NOAA TECHNICAL MEMORANDUM NMFS-SEFSC-492

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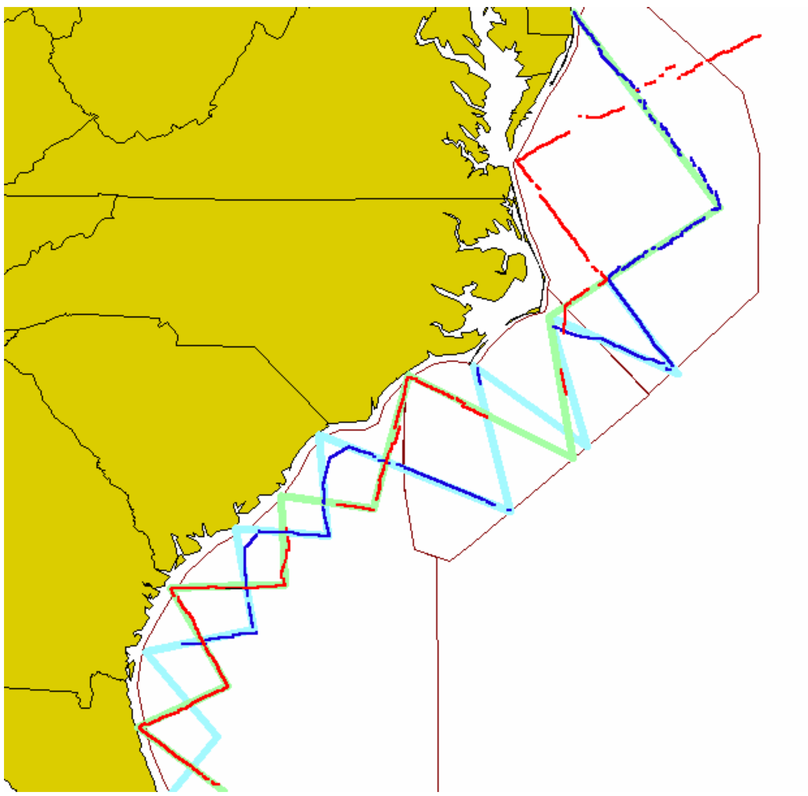

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
NOAA Fisheries
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149

January 2003

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January 2003

NOTICE

This report should be cited as follows:

Garrison, L.P., *et al*. 2002. A Marine Mammal Assessment Survey of the Southeast US Continental Shelf: February – April 2002. NOAA Technical Memorandum NOAA FISHERIES-SEFSC-492, 50 p.

This report has an internal document No. PRD-01/02-13

Copies of this report can be obtained from:

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Abstract

The Marine Mammal Protection Act (MMPA) requires frequent assessment of marine mammal stocks in US waters, with particular attention to "strategic" species that are classified as either endangered species or depleted relative to their optimum sustainable population size. To augment information on the winter spatial distribution and abundance of marine mammals in the mid-Atlantic region, the NOAA Fisheries SEFSC conducted a population assessment survey covering continental shelf and inner slope waters from Northern Florida to Delaware Bay during February-April 2002 that included both visual and passive hydroacoustic surveys. The survey was conducted under an interagency agreement between NOAA Fisheries and the US Navy that recognizes the need of both agencies for accurate information on the abundance and seasonal spatial distribution of marine mammal stocks.

The primary objectives of the winter 2002 survey were to:

1) Conduct a visual line transect survey of the mid-Atlantic continental shelf and inner slope waters from Northern Florida to Delaware Bay to determine the abundance and spatial distribution of marine mammals.

2) Continue the development and application of passive hydroacoustic methods to detect marine mammals and augment visual observations.

3) Opportunistically collect skin biopsy samples with particular focus on Atlantic bottlenose dolphin.

There were a total of 287 marine mammal groups sighted during the survey from 24 taxonomic groups and at least 15 species. These included Atlantic spotted dolphin, Atlantic bottlenose dolphin, common dolphin, Risso's dolphin, pilot whale, sperm whale, fin whales, beaked whales, and a number of other species. Based upon visual survey effort, minimum estimates of abundance were derived for three major Naval operations areas on the US East Coast for the most commonly encountered species. Continental shelf waters from Cape Hatteras, NC to Florida generally support high abundances of dolphin species, in particular Atlantic spotted dolphin and bottlenose dolphin. North of Cape Hatteras, a much higher diversity of cetacean species was encountered and included significant numbers of fin whales. There is an apparent aggregation of cetacean species in intermediate temperature waters between the shelf break and the Gulf Stream during winter months. Continuing analyses will evaluate the utility of passive hydroacoustic detections to augment visual surveys and assess seasonal patterns in habitat use by cetaceans in US mid-Atlantic continental shelf waters.

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Introduction

The Marine Mammal Protection Act (MMPA) requires frequent assessment of marine mammal stocks in US waters, with particular attention to "strategic" species that are classified as either endangered species or depleted relative to their optimum sustainable population size. The resulting abundance estimates and associated measures of uncertainty are used to determine minimum population sizes and set the maximum allowable mortality rates, termed potential biological removal (PBR), that will allow long term recovery and sustainability of each stock. In addition to direct estimates of abundance, these surveys also allow assessment of spatial distribution with particular attention to associations between marine mammal distribution and habitat variables such as temperature and depth. Most marine mammal species demonstrate seasonal changes in spatial distribution, and assessment surveys in multiple seasons provide a basis for evaluating the mechanisms underlying migration patterns.

The US mid-Atlantic continental shelf and inner slope is an area of high marine mammal occurrence including 23 stocks that are currently managed under the MMPA. Of these, 12 are defined as strategic under the MMPA guidelines either because they are classified as endangered, depleted, or the current mortality associated with human activities exceeds PBR (Waring *et al.*, 2001). The most notable of these includes the northern right whale, *Eubalaena glacialis*, often described as one of the most endangered species of marine mammals in the world. The best estimate of stock size approaches 300 individuals (Kruas *et al.*, 2001), and extensive management actions are currently in place or are being developed to avoid mortality of this species associated with both ship strikes and entanglement in commercial fishing gear. These animals are present in shallow waters of the mid-Atlantic between South Carolina and northern Florida during winter months.

Another strategic stock of particular importance is the coastal morphotype of bottlenose dolphin, *Tursiops truncatus*. Two genetically distinct morphological forms of this species occur over the mid-Atlantic continental shelf, commonly referred to as the coastal and offshore forms. While the habitats of these morphotypes can be distinct, there is at least some overlap in spatial distribution, particularly in continental shelf waters less than 40m depth off the Georgia and South Carolina coasts (P. Rosel, NOAA-NOS, unpublished data). The coastal morphotype experiences mortality rates that exceed PBR in coastal fisheries along the U.S. coast, and has been the subject of recent management activities to reduce the impacts of these fisheries. However, the question of the relative spatial distribution of the two morphotypes has yet to be fully resolved. The two forms cannot be distinguished visually during surveys, and skin samples must be collected for genetic analysis to accurately determine the genetic type of any bottlenose dolphin encountered and to evaluate habitat differentiation between the two forms. Very few biopsy samples have been collected during winter months, and the relative distribution of the two morphotypes during winter remains highly uncertain.

The population estimates for the other primary strategic stocks in this region, fin whale (*Balaenoptera physalus*), sperm whale (*Physter macrocephalus*), and pilot whales (*Globicephala sp.*) are based upon results from shipboard and aerial surveys conducted solely during summer months (Waring *et al*. 2001). The Southeast Fisheries Science Center (SEFSC) last conducted a winter survey in the Atlantic in 1992, during which very little survey effort was accomplished due to poor weather conditions. Thus, the winter spatial distribution of these species in the mid-Atlantic region is largely unknown.

To augment information on the winter spatial distribution and abundance of marine mammals in the mid-Atlantic region, the NOAA Fisheries SEFSC conducted a marine mammal population assessment survey covering continental shelf and inner slope waters from northern Florida to Delaware Bay during February-April 2002. The survey was conducted under an interagency agreement between NOAA Fisheries and the U.S. Navy that recognizes the need of both agencies for accurate information on the abundance and seasonal spatial distribution of marine mammal stocks in this region.

In addition to population abundance estimates, the current survey continued the development of a passive hydroacoustic system for the detection of vocalizing marine mammals. Population estimates of marine mammals to date are almost exclusively based upon visual counts during surveys. However, these estimates suffer from a known negative bias in that some marine mammals are below the surface and are thus not available to a visual observer and/or animals may be on the surface but not seen by the observers due to poor viewing conditions or observer error. These sources of bias are collectively termed visibility bias (Marsh & Sinclair 1989). Passive hydroacoustics provides an alternative method for the detection of marine mammals that can augment visual methods. Diving sperm whales, for example, produce audible echolocation clicks, and animals beneath the surface will be available to the acoustic system that are not available to visual observers. The hydroacoustic system at the SEFSC has been developed during past surveys also supported through interagency agreement with the U.S. Navy (SEFSC, unpublished data). Where depth and weather conditions allowed, a passive hydroacoustic array was towed behind the vessel throughout the visual survey effort to provide a combined visual and acoustic survey of marine mammals in the mid-Atlantic.

The primary objectives of the winter 2002 survey were to:

1) Conduct a visual line transect survey of the mid-Atlantic continental shelf and inner slope waters from northern Florida to Delaware Bay to determine the abundance and spatial distribution of marine mammals.

2) Continue the development and application of passive hydroacoustic methods to detect marine mammals and augment visual observations.

3) Opportunistically collect skin biopsy samples with particular focus on bottlenose dolphin.

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Methodology

The survey was conducted aboard the NOAA ship *Gordon Gunter*, a 75m long oceanographic research vessel configured for both visual and acoustic marine mammal survey operations. The vessel draft allows it to operate in waters >10 m depth, and a flying bridge platform is affixed above the vessel's bridge to provide a visual observation platform 14m above the water level. The *Gordon Gunter* is a converted naval vessel with acoustically quiet diesel-electric engines that generate relatively little low-frequency background noise providing enhanced acoustic signal detection.

Survey Design and Regional Coverage

The survey was designed to cover three primary areas of naval operations in the mid-Atlantic, the Virginia Capes area (VACapes), the Cherry Point area, and the Charleston/Jacksonville area (CHAS/JAX, Figure 1). The survey was designed to cover the continental shelf and inner continental slope for the VACapes and Cherry Point areas and concentrate on the continental shelf only in the CHAS/JAX region. Expected weather conditions made it unlikely to achieve reliable effort in the continental slope waters of this region which extend to the 200 mile limit of the U.S. economic exclusion zone (EEZ). The survey was designed in a "double saw-tooth" pattern to allow efficient and relatively uniform coverage of each operations area. A total of 4,291 km of trackline were planned in the initial design based upon the 62 day operational window for the survey and expected weather conditions (Table 1).

Visual Survey Methods

Visual survey operations were conducted following standard SEFSC and NOAA Fisheries protocols for line transect surveys (Barlow *et al.*, 1995). During "on effort" operations, the vessel proceeded at 10 knots along the designated tracklines. Two visual observers were stationed on the flying bridge and used 25x magnification "bigeye" binoculars to scan for marine mammals. Each of these observers was responsible for the 90° quadrant from the bow to the beam on the left and right side of the vessel respectively. In addition, a third observer on the flying bridge served both as a data recorder and scanned the area immediately ahead of and relatively close to the vessel using unaided eye and 7x handheld binoculars. The maximum visual range for the bigeye observers was approximately 13.6 km (7.3 nautical miles) directly ahead of the vessel. Observers rotated every 40 minutes to avoid fatigue, and environmental information including weather, wind speed and direction, sun position, visibility conditions, swell height, and beaufort sea state were recorded both on rotations and when conditions changed. Visual effort was conducted during all daylight hours where weather and viewing conditions allowed safe and effective survey effort. In general, visual observations were suspended during very poor visibility associated with low-level fog, rain, and when sea state exceeded 5 on the beaufort scale. The ship's location was also recorded at 30-second intervals through an independent GPS antenna connected to the data entry computer.

On observing a potential marine mammal cue such as a splash or blow, the position of the vessel, sighting angle, and distance to the cue was recorded. Distance was recorded using calibrated reticles in the bigeye binoculars or estimated for sightings by the center observer. The vessel continued surveying along the trackline until the cue was confirmed as a marine mammal or it was necessary to break away from standard search procedures to keep track of the sighting location. At that point the observers switched to an "off-effort" closing mode in which the vessel changed direction to approach the marine mammal group for species identification, group size estimation, and potential biopsy sample collection. The actual location of the group, group size, number of calves, sea surface temperature, and depth were recorded using a computerized data entry program. After recording all pertinent sighting information, the vessel returned to the trackline before the observers returned to on effort operations.

In addition to marine mammal sightings, a variety of ancillary observations are recorded including sea turtles, large sharks, pollution, and the presence of visually apparent surface fronts during the survey. These are recorded during survey operations on the computerized data entry system.

Conditionally Independent Observer

An assumption of line-transect survey methods for abundance estimation is that all animals on the trackline are seen by visual observers. This assumption is known to be violated in almost all wildlife surveys, particularly in marine mammal surveys where animals are both difficult to see and are frequently submerged. There are two components to this bias that must be dealt with either analytically or through survey methods. Availability bias is typically related to animal behaviors, such as long dive times, that reduce the likelihood that they will be on the surface within the visual range of the observers. Perception bias is when animals are available to the observers, yet are not sighted due to factors including cryptic coloration of the animals, lack of visual cues, weather and sea state conditions, observer inexperience and observer fatigue. The presence of a second, independently searching visual observer or team of observers is the primary method for quantifying visibility bias. During this survey, we employed the conditionally independent observer (CIO) approach described by Barlow (1995).

The CIO was stationed on the ship bridge or bridge wings below the primary team and operated throughout the survey. The CIO searched primarily ahead of the vessel and 30° to the left and right of the trackline using both 7x binoculars and unaided eye. The CIO was aware of sightings by the primary team through its communication with bridge officers; however, the primary team was not aware of sightings by the CIO.

On sighting a marine mammal group that had not been identified by the primary team, the CIO noted the initial distance and bearing measurement along with position and environmental data. The CIO continued to track the group without notifying the primary team until it was either sighted or "missed" by the primary team. The group was defined as missed when either it 1) passed abeam of the ship, or 2) approached within 20 m of the vessel without being identified by the primary team. For each sighting, the CIO noted whether the group was subsequently sighted or missed by the primary team. Once the group was defined as missed, the CIO notified the primary team and the vessel went into "closing mode" to identify the group. Sightings made by bridge officers or other personnel were also included as CIO sightings. Animals first observed by either team riding the bow were also counted as missed groups.

