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Summer Abundance Estimates of Cetaceans in US North Atlantic Navy Operating Areas

by

Debra L. Palka

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ABSTRACT

The US Fleet Forces Command, Department of the Navy, contracted the consulting firm Geo-Marine, Inc. (GMI) to generate technical reports that provide marine mammal and sea turtle density estimates for Navy operating areas. Some of the needed density estimates are for areas off the northeast US coast, an area that has been surveyed by marine mammal abundance surveys conducted by the Northeast Fisheries Science Center. GMI requested my aid in preparing summer density estimates for the northeast operating areas (NE OPAREA) using data collected from 1998, 1999, 2002, and 2004. The Gulf of Maine Central and Offshore NE OPAREAs had the highest numbers of cetaceans, although the NE OPAREAs with the highest densities (abundance divided by area) were the Gulf of Maine North and Scotian NE OPAREAs (both in Canadian waters). Within US waters, the stratum with the highest density was the Gulf of Maine Central, followed by the Shelf Central, Shelf West, and Georges Bank Central strata. The strata with the lowest densities and lowest species diversity were the Mid-Atlantic and Georges Bank West strata. The 2004 estimates appear to be more representative of a springtime distribution or the transition between spring and summer distributions, while the 2002 and earlier estimates appear to be more representative of mid summer distributions.

INTRODUCTION

The US Fleet Forces Command, Department of the Navy, contracted the environmental consulting firm Geo-Marine, Inc. (GMI) to generate technical reports that provide marine mammal and sea turtle density estimates for Navy operating areas (OPAREAs). These density estimates will be used for the purposes of Navy environmental planning and compliance and will serve as the basis for future documentation under federal reporting requirements.

Some of the needed density estimates are for OPAREAs off the northeast US coast (NE OPAREAs), an area that has been surveyed by marine mammal abundance surveys conducted by the Northeast Fisheries Science Center (NEFSC). GMI requested my aid in providing survey data and in preparing summer density estimates for the NE OPAREA region. In response to this request, I re-analyzed data that were previously collected to estimate abundance of cetaceans detected within and beyond the NE OPAREAs (Figure 1; Table 1). The shipboard and aerial line transect data used in this analysis were collected during the summers of 1998 (Palka 2005a), 1999 (Palka 2000), 2002 (Palka 2005b; in review), and 2004 (Palka in review).

METHODS

Field methods for shipboard surveys

Shipboard data included in this analysis came from the NEFSC 1998, 1999, and 2004 abundance surveys (Figures 2 to 4). The 1998 and 2004 shipboard surveys (Table 2) covered similar areas: an area bounded to the south at the 37°N latitudinal line (off Chesapeake Bay, Virginia), to the north by Georges Bank (41°N), to the west at 74°W, and to the east at the US-Canadian EEZ line at 65° 30'W. This covered waters between approximately the 100 m and 4000 m isobaths. The original study area was divided into two strata defined by bio-geographic habitats: a shelf edge stratum and an offshore stratum that was offshore of the shelf and included the Gulf Stream. The shelf bio-geographic stratum is the sum of the following NE OPAREAs: Shelf West, Shelf Central, and Shelf East. The offshore bio-geographic stratum and the offshore NE OPAREA are similar. Saw-toothed transects were placed to cross the bathymetry gradient and were started at a random point within each stratum.

The 1999 shipboard survey (Table 2) covered shallow waters of the northern Gulf of Maine (to approximately the 100m depth contour), western Scotian Shelf and lower Bay of Fundy (Figure 3). The coastal sections of the Gulf of Maine Central NE OPAREA stratum was surveyed in 1999 by a ship, while the offshore section was surveyed by a plane (Figure 2; see more details about the aerial survey in the next section).

On all of the shipboard surveys, two visual observer teams on independent platforms simultaneously collected data. Data from both teams were needed to estimate *g(0)*, the probability of detecting a group on the track line. Each team was comprised of three observers on duty and one observer at rest. Each platform had three observation stations. Observers changed stations every 30 minutes. Observers searched during daylight hours (usually 6 am to 6 pm with one hour off for lunch), when weather permitted (i.e., when Beaufort sea state conditions were below five, and when there was at least 3.7 km of visibility). Observers searched the area between 90° on both sides of the transect line, and from the ship to the horizon.

Because the ships and target species differed between the three shipboard surveys, the locations of the platforms and searching tools also differed (Table 3). This was done to insure as many animal groups as possible were detected. In the lower density pelagic surveys (1998 and 2004), high-powered binoculars were used by two of the three observers on both teams, while the third on-effort observer searched using naked eye and also recorded the data from all the observation stations on that team. In the higher density coastal survey (1999), all observers on both teams used naked eye and recorded their own sightings.

On all three shipboard surveys, data collected included information on sightings, effort, and environmental factors. For each cetacean group detected, sightings data included time, ship's latitude and longitude, bearing between the transect line and line of sight to the location of the group, radial distance between the ship and the center of the group, species composition, group size (best high and low estimate), swim direction (0° indicates swimming parallel to the track line in the direction the ship was traveling, 90° indicates swimming perpendicular to the track line and towards the right, etc.), behavior (swimming, charging, milling, etc.), and cue (factor that attracted the observer to the group: body, splash, blow, etc.). When binoculars were used, bearings were measured using angle rings around the tripod-mounted binoculars and radial distances were measured using reticles in the eyepiece of the binoculars. When naked eye was used, bearings were measured using calibrated polaruses that were mounted in front of each observer, and radial distances were estimated visually. All observers were trained and tested to ensure accurate radial distances. The "best" estimate for group size was used in the abundance estimates because this value was the result of assessing the group size as often as possible as the group passed by the ship. Species were identified to the lowest taxonomic level possible. When not possible to reliably distinguish an animal to the species level, species groupings were used, such as, pilot whale spp., which could be either a short-finned (*Globicephala macrorhynchus*) or long-finned (*G. melas*) pilot whale. Another example is, unidentified dolphin, which could be any dolphin species. Groups identified to a level with the word "unidentified" were included in abundance estimates that were separate from abundance estimates derived from groups identified to a specific species. Therefore, all abundance estimates of a specific species are negatively biased because an unknown proportion of groups of that species were detected but were included in the unidentified abundance estimate.

When high-powered binoculars were used (1998 and 2004), it was not always possible to confirm the species identification or group size. For many of the unidentified groups within about 5.5 km (3 nautical miles) of the ship, the ship went off-effort and approached the group to a distance from which it was possible to confirm the identification and group size. When a group was approached, both teams were off-effort, so any additional sightings were not recorded. On-effort sightings were resumed when the ship was back on the original track line. When naked eye was used, the ship did not go off-effort to identify species.

At the beginning of each track line segment (called a leg) and when conditions changed, effort and environmental data were collected. These data included: time, observer at each observation station, ship's position (latitude and longitude), ship's speed and course, wind speed and direction, water depth, surface temperature, air temperature, swell height and direction (relative to the ship's track line), Beaufort sea state (0 to 4.9 in 0.1 increments), direction of sun (relative to the ship's track line), magnitude of glare (none, slight, moderate, and excessive), and distance with clear visibility.

Field methods for aerial surveys

Aerial data included in this analysis came from the NEFSC 1998, 1999, 2002, and 2004 summer abundance surveys (Figures 2 to 5). All of these aerial surveys were conducted on the NOAA DeHavilland Twin Otter DHC-6, Series 300 aircraft (Table 2). The portion of the study area covered by all the aerial surveys extended from waters south of Rhode Island, northward through the Gulf of Maine to the lower Bay of Fundy and to Scotian waters south of Nova Scotia. The 1998 and 2004 aerial surveys also covered shelf waters along the Mid-Atlantic states of New York to Virginia. The original aerial survey study areas were divided into bio-geographic habitat strata: a southern region below Long Island, NY (Mid-Atlantic NE OPAREA), a central region consisting of Georges Bank (NE OPAREAs Georges East, Georges Central, and Georges West), and a northern region consisting of the Gulf of Maine, lower Bay of Fundy, and southern Scotian shelf (NE OPAREAs Gulf of Maine (GOM) south, GOM central, GOM north, and Scotian).

During all surveys, track lines were flown 182 m (600 feet) above the water surface, at about 200 km/hr (110 knots), when Beaufort sea state conditions were below four, and when there was at least 3.7 km (2 nmi) of visibility. During all surveys, there were two pilots and five scientists onboard. Three scientists were observers searching for animals using the naked eye; the fourth scientist was at rest; and the fifth scientist recorded the data. The recorder worked at this position for the entire survey. The other four scientists rotated between the three observation stations and the rest station. Rotations occurred at the end of track lines or about every 30-40 minutes. Two observers, located behind the pilots, looked through side-viewing large bubble windows, where one observer was on each side of the plane. The third observer was at the back of the plane lying on the ground to look through a belly window. The belly window observer was limited to approximately a 28° view on both sides of the track line. The bubble window observers concentrated searching from straight down (0°) up to about 45° from the track line; the area from 45° to the horizon (90°) was also searched, though less frequently. Handheld binoculars were available to confirm species identifications and group sizes, if desired.

