# 2.0 AERIAL AND SHIPBOARD SURVEY METHODOLOGY

## 2.1 AERIAL SURVEY DESIGN

### *2.1.1 Survey Effort*

Aerial surveys were conducted once monthly after the shipboard surveys between February and May 2008 and twice monthly (when possible) between January and June 2009. The surveys were flown in accordance with the Geo-Marine, Inc. (GMI) Aerial Survey Requirements and Provisions (**Appendix A**). The surveys were designed to determine marine mammal and sea turtle distribution and estimate abundance/density using line transect methods (see Buckland 2001). The survey aircraft for the 2008 surveys was a twin-engine, high-winged Cessna Skymaster 337 with bubble windows on each side of the aircraft to allow unobstructed views of the trackline directly beneath the plane. During the 2009 surveys, a Cessna Skymaster without bubble windows was used so visibility below the aircraft was limited. Surveys were flown at ~229 m (750 ft) altitude and a speed of ~220 kilometers per hour (kph; 110 knots [kts]) during daylight hours when there was at least 3.7 km (2 NM) visibility and a Beaufort sea state (BSS) of less than 6.

For the February 2008 survey, pre-determined transect lines (tracklines) were spaced 3.7 km (2 NM) apart and orientated perpendicular to the coastline. The 34 tracklines were divided (even or odd numbered) and flown during separate morning and afternoon sessions (i.e., half were flown in the morning and half in the afternoon). New transect protocol following NOAA survey methodology was initiated for the March 2008 survey and continued for the rest of the aerial surveys. Before each monthly survey, tracklines were randomly generated in a double saw-tooth pattern (see **Figure 2-1** in **Section 2.1** of **Volume II: Avian Studies**) using the program Distance 5.0 (Buckland et al. 2004; Thomas et al. 2010). This design provided comparable spatial and temporal coverage of the entire Study Area and allowed the entire Study Area to be surveyed in one day, thereby minimizing the temporal variation. On each day of the survey, a coin toss determined whether the surveys would start at the north or south end of the Study Area.

Additional strip transects were flown along the coastline (at low tide) when possible to assess the presence/absence of pinnipeds in the Study Area. Pinnipeds at haulout sites were recorded and groups were photographed to assist with species identification and group size estimation. No flights were purposefully flown directly over haulout sites in accordance with NMFS requirements.

Visual observations were recorded by a team of three people during the 2008 surveys. Two experienced observers searched for animals at the surface from directly beneath the aircraft out to a perpendicular distance of ~1,500 m (~4,900 ft). The third person acted as data recorder and was stationed in the co-pilot seat. During the 2009 surveys, flight protocols followed those stated above with some modifications. A co-pilot was added so there was no room in the plane for a dedicated data recorder. Therefore, the two experienced observers were responsible for observations and recording data. This necessitated changes in data recording and sighting protocols in order to maintain observer vigilance. The protocols adopted were those used for two-observer aerial surveys for North Atlantic right whales (*Eubalaena glacialis*) in a Cessna Skymaster off the southeast U.S. (Schulte and Taylor 2009). The two observers sat in the rear seats, one on the right side, and one on the left side. One observer recorded the time and position of each sighting on a laptop while the second observer recorded the sighting information on a digital tape recorder.

### *2.1.2 Data Logging*

The aircraft's position along the trackline (in addition to all other survey information) was collected every 10 seconds (s) on a computer interfaced with the aircraft's global positioning system (GPS) via a custom data acquisition program. Environmental conditions (e.g., BSS, solar glare, water color, and transparency) which may affect the ability to detect animals were recorded prior to the start of each trackline and updated as needed while on effort. All sighting data, including time, position, group size, species, and behavior, were recorded. During the 2008 surveys, the voice-operated recording (VOR) data entry program was used to record all pertinent data. During the 2009 surveys, the data entry program Logger 2000 was used and augmented by voice notes using a hand-held digital recorder.

### *2.1.3 Recording Sightings*

During the 2008 surveys, when an animal was sighted perpendicular to the aircraft along the trackline, the angle to the sighting (≤60 degrees [°]) was determined either using a digital inclinometer or 10° intervals (bins) marked on the aircraft windows for calculation of perpendicular sighting distances. During the 2009 surveys, the perpendicular sighting distances were calculated based on GPS locations. Therefore, when an animal or group was sighted, the GPS point on the trackline was recorded, and a second GPS location was recorded directly over the sightings. The perpendicular sighting distance was calculated from these two GPS locations using a global information system (GIS) distance measurement algorithm. This 2009 survey method differed from that used during the 2008 surveys due to the absence of a dedicated data recorder and the need to incorporate an approach that maximizes observation time from the aircraft. The GPS method has been proven to provide very accurate distance estimates (Marques et al. 2006).