Biopsy Skin Sample Collection

When possible, biopsy samples of skin and blubber were collected from marine mammals riding the vessel bow, with particular attention to collecting samples from *Tursiops truncatus* for stock identification. Given that biopsy collection was a low priority on this survey and the relative difficulty of collecting samples from the bow of the *Gordon Gunter*, marine mammal groups were rarely pursued for an extensive period of time. Samples were collected using a modified .22 caliber dart rifle fitted with custom designed biopsy heads that extract a small plug of tissue from the animals. Great care was taken to avoid significant injury to the animals, and all biopsy attempts and resulting animal behaviors were recorded as required under sampling permits. Both photographic and video records of biopsy attempts were taken during these operations. Biopsy sampling was attempted after all pertinent group size and biological information was recorded by the observer team. Biopsy samples were stored in DMSO and frozen at –80°C to preserve genetic material for later analysis.

Passive Acoustic Operations

Passive acoustic operations were conducted in concert with the visual survey effort throughout the survey. The hydroacoustic arrays were used for the following purposes:

1. To collect high quality examples of vocalizations from all available cetaceans,

2. To collect data on the acoustic availability of cetacean species under varying conditions (i.e., during biopsy attempts),

3. To determine presence or absence of cetaceans at times when visual survey effort was not possible,

4. To determine how passive acoustics could best supplement visual survey methods, and

5. Evaluate the utility of passive acoustics in the role of an independent observer during shipboard cetacean surveys.

The passive acoustics portion of the survey was conducted in conjunction with and along the same track as the visual survey, depth permitting. Additionally, there were periods during which no visual survey effort was underway due to high sea states and winds, or darkness, during which passive acoustics monitoring continued. These acoustic surveys did not necessarily coincide with the prescribed visual survey trackline.

The primary passive acoustics collection tools used during this survey were a pair of towed hydrophone arrays. Array A1 was a two-element broadband array that could be trailed behind the ship at any distance up to 450 m astern. Array A2 was a five-element broadband array that could be set up to 800 m astern. Both arrays could be towed at any speed up to 11 knots. Array A1 was used in water depths from 20 m to 40 m, and array A2 was used in water deeper than 40 m. A1 was normally deployed 200 m astern of the *Gordon Gunter* while A2 was normally deployed 350 m astern. There was no acoustic effort in water shallower than 20 m to avoid damaging an array due to entanglement. The 2 element array A1 is deployed by hand off the stern of the ship, while the five-element array A2 assembly is deployed from a hydraulic powered deck winch.

The towed arrays are 100-meter long Kevlar reinforced cable assemblies with high gain hydrophones spaced along the cable. Each element is a piezoelectric ceramic striped cylinder with the cable assembly and strength member passing through the center. Each sensor, along with its associated signal conditioning, filtering, and line drive electronics, is contained within a hydrodynamically shaped tow body assembly. The frequency response is essentially flat at –127 dB from about 2 kHz to 15 kHz then climbs to a resonance peak at about 35 kHz with a level of –121 dB, then drops off at roughly –15 dB per octave after resonance. Below 1.5 kHZ, the sensors roll of at roughly 6 dB per octave to help reduce low frequency tow and impulse noise.

The data from the arrays were fed into the acoustics lab for amplification, filtering, recording and monitoring. Digital audio tape recordings of signals of interest were made using multi-channel digital tape recorders. These tape recordings were limited to 10Hz – 24kHz in bandwidth. Digital recordings of up to 50 kHz were made directly to computer hard disk when warranted. The array signals were constantly monitored by two teams of operators. Signals were then passed from the recording equipment to a desktop computer for monitoring and high frequency recording. The software package "Ishmael" was used to monitor signals and make high bandwidth recordings. The bearings to signals of interest generated by "Ishmael" were then passed to a second PC for display. This PC was connected to a GPS receiver and loaded with the "WhalTrak" software package. "WhalTrak" displayed the ship's current position and track in a graphics display window, overlaying lines of bearing as instructed by the operators. This provided the acoustics team with a clearer picture of how acoustic detections related to visual sightings of cetaceans and other possible sources of sound, such as ship traffic. "WhalTrak" was also employed to make time and position stamped flat ASCII files of the ship's track, any bearings sent to it, and any comments entered by the acoustics team.

Environmental Data

Environmental data were collected during the survey to both calibrate sound propagation models for the acoustic signals and to examine the relationships between habitat characteristics and marine mammal spatial distribution. Vertical CTD profiles were made at the beginning and end of each survey day to provide hydrographic data to calculate sound velocity. During survey operations, continuous measures of sea surface temperature, water depth, salinity, air temperature, wind speed, and other variables were collected using a variety of shipboard sensors. These data were recorded at 60 second intervals throughout the cruise and are stored using the shipboard scientific computing system (SSCS).

Analytical Methods – Visual Line Transect Abundance Estimation

The standard theory for line-transect sampling is well developed and has been routinely applied in a variety of wildlife population assessments in both terrestrial and marine habitats (Buckland *et al.* 1993). Given a random distribution of a survey line relative to the distribution of a population of interest, then the probability of observing an animal at any distance away from the transect line is equal. Assuming that all animals or groups of animals within a particular distance (W = strip width) on either side of the line are observed, then the density of animals in the area is:

$$(1) \qquad D = \frac{n}{2LW},$$

where n is the number of groups observed and L is the length of the transect line.

However, line transect theory as described in Buckland *et al.* (1993) recognizes that the probability of observing an animal or group generally declines with increasing distance away from the trackline. The distance sampling approach therefore examines the distribution of sighting frequency as a function of distance away from the trackline and corrects the density estimate for the sighting function, g(x). The sighting function can take any integrable form, however in practice it is generally constrained to be monotonically decreasing vs. the distance away from the trackline, x. The probability of sighting an animal within a strip is then the area under this function divided by the total strip width:

$$(2) \quad P_a = \frac{\int_0^w g(x)dx}{W}.$$

To calculate the probability of sighting an animal at any distance away from the trackline, the sighting function is rescaled to the probability distribution function (pdf), $f(x)$ as:

$$(3) \qquad f(x) = \frac{g(x)}{\int_0^w g(x)dx}.$$

The assumption is made that the sighting probability on the trackline is unity (g(0) = 1) allowing one to solve for the pdf at x = 0 as:

$$(4) \qquad f(0) = \frac{1}{\int_0^w g(x)dx},$$

and the quantity μ, or the effective strip half-width is:

$$(5) \qquad \mu = \int_0^w g(x)dx,$$

alternatively expressed as $\mu = P_a W$. The group density estimate given in eqn. 1 is therefore modified to:

$$(6) \qquad D = \frac{n}{2L\mu}.$$

This approach makes the assumption that the probability of sighting animals on the trackline, g(0), is 1. This is required to accomplish the formulation of eqn. 4 and the solution for the effective strip width. In practice, it is likely that some animals will be missed on the trackline, and therefore g(0) is < 1. The failure of this assumption introduces a direct, negative bias in the density estimate. This source of bias is termed "visibility bias".

In the case of marine mammal surveys, the relevant measure is the perpendicular distance from the trackline to the center of a group of animals. To calculate the absolute abundance of animals within a region of area, *A*, equation 6 is modified by multiplying by the average group size for the species, *E(s)*:

$$(7) \qquad N = \frac{nAE(s)}{2L\mu}.$$

Variance in the abundance estimate is calculated following the delta method outlined by Seber (1982) for combining uncorrelated variances. Thus, the variance in the density estimate is given as:

$$(8) \quad \mathrm{var}(D) = D^{-2} \cdot \left\{ \frac{\mathrm{var}(n)}{n^2} + \frac{\mathrm{var}(f(0))}{f(0)^2} + \frac{\mathrm{var}(E(s))}{E(s)^2} \right\}$$

where var(x) indicates the variance of the respective quantities. The variance of mean group size [var(E(s))] is calculated using the standard expression for variance and the variance of the inverse sighting function [*f(0)*] is calculated based upon the maximum likelihood fitting procedure used to derive the sighting function. The quantity var(n) is the variance of the expected number of animals observed during the survey. The sampling unit in for the current survey is considered a single transect line or a single day's effort. For each of k defined effort units where l_i is the length of each unit and L is the sum of all transect lengths, then var(n) is estimated as:

$$(9) \qquad \text{var}(n) = L\sum_{i=1}^{k} l_i\left(\frac{n_i}{l_i} - \frac{n}{L}\right)^2 \Big/ (k-1),$$

where n_i is the number of groups seen on transect i and n is the total number of groups observed during the survey. This variance estimator assumes both independence of encounter rates between transect lines and that the mean encounter rates (n/l) are normally distributed. Severe violations of these assumptions due to spatial contagion may result in inaccurate variance estimation. To account for these factors, variance may also be calculated through non-parametric bootstrap resampling of sampling units (Buckland *et al.* 1993).

Results

Survey Effort

The survey covered the majority of the planned tracklines, however lower than expected effort occurred in both the Cherry Point and Virginia Capes regions where consistently high winds and bad weather occurred throughout the survey period (Table 1, Figure 2). However, due to favorable weather in the southern part of the survey, additional effort was expended in the continental slope area of the Chas/JAX region (Figure 2), and survey effort was accomplished inside a naval operations area in the eastern Gulf of Mexico (Figure 3).

Marine Mammal Sightings and Regional Distribution

There were a total of 287 marine mammal groups sighted during the entire survey from 24 taxonomic groups and at least 15 species (Table 2). The most common species were Atlantic spotted dolphin (*Stenella frontalis*) and bottlenose dolphin (*Tursiops truncatus*). In the Charleston/Jacksonville region, the vast majority of sightings were from these two species, reflecting the concentration of survey effort on the continental shelf in this region (Table 3a). Pilot whales (*Globicephala sp.*), false killer whale (*Psuedorca cassidens*), one Northern right whale (*Eubalaena glacialis*), and one sperm whale (*Physeter macrocephalus*) were also sighted. The Cherry Point region sightings were also dominated by Atlantic spotted and bottlenose dolphins, and included sightings of dwarf/pygmy sperm whales (*Kogia sp.*), pilot whale, and both Mesoplodon and Ziphiid beaked whales (Table 3a). A greater diversity of marine mammal species were encountered in the Virginia capes region and included common dolphin (*Delphinus delphi*), bottlenose dolphin, Risso's dolphin (*Grampus griseus*), and striped dolphins (*Stenella coeruleoalba*). Large and medium whales including fin whale (*Balaenoptera physalus*), sperm whale, and pilot whales were also encountered with relative frequency in this area (Table 3b). Very few sightings were made during the effort in the Gulf of Mexico region, and these included Atlantic spotted, bottlenose, and Risso's dolphin (Table 3b, Figure 3).

Atlantic spotted dolphin was very frequently encountered in the relatively shallow continental shelf waters between 10-50m depth, particularly south of Cape Fear, North Carolina. Their abundance declined at higher latitudes, and only one spotted dolphin group was encountered north of Cape Hatteras (Figure 4). Likewise, bottlenose dolphin were abundant in shallow waters in the Charleston/Jacksonville area, and were found progressively further offshore with increasing latitude (Figure 4). Risso's dolphins were encountered primarily in deep water just off the continental shelf in the Virginia capes area, but one group was also encountered over the continental slope in the Charleston/Jacksonville region (Figure 4). The remaining identified dolphin species including common dolphin, striped dolphin, and Clymene's dolphins were encountered only in the Virginia Capes region. Common dolphin occurred across the depth range, while the two *Stenellid* species occurred in deep waters of the continental slope (Figure 5).

Beaked whales, *Kogia sp.*, melonheaded whale, and false killer whale were infrequently observed during the survey. This is consistent with previous surveys where these species have been collectively described as "cryptic" species (Barlow 1995, Mullin *in press*) because they generally surface for very short intervals, have a relatively small body size, and often have cryptic coloration. Of these species, the beaked whales and *Kogia sp.* were observed in continental slope water of the Cherry Point region (Figure 6). Two false killer whales were sighted in the continental slope area of the Charleston/Jacksonville region (Figure 6).

The large whales and pilot whale were most often encountered in the Virginia Capes region (Figure 7). Fin whales (*Balaenoptera physalus*) and other unspecified baleen whales (*Balaenoptera sp.*) were the most commonly encountered large whale. The majority of fin whale sightings occurred in a cluster near the continental shelf break in the northern edge of this region, while the *Balaenoptera sp.* sightings occurred in deep waters of the continental slope. Sperm whales were also sighted in deeper slope waters of the Virginia capes region, along with pilot whales (Figure 7). Sperm whale and pilot whale sightings also occurred in the deeper waters of the Charleston/Jacksonville region, and one right whale sighting occurred in the very nearshore waters off of Georgia (Figure 7).

<u>Preliminary Abundance Estimates from Visual Surveys</u>

Data Selection and Analysis stratification

Animal size and behavior are primary factors that effect both availability to and detection probabilities for visual observers. Ideally, the sighting functions developed for the line transect analysis of abundance would be done independently for each species to reflect these differences; however, in practice sample sizes for individual species generally preclude individual sighting functions. To address this issue Barlow (1995) recommended grouping species by these characteristics and applying a common sighting function within groups. This process has been previously applied by SEFSC researchers (Mullin, *in press*) and was similarly applied here (Table 4, Table 5). In addition, abundance estimates were only developed for species with >2 on effort sightings. With fewer than 2 sightings, variability in the encounter rates is extremely high and the calculated variance for mean group size is highly uncertain or cannot be estimated.

Group size may also have a significant effect on the availability and probability of sighting a marine mammal group during a visual survey. In a sufficiently large group of dolphins, for example, there is a high probability that at least one animal will be on the surface at all times, and therefore the entire group is available to the survey team. Group size bias can be addressed through regression of sighting distance vs. group size (Buckland *et al.* 1993). However, where there is no clear pattern in this relationship, the regression procedure may not demonstrate a statistically significant result. Therefore, Barlow (1995) recommended post-stratifying the analyses by group size where sample size allows to avoid biasing the abundance estimates and improve precision, particularly in cases where there is large variation in group size. Based upon a preliminary evaluation of the sighting data, we have post-stratified analyses for dolphin species based upon group sizes less than and greater than or equal to 20 animals.

A fundamental assumption of line transect analyses is that animals are observed prior to responding to the survey platform. The analysis stems from the assumption that line transects are placed randomly with respect to animal distribution, and this assumption is clearly violated if there is strong positive or negative response to the vessel (Buckland *et al.* 1993). This is a common difficulty encountered in ship board marine mammal surveys, as dolphin species in particular, may be attracted to the vessel at considerable distances (Palka & Hammond, 2001). There is strong evidence of attraction to the vessel during the current survey as evinced by a strongly skewed sighting function, particularly for dolphin species (Figure 8). In some cases, animals that were feeding or milling at the time of first observation changed their behavior and turned to approach the vessel at distances greater than 2 km (L. Garrison, personal observation). Particularly in southern areas with Atlantic spotted dolphins and/or during poor viewing conditions, a considerable number of survey sightings occurred when animals surfaced within 400m of the vessel and were already approaching to bowride. These animals were clearly demonstrating attractive behavior and were seen only because they chose to approach the vessel. To avoid potentially serious positive biases in the abundance estimates, we have chosen not to use sightings of dolphins that were first observed within 500m radial distance from the vessel. These animals were effectively missed by the primary visual observers using bigeye binoculars that have a visual range of several miles from the vessel. The presence of these missed animals in the viewing area indicates a significant degree of visibility bias during the survey and a resulting negative bias in the derived abundance estimates.