During all surveys, when an animal group was observed the following data were collected: time group passed perpendicular to the window; species identification; group size; angle of declination from the track line (measured by inclinometers or marks on the windows); cue (animal, splash, blow, footprint, birds, vessel/gear, windrows, or other); swim direction (0° indicates swimming parallel to the track line in the direction the plane was flying, 90° indicates swimming perpendicular to the track line and towards the right, etc.); if the animal appeared to react to the plane (yes or no); if the animal was diving (yes or no), and; comments, if any.

At the beginning of each leg and when conditions changed, the following data were collected: initials of persons in the two pilot seats and three observation stations; Beaufort sea state (0 to 3.9 in 0.1 increments); water color (deep blue, blue, greenish blue, green, light green, yellowish green, yellow green, green yellow, greenish yellow, or yellow); percentage of cloud cover (0-

100%); angle glare started and ended at (0-359°, where 0° was the track line in the direction of flight and 90° was directly abeam to the right side of the track line, etc.); magnitude of glare (none, slight, moderate, and excessive); and subjective overall quality for each observer (excellent, good, moderate, fair, and poor). Data collected in poor conditions were not used in the abundance estimate.

To estimate *g(0)*, the Hiby circle-back data collection method (Hiby 1999) was used for harbor porpoise sightings only during the 1998 survey, and for all species after that. The aerial Hiby circle-back method is comparable to the two-team shipboard method. Both methods result in data used to estimate *g(0)*. The circle-back method modified standard single-plane line-transect methods by circling back and re-surveying a portion of the track line (Figure 6). The portions of track lines that were re-surveyed were called "trailing" legs. The portions of the track lines that initiated a circle were called "leading" legs, and the portions of the track lines that were between the end of a trailing leg and the beginning of the subsequent leading leg were called "single-plane" legs. As in the case of two teams on a ship, *g(0)* can be estimated using the aerial data collected during the leading and trailing legs, as they are comparable to data collected by two teams. That is, data collected on trailing legs corresponded to data from a second team, data collected on leading legs corresponded to data from a primary team when a second team was on-effort, and data collected on single-plane legs corresponded to data collected by the primary team when the second team was off-effort.

For starting a circle, the criterion was a small group (≤ 5 animals) of cetaceans or turtles that was the only sighting of the same species within a 30-second time period. The circle-back procedure was as follows (Figure 4):

1. Time and location of an initial sighting when it passed abeam of the plane was recorded and started a 30-second timer (Point 1 in Figure 6),
2. During the 30 seconds, additional sightings were recorded. If more than one additional sighting of the same species that triggered the circle was recorded during this 30 seconds, then the circle-back procedure was aborted, because the density may be too high to accurately determine if a group of animals was the same group on both the leading and trailing legs of the track line.
3. At the end of the 30 seconds, if the criterion in number 2 was passed, the plane started to circle back and the observers went off-effort. The time leaving the track line was recorded, which also started another timer for 120 seconds (Point 2 in Figure 6).
4. During this 120 seconds the plane circled back 180° and traveled parallel to the original track line about 1.5 km (0.8 nmi) away, in the opposite direction, and on either side of the original track line.
5. At the end of the 120 seconds, the plane started to fly back to the track line (Point 3 in Figure 6).
6. When the plane intercepted the original track line, the time was recorded, observers went back on-effort, they started searching again, and a 5-minute timer was started (Point 4 in Figure 6).
7. All sightings were then recorded.

8. The circle-back procedure was not initiated again until a sighting was made after the 5-minute timer expired (Point 5 in Figure 6). This was to ensure forward progress on the track line.

Shipboard analytical methods

In the original analyses for 1998, 1999, and 2004 shipboard data, abundance estimates were calculated for large bio-geographic habitat strata (Palka 2000; 2005a; in review). The 1998 and 2004 data, collected while surveying with high-powered binoculars, were investigated to determine if animals responded to the ship. To estimate the abundance for those species that demonstrated responsive movements, the Palka-Hammond analytical method (Palka & Hammond 2001) was used. To estimate the abundance of all other species, the direct-duplicate method (Palka 1995) was used. Covariates were investigated to determine if any can improve the detection function of the 1998 (Palka 2005) and 2004 data (Palka in review).

To estimate abundance within the smaller NE OPAREA strata, the survey track line and sighting data were first divided into the NE OPAREA strata. Track line lengths, sighting rates and average group sizes within each NE OPAREA stratum were then calculated using only the data with a NE OPAREA. Using the direct-duplicate method (Palka 1995), the abundance (N_{il}) for species l (within species group j) from NE OPAREA stratum i was then estimated as the product of the density (D_{il}) and area (A_i) of stratum i: $N_{il} = D_{il} \bullet A_i$. Density ($D_{il}$), was calculated as:

$$D_{il} = \frac{D_{il.upper} \cdot D_{il.lower}}{D_{il.dup}} \tag{1}$$

where

D_{upper} = density, assuming $g(0) = 1$, using only the upper team's data in Eq. 2;
D_{lower} = density, assuming $g(0) = 1$, using only the lower team's data in Eq. 2;
D_{dup} = density, assuming $g(0) = 1$, using only duplicate sighting's data in Eq. 2.

and

$$D_{ilk} = \frac{n_{ilk} \cdot E(s)_{ilk}}{2 \cdot L_i \cdot ESHW_{jk}} \tag{2}$$

where

n = number of groups detected;
$E(s)$ = expected group size;
L = length of transect line while on-effort;
$ESHW$ = Effective Strip Half Width;
= inverse of the sighting probability density at zero perpendicular distance using data with a perpendicular distance of less than or equal to w;

w = maximum perpendicular distance used in analysis;
k = team: *upper*=upper team, *lower*=lower team, *dup* = duplicate sightings;
j = species group;
l = species;
I = stratum.

Duplicate sightings were defined as groups seen by both the upper and lower teams, though not necessarily at exactly the same time. During the analysis phase, the duplicate sightings were determined by a computer program that compared the position of sightings detected by each team. Timing, swim direction, and species identification were taken into account when comparing the position of a sighting from one team to the predicted position of previous sightings from the other team.

Species groups (j) were defined as an individual species when there were a sufficient number of sightings for an individual species. This occurred for offshore bottlenose dolphins, common dolphins, Risso's dolphins, white-sided dolphins, harbor porpoises, humpback whales (during 1999 only), minke whales, right whales, and sperm whales (Table 4). A species group was defined as several species pooling together when it was not possible to distinguish the species while in the field, and/or there were an insufficient number of sightings per individual species, and the species within a species group had similar behaviors and so approximately equal chances of being detected. This occurred for pilot whales (pooled short-finned and long-finned pilot whales); cryptic whales (pooled beaked whales and Kogia spp.); and pelagic dolphins (pooled spotted, spinner, and striped dolphins). During 1998 and 1999, "large whales" was defined as pooling fin whales, sei whales, and animals identified as either fin or sei whales. During 2004, "large whales" was defined as pooling humpback whales, fin whales, sei whales, animals identified as either a fin or sei whale, and animals identified as an unknown large whale. Pilot whales and beaked whales were pooled because it was not always possible to positively identify the species. The other species groups were formed because of insufficient sample sizes of each individual species.

During 1998 and 2004, because binoculars were used, the angle and radial distances could have been rounded when recorded (Palka in review). If present, to correct for rounding error, recorded values were smeared using Method 2 of Buckland and Anganuzzi (1988) before further analyses were conducted.

The *ESHW* for each species group l and team k ($ESHW_{lk}$) was estimated in the initial analyses using data pooled over all bio-geographic habitat strata (Table 4). The 1998 and 2004 estimates of *ESHW* were corrected for heterogeneities by incorporating significant covariates into the detection function using the computer package DISTANCE 4 (Buckland *et al.* 2001). The 1999 data have not yet been investigated to determine if covariates improve the *ESHW* estimates. Model and covariate selection was based on minimum Akaike Information Criterion (AIC). The following animal-related covariates were investigated: group size, group behavior (swimming, porpoising, and charging), and initial cue (body, splash, and blow). The following survey-related covariates were investigated: observer experience level (highest sighting rate, intermediate sighting rate, lower sighting rate), Beaufort sea state (0 to 4.9 in 0.1 increments), and wind speed. The following covariates that could be either animal-related or survey-related were also investigated: sea surface water temperature (SST), bottom depth, and bottom slope. In addition, for the 2004 data, the time period the data were collected – time period 1 (23 June to 12 July 2004) versus time period 2 (16 July to 4 August 2004) – was also included as a covariate to investigate if the different sets of observers had an effect. A complete description of the covariates is in Appendix 1 of Palka (in review). Potential detection function models without covariates included the uniform with cosine adjustments, half-normal with polynomial or cosine adjustments, and hazard-rate with polynomial or cosine adjustments. Potential detection function models with covariates included the hazard rate with polynomial or cosine adjustments and half-normal with polynomial or cosine adjustments.

Estimates of *g(0)* for each species group and team was determined in the initial analyses using data pooled over all bio-geographic habitat strata (Table 5). The 1998 and 2004 *g(0)* estimates included effects of covariates, when significant.

In cases of no duplicate sightings for a species group within a NE OPAREA, it was not possible to use Eq. 1. Instead, if within a NE OPAREA there were data from only one team, the abundance estimate for that NE OPAREA was the product of the abundance estimated from the data of the only team available and the species group-team-specific estimate of *g(0)* as determined in the original analysis. If within a NE OPAREA there were data from both teams, but no duplicates, then the abundance estimate was the sum of the upper and lower team-*g(0)* corrected abundance estimates.

