aviation, and his highly skilled pilots: Dave Huddle, Stan Huddle, Cameron Radford, Ryan Macgregor, Greg Souther, Collin Mendenhall, Rocky Walker, John Estes, Rich Waterman, and Bob Stickle, for excellent flying and a high level of professionalism. We thank U.S. Fleet Forces Command and NAVFAC Atlantic (Joel Bell) for their support of this work. Surveys were conducted under NOAA Scientific Permit Nos. 948-1692, 16473, and 20527 held by UNCW, and NOAA General Authorization Letter of Confirmation Nos. 808-1798, 16185 and 19903 held by Duke University.

# 10. References

Bates, D. M. & Venables, W. N. 2016. R library *Splines.*

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. 2001. *Introduction to distance sampling: estimating abundance of biological populations.* Oxford University Press, London. 432pp.

Foley, H. J., R. C. Holt, R. E. Hardee, P. B. Nilsson, K. A. Jackson, A. J. Read, D. A. Pabst, and W. A. McLellan. 2011. Observations of a western North Atlantic right whale (*Eubalaena glacialis*) birth offshore of the protected southeast U.S. critical habitat. *Marine Mammal Science* 27: E234-E240.

Hardin, J. and Hilbe, J. 2002. Generalized Estimating Equations. Chapman & Hall/CRC. London.

Hedley, S.L., Buckland, S.T. and Borchers, D.L. 1999. Spatial modelling from line transect data. *Journal of Cetacean Research Management.* 1: 255-264.

Hedley, S.L., Buckland, S.T. and Borchers D. L. 2004. Spatial distance sampling models. In *Advanced Distance Sampling.* Buckland S.T., Anderson D.R., Burnham K.P., Laake J.L., Borchers D.L. and Thomas L. (Eds) Oxford University Press, Oxford.

Horvitz, D.G. and Thompson, D.J. 1952. A generalization of sampling without replacement from a finite universe. *Journal of the American Statistical Association.* 47: 663 – 685.

Laake, J., Borchers, D., Thomas, L., Miller, D. and Bishop, J. mrds. 2013 Url: http://cran.r-project.org/web/packages/mrds/index.html.

Marques, F.F.C. 2001. Estimating wildlife distribution and abundance from line transect surveys conducted from platforms of opportunity. Ph.D. Thesis. University of St Andrews.

Natarajan, N. Lipsitz, S. Parzen N. & Lipschultz, S. (2007) A measure of partial association for generalized estimating equations. Statistical Modelling 7(2) 175-190.

Paxton, C. G. M. (2018) Analysis of the UNCW and Duke University aerial and shipboard surveys of the Jacksonville USWTR for the period January 2009 to November 2017. Report number CREEM-XXXXX-2018-1. Provided to UNCW, December 2018 (unpublished).

R Development Core Team. 2018 R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Read, A.J., S. Barco, J. Bell, D.L. Borchers, M.L. Burt, E.W. Cummings, J. Dunn, E.M. Fougeres, L. Hazen, L.E.W. Hodge, A.M. Laura, R.J. McAlarney, P. Nilsson, D.A. Pabst, S.Z. Schneider, K.W. Urian, D.M. Waples & W.A. McLellan. 2014. Occurrence, distribution and abundance of cetaceans in Onslow Bay, North Carolina, USA. *Journal of Cetacean Research and Management* 14: 23–35

Reynolds, R.W., Rayner, N.A., Smith, T.M., Stokes, D.C. and Wang, W. 2002. An improved in situ and satellite SST analysis for climate. *J. Climate* 15: 1609 – 1625.

This page intentionally left blank.