Finally, abundance estimates were stratified by naval operations area. For the Charleston/Jacksonville area only survey effort and sightings on the continental shelf (<200 m depth) was used given that the vast majority of survey effort was expended in this habitat, and sighting rates are thus most representative of the continental shelf in this region.

Abundance Estimates-Dolphin Species

A common sighting probability function was fit for all dolphin species across the three survey regions; however, separate sighting functions were fit for dolphin group sizes <20 and >= 20 individuals. As discussed above, all groups first seen at radial distances < 500 m from the vessel were removed from the analysis. As outlined in Buckland *et al.* (1993) the number of sightings as a function of perpendicular distance from the trackline was examined to identify a right truncation distance beyond which the sighting rate dropped off dramatically. For groups <20 animals, the truncation distance corresponded to 1600 m from the trackline resulting in removal of 20/112 on effort groups. The truncation distance for group sizes >= 20 was 2300 m resulting in truncation of 9/45 on effort groups.

The sighting function for each group size was fit by selection of either hazard rate or half-normal key functions with cosine or polynomial adjustment terms. The best-fitting model was selected using the minimum Akaike's Information Criterion (AIC, Buckland *et al.* 1993). For group sizes <20, the best fitting function was a half-normal key function with 2nd and 3rd order cosine adjustment terms (Figure 9a). This model provided a good fit to the sighting data as indicated by a non-significant goodness of fit chi-square (Chi-square = 3.916, df = 4, p = 0.4113). The effective half strip width (ESW) for this function was 740.77 m (coefficient of variation (CV) = 15.96 %).

The best fitting sighting function for group sizes >= 20 was likewise a half-normal key function but with 2nd order cosine adjustment terms (Figure 9b). The model provided a good fit to the data (Chi-square = 7.423, df = 5, p = 0.1904). The calculated ESW was predictably higher than that for groups <20 animals and was 1,172.7 m (CV = 20.91 %).

Regional abundance estimates for Atlantic spotted dolphin, bottlenose dolphin, common dolphin, and striped dolphin are presented in Table 4. Across the entire survey are, the total abundance estimate for spotted dolphin was 19,812 (%CV = 27.3) and that for bottlenose dolphin was 17.727 (%CV = 25.9). The estimate for common dolphin was 79,229 (%CV = 81.8) and 45,237 (%CV = 68.4) for striped dolphin in the Virginia Capes region (Table 4).

Abundance Estimates – Large Whales

Due to the lack of on effort sightings in other regions, the abundance estimates for the large whales and pilot whales are restricted to the Virginia Capes area. There was relatively little variation in group size for these species, and preliminary analysis indicated no significant effect of group size on sighting distances. Unlike the dolphin species, there was no indication or expectation of attraction to the vessel for the large whale species. However, there was one sighting of a fin whale that occurred within 500m of the vessel when the animal surfaced nearly directly ahead of the boat. This sighting was retained in the analysis. In addition to the 7 identified Fin whale sightings, there were two additional sightings that could only be classified as *Balaenoptera sp.* As the other baleen whales including sei whales, blue whales, and minke whales are much less common in this area than fin whales, these unclassified *Balaenoptera sp.* sightings were included in the abundance estimate for fin whale.

A common sighting function was fit across all on effort sightings of sperm whale, fin whale (including *Balaenoptera sp*.), unidentified large whale, and pilot whale sightings in the Virginia Capes region, a total of only 21 on effort sightings. An initial evaluation of the sighting distribution suggested a right truncation distance of 8,000m, removing 1 unidentified large whale sighting from the analysis. Due to the small sample size, the sightings were grouped into wide 2000m distance intervals to fit the sighting function. Several alternative functions including adjustment terms were fit to the sighting data, and the best function (minimum AIC) was the half-normal key with no adjustment terms (Figure 10). This function provided a good fit to the data (Chi-square = 0.3257, 3 df, p = 0.8497) and the resulting effective strip width was 3,693 m (CV = 17.89 %).

Abundance estimates and associated variance for the large whales in the Virginia capes region are shown in Table 5. The estimate for fin whale (including *Balaenoptera sp.*) was 230 animals (CV = 48.26%), for sperm whale the estimate was 142 (CV = 85.36%), and for pilot whale 727 (CV = 73.65%, Table 5).

Summary abundance estimates for both dolphin and whale species across the entire survey region are shown in Table 6.

<u>Distribution with Respect to Habitat Variables</u>

Environmental variables including temperature, depth, and the presence of frontal zones likely have a strong effect on the seasonal spatial distribution of marine mammals. Furthermore, it is likely that different stocks within the same species demonstrate different responses to habitat variables and therefore spatial distribution. In this preliminary analysis, we examined the relationships between sea surface temperature and depth and the number of sightings for five species of dolphins commonly encountered in the survey: Atlantic spotted dolphin, bottlenose dolphin, common dolphin, striped dolphin, and Risso's dolphin.

The majority of bottlenose dolphin sightings occurred in waters of relatively high temperature, though there were apparent regional differences in distribution relative to temperature (Figure 11a-c). In the Charleston/Jacksonville region, the peak in bottlenose dolphin sightings occurred in the 19-21°C temperature range (Figure 11a). Bottlenose dolphin were more commonly found in warmer waters >22 °C in the Cherry Point region (Figure 11b), and to some extent in the Virginia Capes region though there were very few sightings in the northern area (Figure 11c). The depth distribution also reflects this regional difference, as bottlenose dolphin were found most commonly in progressively deeper water with increasing latitude (Figure 12).

Atlantic spotted dolphin distributions also suggest regional differences in habitat preferences. Spotted dolphins were found primarily in the 18-20 degree temperature range in the Charleston/Jacksonville region in very shallow waters (Figure 11a), but seemed to have a broader temperature and depth distribution in the Cherry Point region (Figure 11b, Figure 12).

Those species that were observed primarily in the Virginia Capes region most commonly occurred in intermediate temperature waters between 9-14 °C (Figure 11c). However, common dolphin were also present in shallow, cold water in this region. This temperature range corresponds to a broad depth range in slope waters off the continental shelf between 200-3000 m depth (Figure 12c).

This intermediate temperature region seemed to be a particular area of aggregation for both dolphins and large whale species. The region just south of 38° N latitude off the shelf break was an area where many different species were encountered in close proximity including common dolphin, Risso's dolphin, striped dolphin, and *Balaenoptera* whales (Figure 4, Figure 7). To further evaluate spatial patterns, we show the distribution of marine mammal sightings in the Virginia Capes region with respect to a satellite derived sea surface temperature image from March 1, 2002 corresponding to the timing of the majority of these sightings. This image demonstrates the importance of the region between the cold continental shelf waters and the very warm gulf stream waters as an area of aggregation for these species (Figure 13). Bottlenose dolphin, pilot whale and to a lesser extent sperm whale were more strongly associated with warmer gulf stream water (Figure 13).

CIO observations and visibility bias

In most cases, sightings made by the CIO were of animals that surfaced within 300 meters of the vessel and were approaching the ship to bowride. These included primarily Atlantic spotted and bottlenose dolphins, but also included 2 sightings of false killer whale and an unidentified small cetacean, possibly *Kogia sp.* The vast majority of CIO sightings were also seen by the primary team prior to the animals coming within 20 meters of the bow. There are too few (<20) CIO-only sightings to generate a reliable sighting function and thereby directly estimate sighting probabilities during the survey. However, the frequency of CIO sightings and primary team sightings of animals that first appeared within 600 meters of the vessel do provide information on sighting probabilities. The frequency of these types of sightings in combination with the CIO sightings will be used to evaluate the factors that may contribute to reduced sighting probabilities. These include weather conditions such as sea state and swell and regional differences in animal behavior. These analyses are currently underway and will be used to guide and improve future survey efforts.

Passive acoustic observations

A large number of passive acoustic detections occurred during the survey of the many dolphin species encountered, sperm whales, and pilot whales. The majority of the visual sightings were accompanied by either initial or subsequent acoustic detection. In addition, there were many acoustic detections that were not detected by the visual observers. The acoustic signals collected during the survey are currently being analyzed and reconciled with the visual sighting records. The results from this comparison will include an initial analysis of the utility of acoustic detections to evaluate visibility bias.

Biopsy collections

36 skin biopsy samples were collected during the survey from common dolphin, spotted dolphin, and bottlenose dolphin (Figure 14). This includes 22 samples collected from bottlenose dolphin that will be used to augment the assessment of stock identification for the animals encountered during this survey and during aerial surveys of nearshore waters also conducted during winter 2002.

Discussion

The species encountered during the current survey and resulting abundance estimates are generally consistent with the findings from previous surveys on the US Atlantic continental shelf. Continental shelf waters from Cape Hatteras, NC to Florida generally support high abundances of dolphin species, in particular Atlantic spotted dolphin and bottlenose dolphin. North of Cape Hatteras in the Virginia Capes region, a much higher diversity of cetacean species was encountered and included significant numbers of fin whales. There is an apparent aggregation of cetacean species in intermediate temperature waters between the shelf break and the Gulf Stream during winter months. Results for major species of interest in Atlantic waters are discussed below.

In addition to the survey effort expended on the Atlantic continental shelf, opportunistic sampling of the eastern Gulf of Mexico continental shelf was undertaken with a particular focus on a naval operations area near the west coast of Florida. Very few animals were encountered during the survey effort in this region, but included spotted dolphin, bottlenose dolphin, and Risso's dolphin. Throughout the transit along the eastern Gulf of Mexico, very few cetaceans were encountered or observed. However, this region was an area of relatively frequent occurrence of sperm whales, including mother-calf pairs, in this area during early spring of 2001 (SEFSC Unpublished data). An anomalous "black water" event associated with an algal bloom was occurring along the Gulf coast of Florida during the survey period, perhaps contributing to the relatively low encounter rates of cetaceans during the current survey.

Common Dolphin

Common dolphin was encountered in the Virginia Capes region and was broadly distributed across the continental shelf and along the continental shelf break. Only 20 groups of common dolphin were sighted; however, many of these groups were extremely large. Several groups were over 150 animals, and the largest group was estimated at 798 animals. This large variation in group size contributed to the high degree of uncertainty in the abundance estimates for common dolphin derived from this survey. The combined estimate was 45,237 animals with a 68.7% coefficient of variation (CV). This is within the range of the entire population estimate based upon summer surveys from Maryland to the Gulf of St. Lawrence of approximately 31,000 animals (CV = 32%, Waring *et al.,* 2001). During the summer surveys, common dolphins occurred solely along the shelf break, the southern flank of Georges Bank, and in the Gulf of Maine north of Delaware Bay (Waring, *et al.*, 2001). In a summer 1998 survey of shelf and slope waters south of Delaware Bay no common dolphins were observed (Mullin, *in press*) , and only two small groups were observed in summer 1999 (SEFSC, unpublished data). These results suggest that a significant portion of the common dolphin population migrates southward onto the mid-Atlantic continental shelf and slope during winter months, consistent with findings from aerial surveys conducted during winter in the early 1980s (CETAP, 1982).

Common dolphin is currently defined as a strategic stock under the MMPA because mortality rates due to fishery activities greatly exceed PBR (Waring *et al.* 2001). Common dolphin is taken relatively frequently in gillnet and bottom trawl fisheries in the mid-Atlantic and northeast United States and are also hooked in pelagic longline fisheries. The current study suggests that the bulk of the population may be vulnerable to fishing and other human activities in mid-Atlantic continental shelf and inner slope waters during winter.

Bottlenose Dolphin

Bottlenose dolphin was encountered throughout the survey range and was the second most common species seen during the survey. There are two genetically, morphometrically, and ecologically distinct types of bottlenose dolphin in mid-Atlantic continental shelf waters (Hersh & Duffield, 1990). It is probable that the bulk of the two populations do not overlap with one another, however spatial overlap between the two morphotypes has been demonstrated in waters <30m depth over the continental shelf off of Georgia and South Carolina (P. Rosel, NOAA, unpublished data). The coastal morphotype has been the subject of considerable recent management action as it suffers a significant level of mortality in coastal gillnet fisheries in nearshore waters of North Carolina and Virginia (Waring *et al.* 2001). The bulk of the coastal morphotype population likely resides in waters <10m depth and therefore outside of the coverage of the current survey.

One notable spatial pattern in bottlenose dolphin distribution is that they occurred progressively further offshore with increasing latitude. This is consistent with the findings of previous summer surveys (SEFSC, unpublished data) and suggests that the coastal and offshore morphotype populations diverge at higher latitudes. During summer north of Cape Hatteras, NC previous surveys have observed a high abundance of bottlenose dolphins close to shore in waters <25 m depth, a region of very low abundance between 25-100m depth, and then a high abundance of presumably offshore morphotype animals along the continental shelf break and inner slope (Kenney, 1990; SEFSC, unpublished data). During winter, the coastal form migrates south of Cape Hatteras, a pattern confirmed by aerial surveys also conducted during winter 2002 where no bottlenose dolphins were observed in nearshore waters north of Manteo, NC (SEFSC, unpublished data). In the Virginia Capes region during the current survey, bottlenose dolphins were observed in deeper water at the continental shelf break, and it is likely that these animals were of the offshore morphotype. In the Cherry Point region, bottlenose dolphins were also encountered in primarily warm, deep waters on the outer continental shelf. However, during the winter 2002 aerial survey, there was a very high abundance of dolphins close to shore between Cape Hatteras and Cape Lookout NC (SEFSC, unpublished data). Preliminary results of biopsy samples collected during fall and winter of 2002 indicated that the offshore morphotype occurred close to shore in this region (A. Hohn, SEFSC, unpublished data) suggesting potential mixing of the two populations in this area. In the Charleston/Jacksonville region, it is very likely that the two populations overlap with each other, particularly in water <40m depth. Continued analysis of genetic samples collected during the current survey and in localized sampling efforts during winter 2002 will allow a more complete analysis of the relative distribution of the two morphotypes in during winter months.

The vast majority of the bottlenose dolphin encountered during this survey are most likely from the offshore morphotype. The current coastwide abundance estimate of 17,727 (CV = 26.3%) is not significantly different from an estimate of 13,944 (CV = 38%) for offshore bottlenose dolphin based upon a shipboard survey during the summer 1998 (Mullin *in press*). The 1998 survey covered the same general latitudinal range, but also included survey effort on the outer continental slope to the US EEZ suggesting that the majority of the offshore bottlenose dolphin population occurs on the continental shelf or inner slope in mid-Atlantic waters. Offshore morphotype bottlenose dolphin also occur in waters further north on the continental shelf and southern flank of Georges Bank, and their abundance during summer was estimated at 16,689 (CV = 32%, Waring *et al.*, 2001) resulting in a coast wide estimate for the offshore morphotype of 30,633 (CV = 25%) animals. It is likely, however, that at least a small proportion of the animals encountered during both the current survey and the 1998 survey were of the coastal morphotype and the resulting abundance estimates may therefore be positively biased. However, the surveys did not include waters <10m depth where the majority of the coastal stock occurs, particularly in the waters of South Carolina and Georgia.