It was assumed the best species abundance estimates were from the larger bio-geographic habitat strata analysis and not the smaller NE OPAREA strata analysis. Because the NE OPAREA strata were subsets of the bio-geographic habitat strata, it was possible to correct the NE OPAREA stratum-specific abundance estimates so that the sum of the abundance from all the NE OPAREA strata equaled the sum from the applicable bio-geographic habitat strata. That is, the best abundance within NE OPAREA stratum i for species l (BN_{il}) was estimated as a proportion of the best abundance estimate derived from the bio-geographic habitat strata (N_{biogeo}):

$$BN_{il} = \frac{N_{il}}{\sum_i N_{il}} \bullet N_{l \cdot biogeo} \tag{3}$$

where N_{il} was estimated using Eqs. 1 and 2 and $N_{j.biogeo}$ was estimated in the original analysis (Appendix I).

Coefficient of variations (CV) of the abundance estimates were determined using bootstrap re-sampling techniques (Efron and Tibshirani 1993). Portions of the track line within each NE OPAREA were re-sampled with replacement, so that the track line length within a NE OPAREA from a bootstrap iteration was approximated equal to the actual track line length within that NE OPAREA. The re-sampled portions of the track line were defined as “legs” of effort in which each leg was about 9.3 km (5 nmi) long, and all conditions (weather and position of observers) were similar. For each of the 1000 bootstrap iterations, the abundance estimate of each species within each stratum (BN_{il}^{boot}) was estimated using the above equations. The CV of an abundance estimate within a stratum was:

$$CV(BN_{il}) = \frac{stdev\ (BN_{il}^{boot})}{BN_{il}} \tag{4}$$

Aerial analytical methods

Abundance estimates from the 1998, 1999, 2002, and 2004 aerial surveys were originally calculated using larger bio-geographic habitat strata (Palka 2000; 2005b; in prep). To estimate abundance within the smaller NE OPAREA strata, the survey data were first divided into the NE OPAREA strata, then track line lengths, sighting rates, and average group sizes within each NE OPAREA stratum were calculated.

Abundance of a species was calculated in a three-step procedure. First, abundance uncorrected for *g(0)* was estimated for each year using data collected during that year on the single-plane and leading (SL) legs (i.e., corresponding to a conventional single plane survey). Second, using only the 2002 and 2004 data, an estimate of $g(0)_{leading}$ was derived from the data pooled over years collected by the "two teams;" that is, from the leading and trailing legs. Finally, to obtain an abundance estimate corrected for *g(0)* for all years, $g(0)_{leading}$, obtained in step 2 was applied to the abundance estimate derived from the SL legs obtained in step 1. That is, the same estimate of *g(0)* was applied to each year's data.

Because the criteria used to start a circle was the detection of a small group of animals (≤ 5 animals), the estimate of *g(0)* was only applicable to groups of animals with ≤ 5 animals. Consequently, it was assumed the estimate of *g(0)* for group sizes of over five was one.

In summary, abundance from year *y* in stratum *i* of species *l* that belongs to species group *j* (N_{ily}) was estimated as:

$$\begin{aligned} N_{ily} &= N_{ilysmall.SL} + N_{ilylarge.SL} \\ &= \left(\frac{n_{ilysmall.SL} \cdot E(s)_{ilysmall.SL}}{2 \cdot L_{iy.SL} \cdot ESHW_{jy.SL}} \bullet g(0)_{j.small.leading} \right) \bullet A_i \quad + \left(\frac{n_{ilylarge.SL} \cdot E(s)_{ilylarge.SL}}{2 \cdot L_{iy.SL} \cdot ESHW_{jy.SL}} \right) \bullet A_i \end{aligned} \tag{5}$$

where

$n_{small.SL}$	= number of groups ≤ 5 seen on the single and leading (SL) legs;
$n_{large.SL}$	= number of groups > 5 seen on the single and leading legs;
$E(s)_{small.SL}$	= expected group size of groups ≤ 5 seen on the single and leading legs;
$E(s)_{large.SL}$	= expected group size of groups > 5 seen on the single and leading legs;
$ESHW_{j.SL}$	= Effective half strip width of species group *j* using data from the single-plane and leading legs;
	= inverse of the sighting probability density at zero perpendicular distance using data with a perpendicular distance of less than or equal to *w*;
w	= maximum perpendicular distance used in analysis;

L_{SL} = length of transect line while on-effort on the single and leading legs;
A_i = area of stratum i
i = stratum;
j = species group of which species l belongs to;
l = species;
y = year: 1998, 1999, 2002 or 2004.

and *g(0)* for all years, for species *l* that were in groups of size 5 or less when detected during the leading legs was estimated using data only from 2002 and 2004:

$$g(0)_{j.small.leading} = \frac{n_{lsmall.dup} \cdot ESHW_{j.trailing}}{n_{lsmall.trailing} \cdot ESHW_{j.dup}} \tag{6}$$

where

$n_{small.dup}$ = number of groups ≤ 5 seen on both the leading and trailing legs;
$n_{small.trailing}$ = number of groups ≤ 5 seen on the trailing legs;
$ESHW_{j.trailing}$ = Effective half strip width of species group j using data from the trailing legs;
$ESHW_{j.dup}$ = Effective half strip width of species group j using data from the duplicate sightings seen during the leading and trailing legs;

Ideally, the estimates of *E(s)*, *ESHW*, and *g(0)* would be estimated separately for each species. However, sample sizes were small, especially for those relatively rare species. Thus, estimates of *g(0)* and the *ESHW* were derived for groups of species, sometimes over years. (Table 6). Species groups were defined to meet the following criteria: include all species detected, have a sufficiently large sample size, and have similarities in the physical and behavioral attributes that affect the detectability of these animals. Three species groups were defined. One group consisted of only harbor porpoises. A second group was small cetaceans: common dolphins, bottlenose dolphins, white-sided dolphins, Risso's dolphins, pilot whales, and unidentified dolphins. The third group was large cetaceans: minke whales, fin whales, sei whales, right whales, humpback whales, beaked whales, and unidentified whales.

Using the computer package DISTANCE (version 4), the various *ESHW*s were estimated from a detection model of unbinned perpendicular distances. The perpendicular distances were right truncated, when appropriate. For the 2002 and 2004 data, the detection models accounted for heterogeneities by including significant covariates, where a significant covariate was a covariate that contributed to a significantly improved fit as defined by the AIC criterion. Choices of covariates included group size, initial cue (body of animal, splash, or blow), percent cloud cover (0 to 100), Beaufort sea state (0 to 3.9 in 0.1 increments), average subjective quality of the sighting conditions (excellent=1, good=2, moderate=3, fair=4, poor=5, in 0.1 increments), water color (deep blue, blue, greenish blue, green, light green, yellowish green, yellow green, green yellow, greenish yellow, or yellow) and species. Potential models without covariates included the uniform with cosine adjustments, half-normal with polynomial or cosine adjustments, and hazard-rate with polynomial or cosine adjustments. Potential models with covariates included the hazard rate with polynomial or cosine adjustments and half-normal model with polynomial or cosine adjustments.

It was assumed the best species abundance estimates were from the larger bio-geographic habitat strata analysis and not the smaller NE OPAREA strata analysis. Because the NE OPAREA strata were subsets of the bio-geographic habitat strata, it was possible to correct the NE OPAREA stratum-specific abundance estimates so that the sum of the abundance from all the NE OPAREA strata equaled the sum from the applicable bio-geographic habitat strata. That is, the best abundance within NE OPAREA stratum i for species l (BN_{il}) was estimated as a proportion of the best abundance estimate derived from the bio-geographic habitat strata (N_{biogeo}), as defined in Eq. 3.

The CVs of the abundance estimates were estimated using the delta method (Buckland *et al.* 2001). Bootstrapping such as was done for the shipboard data would have been preferred; however, the complications of having leading and trailing legs that have to be paired together made re-sampling the track lines difficult. Thus, the CV of the small and large abundance estimates within NE OPAREA stratum i for species l that was within species group j was estimated as:

$$CV(BN_{il.small.SL}) = \sqrt{CV^2(n_{il.small.SL}) + CV^2(\bar{s}_{il.small.SL}) + CV^2(ESHW_{j.SL}) + CV^2(g_{j.small}(0))}$$
$$CV(BN_{il.large.SL}) = \sqrt{CV^2(n_{il.large.SL}) + CV^2(\bar{s}_{il.large.SL}) + CV^2(ESHW_{j.SL})} \tag{7}$$

where

$$CV(\bar{s}_{il..SL}) = \frac{\sqrt{\dfrac{\sum_{m=1}^{n_{vi}} (s_{mi} - \bar{s}_{il..SL})}{n_{vi}(n_{vi}-1)}}}{\bar{s}_{il..SL}} \tag{8}$$

s_{mi} equals the size of group m in stratum i, and n_{vi} equals the number of observations of species l within stratum i, and

$$CV(n_{il..LS}) = \frac{\sqrt{T \cdot \dfrac{\sum_{m=1}^{p} t_m \cdot \left(\dfrac{n_m}{t_m} - \dfrac{n}{T}\right)^2}{p-1}}}{n_{il}} \tag{9}$$

where there are p legs (track lines with no changes) within stratum i, $n = \sum n_m$, $T = \sum t_m$, t_m was the length of the mth track line, and n_m was the number of groups detected on the mth track line.