During both the 2008 and 2009 surveys, the observers went into off-effort mode at the time of a sighting to verify species identification and estimate group sizes. The species identification, best estimate of group size, behavior, time, position, and associated animals were also recorded. This information was relayed to the data recorder. A circle-back procedure was used if necessary to verify species identification and estimate group sizes. Attempts were made to photograph all the animals in a sighting to compare with other photo-identification databases.

Sightings of non-target species (species other than marine mammals or sea turtles) were recorded opportunistically throughout the survey period. In addition to records of fish, sharks, and rays, locations of commercial fishing vessels were documented. This information is summarized in **Volume II**.

## 2.2 SHIPBOARD SURVEY DESIGN

### *2.2.1 Survey Effort*

Shipboard survey effort was conducted monthly between January 2008 and December 2009 on the University of Delaware's R/V *Hugh R. Sharp* (44.5 m [146 ft] in length). The surveys were conducted in accordance with the GMI Shipboard Survey Safety Plan (**Appendix B**). A single platform and standard line transect methods were used (Buckland 2001). The surveys were conducted along predetermined tracklines at 18.5 kph (10 kts) along the designated trackline. Before each monthly survey, tracklines were randomly generated in a double saw-tooth pattern (see **Figure 2-1** in **Section 2.1** of **Volume II: Avian Studies**) using the program Distance 5.0 (Buckland et al. 2004; Thomas et al. 2010) to cross the bathymetry gradient and to maximize uniform coverage of the Study Area. The starting point and time of each cruise was chosen based on the timing of high tide and weather conditions due to the docking criteria of the R/V *Hugh R. Sharp*. Tracklines were altered only if sea state, glare, or weather inhibited the survey effort. In these cases, the vessel diverted off the established trackline up to 30° from the established course. This deviation continued only until the ship was 18.5 km (10 NM) from the original trackline; at this point the ship turned back toward the waypoint of the original trackline.

Visual observations were recorded from the flying bridge (10 m [32.81 ft] above water) during daylight hours (roughly sunrise to sunset) when weather permitted. The marine mammal/sea turtle observer team consisted of six individuals; three observers were actively on duty at any one time. On-duty observers consisted of one observer searching with 25x150 power Fujinon binoculars ("bigeyes") mounted on a pedestal on the port side of the vessel while another observer searched through bigeye binoculars mounted on the starboard side. The third observer served as the data recorder and also searched the water with unaided eyes and 7x hand-held binoculars between the port and starboard bigeye observers. Each observer scanned out to the horizon from abeam (90°) on his/her side of the ship to 10° to the opposite side of the bow (100° in all). The 20° along the ship's trackline thus received overlapping coverage by the two bigeye observers. Observers rotated through these three stations every 40 minutes (min). During each rotation, at least one of the on-duty observers was highly experienced in survey techniques and marine mammal/sea turtle identification.

Survey operations were suspended when wind conditions reached a 6 or higher on the Beaufort scale since visibility was too poor for survey effort to continue. Survey effort was also suspended when rain or fog reduced visibility to 1.9 km (1 NM) or less along the trackline or when greater than 50% of the horizon was obscured.

### *2.2.2 Data Logging*

The data recorder entered a log of weather conditions (BSS, wind speed, swell height and direction, direction of sun, visibility, etc.), visual effort (on or off), sightings, and other survey information into the computer mounted on the flying bridge. All data were recorded using WinCruz, a computer program developed by NMFS-Southwest Fisheries Science Center (SWFSC). The weather conditions were recorded every 40 min (when observers rotated positions) and updated when conditions changed. The GPS position of the vessel, as well as the vessel's course and speed, was automatically recorded every 2 min via an integrated, stand-alone GPS unit on the flying bridge. Detailed paper forms were completed for each marine mammal sighting to supplement and expand upon information recorded in WinCruz. The initial time of the sighting and the angle and reticle of the sighting (recorded from the bigeye binoculars) were listed on each sighting form as a backup to the computer file. Other information on taxonomic identification (including a sketch showing diagnostic features) and the behavior of the animals observed was also documented on the sighting form and used to verify species identification. Each observer maintained a log book which was used primarily to record estimates of the number of individuals (group size) and taxonomic composition (in percentages) for each sighting documented by the observer. Three estimates of group size (best, maximum, and minimum) were recorded for all sightings. Estimates of group size and the percent taxonomic composition were made independently by each observer without discussion among other observers so that the data were not observer-biased. At the end of the day, the chief scientist was responsible for collecting the log books and adding the estimates of group size and composition to the sighting records in the WinCruz dataset.