<u>Atlantic Spotted Dolphin</u>

Atlantic spotted dolphin were observed primarily over continental shelf waters south of Cape Hatteras. This is also consistent with the summer distribution of spotted dolphins based upon the 1998 (Mullin *in press*) and 1999 (unpublished data) SEFSC ship surveys. As with bottlenose dolphin, there are two genetically distinct morphotypes of spotted dolphin in US Atlantic waters (Perrin *et al.* 1994). North of Cape Hatteras, spotted dolphins are observed in very deep waters (>1000m) well off the shelf break, and this likely represents the bulk of the offshore stock (Waring *et al.* 2001). With limited effort in the deeper continental slope waters off of Florida, two groups of spotted dolphins were observed and likewise several spotted dolphin groups were observed in this region during the 1998 survey (Mullin *in press*). It remains unclear whether these animals are of the offshore or coastal morphotype, and further genetic sampling in this region is required to better delineate the habitat preferences of the two stocks.

The current abundance estimate of 19,812 (CV = 26.9%) animals is very similar to the estimate of 20,326 (CV = 60%) animals for the 1998 summer survey (Mullin *in press*). Spotted dolphin is rarely taken in commercial fishing operations and other activities, and the species is not currently defined as a strategic or depleted stock (Waring *et al.* 2001).

<u>Risso's Dolphin</u>

Risso's dolphin most commonly occurs along the shelf break and inner continental slope in the northwest Atlantic. The bulk of observations during summer months occurred along the southern flank of Georges Bank and in shelf break waters north of New Jersey (Waring *et al.* 2001, CETAP 1982). In winter, the range in the northeast US extends further offshore into oceanic waters north of Cape Hatteras. Risso's dolphin has shown a strong association with shelf-break waters in a number of different ocean basins. In the northern Gulf of Mexico, Risso's dolphin were strongly associated with regions with strong gradients in bathymetry, and it was hypothesized that they concentrated in frontal systems along the shelf where intermediate water temperatures and high food concentration occurred (Baumgartner 1997, Baumgartner *et al.* 2001). The Risso's dolphins observed in the Virginia Capes region during the current study were also observed near the shelf-break in waters of intermediate temperatures. The high abundance of fin whales and other species within this area suggests that food availability or some other factor likely associated the shelf-break frontal system results in a concentration of marine mammals in this region.

Beaked Whales

There are four species of beaked whales from the genus *Mesoplodon* that occur in Northwest Atlantic waters: *M mirius* (True's beaked whale), *M. europaeus* (Gervais' beaked whale, *M. densirostris* (Blainville's beaked whale), and *M. bidens* (Sowerby's beaked whale). These four species in addition to Cuvier's beaked whale (*Ziphius cavirostris*) are difficult to distinguish at sea and are thus assessed as undifferentiated beaked whales (Waring *et al.* 2001). As in previous assessments, these species are classified as cryptic due to their relatively small body size, short surfacing intervals, and long dive times (Barlow 1995). Thus, these animals are difficult to observer during visual surveys and are rarely encountered.

During the current survey, three beaked whales were observed in the continental slope waters of the Cherry Point region. This is consistent with the general finding that beaked whales primarily are observed in deep waters near the continental shelf break (Waring *et al* 2001). In addition, beaked whales of all species are commonly stranded along the North Carolina coastline (SEFSC, unpublished data). The bulk of beaked whale sightings during summer surveys have occurred in continental slope waters between Delaware and the southern flank of Georges Bank, with occasional sightings in southern areas (Waring *et al.* 2001). Based upon 8 sightings during the 1998 summer survey, beaked whale abundance was estimated at 596 (CV = 50%) animals (Mullin *in press*); however, it is likely that this estimate is negatively biased because it was not corrected for the long dive times of these species.

Beaked whales are currently considered a strategic stock due to the high degree of uncertainty in the abundance estimates and stock structure. There is also significant concern with these species due to documented mortality events in other regions associated with sound production during naval activities (Waring *et al.*, 2001). Considerable additional research is necessary to adequately assess beaked whale stocks in Atlantic waters.

Pilot Whale

There are two species of pilot whale on the US continental shelf and inner slope waters. Long-finned pilot whale (*Globicepahla melas*) is generally distributed in the northern end of the range from Florida to the Gulf of Maine while short-finned pilot whale (*Globicephala macrorhynchus*) occurs in the southern portion of the range. The species boundary is generally considered to be in the North Carolina – New Jersey region (Waring *et al.* 2001), corresponding roughly to the Virginia Capes area in the current study. Since the two species cannot be distinguished visually during surveys, it is unclear which species, or whether a mix of the two were observed in the Virginia Capes area during the current survey. It is likely that the pilot whales observed over the continental slope off of Florida were short-finned pilot whales.

The abundance estimate for the current survey of 727 animals (CV = 0.74) is considerably lower than a combined estimate of 14,254 (CV = 0.30) encompassing the area from the Gulf of St. Lawrence to Florida. The bulk of the pilot whale population likely occurs north of the survey area. Pilot whales are generally found in association with high relief areas and submerged banks or along the northern edge of the Gulf stream wall (Waring *et al.* 1992). The pilot whales observed in the current survey in the Virginia Cape region were associated with very warm Gulf Stream water. Seasonal movements of pilot whales suggest a spring and summer northern migration onto Georges Bank and the Gulf of Maine, and perhaps a southern and offshore migration during winter (Payne & Heinemann, 1993). The association of pilot whales with warm water during this study is consistent with those movement patterns. Likewise, the occurrence of pilot whales, likely *G. macrorhynchus*, in deep continental slope waters in the southern regions is consistent with studies during summer months (Waring *et al*., 2001).

Pilot whales are taken frequently in bottom trawl, gillnet, and pelagic longline fisheries along the US mid-Atlantic and north Atlantic coasts (Yeung, 1999; Waring *et al.*, 2001). The association of pilot whales with frontal zones and relief areas is likely correlated with high abundances of fish prey species and their predators. The fisheries that target these large pelagic predators including tunas and swordfish thus have considerable overlap with pilot whale distributions and potential interactions. Notably, one group of pilot whales was observed during this survey in very close association (< 200m) from a pelagic longline off the coast of North Carolina.

Fin Whale

Fin whales are the most common large whales observed in US mid-Atlantic continental shelf waters (Hain *et al.* 1993, Waring *et al.* 2001). During spring, summer and fall, fin whales are broadly distributed across the continental shelf and along the shelf break, and tend to aggregate in the great south channel of Georges Bank and inshore Gulf of Maine (Hain *et al.* 1993, Waring *et al.* 2001). Fin whale was less common on the continental shelf during winter (Hain *et al.* 1993). During the current survey, fin whales were encountered aggregated in a localized area near the continental shelf break. This was a region of intermediate temperature waters between 9-13 °C. This temperature range corresponds to the modal temperature of 12-14 °C of fin whale sightings during the 1982 CETAP aerial surveys. The findings of the current study are consistent with those of the CETAP data showing that the deep continental shelf waters off of Delaware bay are an important area of winter aggregation for fin whales (Hain *et al.*, 1993)

The abundance estimate from the current survey of 230 animals (CV = 48.3%) is well below the population estimate of 2,814 animals used in the current assessment (Waring *et al.*, 2001). This is not surprising as the bulk of the fin whale population likely occurs well north of the study area on the Nova Scotian shelf and/or in waters further offshore.

Continuing Analyses

The results presented here provide a broadscale assessment of the occurrence and abundance of marine mammals in three large areas of the US Atlantic continental shelf. All of these abundance estimates should be considered minimum estimates as they are not corrected for dive times and visibility bias. In addition to the visual effort, passive hydroacoustic effort was accomplished through much of the survey and included many acoustic detections, particularly of large whales, that were not observed visually. The additional acoustic detections will be used to augment presence/absence information derived from visual sightings, and will be incorporated into analyses of sighting probabilities. We are also continuing our analysis of sighting probabilities based upon the conditionally independent observer sightings for incorporation into corrected abundance estimates. Finally, we are exploring more detailed modeling efforts to evaluate habitat associations of the major species encountered during this survey. These analyses will allow a more detailed assessment of the habitats and localized spatial areas where aggregations of marine mammals are likely to occur. Results from the current survey represent the first assessment of winter habitat preferences for these species in mid-Atlantic waters in the last 10 years. In combination with results from the summer 1998 and 1999 efforts, the surveys will form the basis of habitat preference models for cetaceans over the US mid-Atlantic continental shelf.

Improvements in Future Surveys

The primary limitation of the current survey methodology employed by SEFSC is an inability to account for visibility bias in abundance estimation. As a result, all abundance estimates derived solely from visual effort should be considered minimal estimates. In addition, using current methodologies, it is difficult to account for changes in animal visibility under varying survey conditions. This is particularly relevant for winter surveys where a significant amount of effort must be expended under marginal sighting conditions. There are two methods to adequately address these issues, both of which will be incorporated into future SEFSC marine mammal assessment surveys. First, the passive hydroacoustic approach provides an additional source of marine mammal detections that does not face the same limitations as the visual survey. The results from the hydroacoustic effort expended during the survey will be directly compared to those from the visual effort to provide a preliminary analysis of sighting probabilities under varying conditions. The appropriate application of acoustic detections to augment visual surveys is an area of active research within both the SEFSC and other NOAA fisheries regions.

Second, the incorporation of a second independent team of visual observers will greatly improve the abundance estimates resulting from visual surveys. A second team of visual observers during a survey provides an independent estimate of abundance from the same sighting platform and allows application of a suite of approaches based upon mark-recapture statistics to quantify visibility bias during the survey (e.g., Laake 1999; Borchers *et al.* 1998a). A second team of observers also allows a more flexible analysis of the role of environmental factors on sighting probabilities (e.g., Borchers *et al.* 1998b) and can be used to account for animal attraction to the vessel (Palka & Hammond, 2001). The *Gordon Gunter* is an ideal platform for incorporating a second team of observers. Bigeye binoculars can be affixed on bridge wings several meters below the flying bridge that would allow full visibility on either side of the vessel and are still approximately 10m above the water surface. SEFSC has recently incorporated the two-team methods into aerial surveys for bottlenose dolphins with considerable success and plans to incorporate this approach into all future assessment surveys.

<u>Future Survey Needs</u>

The results of the current survey and previous assessment surveys indicate a consistent association of cetacean species with major oceanographic features along the shelf-break front and the boundary between Gulf Stream and continental slope waters. These frontal zones are likely areas where oceanographic processes such as upwelling and convergence zones create local patches of high primary and secondary production, high fish biomass, and therefore high abundances of marine mammals. The resulting spatially patchy distribution of marine mammals contributes to the relatively low encounter rates and high uncertainty associated with abundance estimates. For example, much of the variability in the common dolphin abundance estimate resulted from the extreme variation in group size. As previously noted, in one instance a group of approximately 800 animals was encountered, and this within the same general region where fin whales, Risso's dolphin, and large groups of striped dolphins occurred. Likewise, pilot whales have shown a strong association with boundary regions of the Gulf Stream in the Atlantic and in frontal zones in other basins. Due to the concentration of pelagic fish and squid species, these frontal zones are often an area of high fishery activity as well, perhaps contributing to interactions with marine mammals.

The broadscale design of past assessment surveys has resulted in relatively little effort within frontal zones. As a result, there are usually few encounters with species associated with these areas and high uncertainty in abundance estimates. Further, there has been no directed effort to evaluate the oceanographic processes and prey fields that supports these localized aggregations of marine mammals in the mid-Atlantic. An integrated physical and biological evaluation of marine mammal habitat was recently conducted in the Gulf of Mexico (Davis *et al.* 2002) and a survey concentrating on the shelf break zone along the southern flank of Georges Bank is currently being planned by the Northeast Fisheries Science Center (G. Waring, NEFSC, personal communication). Future surveys will include integrated effort to characterize the physical and biological habitat that supports large aggregations of marine mammals.

Conclusions

The winter 2002 marine mammal survey provided an assessment of the winter distribution of cetaceans in mid-Atlantic continental shelf and inner slope waters between Florida and Delaware Bay. Minimum abundance estimates for major Naval operations areas have been derived based upon visual survey effort. In addition, biopsy samples from Atlantic bottlenose dolphin were collected during the survey that will be used to better define the winter habitat boundaries for the coastal and offshore morphotypes. Continuing analyses include evaluation of habitat associations, environmental factors influencing sighting probabilities, and assessing the utility of passive hydroacoustic detections to augment visual survey efforts.

Acknowledgments

The winter 2002 assessment survey could not have been conducted without the dedication of numerous individuals who planned and participated in the surveys. This included Dr. Keith Mullin, Wayne Hoggard and Carol Roden of the SEFSC Pascagoula, MS laboratory. Diligent visual observers are essential to accomplishing the mission of these surveys, and we recognize the work of observers Chris Andrews, Dr. Joel Bell, Maria Cordona, Carol Fairfield, Paul Felts, Kathy Foley, Annie Gorgone, Dean Landi, Lanora Lang, Jennifer Lawrence, Aaron Mooney, Laura Morse, Dr. Debra Palka, Grisel Rodriguez, Carrie Sinclair, Aaron Thode, Juan Carlos Salinas Vargas, and Eric Zolman. The officers and crew of the NOAA ship *Gordon Gunter* provide consistent, highly professional mission support and contribute significantly to the quality of assessment surveys conducted by SEFSC. Biopsy samples were collected under permit from NOAA fisheries Office of Protected Resources #779-1633-00 and the survey was conducted SEFSC's research permit #779-1339. The survey was supported by the Chief of Naval Operations, Environmental RDT&E Program (Code N45) under an interagency agreement with NOAA Fisheries Southeast Fisheries Science Center, Miami Laboratory.

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Table 1. Summary of planned and exectued survey effort during the winter 2002 marine mammal survey.

Region	Region area (km^2)	Planned Effort (km)	Actual Effort (km)
Charleston / Jacksonville	72,054*	1891	2343.9*
Cherry Point	65,580	1123	880.3
Virginia Capes	125,930	1277	961.5
Gulf of Mexico	N/A	0	406.8
Total		**4,291**	**4,592.4**

* Charleston/Jacksonville total effort includes unplanned trackline opportunistically sampled in waters > 200 m depth. Due to limited effort, the given region area and all abundance estimates are based only upon effort and sightings on the continental shelf. 1902.1 km of survey effort was accomplished on the continental shelf in this region.

Table 2. Summary of all marine mammal sightings during mid-Atlantic cetacean survey, February-April 2002. "On-Effort" indicates the total number of marine mammal herds observed while on trackline during survey operations.