RESULTS

Shipboard surveys

The 1998 shipboard survey covered 4,270 km in the three Shelf strata and the Offshore stratum (Table 1). The 1999 shipboard survey covered 2,382 km in the Gulf of Maine North, Gulf of Maine Central, and Scotian strata. The 2004 shipboard survey covered 3,991 km of track lines in the three Shelf strata and the Offshore stratum.

As determined in the original analyses, two species demonstrated responsive movement. During the 2004 survey, Risso's dolphins avoided the ship. During the 1998 and 2004 surveys, pilot whales spp. were attracted to the ship.

Estimates of *ESHW* for each species group for the upper team, lower team, and duplicate sightings, as derived in the original analysis, were generally in the 1500 to 3000 m range for the surveys using high-powered binoculars (1998 and 2004; Table 4) and in the 200 to 1500 m range for the 1999 survey in which observers searched with naked eye. At least one covariate was found to be significant for at least one of the years for the detection function of all species investigated (Table 4). Group size, Beaufort sea state (or wind speed), and cue were the most commonly significant covariates.

As derived in the original analysis for the upper and lower teams, estimates of $g(0)$ for harbor porpoises and beaked whales were the lowest (about 0.25), while some of the dolphins were the highest (about 0.8) (Table 5). Estimates of $g(0)$ when searching with naked eye (during 1999) were, in general, lower than estimates of $g(0)$ when using high-powered binoculars (during 1998 and 2004).

Aerial surveys

The 1998 aerial survey in the Mid-Atlantic stratum covered 1,734 km of track lines. The 1999 aerial survey covered 3,741 km in the Gulf of Maine Central, Gulf of Maine South, Georges East, Georges Central, and Scotian stratum (Table 1). The 2002 aerial survey covered 7,487 km in three Gulf of Maine strata, three Georges Bank strata, two Shelf strata, and the Scotian stratum. The 2004 aerial survey covered 3,991 km of track lines in the three Gulf of Maine, three Georges Bank, three Shelf, and Offshore strata (Table 1).

From the pooled 2002 and 2004 aerial data, the original estimates of the *ESHW* and $g(0)_{leading}$ were lowest for harbor porpoises, higher for small cetaceans, and highest for the large whales (Table 6). Cue was a significant covariate for the model of the detection function for large whales, as was size for harbor porpoises. There were no significant covariates for small cetaceans (Table 6).

Joint aerial and shipboard abundance estimates

Combining the 1998 and 1999 aerial and shipboard surveys provides one set of abundance estimates for all species located within all of the strata for the months of July and August. Combining the 2004 shipboard and aerial surveys provides another set of abundance estimates for all species that were located within all strata, but during the months of June and July.

The total abundance over all strata and all species covered during 1998/99 was nearly the same as during 2004: 279,583 versus 256,737, respectively (Table 7). However, the distribution of animals between the two years differed. During 1998/99 the most populated strata (with over 50,000 animals) were the Offshore, Gulf of Maine Central, and Scotian strata (Tables 8-11). During 2002, although the survey only covered the northern strata, the Gulf of Maine Central stratum was the only stratum with over 50,000 animals (Table 12). During 2004, only the Offshore stratum had over 50,000 animals (Tables 13-14).

The Gulf of Maine Central and Offshore strata had the highest numbers of cetaceans (Table 7), although the strata with the highest densities (abundance divided by area) were the Gulf of Maine North and Scotian strata (both mostly in Canadian waters). Within US waters, the stratum with the highest density was the Gulf of Maine Central, followed by the Shelf Central, Shelf West, and Georges Bank Central strata (Table 7). The strata with the lowest densities and lowest species diversity were the Mid-Atlantic and the western part of Georges Bank.

DISCUSSION

The 2002 aerial survey was not able to complete the planned track lines in the GOMN stratum north of Grand Manan Island, Nova Scotia, Canada. In the summer, many harbor porpoises and right whales, along with fewer animals of other species such as fin whales, humpback whales, and minke whales, usually inhabited the GOMN stratum. Thus, the 2002 estimates for the GOMN are biased low.

The 2002 aerial survey was only conducted in the Gulf of Maine and Georges Bank regions. Thus, the lack of estimates for the Shelf, Offshore, and Mid-Atlantic strata for 2002 are an indication of no survey effort, not an indication of depleted numbers of animals.

As noted above, the strata with the lowest densities and lowest species diversity were the Mid-Atlantic and the western part of Georges Bank. However, the survey effort in these two strata was the lowest, after the Offshore stratum (Table 1). Thus, to be confident with this generalization, more future survey effort is needed in the Mid-Atlantic and Georges Bank West strata.

The 2004 aerial survey was conducted from 12 June to 12 July, which was several weeks earlier than the 2002 and other past surveys. It is generally known that cetaceans that inhabit the Gulf of Maine during the summer (e.g., harbor porpoises, white-sided dolphins, humpback whales, minke whales, and pilot whales) enter the Gulf of Maine in early summer and appear to peak in abundance during August. Comparing the 2002 to 2004 estimates illustrate this movement into the Gulf of Maine. That is, for the southern strata (GOMS, GeorgesW, and GeorgesC), the 2004 estimate was larger than the 2002 estimate, and for the more northern stratum (GOMC) it was the opposite, the 2002 estimate was larger than the 2004 estimate. In addition, species thought to be more numerous in springtime US waters, like sei whales and common dolphins, were more numerous in the 2004 survey as compared to the 2002 survey. Thus, the 2004 distributions and estimates appear to be more representative of springtime distribution or the transition period between spring and summer, while the 2002 and earlier distributions and abundance estimates appear to be more representative of summertime.

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Table 1. Statistics about each NE OPAREA stratum: area (/km^2) and track line length (km), by year and platform.

NE OPAREA Stratum	Area (/km^2)	Track line length (km)							total length/ area (/km)
		1998 plane	1998 ship	1999 plane	1999 ship	2002 plane	2004 plane	2004 ship	
GOM North	9,862	0	0	0	777	155	384	0	0.133
GOM Central	53,651	0	0	1,699	1,200	2,467	1,930	0	0.136
GOM South	24,504	0	0	777	0	1,131	1,234	0	0.128
Georges East	31,041	0	0	713	0	1,161	645	0	0.081
Georges Center	11,534	0	0	196	0	347	451	0	0.086
Georges West	28,214	0	0	0	0	967	1,106	0	0.073
Shelf East	21,471	0	1,211	0	0	554	143	581	0.116
Shelf Center	15,791	0	824	0	0	204	39	750	0.115
Shelf West	16,515	0	827	0	0	0	14	735	0.095
Offshore	139,237	0	1,408	0	0	0	0	1,925	0.024
Scotian	17,135	0	0	358	404	502	152	0	0.083
Mid Atlantic	48,593	1,734	0	0	0	0	1,252	0	0.061
TOTAL	417,548	1,734	4,270	3,741	2,382	7,487	7,349	3,991	0.074

Table 2. Dates and platform specifications of each survey.

Year	Platform	Platform Name	Platform Length (m)	Dates
1998	Ship	*R/V Abel-J*	32	06 Jul - 04 Aug 08 Aug - 06 Sep
1998	Plane	NOAA Twin Otter	15.8	18 Jul – 21 Aug
1999	Ship	*R/V Abel-J*	32	28 Jul - 31 Aug
1999	Plane	NOAA Twin Otter	15.8	10 Aug - 29 Aug
2002	Plane	NOAA Twin Otter	15.8	19 Jul - 16 Aug
2004	Ship	*R/V Endeavor*	53	23 Jun - 12 Jul 16 Jul - 04 Aug
2004	Plane	NOAA Twin Otter	15.8	12 Jun - 12 Jul

Table 3. For each shipboard survey, the following were identified: ship, target species, searching tools, and height of the two platforms (meters above the water line).

Year	Ship	Target species	Searching tool		Height of platform (m)	
			Upper team	Lower team	Upper team	Lower team
1998	*R/V Abel-J*	Pelagic, warm water species	20x60 binos	25x150 binos	14	9
1999	*R/V Abel-J*	Coastal, cold-water species	Naked eye	Naked eye	14	9
2004	*R/V Endeavor*	Pelagic, warm water species	20x60 binos	25x150 binos	17.6	10.2

Table 4. From the 1998, 1999, and 2004 shipboard surveys, for each species group, estimates of the *ESHW* (in meters), its CV, and significant covariates (when the data were adjusted for rounding) as derived in the original abundance estimate analyses. Covariates include: Beauf = Beaufort sea state; WTemp = sea surface water temperature; Wind = wind speed; Size = group size; Behav = behavior category; Cue = cue category; Depth = bottom depth; ObserverGrp = observer group; Slope = bottom slope; Period = first or second time period; None = no covariate found significant; NA = group size was the only covariate that was investigated.