# Appendix 1

Aerial survey effort, including number of tracklines, kilometers, and Hobbs hours flown in the Jacksonville study area, January 2009 - November 2017.

| Date | Number of Tracklines | Kilometers Flown | Hobbs Hours |
|---|---|---|---|
| 27-Jan-2009 | 6 | 505.95 | 4.2 |
| 28-Jan-2009 | 4 | 345.55 | 2.5 |
| 26-Feb-2009 | 10 | 861.83 | 7.3 |
| 27-Feb-2009 | 10 | 842.76 | 7.7 |
| 31-Mar-2009 | 5 | 431.68 | 3.5 |
| 9-Jun-2009 | 6 | 514.30 | 3.5 |
| 10-Jun-2009 | 10 | 857.69 | 7.0 |
| 11-Jun-2009 | 4 | 318.65 | 3.7 |
| 15-Jul-2009 | 6 | 507.72 | 4.7 |
| 16-Jul-2009 | 10 | 857.08 | 7.3 |
| 17-Jul-2009 | 4 | 344.28 | 2.5 |
| 4-Aug-2009 | 6 | 507.22 | 4.4 |
| 5-Aug-2009 | 8 | 689.73 | 5.3 |
| 6-Aug-2009 | 6 | 513.15 | 4.8 |
| 14-Sep-2009 | 4 | 343.44 | 3.2 |
| 15-Sep-2009 | 10 | 854.05 | 8.0 |
| 16-Sep-2009 | 6 | 512.18 | 6.4 |
| 18-Sep-2009 | 10 | 856.91 | 8.1 |
| 30-Sep-2009 | 10 | 763.46 | 7.3 |
| 1-Oct-2009 | 10 | 821.53 | 7.6 |
| 17-Nov-2009 | 6 | 517.49 | 4.0 |
| 18-Nov-2009 | 10 | 856.86 | 7.5 |
| 20-Nov-2009 | 4 | 345.13 | 3.2 |
| 8-Dec-2009 | 10 | 865.77 | 5.3 |
| 10-Dec-2009 | 2 | 86.11 | 2.0 |
| 22-Dec-2009 | 10 | 860.03 | 7.8 |
| 7-Jan-2010 | 10 | 862.41 | 7.7 |
| 19-Jan-2010 | 10 | 856.01 | 7.3 |
| 20-Jan-2010 | 10 | 832.95 | 7.3 |
| 27-Jan-2010 | 10 | 862.24 | 5.6 |
| 28-Jan-2010 | 6 | 507.52 | 5.8 |
| 19-Feb-2010 | 10 | 863.76 | 6.5 |
| 20-Feb-2010 | 10 | 846.63 | 8.0 |

| Date | Number of Tracklines | Kilometers Flown | Hobbs Hours |
|---|---|---|---|
| 21-Feb-2010 | 10 | 835.48 | 8.3 |
| 20-Mar-2010 | 8 | 681.71 | 7.5 |
| 24-Mar-2010 | 5 | 505.96 | 5.0 |
| 31-Mar-2010 | 6 | 497.64 | 4.7 |
| 1-Apr-2010 | 10 | 833.99 | 8.1 |
| 2-Apr-2010 | 10 | 822.01 | 8.8 |
| 3-Apr-2010 | 6 | 411.02 | 4.2 |
| 6-May-2010 | 2.5 | 184.33 | 3.9 |
| 7-May-2010 | 7.5 | 636.00 | 6.1 |
| 4-Jun-2010 | 10 | 858.78 | 6.3 |
| 5-Jun-2010 | 10 | 816.50 | 5.3 |
| 6-Jun-2010 | 10 | 832.30 | 6.6 |
| 7-Jun-2010 | 6 | 511.50 | 3.4 |
| 28-Jul-2010 | 6 | 507.65 | 4.2 |
| 29-Jul-2010 | 6 | 513.73 | 4.4 |
| 3-Aug-2010 | 6 | 511.30 | 4.2 |
| 4-Aug-2010 | 10 | 849.67 | 7.7 |
| 5-Aug-2010 | 4 | 343.78 | 2.9 |
| 8-Sep-2010 | 4 | 291.69 | 4.4 |
| 9-Sep-2010 | 8 | 664.89 | 8.7 |
| 10-Sep-2010 | 8 | 685.67 | 4.6 |
| 18-Oct-2010 | 4 | 329.85 | 3.6 |
| 19-Oct-2010 | 10 | 860.94 | 6.7 |
| 20-Oct-2010 | 4 | 344.36 | 2.5 |
| 18-Nov-2010 | 10 | 860.10 | 7.7 |
| 21-Dec-2010 | 8 | 683.05 | 6.6 |
| 29-Dec-2010 | 6 | 513.48 | 4.4 |
| 30-Dec-2010 | 8 | 675.62 | 7.7 |
| 15-Jan-2011 | 6 | 516.21 | 3.7 |
| 16-Jan-2011 | 4 | 344.07 | 3.1 |
| 31-Jan-2011 | 10 | 836.45 | 7.8 |
| 22-Feb-2011 | 4 | 345.49 | 4.5 |
| 26-Feb-2011 | 4 | 337.53 | 4.4 |
| 27-Feb-2011 | 6 | 500.15 | 5.3 |
| 8-Apr-2011 | 8 | 685.30 | 7.5 |
| 9-Apr-2011 | 10 | 855.87 | 6.9 |
| 19-May-2011 | 6 | 513.27 | 3.9 |
| 20-May-2011 | 10 | 820.44 | 7.2 |