### *2.2.3 Recording Sightings*

When an individual or group of marine mammals was sighted, the observer team went into off-effort mode so that all observers could stop actively searching and focus on the sighting. Observers measured the angle and distance from the ship to the sighting. The pedestals of the bigeye binoculars were fitted with azimuth rings for measurement of horizontal angles (b) between the trackline and the animals. Vertical angles from the horizon to the animals were measured with reticle scales in the ocular lenses of the binoculars. Reticle values were converted to angular values and to radial distance (R) from the observer based on the average eye height of observers on the flying bridge above the water's surface. The WinCruz program automatically calculated this conversion of reticle value to radial distance. The perpendicular sighting distance (y) between the animals and the trackline was calculated as $y = R*\sin(b)$ where R was the radial distance to the animals and b was the horizontal angle of the animals from the trackline (Lerczak and Hobbs 1998).

The vessel remained in passing mode if species identification and group estimates could be obtained while remaining on the trackline. If necessary, the vessel turned off the trackline to approach the individual or group (closing mode) to obtain this information. The vessel's speed and course were altered as necessary to obtain sighting data. A balance was kept between spending time off effort approaching animals and spending time searching on effort. Attempts were made to photograph all the animals in a sighting to document species identification and to obtain photographs that can be compared to other photo-identification databases for possible matches.

Once all the necessary data were collected for the sighting, the vessel resumed the same course and speed as prior to the sighting. If the vessel had to turn off the trackline for the sighting, then the vessel would resume a course back to the original trackline, and the team would go back on effort as long as the distance from the planned trackline was less than 9 km (5 NM). If the vessel was farther than 9 km (5 NM) from the original trackline, the team would plot a new course to the next waypoint.

Sightings that were made while the survey team was off effort were also recorded. In some cases, another marine mammal or turtle sighting was observed while the vessel was in off-effort mode approaching the original sighting. Also, an occasional sighting was made by off-duty personnel; these sightings were only reported after the animal(s) passed abeam of the ship and were recorded as off-effort sightings. All off-effort sightings are included in this report but could not be used in the generation of abundance and density estimates because they did not meet the criteria for the analyses.

Sightings of non-target species (species other than marine mammals or sea turtles) were recorded opportunistically throughout the survey period. In addition to records of fish, sharks, and rays, locations of commercial fishing vessels were documented. This information is summarized in **Volume II**.

### 2.3 Data Processing and Quality Assurance/Quality Control

Data collected from the aerial and shipboard line transect surveys were reviewed daily for accuracy. Data Quality Assurance (QA)/Quality Control (QC) procedures included verifying that weather conditions, viewing conditions, observer information, species identification, group size, and location information were all correctly recorded. The sighting sheets were also checked for completeness and readability. The chief scientist compared digital data with data captured through sighting sheets, daily sighting logs, behavior data sheets, and error correction logs. All corrections found either through notes logged on the computer or on the aerial survey error logs were documented and confirmed by the chief scientist. These QA/QC procedures allowed any flaws in the data to be corrected immediately and prevented errors from progressing through data analysis. All data files were backed up on external hard drives, digital video discs (DVDs), and GMI's network.

#### *2.3.1 Seasons*

The following periods were used as seasonal designations in the analysis of marine mammal and sea turtle sightings data:

Winter: 18 December – 09 April
Spring: 10 April – 21 June
Summer: 22 June – 27 September
Fall: 28 September – 17 December

These seasons were calculated based on three years (01 January 2007 to 31 December 2009) of SST data derived from the NASA (National Aeronautics and Space Administration), MODIS (Moderate Resolution Imaging Spectroradiometer), Level 3 data collected onboard the Aqua Earth Observing System satellite. These data were post processed by the Rutgers Coastal Ocean Observation Lab (RU COOL) and were originally supplied by the NASA Goddard Earth Sciences Data and Information Services Center. Winter and summer are defined as the time periods when the change in sea surface temperature (SST) is less than the median change, and winter is distinguished from summer by comparing the SST of each sampled day against the mean SST of all sampled days (i.e., the SST of days in winter will be less than the mean SST, and the SST of days in summer will be greater than the mean SST). Spring and fall are defined as the time periods when the change in SST is greater than the median change, and spring is distinguished from fall by comparing the sign of change between each sampled day on the curve (i.e., in spring the SST is increasing and in fall the SST is decreasing, so the sign of a value in spring is positive and the sign of a value in fall is negative). Although some seasons may be shorter or longer than the standard seasonal definitions, the intuitive meaning for each of the seasons still applies. That is, winter and summer are still the times of year with the lowest and highest temperatures, respectively, while spring and fall represent transitional periods between the two temperature extremes.

#### *2.3.2 Calculation of Survey Effort*

Shipboard survey data were collected as a series of latitude and longitude points every 2 min while a series of latitude and longitude points were collected every 10 s on the aerial surveys. Daily survey effort was calculated as a summation of the distance between each successive point after the coordinates were converted from degrees to radians. After converting to radians, the coordinates were used to calculate the great circle distance in kilometers between successive latitude and longitude positions. All of the individual distances between points were summed for each day to produce an estimate of daily effort for each survey. All of the daily effort estimates were summed to obtain a total estimate of effort for all days and surveys combined.