Species Group[1]	Team[4]	1998		1999		2004	
		Covariate	*ESHW* (CV)	Covariate	*ESHW* (CV)	Covariate	*ESHW* (CV)
Beaked W. spp/ Kogia spp.	Up	Beauf	1418.3 (0.11)			None	2268.8 (0.10)
	Low	None	1570.0 (0.06)			Depth	2140.6 (0.17)
	Dup	None	1037.8 (0.21)			None	3107.0 (0.15)
Offshore Bottlenose D.	Up	None	815.8 (0.13)			None	1440.7 (0.10)
	Low	Wtemp, Wind	1505.1 (0.11)			Cue	1912.8 (0.13)
	Dup	None	715.8 (0.15)			Cue	1259.8 (0.17)
Common D.	Up	Cue	1134.3 (0.15)			None	1584.3 (0.11)
	Low	Cue, Wind	1077.0 (0.19)			Behav	1473.3 (0.11)
	Dup	None	992.6 (0.11)			Wind	1701.4 (0.11)
Sperm W.	Up	None	2246.8 (0.10)			ObserverGrp	2538.6 (0.11)
	Low	Cue	2307.0 (0.15)			Size	3404.8 (0.08)
	Dup	None	2407.4 (0.17)			Slope	1894.4 (0.13)
Striped/ Spotted/ Spinner D.[2]	Up	Wind	1265.7 (0.18)			Size	2089.6 (0.13)
	Low	Size	1929.9 (0.11)			None	2280.7 (0.05)
	Dup	Size	1585.1 (0.17)			Size	3081.8 (0.07)
Large W.[3]	Up	Beauf	1213.2 (0.27)	NA	1105.0 (0.16)	WTemp	3112.8 (0.18)
	Low	Size, Wind	1132.8 (0.42)		1010 (0.21)	WTemp	2467.7 (0.15)
	Dup	None	1151.6 (0.17)		878.0 (0.16)	WTemp	2096.0 (0.29)
Risso's D.	Up[5]	None	1381.6 (0.08)			Wind	1799.1 (0.07)
	Low	None	1218.9 (0.08)			Cue	3084.0 (0.12)
	Dup	None	1100.2 (0.09)			None	2433.0 (0.26)

Species Group[1]	Team[4]	1998		1999		2004	
		Covariate	*ESHW* (CV)	Covariate	*ESHW* (CV)	Covariate	*ESHW* (CV)
Pilot W. spp.	Close	Behav	1209.7 (0.17)			None	1658.8 (0.29)
	Far	None	1362.2 (0.32)			None	2832.5 (0.22)
	Dup	Cue	1153.6 (0.21)			None	2324.6 (0.25)
Harbor P.	Up			NA	375.0 (0.05)		
	Low				236.0 (0.06)		
	Dup				270.0 (0.07)		
Humpback W.	Up			NA	1104.0 (0.25)		
	Low				1464.0 (0.13)		
	Dup				1590.0 (0.24)		
Minke W.	Up			NA	509.0 (0.14)		
	Low				358.0 (0.15)		
	Dup				325.0 (0.16)		
Right W.	Up			NA	1215.0 (0.16)		
	Low				1461.0 (0.21)		
	Dup				974.0 (0.16)		
Whitesided D.	Up			NA	518.0 (0.24)		
	Low				446.0 (0.24)		
	Dup				550.0 (0.30)		

1 W. = whale; D. = dolphin; P. = porpoise; and spp. = multiple species.

2 Spinner dolphins were only seen during the 1998 survey.

3 Large Whales during 1998 and 1999 included fin whales, animals identified as either a fin or sei whale, and sei whales. Large Whales during 2004 included humpback whales, fin whales, sei whales, animals identified as either a fin or sei whale, and animals identified as an unknown large whale.

4 Teams are upper, lower, and duplicate when it was assumed there was no reaction to the ship, while teams are close, far, and duplicate when it was assumed there was reactive movement to the ship.

5 For Risso's dolphins, teams for 1998 and 1999 (on the *R/V Abel-J*) are upper, lower, and duplicate (no reaction to ship), while teams for 2004 (on the *R/V Endeavor*) are close, far, and duplicate (reactive movement to ship).

Table 5. Estimates of *g(0)* for the upper and lower teams for the 1998, 1999, and 2004 shipboard surveys as derived in the original analyses. - = species not detected or not analyzed during that year.

Species	*g(0)* (CV)					
	1998		1999		2004	
	Upper team	Lower team	Upper team	Lower team	Upper team	Lower team
Beaked W.	0.50 (0.66)	0.46 (0.63)	-	-	0.27 (0.48)	0.31 (0.54)
Kogia spp.	0.50 (0.66)	0.46 (0.63)	-	-	0.55 (0.60)	0.29 (0.66)
Bottlenose D.	0.93 (0.61)	0.69 (0.58)	-	-	0.62 (0.31)	0.67 (0.32)
Common D.	0.52 (0.89)	0.76 (0.87)	-	-	0.53 (0.41)	0.64 (0.33)
Risso's D.	0.51 (0.36)	0.61 (0.31)	-	-	0.77 (0.43)	0.84 (0.37)
Pilot W.	0.59 (0.68)	0.50 (0.65)	-	-	0.66 (0.39)	0.67 (0.36)
Sperm W.	0.36 (0.66)	0.28 (0.67)	-	-	0.57 (0.40)	0.46 (0.39)
Striped D.	0.76 (0.77)	0.61 (0.77)	-	-	0.42 (0.26)	0.57 (0.25)
Spotted D.	0.76 (0.77)	0.61 (0.77)	-	-	0.37 (0.30)	0.94 (0.25)
Spinner D.	0.76 (0.77)	0.61 (0.77)	-	-	-	-
Fin or Sei W.	0.68 (0.80)	0.32 (0.87)	0.48 (0.25)	0.59 (0.19)	0.37 (0.62)	0.94 (0.61)
Fin W.	0.68 (0.80)	0.32 (0.87)	0.48 (0.25)	0.59 (0.19)	0.37 (0.62)	0.94 (0.61)
Sei W.	0.68 (0.80)	0.32 (0.87)	0.48 (0.25)	0.59 (0.19)	0.37 (0.62)	0.94 (0.61)
Humpback W.	-	-	0.38 (0.28)	0.30 (0.27)	0.70 (0.62)	0.88 (0.61)
Bottlenose W.	-	-	-	-	0.49 (0.62)	0.49 (0.61)
Unid W.	-	-	-	-	0.28 (0.62)	0.21 (0.61)
Harbor P.	-	-	0.35 (0.16)	0.54 (0.14)	-	-
Minke W.	-	-	0.69 (0.20)	0.70 (0.20)	-	-
Right W.	-	-	0.29 (0.25)	1.0 (0.19)	-	-
White-sided D.			0.27 (0.41)	0.38 (0.26)	-	-

Table 6. From the 1998, 1999, 2002 and 2004 aerial surveys, for each species group, estimates of (A) $g(0)_{leading}$, and (B) *ESHW* (in meters) and significant covariates; all were derived in the original analyses. The "teams" are the single and leading legs (SL), trailing legs (trail), and duplicates (dup). The covariates are: Beauf = Beaufort sea state, WTemp = sea surface water temperature, Wind = wind speed, Size = group size, Behav = behavior category, Cue = cue category, Depth = bottom depth, ObserverGrp = observer group, Slope = bottom slope, Period = first or second period, None = no covariate found significant.

A. *g(0)*

Species Group	$g(0)_{leading}$ (CV)
	1999, 1998, 2002, 2004
Large whales	0.53 (0.54)
Small cetaceans	0.43 (0.37)
Harbor porpoise	0.36 (0.57)

B. *ESHW*

Species Group	Team	2002, 2004		*ESHW* (CV)	
		Cov	*ESHW* (CV)	1998	1999
Large whales	SL	Cue	452.0 (0.07)	1,271.3 (0.04)	150.0 (0.16)
	trail	None	837.0		-
	dup	None	617.4		-
Small cetaceans	SL	None	256.9 (0.05)	BD* 296 (0.33) WD* 1,406 (0.11)	180.0 (0.16)
	trail	None	319.9		-
	dup	None	375.0		-
Harbor porpoise	SL	Size	155.6 (0.06)		155.6 (0.06)
	trail	None	175.7 (0.14)		-
	dup	None	270.0 (0.15)		-

BD* = bottlenose dolphin, both coastal and offshore
WD*= white-sided dolphin

Table 7. Summary of abundance estimates for all areas, years, and species.

Species	Year	Stratum GOMN	GOMC	GOMS	Scotian	GeorgesW	GeorgesC
Beaked W.	99						
	02				156		
	04		147				
Bottlenose D., offshore	99		455				
	02				399	682	1,278
	04						
Bottlenose W.	02						
	04						
Common D.	99						
	02			84			1,493
	04		3,793	8,891	1,815	5,263	11,551
Fin W.	99	176	387	399	204		742
	02		347	500	192	52	
	04		429	734		157	
Fin or Sei W.	99	36	33		104		
	02		39	77			
	04	71	309	221			
Grampus (Risso's D.)	99				1,561		
	02		3,358		5,488		
	04						
Harbor porpoise	99	21,642	15,745		37,185		
	02	11,931	32,219		1,864		
	04	27,224	25,028				
Humpback W.	99	70	417	199	199		
	02		98	33			200
	04	38	41		501		227
Kogia spp.	99						
	02						
	04						
Minke W.	99	868	407		730		
	02		130	65	51		
	04	145		28			
Pilot W.	99		3,003				978
	02		1,443		2,840		
	04		874	1,044			4,412
Right W.	99	192	2				
	02			172			
	04		177	190			
Sei W.	99	94					
	02				57		
	04		94	200			
Sperm W.	99						
	02		41				310
	04						
Spinner D.	99						
Spotted D.	99						
	02						
	04						
Striped D.	99						
	02						
	04						
Unid D.	99		15,831		1,331		
	02	86	611	29	231	853	
	04		1,078				1,377
Unid W.	99		147	798			
	02		91	15	71		
	04	98	106	126	429		
Whitesided D.	99	5,724	17,267	1,233	15,381		
	02		17,153	6,324	18,338		
	04		693	2,102			
TOTAL	98/99	28,802	53,694	2,629	56,695	0	1,720
	02	12,017	55,530	7,299	29,687	1,587	3,281
	04	27,576	32,769	13,536	2,745	5,420	17,567
	Ave Abun	22,798	47,331	7,821	29,709	3,504	7,523
	Ave Density	2.31	0.88	0.32	1.73	0.12	0.65

Table 7. Continued. Summary of abundance estimates for all areas, years, and species.