Species Name	Common Name	Number of Groups	On-Effort
Stenella frontalis	Atlantic spotted dolphin	94	65
Balaenoptera sp.	Rorqual Whales	3	2
Tursiops truncatus	Bottlenose dolphin	62	50
Delphinus delphis	Common Dolphin	20	17
Balaenoptera physalus	Fin Whale	8	7
Kogia sp.	Pygmy/Dwarf Sperm Whale	2	1
Peponocephala electra / Kogia sp.	Melonheaded Whale/Pygmy Sperm Whale	1	1
Peponocephala electra	Melonhead	1	1
Mesoplodon sp.	Mesoplodon Beaked Whales	1	1
Globicephala sp.	Pilot Whale	10	7
Pseudorca crassidens	False Killer Whale	2	0
Eubalaena glacialis	Northern Right Whale	1	1
Grampus griseus	Risso's Dolphin	9	8
Stenella clymene	Clymene Dolphin	1	1
Physeter macrocephalus	Sperm Whale	5	4
Stenella sp.	Un-id Stenella Dolphin	4	2
Stenella coeruleoalba	Striped Dolphin	11	9
Tursiops truncatus/Stenlla frontalis	Bottlenose or Spotted Dolphin	7	5
Un-identified Beaked Whale	Un-id Beaked Whale	1	1
Un-identified Dolphin	Un-id Dolphin	31	25
Un-identified Large Whale	Un-id Large Whale	6	4
Un-identified Odontocete	Un-id Toothed Whale	4	3
Un-identified Small Whale	Un-id Small Whale	2	2
Ziphius sp.	Ziphiid beaked whales	1	1
Total		**287**	**218**

Table 3a. Number of marine mammal herds sighted by survey region during mid-Atlantic cetacean survey, February-April 2002. "On-Effort" indicates the total number of marine mammal herds observed while on trackline during survey operations.

Species Name	**Common Name**	**Number of Groups**	**On-Effort**
Charleston/Jax Region			
Stenlla frontalis	Atlantic spotted dolphin	73	51
Tursiops truncatus	Bottlenose dolphin	39	34
Globicephala sp.	Pilot Whale	2	1
Pseudorca crassidens	False Killer Whale	2	0
Eubalaena glacialis	Northern Right Whale	1	1
Grampus griseus	Risso's Dolphin	1	1
Physeter macrocephalus	Sperm Whale	1	1
Stenella sp.	Un-id Stenella Dolphin	3	2
Tursiops truncatus/Stenlla frontalis	Bottlenose or Spotted Dolphin	6	4
Un-identified Dolphin	Un-id Dolphin	16	12
Un-identified Small Whale	Un-id Small Whale	1	1
Cherry Point Region			
Stenlla frontalis	Atlantic spotted dolphin	15	10
Tursiops truncatus	Bottlenose dolphin	13	8
Kogia sp.	Pygmy/Dwarf Sperm Whale	2	1
Mesoplodon sp.	Mesoplodon Beaked Whales	1	1
Globicephala sp.	Pilot Whale	1	0
Stenella sp.	Un-id Stenella Dolphin	1	0
Tursiops truncatus/Stenlla frontalis	Bottlenose or Spotted Dolphin	1	1
Un-identified Beaked Whale	Un-id Beaked Whale	1	1
Un-identified Dolphin	Un-id Dolphin	4	3
Un-identified Large Whale	Un-id Large Whale	1	1
Un-identified Small Whale	Un-id Small Whale	1	1
Ziphius sp.	Ziphiid beaked whales	1	1

Table 3b. Number of marine mammal herds sighted by survey region during mid-Atlantic cetacean survey, February-April 2002. “On-Effort” indicates the total number of marine mammal herds observed while on trackline during survey operations.

Species Name	**Common Name**	**Number of Groups**	**On-Effort**
Virginia Capes Region			
Stenlla frontalis	Atlantic spotted dolphin	2	2
Balaenoptera sp.	Rorqual Whales	3	2
Tursiops truncatus	Bottlenose dolphin	9	7
Delphinus delphis	Common Dolphin	20	17
Balaenoptera physalus	Fin Whale	8	7
Peponocephala electra / Kogia sp.	Melonheaded Whale/Pygmy Sperm Whale	1	1
Peponocephala electra	Melonheaded Whale	1	1
Globicephala sp.	Pilot Whale	7	6
Grampus griseus	Risso's Dolphin	7	6
Stenella clymene	Clymene’s Dolphin	1	1
Physeter macrocephalus	Sperm Whale	4	3
Stenella coeruleoalba	Striped Dolphin	11	9
Un-identified Dolphin	Un-id Dolphin	11	10
Un-identified Large Whale	Un-id Large Whale	5	3
Un-identified Odontocete	Un-id Toothed Whale	4	3
Gulf of Mexico Region			
Stenlla frontalis	Atlantic spotted dolphin	4	2
Tursiops truncatus	Bottlenose dolphin	1	1
Grampus griseus	Risso's Dolphin	1	1

Table 4a. Abundance estimates for Atlantic spotted and bottlenose dolphin in the Charleston/Jacksonville and Cherry Point regions.

	Number of Groups	Encounter Rate N/L (%CV)	Mean Group Size (%CV)	Group Density (% CV) groups km^{-2}	Animal Density (%CV) n km^{-2}	Abundance Estimate	Abundance 95 % CI
Charleston/Jacksonville Region							
Atlantic Spotted Dolphin							
Group Size < 20	27	0.014 (30.1)	8.2 (11.9)	0.0096 (34.1)	0.0784 (36.0)	5,648	2,905-10,978
Group Size >= 20	11	0.006 (42.9)	36.8 (17.9)	0.0025 (47.7)	0.0907 (50.1)	6,539	2,615 – 16,346
Total					**0.1691 (31.2)**	**12,187**	**6,816 – 21,789**
Bottlenose Dolphin							
Group Size < 20	23	0.012 (33.2)	6.3 (16.5)	0.0082 (36.8)	0.0511 (40.3)	3,679	1,755 – 7,714
Group Size >= 20	3	0.002 (98.1)	60.7 (24.1)	0.0006 (102.1)	0.0408 (103.1)	2,938	580 – 14,875
Total					**0.0918 (49.5)**	**6,617**	**2,647 – 16,540**
Cherry Point Region							
Atlantic Spotted Dolphin							
Group Size < 20	5	0.005 (32.7)	8.6 (29.6)	0.0038 (36.4)	0.0329 (46.9)	2,162	924 – 5,058
Group Size >= 20	3	0.006 (61.8)	57.3 (10.5)	0.0015 (65.2)	0.0833 (66.1)	5,463	1,734 – 17,120
Total					**0.116 (49.2)**	**7,625**	**3,140 – 8,960**
Bottlenose Dolphin							
Group Size < 20	1	0.0011 (75.4)	16.0 (8.5*)	0.0008 (77.1)	0.0123 (77.5)	804	217 – 2,974
Group Size >= 20	4	0.045 (39.8)	30.8 (8.5)	0.0019 (44.9)	0.0596 (45.7)	3,906	1,703 – 8,960
Total					**0.0718 (40.1)**	**4,711**	**2,255 – 9,842**

Table 4b. Abundance estimates for Atlantic spotted and bottlenose dolphin in the Virginia Capes region.

Virginia Capes Region							
	Number of Groups	**Encounter Rate N/L (%CV)**	**Mean Group Size (%CV)**	**Group Density (% CV) groups km^{-2}**	**Animal Density (%CV) n km^{-2}**	**Abundance Estimate**	**Abundance 95 % CI**
Bottlenose Dolphin							
Group Size < 20	2	0.002 (56.3)	12.5 (20.0)	0.0014 (58.5)	0.0176 (61.8)	2,210	747 – 6,536
Group Size >= 20	3	0.003 (47.5)	25 (10.4)	0.0013 (51.8)	0.0333 (52.9)	4,188	1,625 – 10,791
Total					**0.0508 (40.7)**	**6,398**	**3,035 – 13,487**
Common Dolphin							
Group Size < 20	5	0.005 (47.8)	7.4 (22.8)	0.0035 (50.4)	0.0259 (55.3)	3,271	1,221 – 8,760
Group Size >= 20	6	0.006 (72.4)	226.7 (40.1)	0.0026 (75.3)	0.6032 (85.3)	75,958	18,562 – 310,830
Total					**0.6292 (81.8)**	**79,229**	**20,252 – 309,957**
Striped Dolphin							
Group Size < 20	1	0.001 (63.3)	19 (12.3*)	0.0007 (65.2)	0.0134 (66.4)	1,679	531 – 5,312
Group Size >= 20	4	0.004 (67.1)	195 (12.3)	0.0018 (70.3)	0.346 (71.3)	43,558	12,834 – 147,830
Total					**0.359 (68.7)**	**45,237**	**13,829 – 147,972**

Table 5. Abundance estimates for large whale species and pilot whale in the Virginia Capes regions

Virginia Capes Region							
	Number of Groups	**Encounter Rate N/L (%CV)**	**Mean Group Size (%CV)**	**Group Density (% CV) groups km^{-2}**	**Animal Density (%CV) n km^{-2}**	**Abundance Estimate**	**Abundance 95 % CI**
Fin Whale	9	0.0094 (41.6)	1.44 (16.8)	0.0013 (45.3)	0.0018 (48.3)	230	84 - 631
Sperm Whale	3	0.0031 (82.5)	2.67 (12.5)	0.0004 (84.4)	0.0011 (85.4)	142	25 - 816
Pilot Whale	6	0.0062 (67.6)	6.83 (23.1)	0.0008 (69.9)	0.0058 (73.7)	727	159 - 3,317

Table 6. Summary of abundance estimates from the winter 2002 marine mammal survey.

Species	Charleston/ Jacksonville (%CV)	Cherry Point (%CV)	Virginia Capes (%CV)	Total Abundance (% CV)	Total Abundance 95% CI
Dolphin Species					
Atlantic Spotted Dolphin	12,187 (31.2)	7,625 (49.2)	-	19,812 (26.9)	11, 971 – 32,788
Bottlenose Dolphin	6,617 (50.9)	4,711 (40.1)	6,398 (40.7)	17,727 (26.3)	10,828 – 29,020
Common Dolphin	-	-	79,229 (81.8)	79,229 (81.8)	20,252 – 309,957
Striped Dolphin	-	-	45,237 (68.7)	45,237 (68.7)	13,829 – 147,972
Whale Species					
Fin Whale	-	-	230 (48.3)	230 (48.3)	84 - 631
Sperm Whale	-	-	142 (85.4)	142 (85.4)	25 - 816
Pilot Whale	-	-	727 (73.7)	727 (73.7)	159 - 3,317

Figure 1. Planned tracklines for the winter 2002 marine mammal survey. Survey regions corresponding to naval operations areas and bathymetry to 200m depth are shown.

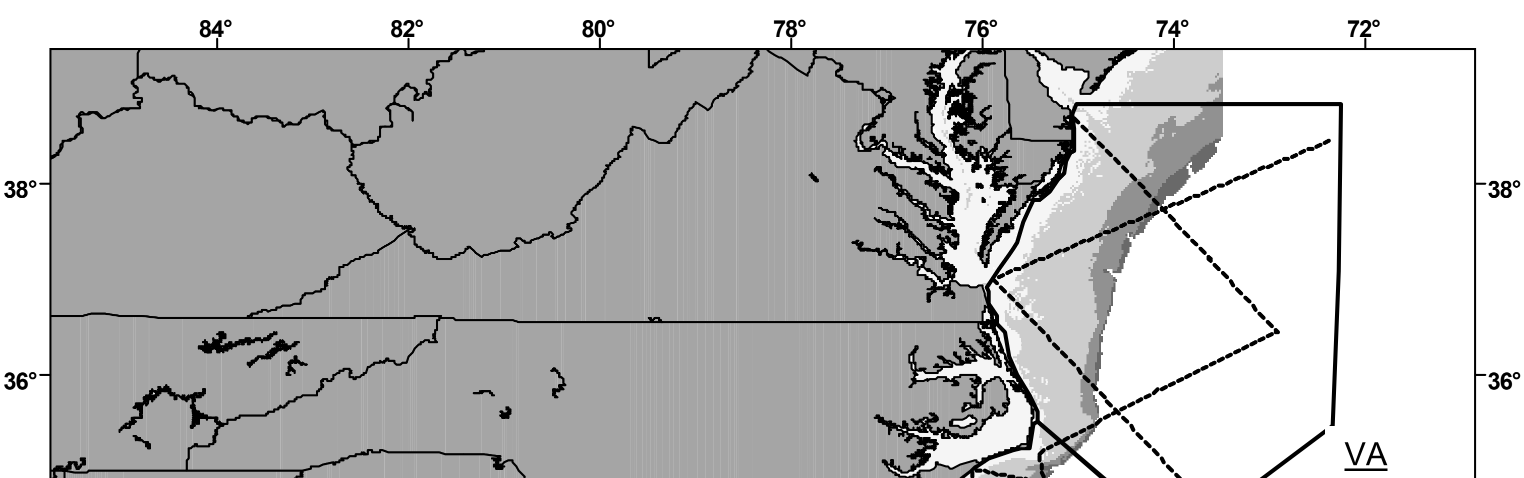


Figure 2. On effort tracklines on the US Atlantic continental shelf during the winter 2002 marine mammal survey. Survey regions corresponding to naval operations areas and bathymetry to 200m depth are shown.

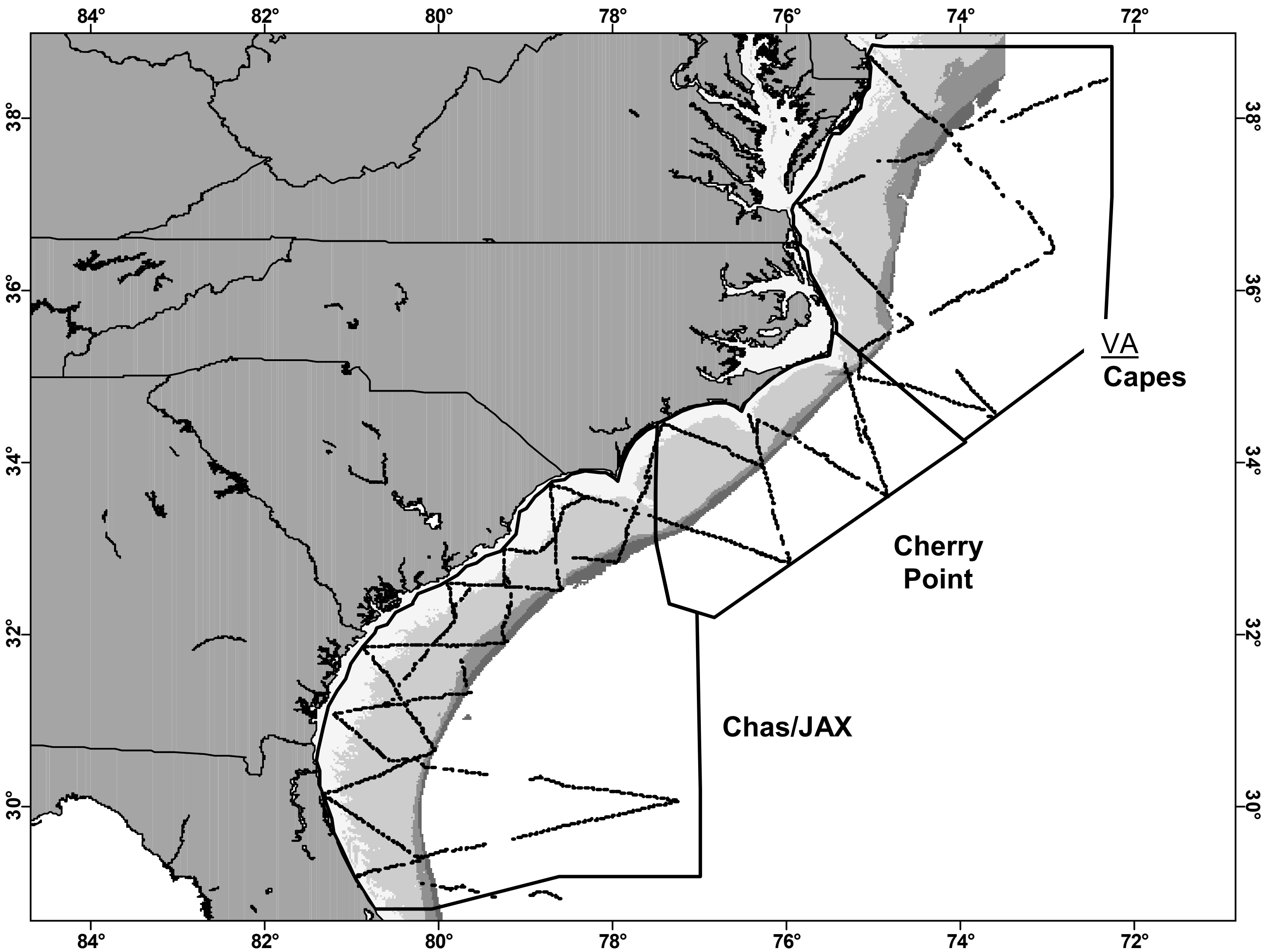


Figure 3. Additional survey effort in the eastern Gulf of Mexico and sightings of spotted, bottlenose, and Risso's dolphin.