| Date | Number of Tracklines | Kilometers Flown | Hobbs Hours |
|---|---|---|---|
| 21-Jun-2011 | 6 | 512.43 | 5.0 |
| 22-Jun-2011 | 6 | 517.21 | 3.8 |
| 20-Jul-2011 | 10 | 860.875 | 7.4 |
| 21-Jul-2011 | 10 | 853.40 | 7.0 |
| 17-Aug-2011 | 10 | 856.86 | 8.1 |
| 18-Aug-2011 | 10 | 793.96 | 7.4 |
| 29-Sep-2011 | 10 | 853.50 | 7.0 |
| 30-Sep-2011 | 6 | 509.50 | 4.3 |
| 17-Oct-2011 | 10 | 849.65 | 7.1 |
| 23-Jan-2012 | 6 | 478.7 | 4.5 |
| 24-Jan-2012 | 10 | 851.0 | 7.9 |
| 25-Jan-2012 | 4 | 328.3 | 4.4 |
| 29-Mar-2012 | 8 | 551.5 | 6 |
| 18-Apr-2012 | 10 | 861.2 | 6.9 |
| 19-Apr-2012 | 10 | 862.0 | 6.4 |
| 16-May-2012 | 10 | 751.8 | 6.3 |
| 17-May-2012 | 10 | 847.6 | 7.7 |
| 6-Jul-2012 | 10 | 858.7 | 7.6 |
| 7-Jul-2012 | 10 | 841.1 | 7.4 |
| 22-Sep-2012 | 10 | 769.6 | 7.5 |
| 23-Sep-2012 | 6 | 514.7 | 4.1 |
| 4-Nov-2012 | 10 | 844.2 | 7.2 |
| 5-Nov-2012 | 6 | 493.3 | 3.4 |
| 22-Mar-2013 | 10 | 864.3 | 6.4 |
| 9-May-2013 | 10 | 836.4 | 8 |
| 10-May-2013 | 10 | 803.7 | 7.6 |
| 20-Jun-2013 | 6 | 510.7 | 4.2 |
| 21-Jun-2013 | 6 | 386.9 | 4.8 |
| 4-Sep-2013 | 10 | 839.7 | 7.4 |
| 5-Sep-2013 | 10 | 839.6 | 7.9 |
| 6-Sep-2013 | 3 | 175.9 | 2.4 |
| 17-Oct-2013 | 8 | 656.2 | 7.0 |
| 20-Jan-2014 | 10 | 849.8 | 7.5 |
| 21-Jan-2014 | 2 | 164.7 | 1.7 |
| 16-Feb-2014 | 8 | 674.1 | 6.4 |
| 17-Feb-2014 | 10 | 818.2 | 8.1 |
| 18-Feb-2014 | 8 | 661.5 | 6.1 |
| 14-Mar-2014 | 10 | 844.2 | 7 |