Species	Year	Stratum						TOTAL
		GeorgesE	ShelfW	ShelfC	ShelfE	Offshore	MidAtlantic	
Beaked W.	98		219	3	1,205	1,455		2,882
	02				532			688
	04		251	13	216	2,212		2,839
Bottlenose D., offshor	98		2,118	2,503	1,113	338	13,074	19,601
	02	536			1,384			4,279
	04		1,364	2,390	2,721	2,942	370	9,787
Bottlenose W.	02							0
	04					292		292
Common D.	98		2,910	5,836	2,603			11,349
	02	4,677			643			6,897
	04	10,939	10,382	6,886	27,770	3,258		90,548
Fin W.	98/99	551	23	146	146	36	62	2,872
	02	616		412	69			2,188
	04	149						1,469
Fin or Sei W.	98/99		6	24	201			404
	02	96						212
	04	134	7	50	99			891
Grampus (Risso's D.)	98		2,492	2,550	4,197	6,853		17,653
	02	516			848			10,210
	04		4,828	5,089	3,234	1,882		15,033
Harbor porpoise	99	2,728						77,300
	02							46,014
	04	730						52,982
Humpback W.	99							885
	02	684			58			1,073
	04		9		15			831
Kogia spp.	98			7	19	89		115
	02							0
	04		225			133		358
Minke W.	99							2,005
	02	40		116				402
	04				212		55	440
Pilot W.	98		906	1,162	1,250	1,133		8,432
	02	1,026			1,885			7,194
	04	4,708	323	38	2,204	2,123		15,726
Right W.	99							194
	02							172
	04							367
Sei W.	98				10			104
	02							57
	04				7			301
Sperm W.	98		231	120	377	2,471		3,199
	02	50						401
	04		333	329	27	1,918		2,607
Spinner D.	98			18				18
Spotted D.	98				964	31,079		32,043
	02							0
	04		1,442			2,136		3,578
Striped D.	98		5,672	2,523	3,645	29,929		41,769
	02							0
	04		1,500	1,161	1,005	48,388		52,054
Unid D.	99							17,162
	02	2,139		523	768			5,240
	04							2,455
Unid W.	99							945
	02	205			54			436
	04		17	3	457	99	49	1,384
Whitesided D.	99	847					199	40,651
	02	8,353			26,817			76,985
	04							2,795
TOTAL	98/99	4,126	14,577	14,892	15,730	73,383	13,335	279,583
	02	18,938	0	1,051	33,058	0	0	162,448
	04	16,660	20,681	15,959	37,967	65,383	474	256,737
	Ave Abun	13,241	17,629	10,634	28,918	69,383	6,905	232,923
	Ave Densit	0.43	0.62	0.67	1.35	0.50	0.05	0.56

Table 8. 1998 shipboard abundance estimates (and its components) for each species within each NE OPAREA stratum.

Offshore

Species	Team	Num of groups	Avg group size	Abundance (CV)
Beaked W. spp	Up Low Dup	17 15 7	2.4 2.2 2.7	1,455 (0.13)
Offshore Bottlenose D.	Up Low Dup	2 2 2	10.0 6.5 6.5	338 (0.77)
Fin W.	Up Low Dup	1 1 1	1.0 1.0 1.0	36 (1.05)
Risso's D.	Up Low Dup	17 14 9	7.4 15.8 10.9	6,853 (0.19)
Kogia spp.	Up Low Dup	0 3 0	- 1.0 -	89 (1.36)
Pilot W. spp.	Up Low Dup	4 2 1	4.5 7.5 6.0	1,133 (0.77)
Sperm W.	Up Low Dup	21 18 6	1.7 1.9 2.0	2,471 (0.14)
Spotted D.	Up Low Dup	9 9 8	36.6 63.1 48.1	31,079 (0.03)
Striped D.	Up Low Dup	17 20 13	62.0 42.7 51.5	29,929 (0.12)
Total	-	-	-	73,383 (0.05)

Shelf East

Species	Team	Num of groups	Avg group size	Abundance (CV)
Beaked W. spp	Up Low Dup	30 38 8	2.7 2.7 3.3	1,205 (0.23)
Offshore Bottlenose D.	Up Low Dup	14 11 7	12.9 13.5 9.6	1,113 0.35)
Common D.	Up Low Dup	16 17 11	25.4 44.5 48.7	2,603 (0.43)
Fin W.	Up Low Dup	18 5 4	1.1 1.2 1.3	146 (0.43)
Fin or Sei W.	Up Low Dup	3 6 1	1.0 1.5 1.0	201 (0.86)
Risso's D.	Up Low Dup	41 55 20	8.2 8.0 7.7	4,197 (0.27)
Kogia spp.	Up Low Dup	3 0 0	1.0 - -	19 (1.60)
Pilot W. spp.	Up Low Dup	16 21 11	11.1 12.0 14.6	1,250 (0.33)
Sei W.	Up Low Dup	2 0 0	1.0 - -	10 (0.86)
Sperm W.	Up Low Dup	20 18 8	1.6 1.6 1.3	377 (0.41)
Spotted D.	Up Low Dup	4 6 2	9.0 12.8 16.5	964 (1.05)
Striped D.	Up Low Dup	14 14 9	50.9 41.4 50.3	3,645 (0.42)
Total	-	-	-	15,730 (0.16)

Table 8. Continued. 1998 shipboard abundance estimates (and its components) for each species within each NE OPAREA stratum.

Shelf Central

Species	Team	Num of groups	Avg group size	Abundance (CV)
Beaked W. spp	Up Low Dup	1 0 0	1.0 - -	3 (1.39)
Offshore Bottlenose D.	Up Low Dup	23 31 15	17.3 17.3 18.6	2,503 (0.21)
Common D.	Up Low Dup	9 14 5	72.3 41.4 63.6	5,836 (0.43)
Fin W.	Up Low Dup	7 3 1	1.0 1.0 1.0	146 (0.61)
Fin or Sei W.	Up Low Dup	3 3 3	1.0 1.0 1.0	24 (0.62)
Risso's D.	Up Low Dup	48 50 23	6.5 5.5 6.9	2,550 (0.36)
Kogia spp.	Up Low Dup	1 0 0	1.0 - -	7 (1.81)
Pilot W. spp.	Up Low Dup	6 7 2	11.0 11.9 11.5	1,162 (0.63)
Sperm W.	Up Low Dup	10 5 2	1.6 1.6 2.5	120 (0.60)
Spinner D.	Up Low Dup	0 1 0	- 6.0 -	18 (1.41)
Striped D.	Up Low Dup	10 12 8	40.4 57.8 59.9	2,523 (0.47)
Total	-	-	-	14,892 (0.20)

Shelf West

Species	Team	Num of groups	Avg group size	Abundance (CV)
Beaked W. spp	Up Low Dup	6 9 3	3.7 3.7 4.7	219 (0.39)
Offshore Bottlenose D.	Up Low Dup	22 38 13	11.4 18.8 22.2	2,118 (0.24)
Common D.	Up Low Dup	5 11 5	79.2 67.3 103.2	2,910 (0.44)
Fin W.	Up Low Dup	3 1 0	2.0 4.0 -	23 (0.98)
Fin or Sei W.	Up Low Dup	1 0 0	1.0 - -	6 (1.36)
Risso's D.	Up Low Dup	20 37 11	7.7 12.8 13.0	2,492 (0.36)
Pilot W. spp.	Up Low Dup	12 17 9	9.2 10.8 12.6	906 (0.38)
Sperm W.	Up Low Dup	16 8 5	2.2 3.9 4.6	231 (0.57)
Striped D.	Up Low Dup	6 10 5	93.8 63.8 57.0	5,672 (0.52)
Total	-	-	-	14,577 (0.23)

Table 9. 1998 aerial abundance estimates (and its components) for each species within the MidAtlantic stratum. N = number of groups. S=average group size. sm= small groups (<=5), lg = large groups (>5). SL = leading and single portion of the track line.

MidAtlantic

Species	Team	N		S		Abun (CV)
		Sm	Lg	Sm	Lg	
Bottlenose D., offshore & coastal	SL	24	8	2.1	20.0	13,074 (0.67)
Fin W.	SL	2	0	1.5	-	62 (1.03)
Whitesided D.	SL	0	1	-	20.0	199 (0.92)
Total	-	-	-	-	-	13,335 (0.66)

Table 10. 1999 shipboard abundance estimates (and its components) for each species within each NE OPAREA stratum.