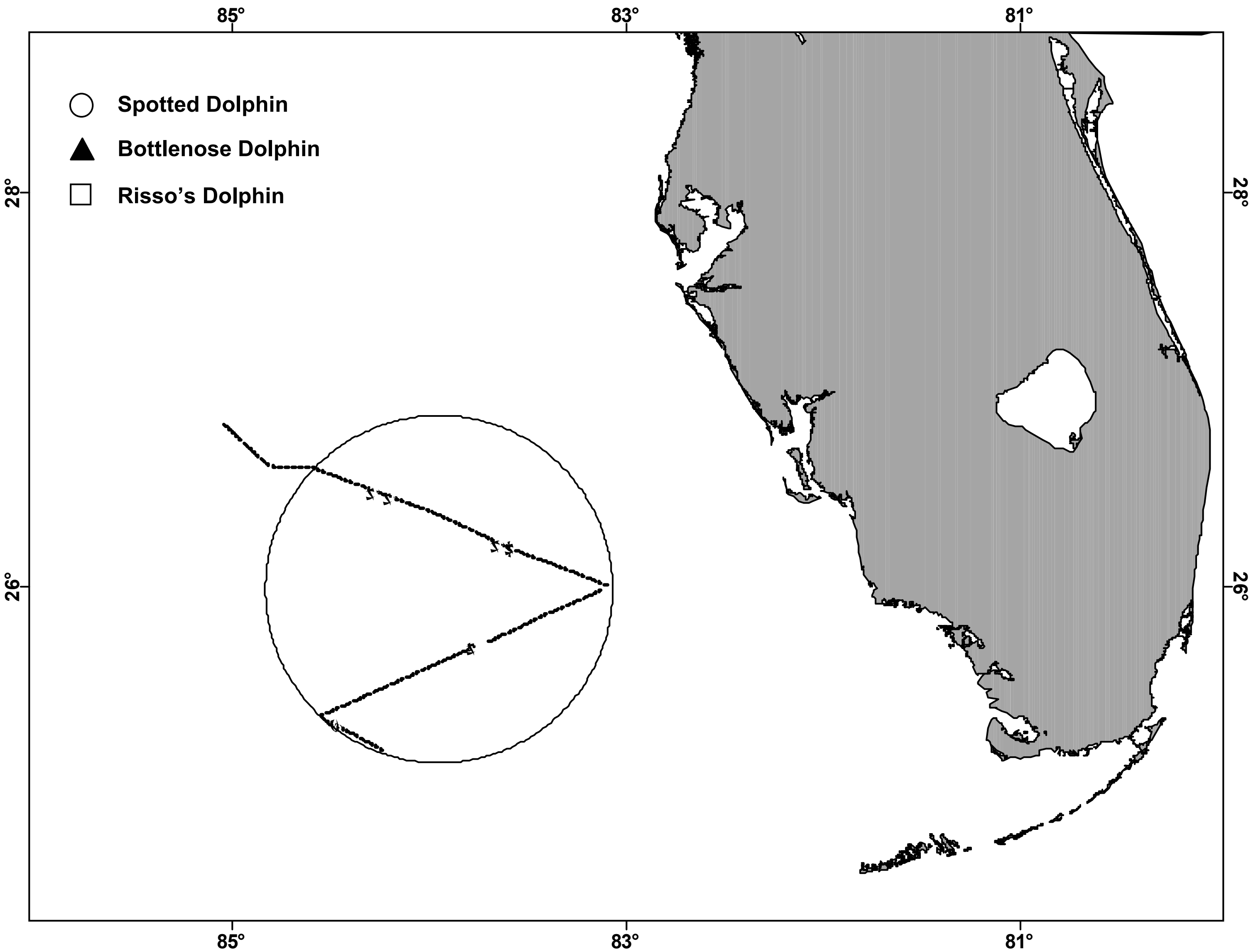
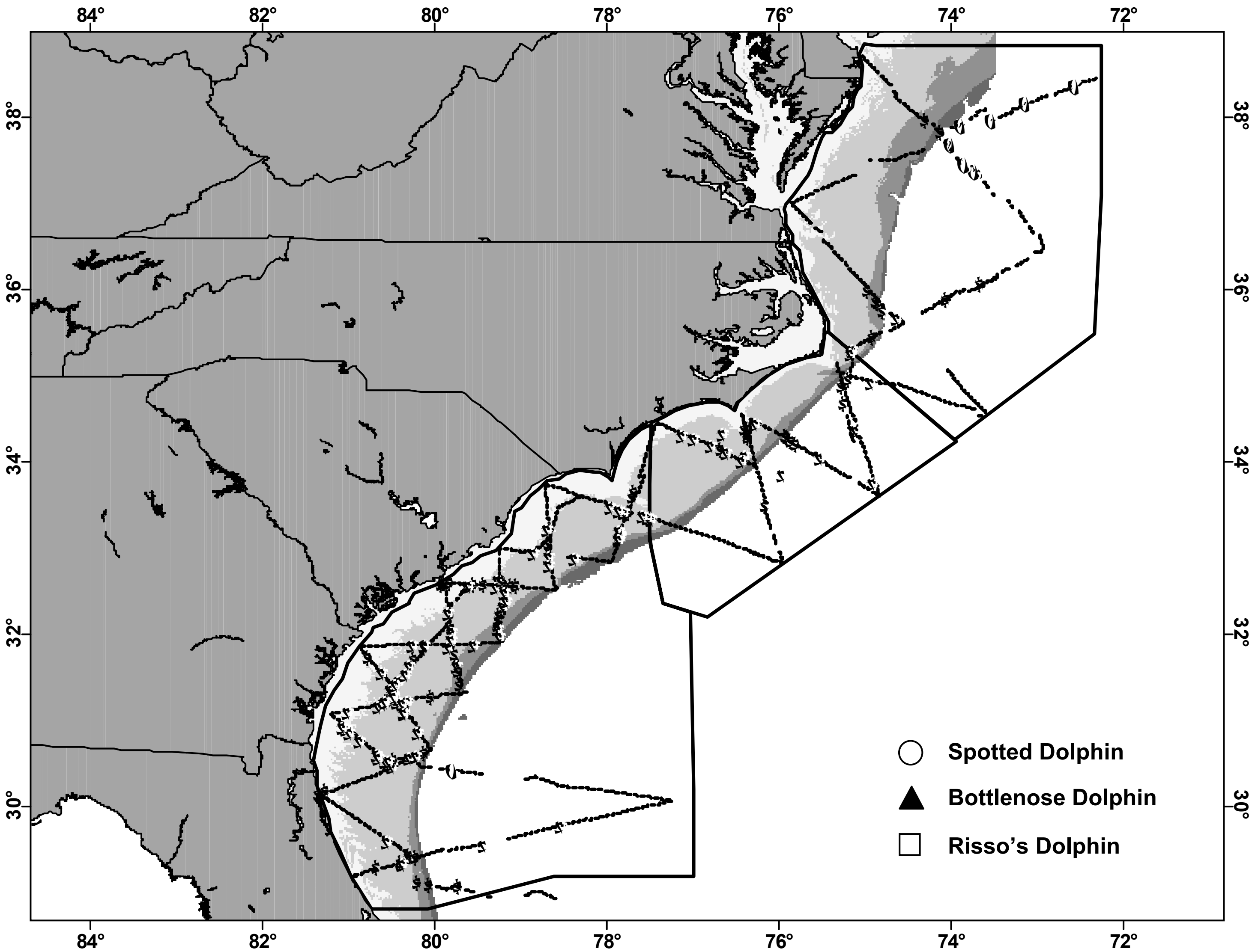


Figure 4. Sightings of Atlantic spotted dolphin, bottlenose dolphin, and Risso's dolphin in the mid-Atlantic during the winter 2002 survey.



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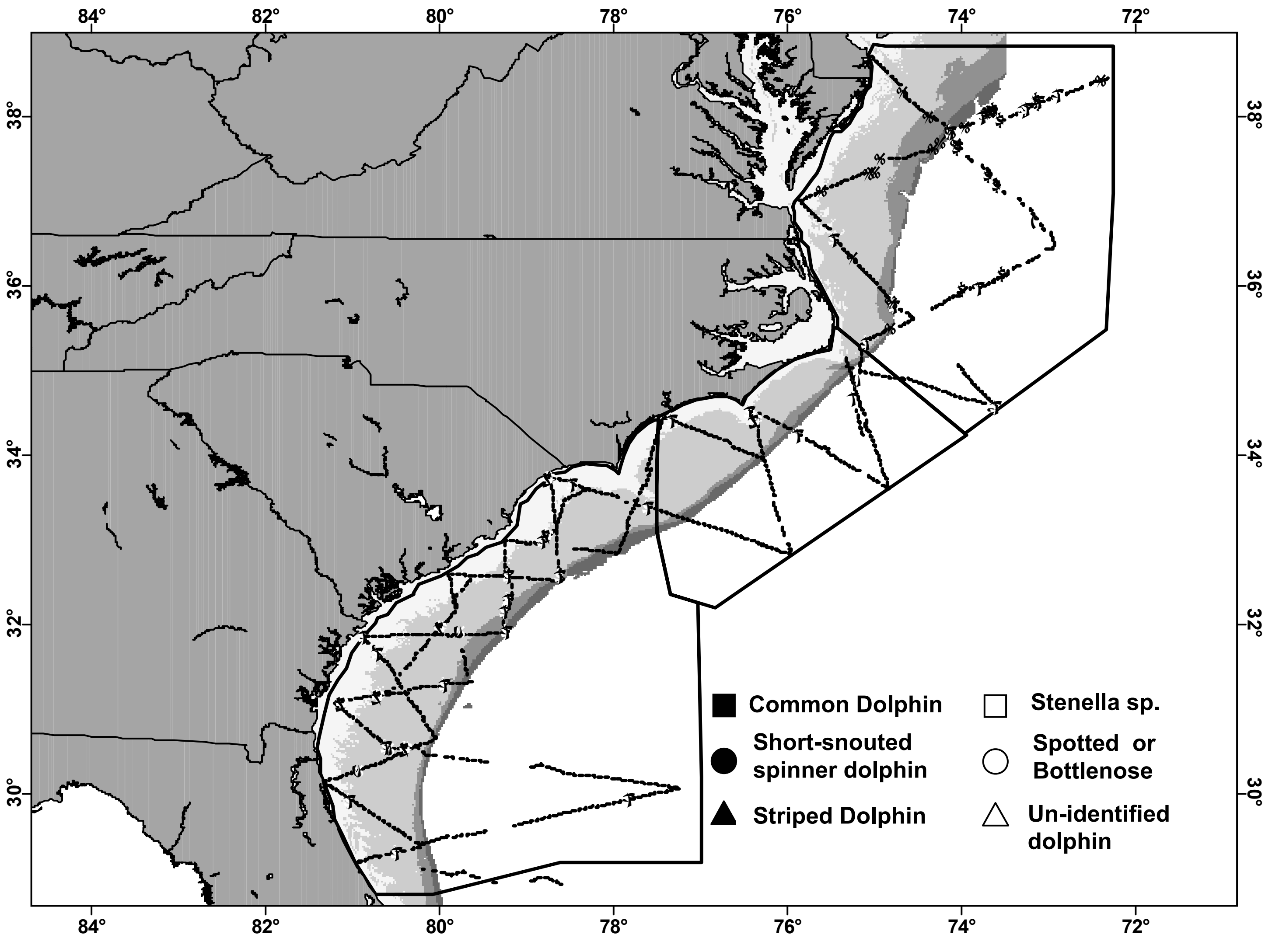


Figure 6. Sightings of cryptic species and beaked whales in the mid-Atlantic during the winter 2002 survey.