| Date | Number of Tracklines | Kilometers Flown | Hobbs Hours |
|---|---|---|---|
| 15-Mar-2014 | 10 | 857.0 | 7.2 |
| 7-May-2014 | 10 | 849.4 | 8.7 |
| 8-May-2014 | 10 | 851.0 | 7.8 |
| 25-Jun-2014 | 10 | 818.3 | 7.5 |
| 26-Jun-2014 | 6 | 507.0 | 4 |
| 10-Jul-2014 | 10 | 832.2 | 7.1 |
| 11-Jul-2014 | 8 | 624.4 | 5.7 |
| 9-Aug-2014 | 10 | 853.8 | 7.4 |
| 10-Aug-2014 | 6 | 514.9 | 4.3 |
| 11-Sep-2014 | 10 | 828.7 | 7.2 |
| 12-Sep-2014 | 10 | 852.7 | 6.7 |
| 21-Oct-2014 | 10 | 858.2 | 6.7 |
| 22-Oct-2014 | 4 | 344.0 | 2.8 |
| 2-Mar-2015 | 0 | 0.0 | 1.1 |
| 3-Mar-2015 | 8 | 652.45 | 7.2 |
| 4-Mar-2015 | 2 | 158.05 | 3 |
| 15-Apr-2015 | 12 | 602.80 | 6.1 |
| 19-Aug-2015 | 10 | 846.30 | 6.6 |
| 20-Aug-2015 | 10 | 429.10 | 4.0 |
| 14-Oct-2015 | 10 | 854.00 | 6.2 |
| 15-Oct-2015 | 10 | 850.30 | 7.1 |
| 20-Jan-2016 | 6 | 512.65 | 3.8 |
| 21-Jan-2016 | 4 | 324.55 | 3.9 |
| 29-Feb-2016 | 10 | 858.80 | 6.7 |
| 1-Mar-2016 | 14 | 776.40 | 6.8 |
| 2-Mar-2016 | 6 | 518.60 | 4.0 |
| 24-May-2016 | 4 | 338.90 | 3.2 |
| 25-May-2016 | 12 | 782.00 | 7.1 |
| 1-Feb-2017 | 14 | 777.00 | 7.5 |
| 2-Feb-2017 | 6 | 515.30 | 4.5 |
| 9-May-2017 | 14 | 788.20 | 7.5 |
| 10-May-2017 | 6 | 516.70 | 4.0 |
| 11-Jul-2017 | 14 | 771.45 | 7.7 |
| 12-Jul-2017 | 6 | 515.15 | 4.2 |
| 8-Nov-2017 | 12 | 772.55 | 6.8 |
| **144 Days** | **1147 Tracklines** | **93368.6 kms** | **838.8 Hobbs Hrs** |

## Appendix 2

Average Beaufort Sea State (BSS), number of cetacean sightings, and number of sea turtle sightings observed during aerial survey effort in the Jacksonville study area, January 2009 - November 2017.

| Date | Average BSS | Cetacean Sightings | Sea Turtle Sightings |
|---|---|---|---|
| 27-Jan-2009 | 2.65 | 5 | 12 |
| 28-Jan-2009 | 3.73 | 0 | 2 |
| 26-Feb-2009 | 2.93 | 5 | 22 |
| 27-Feb-2009 | 2.39 | 12 | 28 |
| 31-Mar-2009 | 3.09 | 0 | 6 |
| 9-Jun-2009 | 1.20 | 3 | 73 |
| 10-Jun-2009 | 1.62 | 8 | 74 |
| 11-Jun-2009 | 1.74 | 4 | 14 |
| 15-Jul-2009 | 1.30 | 5 | 118 |
| 16-Jul-2009 | 2.68 | 5 | 15 |
| 17-Jul-2009 | 3.51 | 0 | 2 |
| 4-Aug-2009 | 1.20 | 6 | 36 |
| 5-Aug-2009 | 2.18 | 0 | 23 |
| 6-Aug-2009 | 2.21 | 5 | 31 |
| 14-Sep-2009 | 3.09 | 2 | 2 |
| 15-Sep-2009 | 1.73 | 10 | 40 |
| 16-Sep-2009 | 1.10 | 14 | 67 |
| 18-Sep-2009 | 2.18 | 13 | 76 |
| 30-Sep-2009 | 2.34 | 11 | 35 |
| 1-Oct-2009 | 1.42 | 11 | 65 |
| 17-Nov-2009 | 2.32 | 0 | 2 |
| 18-Nov-2009 | 2.03 | 4 | 41 |
| 20-Nov-2009 | 3.45 | 1 | 1 |
| 8-Dec-2009 | 3.28 | 0 | 3 |
| 10-Dec-2009 | 5.00 | 0 | 0 |
| 22-Dec-2009 | 2.39 | 7 | 24 |
| 7-Jan-2010 | 2.43 | 3 | 19 |
| 19-Jan-2010 | 1.92 | 7 | 12 |
| 20-Jan-2010 | 1.67 | 15 | 48 |
| 27-Jan-2010 | 3.10 | 2 | 8 |
| 28-Jan-2010 | 2.13 | 12 | 35 |
| 19-Feb-2010 | 2.58 | 0 | 17 |
| 20-Feb-2010 | 1.52 | 15 | 59 |
| 21-Feb-2010 | 1.13 | 24 | 76 |
| 20-Mar-2010 | 2.33 | 15 | 61 |
| 24-Mar-2010 | 2.07 | 7 | 35 |
| 31-Mar-2010 | 2.60 | 15 | 44 |
| 1-Apr-2010 | 2.25 | 14 | 31 |
| 2-Apr-2010 | 1.34 | 32 | 107 |
| 3-Apr-2010 | 1.46 | 11 | 70 |