Gulf of Maine North

Species	Team	Num of groups	Avg group size	Abundance (CV)
Fin W.	Up Low Dup	10 13 4	1.9 1.3 1.8	176 (0.32)
Fin or Sei W.	Up Low Dup	2 11 0	1.0 1.1 -	36 (0.74)
Harbor P.	Up Low Dup	190 180 57	3.2 3.2 3.6	21,642 (0.17)
Humpback W.	Up Low Dup	6 7 4	1.5 1.6 1.8	70 (0.54)
Minke W.	Up Low Dup	41 30 11	1.0 1.1 1.2	868 (0.19)
Right W.	Up Low Dup	10 37 8	2.2 1.4 1.1	192 (0.02)
Sei W.	Up Low Dup	2 3 2	1.5 1.7 1.5	94 (0.22)
Whitesided D.	Up Low Dup	7 13 2	10.4 11.4 6.0	5,724 (0.88)
Total	-	-	-	28,802 0.22)

Scotian

Species	Team	Num of groups	Avg group size	Abundance (CV)
Fin W.	Up Low Dup	8 7 4	1.0 1.1 1.0	204 (0.28)
Fin or Sei W.	Up Low Dup	2 3 1	1.5 1.0 1.0	104 (0.47)
Harbor P.	Up Low Dup	136 118 63	3.2 3.4 3.7	32,899 (0.11)
Humpback W.	Up Low Dup	5 4 2	1.2 1.5 1.5	199 (0.48)
Minke W.	Up Low Dup	16 10 6	1.0 1.0 1.0	730 (0.22)
Whitesided D.	Up Low Dup	3 6 3	21.3 8.2 23.3	951 (0.72)
Total	-	-	-	35,087 (0.10)

Gulf of Maine Central (coastal only)

Species	Team	Num of groups	Avg group size	Abundance (CV)
Fin W.	Up Low Dup	34 27 17	1.4 1.3 1.4	240 (0.21)
Fin or Sei W.	Up Low Dup	2 12 0	1.0 1.0 -	33 (0.74)
Harbor P.	Up Low Dup	134 137 56	3.0 3.0 3.4	10,218 (0.19)
Humpback W.	Up Low Dup	26 29 13	1.5 1.4 1.4	417 (0.22)
Minke W.	Up Low Dup	34 30 19	1.0 1.0 1.0	407 (0.23)
Right W.	Up Low Dup	0 1 0	- 1.0 -	2 (1.68)
Whitesided D.	Up Low Dup	29 25 14	52.3 36.6 41.4	14,052 (0.16)
Total	-	-	-	25,369 (0.12)

Table 11. 1999 aerial abundance estimates (and its components) for each species within each NE OPAREA stratum. N = number of groups. S=average group size. sm= small groups (<=5), lg = large groups (>5). SL = leading and single portion of the track line. Trail = trailing portion of track line. Dup = sightings detected on both the leading and trailing portions of the track line.

Gulf of Maine Central (center only)

Species	Team	N		S		Abun (CV)
		Sm	Lg	Sm	Lg	
Offshore Bottlenose D.	SL	2	0	1.5	-	455 (1.08)
Fin W.	SL	1	0	1.0	-	147 (1.19)
Harbor P.	SL	11	1	2.2	7.0	5,527 (0.71)
Pilot W.	SL	4	3	1.8	10.0	3,003 (0.74)
Unid D.	SL	1	3	2.0	80.0	15,831 (0.64)
Unid W.	SL	1	0	1.0	-	147 (1.22)
Whitesided D.	SL	1	2	2.0	22.5	3,215 (0.92)
Total	-	-	-	-	-	28,325 (0.41)

Gulf of Maine South

Species	Team	N		S		Abun (CV)
		Sm	Lg	Sm	Lg	
Fin W.	SL	2	0	1.0	-	399 (1.07)
Humpback W.	SL	1	0	1.0	-	199 (1.07)
Unid W.	SL	2	0	2.0	-	798 (0.97)
Whitesided D.	SL	2	0	3.0	-	1,233 (0.83)
Total	-	-	-	-	-	2,629 (0.52)

Georges Bank Central

Species	Team	N		S		Abun (CV)
		Sm	Lg	Sm	Lg	
Fin W.	SL	2	0	1.0	-	742 (1.11)
Pilot W.	SL	0	1	-	6.0	978 (1.03)
Total	-	-	-	-	-	1,720 (0.76)

Georges Bank East

Species	Team	N		S		Abun (CV)
		Sm	Lg	Sm	Lg	
Fin W.	SL	2	0	1.0	-	551 (0.99)
Harbor P.	SL	2	0	3.5	-	2,728 (1.36)
Whitesided D.	SL	0	1	-	7.0	847 (1.04)
Total	-	-	-	-	-	4,126 (0.93)

Scotian

Species	Team	N		S		Abun (CV)
		Sm	Lg	Sm	Lg	
Harbor P.	SL	5	0	2.0	-	4,290 (0.89)
Risso D.	SL	1	0	5	-	1,561 (0.80)
Unid D.	SL	0	1	-	10.0	1,331 (0.84)
Whitesided D.	SL	1	5	4.0	19.8	14,430 (0.63)
Total	-	-	-	-	-	21,612 (0.46)

Table 12. 2002 aerial abundance estimates (and its components) for each species within each NE OPAREA stratum. N = number of groups. S=average group size. sm= small groups (<=5), lg = large groups (>5). SL = leading and single portion of the track line. Trail = trailing portion of track line. Dup = sightings detected on both the leading and trailing portions of the track line, that is, duplicates sightings.

Gulf of Maine North

Species	Team	N		S		Abun
		sm	lg	sm	lg	(CV)
Harbor porpoise	SL trail dup	13 9 5	3 1 1	1.2	7.3	11,931 (0.53)
Unid Dolphin	SL trail dup	1 0 0	0 0 0	1.0	-	86 (1.12)
Total	-	-	-	-	-	12,017 (0.53)

Gulf of Maine Central

Species	Team	N		S		Abun
		sm	lg	sm	lg	(CV)
Fin W.	SL trail dup	8 0 0	0 0 0	1.1	-	347 (0.76)
Fin or sei W.	SL trail dup	1 0 0	0 0 0	1.0	-	39 (1.13)
Risso's D.	SL trail dup	0 0 0	1 0 0	-	80	3,358 (1.06)
Harbor porpoise	SL trail dup	60 7 4	13 4 2	2.3	8.8	32,219 (0.52)
Humpback W.	SL trail dup	3 0 0	0 0 0	1.0	-	98 (0.89)
Minke W.	SL trail dup	4 0 0	0 0 0	1.0	-	130 (0.81)
Pilot W.	SL trail dup	5 1 1	1 1 0	2.6	6.0	1,443 (0.65)
Sperm W.	SL trail dup	1 0 0	0 0 0	1.0	-	41 (1.13)
Unid D.	SL trail dup	4 0 0	1 1 0	2.0	30.0	611 (0.67)
Unid W.	SL trail dup	5 2 0	0 0 0	1.2	-	91 (0.77)
Whitesided D.	SL trail dup	13 0 0	16 1 0	2.5	34.9	17,153 (0.58)
Total	-	-	-	-	-	55,530 (0.36)

Gulf of Maine South

Species	Team	N		S		Abun
		sm	Lg	Sm	Lg	(CV)
Common D.	SL trail dup	1 0 0	0 0 0	1.0	-	84 (1.18)
Fin W.	SL trail dup	13 3 2	0 0 0	1.0	-	500 (0.65)
Fin or Sei W.	SL trail dup	2 2 1	0 0 0	1.0	-	77 (0.84)
Humpback W.	SL trail dup	1 0 0	0 0 0	1.0	-	33 (1.13)
Minke W.	SL trail dup	1 0 0	0 0 0	2.0	-	65 (1.18)
Right W.	SL trail dup	2 1 1	0 0 0	1.5	-	172 (0.98)
Unid. D.	SL trail dup	1 0 0	0 0 0	1.0	-	29 (1.11)
Unid W.	SL trail dup	1 1 1	0 0 0	1.0	-	15 (1.13)
White-sided D.	SL trail dup	3 0 0	7 0 0	2.3	31.3	6,324 (0.63)
Total	-	-	-	-	-	7,299 (0.55)

Georges Bank West

Species	Team	N		S		Abun
		Sm	Lg	Sm	lg	(CV)
Bottlenose D., offshore	SL trail dup	0 0 0	2 0 0	-	7.0	682 (0.74)
Fin W.	SL trail dup	1 0 0	0 0 0	1.0	-	52 (1.19)
Unid. D.	SL trail dup	1 0 0	3 0 0	5.0	13.0	853 (0.86)
Total	-	-	-	-	-	1,587 (0.56)

Table 12. Continued. 2002 aerial abundance estimates (and its components) for each species within each NE OPAREA stratum. N = number of groups. S=average group size. sm= small groups (<=5), lg = large groups (>5). SL = leading and single portion of the track line. Trail = trailing portion of track line. Dup = sightings detected on both the leading and trailing portions of the track line, that is, duplicates sightings.