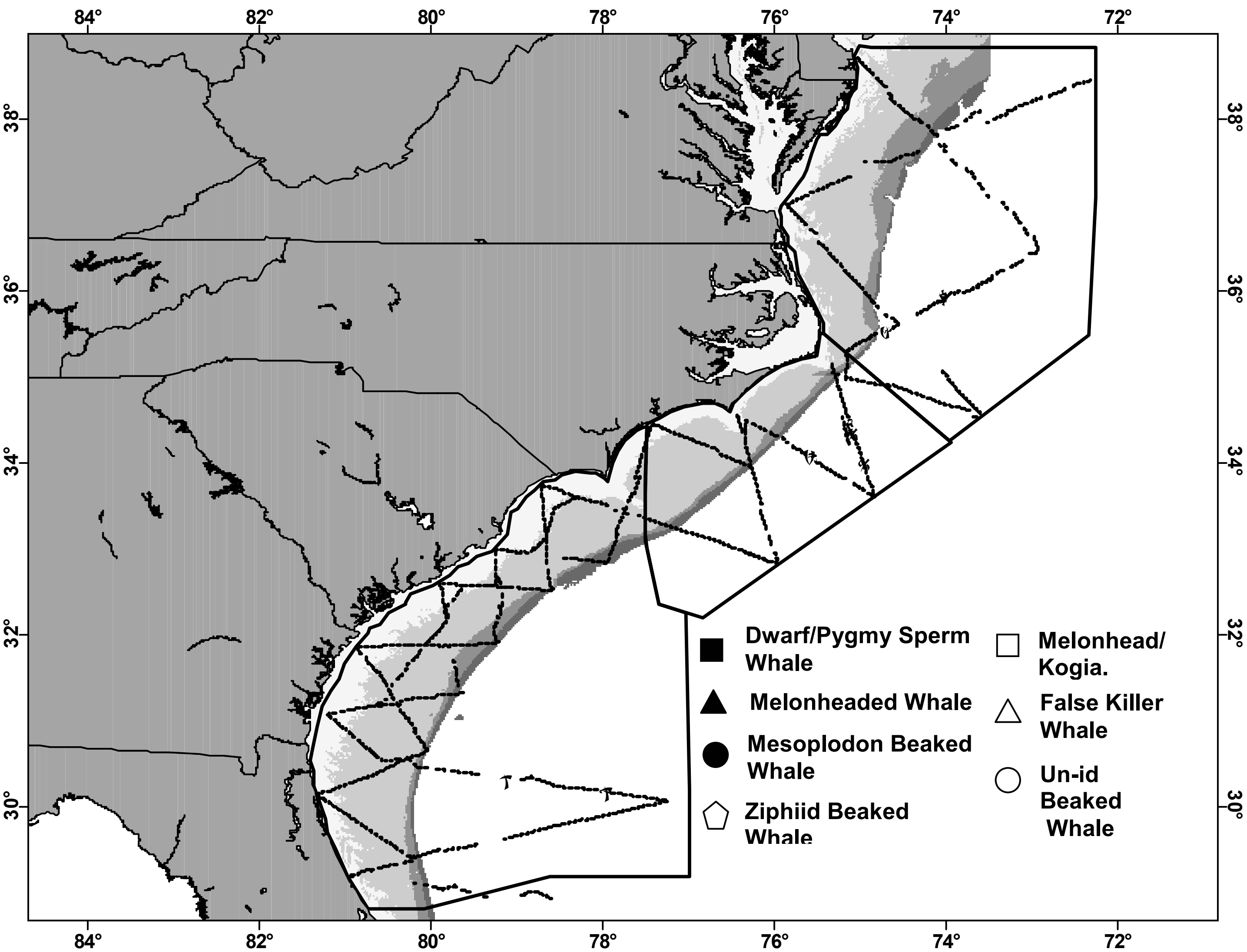
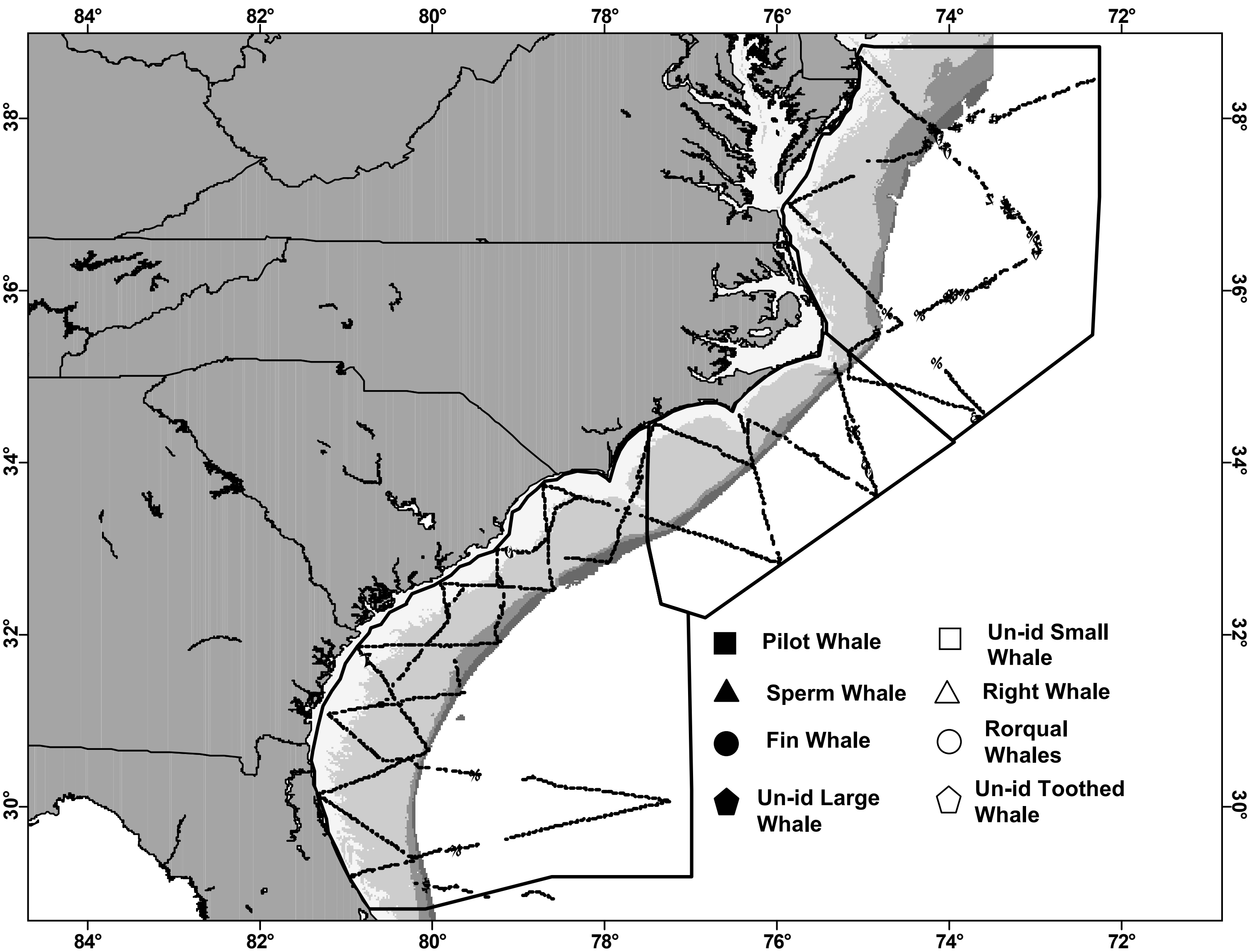


Figure 7. Sightings of pilot whales and large whales in the mid-Atlantic during the winter 2002 survey



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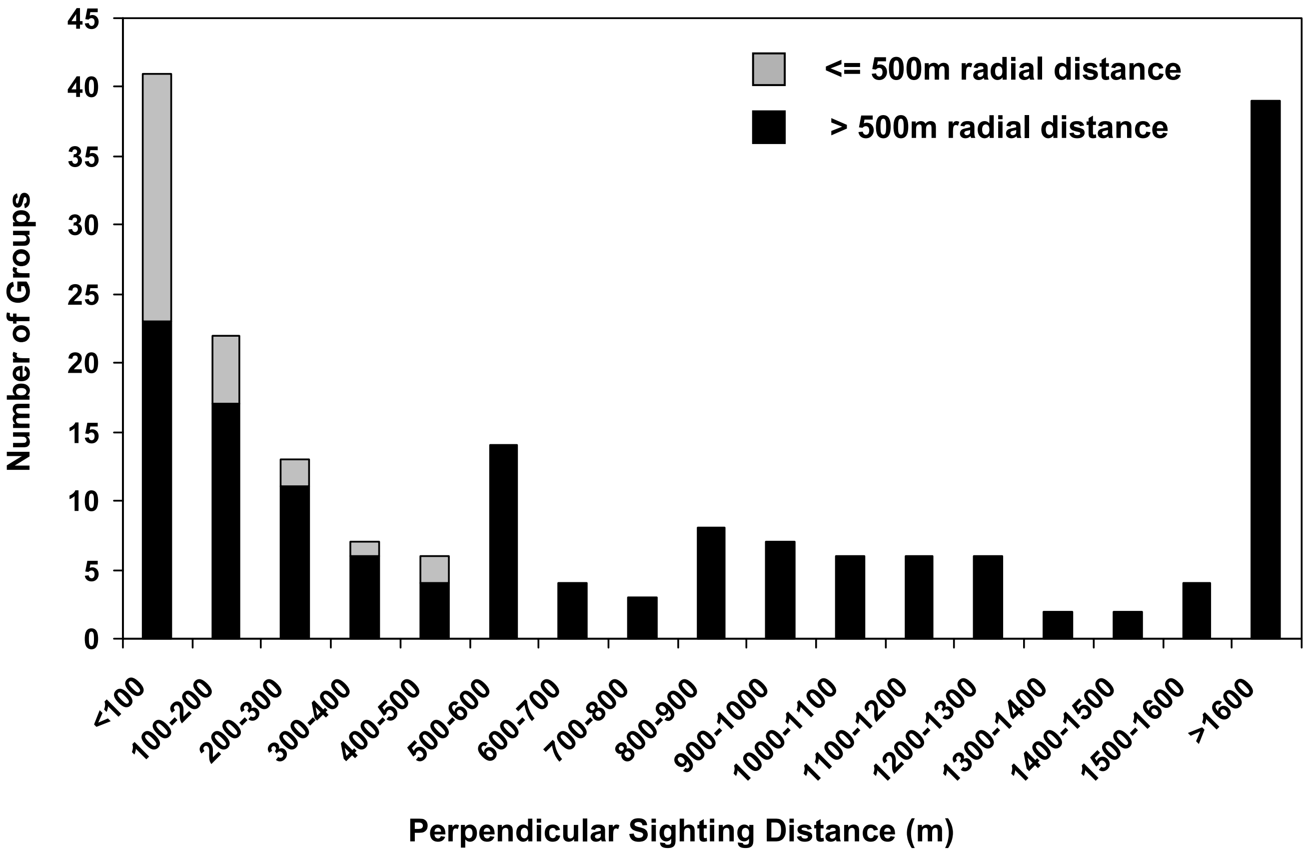

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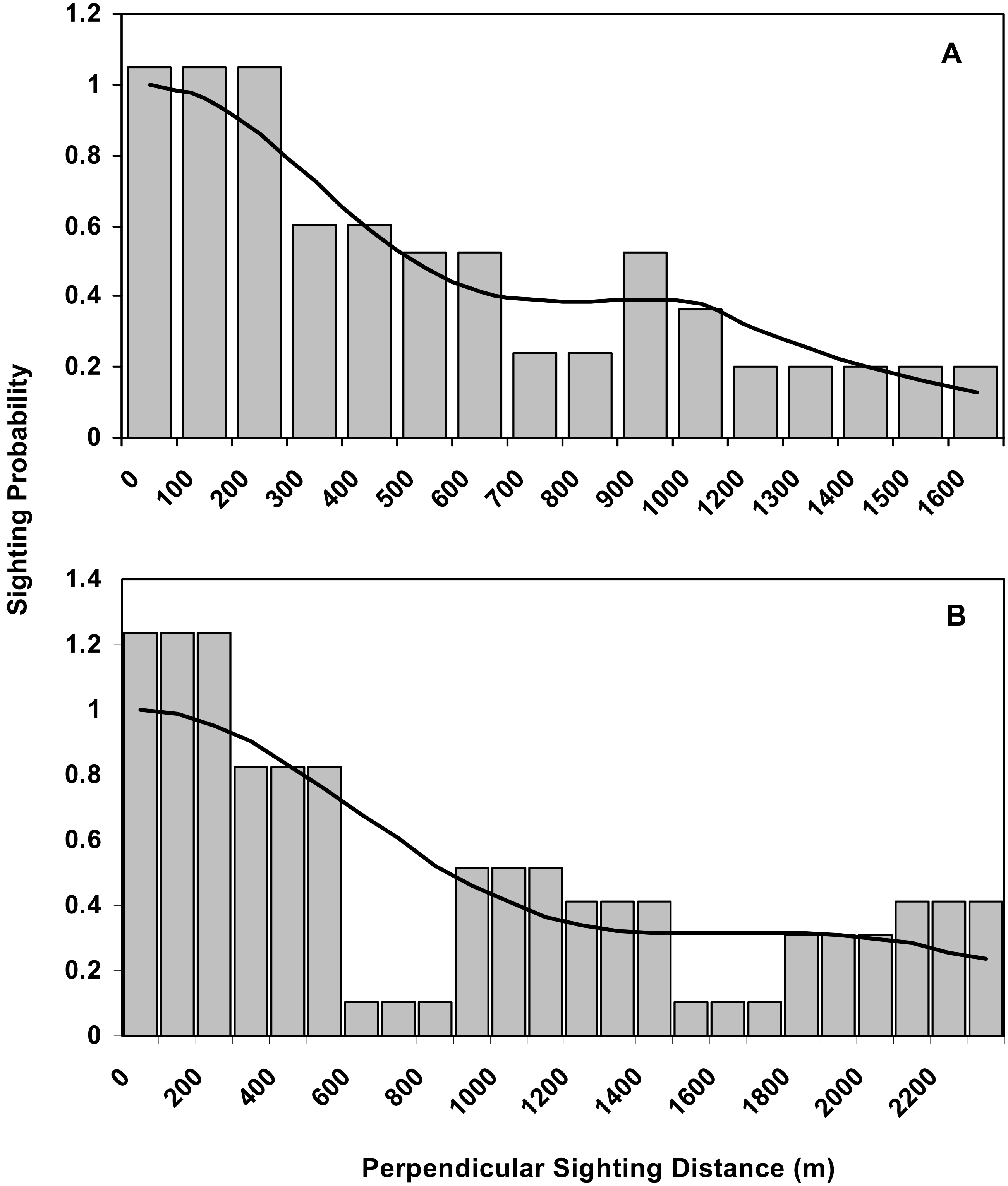