| Date | Average BSS | Cetacean Sightings | Sea Turtle Sightings |
|---|---|---|---|
| 6-May-2010 | 2.44 | 6 | 8 |
| 7-May-2010 | 1.97 | 10 | 69 |
| 4-Jun-2010 | 2.55 | 1 | 8 |
| 5-Jun-2010 | 2.55 | 1 | 4 |
| 6-Jun-2010 | 2.27 | 2 | 17 |
| 7-Jun-2010 | 3.48 | 0 | 2 |
| 28-Jul-2010 | 0.84 | 8 | 104 |
| 29-Jul-2010 | 1.93 | 3 | 18 |
| 3-Aug-2010 | 0.93 | 7 | 65 |
| 4-Aug-2010 | 1.57 | 13 | 66 |
| 5-Aug-2010 | 2.74 | 1 | 1 |
| 8-Sep-2010 | 1.22 | 5 | 10 |
| 9-Sep-2010 | 0.93 | 14 | 48 |
| 10-Sep-2010 | 2.39 | 0 | 7 |
| 18-Oct-2010 | 1.53 | 9 | 17 |
| 19-Oct-2010 | 2.34 | 3 | 6 |
| 20-Oct-2010 | 3.16 | 0 | 0 |
| 18-Nov-2010 | 3.54 | 1 | 7 |
| 21-Dec-2010 | 2.31 | 7 | 27 |
| 29-Dec-2010 | 2.62 | 4 | 17 |
| 30-Dec-2010 | 1.64 | 19 | 42 |
| 15-Jan-2011 | 3.35 | 0 | 8 |
| 16-Jan-2011 | 3.17 | 2 | 6 |
| 31-Jan-2011 | 2.44 | 16 | 69 |
| 22-Feb-2011 | 2.88 | 3 | 14 |
| 26-Feb-2011 | 1.34 | 7 | 33 |
| 27-Feb-2011 | 1.81 | 12 | 83 |
| 8-Apr-2011 | 1.55 | 15 | 44 |
| 9-Apr-2011 | 2.33 | 7 | 36 |
| 19-May-2011 | 3.36 | 2 | 2 |
| 20-May-2011 | 1.90 | 13 | 97 |
| 21-Jun-2011 | 2.00 | 1 | 15 |
| 22-Jun-2011 | 3.00 | 0 | 3 |
| 20-Jul-2011 | 2.76 | 8 | 36 |
| 21-Jul-2011 | 2.66 | 7 | 25 |
| 17-Aug-2011 | 1.74 | 14 | 60 |
| 18-Aug-2011 | 2.51 | 13 | 70 |
| 29-Sep-2011 | 2.54 | 10 | 40 |
| 30-Sep-2011 | 2.48 | 8 | 27 |
| 17-Oct-2011 | 1.72 | 10 | 46 |
| 23-Jan-2012 | 2.28 | 6 | 36 |
| 24-Jan-2012 | 2.44 | 8 | 32 |
| 25-Jan-2012 | 2.08 | 7 | 7 |
| 29-Mar-2012 | 2.81 | 6 | 37 |
| 18-Apr-2012 | 2.95 | 3 | 7 |