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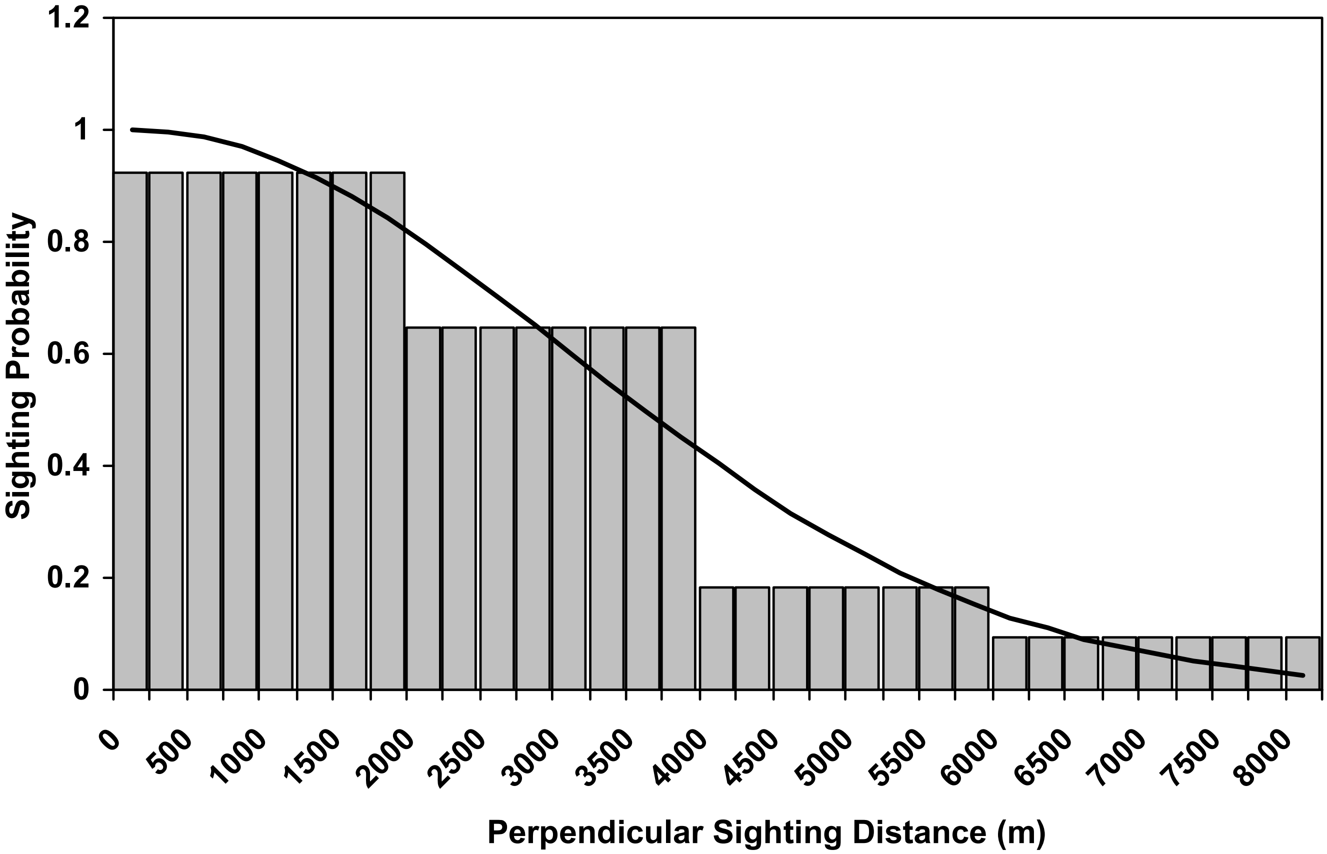

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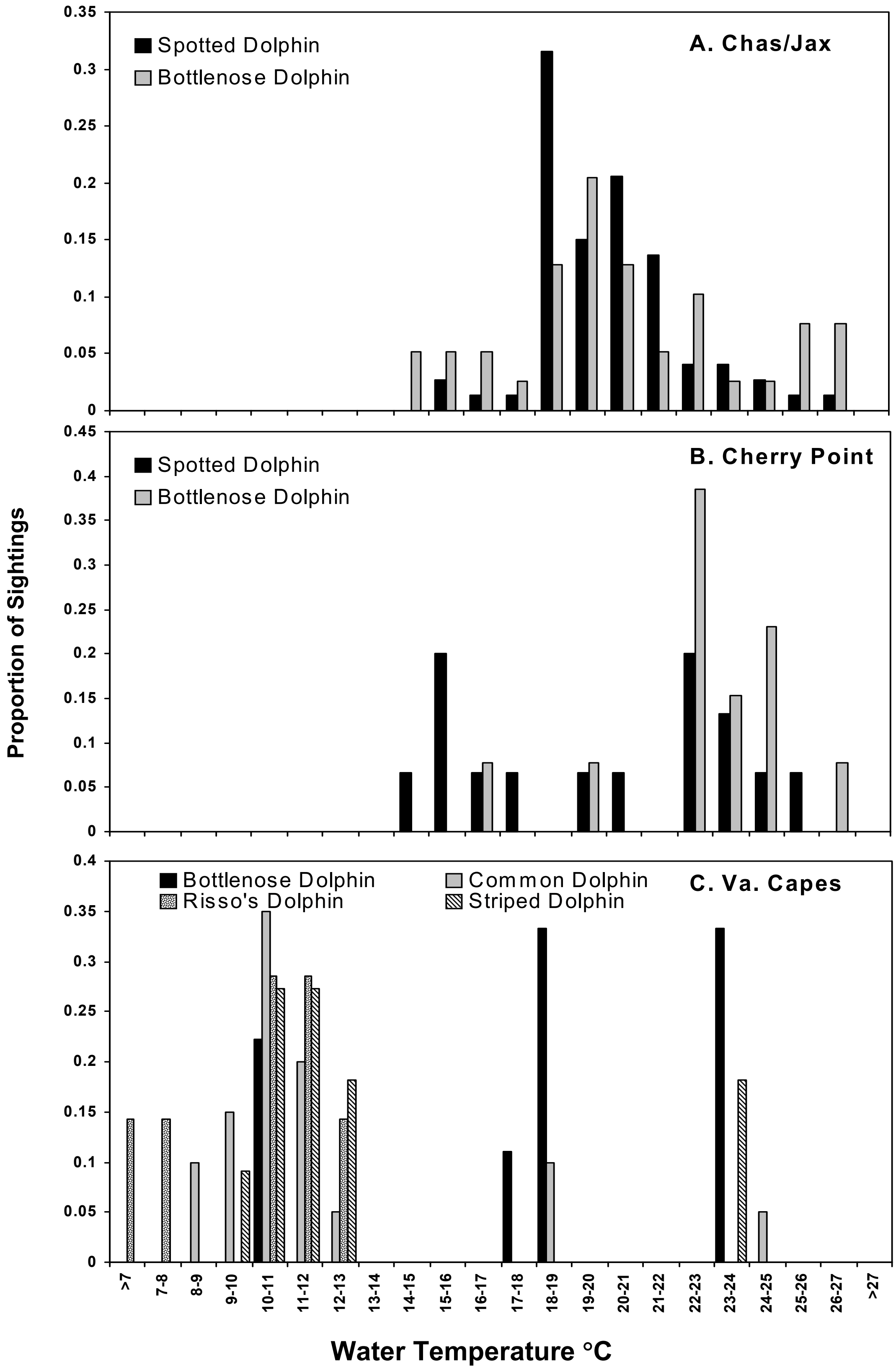

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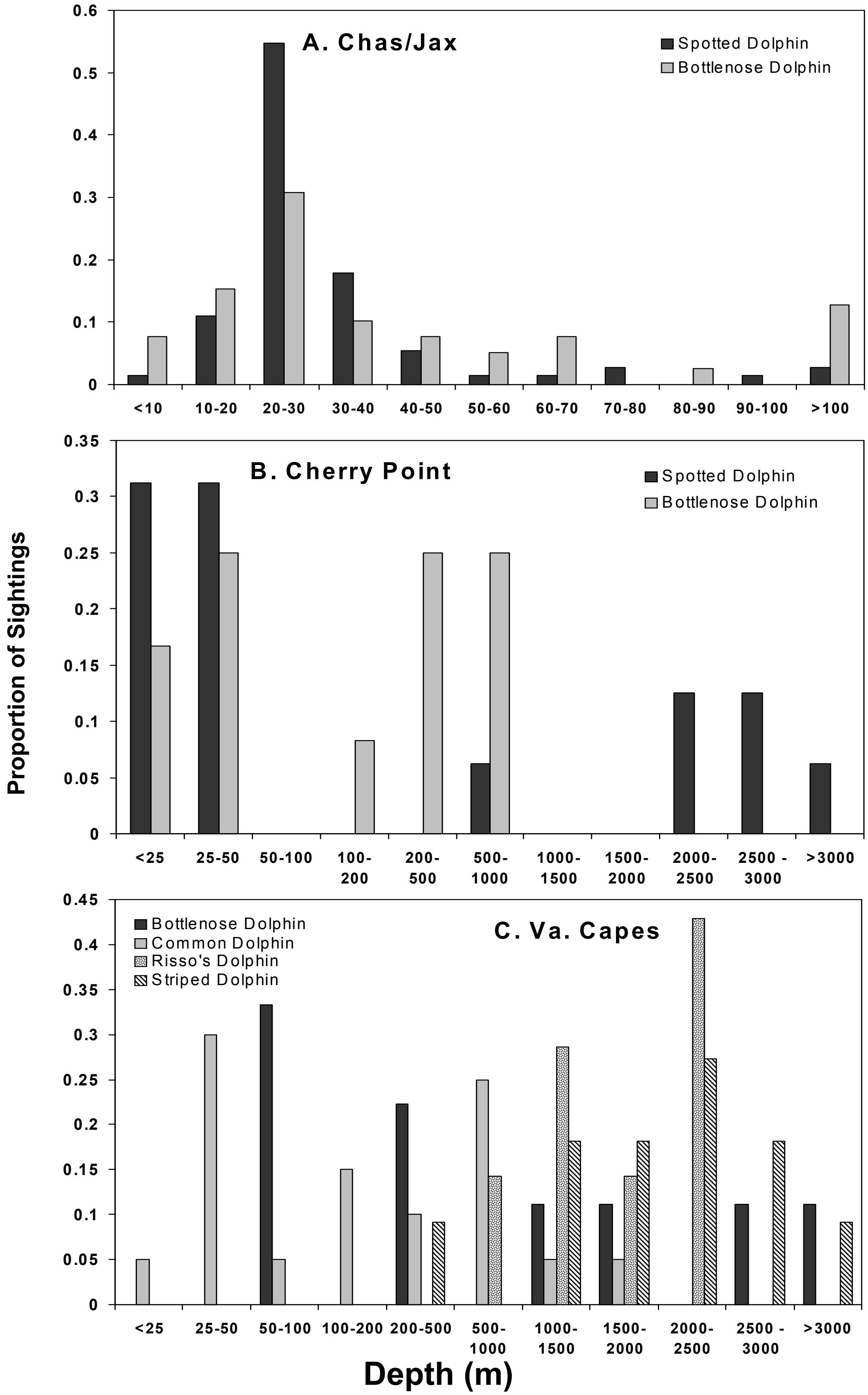
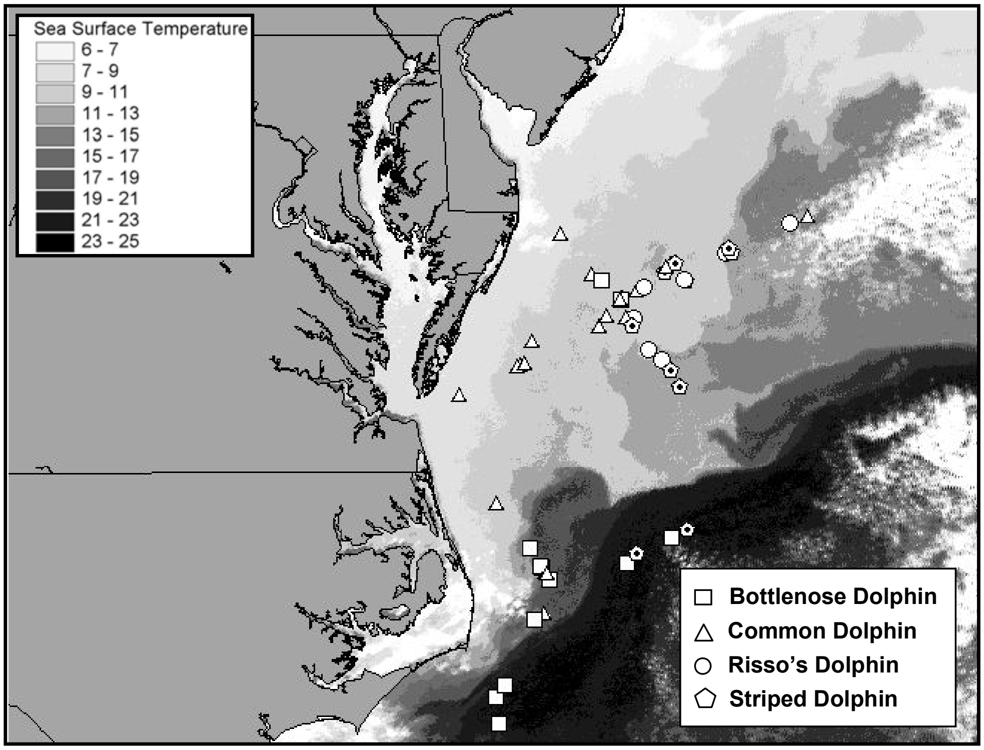


Figure 13. A) Dolphin and B) whale sightings in the Virginia Capes region and sea surface temperature. SST image is from an AVHRR image collected on March 1, 2002 available through the NOAA CoastWatch program Southeast Region.



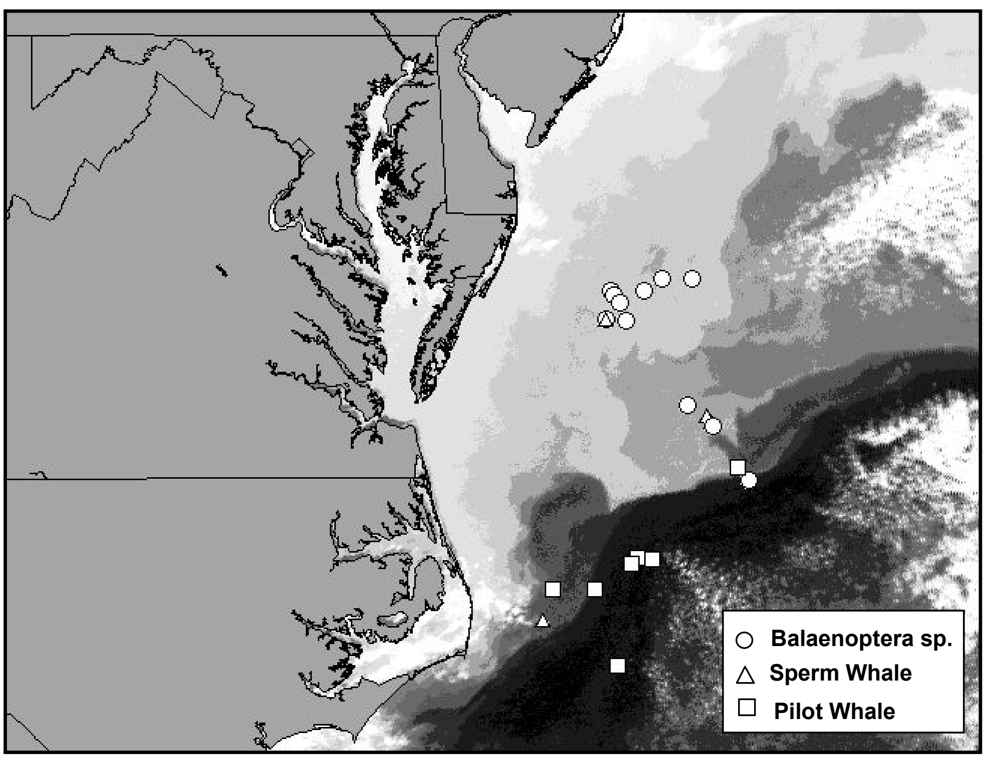


Figure 14. Skin biopsy samples collected during the winter 2002 marine mammal survey.