| Date | Average BSS | Cetacean Sightings | Sea Turtle Sightings |
|---|---|---|---|
| 19-Apr-2012 | 2.95 | 3 | 20 |
| 16-May-2012 | 2.60 | 3 | 20 |
| 17-May-2012 | 1.68 | 5 | 37 |
| 6-Jul-2012 | 2.65 | 7 | 28 |
| 7-Jul-2012 | 2.36 | 9 | 55 |
| 22-Sep-2012 | 2.56 | 9 | 25 |
| 23-Sep-2012 | 3.28 | 2 | 4 |
| 4-Nov-2012 | 3.04 | 7 | 8 |
| 5-Nov -2012 | 3.71 | 0 | 3 |
| 22-Mar-2013 | 2.56 | 3 | 15 |
| 9-May-2013 | 2.10 | 18 | 51 |
| 10-May-2013 | 0.95 | 20 | 49 |
| 20-Jun-2013 | 2.27 | 3 | 11 |
| 21-Jun-2013 | 2.01 | 10 | 23 |
| 4-Sep-2013 | 1.33 | 13 | 72 |
| 5-Sep-2013 | 1.83 | 15 | 43 |
| 6-Sep-2013 | 2.16 | 4 | 7 |
| 17-Oct-2013 | 2.46 | 14 | 30 |
| 20-Jan-2014 | 3.36 | 5 | 2 |
| 21-Jan-2014 | 5.00 | 1 | 0 |
| 16-Feb-2014 | 3.43 | 2 | 7 |
| 17-Feb-2014 | 2.17 | 16 | 23 |
| 18-Feb-2014 | 2.55 | 9 | 29 |
| 14-Mar-2014 | 2.99 | 6 | 3 |
| 15-Mar-2014 | 2.83 | 7 | 25 |
| 7-May-2014 | 1.95 | 8 | 40 |
| 8-May-2014 | 2.92 | 6 | 26 |
| 25-Jun-2014 | 2.34 | 15 | 37 |
| 26-Jun-2014 | 3.17 | 4 | 5 |
| 10-Jul-2014 | 2.12 | 11 | 33 |
| 11-Jul-2014 | 2.23 | 5 | 25 |
| 9-Aug-2014 | 2.44 | 4 | 31 |
| 10-Aug-2014 | 3.26 | 4 | 5 |
| 11-Sep-2014 | 2.37 | 10 | 33 |
| 12-Sep-2014 | 2.64 | 6 | 11 |
| 21-Oct-2014 | 2.68 | 0 | 13 |
| 22-Oct-2014 | 4.00 | 2 | 3 |
| 2-Mar-2015 | na | 0 | 0 |
| 3-Mar-2015 | 1.83 | 17 | 98 |
| 4-Mar-2015 | 3.47 | 2 | 3 |
| 15-Apr-2015 | 2.76 | 2 | 4 |
| 19-Aug-2015 | 2.38 | 9 | 30 |
| 20-Aug-2015 | 2.14 | 2 | 0 |
| 14-Oct-2015 | 3.01 | 1 | 14 |
| 15-Oct-2015 | 3.73 | 6 | 12 |

| Date | Average BSS | Cetacean Sightings | Sea Turtle Sightings |
|---|---|---|---|
| 20-Jan-2016 | 3.26 | 2 | 24 |
| 21-Jan-2016 | 2.06 | 10 | 19 |
| 29-Feb-2016 | 3.14 | 2 | 18 |
| 1-Mar-2016 | 3.02 | 1 | 3 |
| 2-Mar-2016 | 5.46 | 0 | 1 |
| 24-May-2016 | 2.43 | 3 | 24 |
| 25-May-2016 | 2.00 | 4 | 27 |
| 1-Feb-2017 | 2.56 | 6 | 10 |
| 2-Feb-2017 | 2.72 | 4 | 8 |
| 9-May-2017 | 2.36 | 9 | 7 |
| 10-May-2017 | 3.14 | 2 | 6 |
| 11-Jul-2017 | 1.92 | 10 | 26 |
| 12-Jul-2017 | 2.47 | 7 | 22 |
| 8-Nov-2017 | 1.96 | 8 | 18 |
| **144 days** | **Average BSS 2.44** | **968 cetaceans** | **4036 turtles** |