Georges Bank Central

Species	Team	N		S		Abun
		sm	Lg	Sm	Lg	(CV)
Bottlenose D., offshore	SL trail dup	0 0 0	1 0 0	-	23.0	1,278 (1.22)
Common D.	SL trail dup	2 0 0	1 1 0	3.0	20.0	1,493 (0.93)
Humpback W.	SL trail dup	2 0 0	0 0 0	2.0	-	200 (0.93)
Sperm W.	SL trail dup	5 0 0	0 0 0	1.0	-	310 (0.81)
Total	-	-	-	-	-	3,281 (0.64)

Shelf Central

Species	Team	N		S		Abun
		Sm	Lg	Sm	lg	(CV)
Fin W.	SL trail dup	3 1 0	0 0 0	1.0	-	412 (1.00)
Minke W.	SL trail dup	1 0 0	0 0 0	1.0	-	116 (0.89)
Unid. D.	SL trail dup	1 0 0	0 0 0	5.0	-	523 (0.92)
Total	-	-	-	-	-	1,051 (0.61)

Georges Bank East

Species	Team	N		S		Abun
		Sm	Lg	Sm	Lg	(CV)
Bottlenose D., offshore	SL trail dup	0 0 0	1 0 0	-	12.0	536 (1.03)
Common D.	SL trail dup	1 0 0	4 2 2	1.0	25.8	4677 (0.68)
Fin W.	SL trail dup	1 2 0	0 0 0	1.2	-	616 (0.69)
Fin or Sei W.	SL trail dup	1 0 0	0 0 0	2.0	-	96 (1.12)
Risso's D.	SL trail dup	0 0 0	1 0 0	-	10.0	516 (1.04)
Humpback W.	SL trail dup	11 0 0	0 0 0	1.5	-	684 (0.77)
Minke W.	SL trail dup	1 0 0	0 0 0	1.0	-	40 (1.13)
Pilot W.	SL trail dup	4 0 0	0 0 0	2.3	-	1026 (0.85)
Sperm W.	SL trail dup	1 0 0	0 0 0	1.0	-	50 (1.28)
Unid. D.	SL trail dup	1 0 0	2 0 0	5.0	63.5	2139 (1.05)
Unid W.	SL trail dup	7 1 0	0 0 0	1.6	-	205 (0.72)
Whitesided D.	SL trail dup	1 0 0	11 1 0	3.0	22.3	8353 (0.62)
Total	-	-	-	-	-	18,938 (0.35)

Table 12. Continued. 2002 aerial abundance estimates (and its components) for each species within each NE OPAREA stratum. N = number of groups. S=average group size. sm= small groups (<=5), lg = large groups (>5). SL = leading and single portion of the track line. Trail = trailing portion of track line. Dup = sightings detected on both the leading and trailing portions of the track line, that is, duplicates sightings.

Shelf East

Species	Team	N		S		Abun
		Sm	Lg	Sm	lg	(CV)
Beaked W.	SL	3	0			
	trail	0	0	3.0	-	532 (1.10)
	dup	0	0			
Bottlenose D., offshore	SL	2	1			
	trail	0	0	2.0	12.0	1,384 (0.67)
	dup	0	0			
Common D.	SL	0	1			
	trail	0	1	-	10.0	643 (1.10)
	dup	0	1			
Fin W.	SL	1	0			
	trail	0	0	1.0	-	69 (1.05)
	dup	0	0			
Risso's D.	SL	1	1			
	trail	0	0	1.0	9.0	848 (0.85)
	dup	0	0			
Humpback W.	SL	1	0			
	trail	0	0	1.0	-	58 (1.09)
	dup	0	0			
Pilot W.	SL	3	1			
	trail	0	0	2.7	8.0	1,885 (0.85)
	dup	0	0			
Unid D.	SL	1	1			
	trail	0	0	4.0	25.0	768 (0.81)
	dup	0	0			
Unid. W.	SL	1	0			
	trail	0	0	2.0	-	54 (1.11)
	dup	0	0			
Whitesided D.	SL	4	10			
	trail	0	0	2.5	53.5	26,817 (0.60)
	dup	0	0			
Total	-	-	-	-	-	33,058 (0.49)

Scotian

Species	Team	N		S		Abun
		Sm	Lg	Sm	lg	(CV)
Beaked W.	SL	1	0			
	trail	0	0	3.0	-	156 (1.16)
	dup	0	0			
Bottlenose D., offshore	SL	0	1			
	trail	0	1	-	7.0	399 (0.99)
	dup	0	0			
Fin W.	SL	0	1			
	trail	0	0	-	6.0	192 (1.07)
	dup	0	0			
Risso's D.	SL	11	3			
	trail	0	0	2.5	6.7	5,488 (0.52)
	dup	0	0			
Harbor porpoise	SL	1	2			
	trail	0	0	2.0	6.5	1,864 (0.65)
	dup	0	0			
Minke W.	SL	1	0			
	trail	0	0	1.0	-	51 (1.09)
	dup	0	0			
Pilot W.	SL	2	2			
	trail	0	0	4.0	13.5	2840 (0.79)
	dup	0	0			
Sei W.	SL	1	0			
	trail	0	0	1.0	-	57 (1.07)
	dup	0	0			
Unid. D.	SL	2	0			
	trail	0	0	2.5	-	231 (0.88)
	dup	0	0			
Unid. W.	SL	1	0			
	trail	0	0	3.0	-	71 (1.07)
	dup	0	0			
Whitesided D.	SL	2	5			
	trail	0	1	3.5	83.4	18,338 (0.79)
	dup	0	1			
Total	-	-	-	-	-	29,687 (0.51)

Table 13. 2004 shipboard abundance estimates (and its components) for each species within each NE OPAREA stratum.

Offshore

Species	Team	Num of groups	Avg group size	Abundance (CV)
Beaked W. spp	Up	12	2.08	2212 (0.15)
	Low	16	2.38	
	Dup	5	2.20	
Offshore Bottlenose D.	Up	6	18.5	2942 (0.42)
	Low	7	12.9	
	Dup	4	19.0	
Bottlenose W.	Up	0	-	292 (1.34)
	Low	3	4.3	
	Dup	0	-	
Common D.	Up	10	14.5	3258 (0.47)
	Low	8	12.8	
	Dup	6	16.2	
Risso's D.	Up	10	8.3	1882 (0.38)
	Low	8	5.3	
	Dup	6	11.5	
Kogia spp.	Up	6	1.8	133 0.43)
	Low	3	1.7	
	Dup	0	-	
Pilot W. spp.	Up	14	10.1	2123 (0.24)
	Low	13	11.8	
	Dup	9	14.1	
Sperm W.	Up	40	1.8	1918 (0.08)
	Low	39	1.6	
	Dup	21	1.9	
Spotted D.	Up	6	16.8	2136 (0.35)
	Low	4	18.3	
	Dup	4	26.3	
Striped D.	Up	21	84.0	48,388 (0.05)
	Low	31	58.3	
	Dup	20	61.8	
Unid Large W.	Up	9	1.0	99 (0.47)
	Low	2	1.0	
	Dup	0	-	
Total	-	-	-	65,383 (0.05)

Shelf East

Species	Team	Num of groups	Avg group size	Abundance (CV)
Beaked W. spp	Up	3	4.3	216 (0.66)
	Low	5	2.8	
	Dup	2	5.5	
Offshore Bottlenose D.	Up	9	13.2	2721 (0.49)
	Low	14	12.4	
	Dup	7	12.4	
Common D.	Up	32	29.6	14,737 (0.24)
	Low	42	27.9	
	Dup	24	34.3	
Fin or Sei whale	Up	8	1.1	99 (0.15)
	Low	14	1.1	
	Dup	6	1.2	
Risso's D.	Up	12	4.5	3234 (0.39)
	Low	27	5.0	
	Dup	9	4.6	
Humpback W.	Up	2	1.0	15 (0.52)
	Low	2	1.0	
	Dup	2	1.0	
Pilot W. spp.	Up	11	6.5	2204 (0.43)
	Low	17	16.1	
	Dup	7	8.0	
Sei whale	Up	0	-	7 (1.34)
	Low	1	1.0	
	Dup	0	-	
Sperm W.	Up	1	3.0	27 (1.06)
	Low	1	1.0	
	Dup	0	-	
Striped D.	Up	3	35.0	1005 (0.79)
	Low	3	51.7	
	Dup	3	51.7	
Unid Large W.	Up	5	1.0	457 (0.39)
	Low	10	1.0	
	Dup	2	1.0	
Total	-	-	-	24,722 (0.17)

Table 13. Continued. 2004 shipboard abundance estimates (and its components) for each species within each NE OPAREA stratum.

Shelf Central

Species	Team	Num of groups	Avg group size	Abundance (CV)
Beaked W. spp	Up Low Dup	3 1 0	2.0 2.0 -	13 (1.08)
Offshore Bottlenose D.	Up Low Dup	8 12 5	18.0 8.9 8.4	2390 (0.48)
Common D.	Up Low Dup	23 35 18	21.1 30.7 26.2	6886 (0.33)
Fin or Sei W.	Up Low Dup	2 6 1	1.5 1.0 1.0	50 (0.60)
Risso's D.	Up Low Dup	23 38 17	15.1 10.6 17.7	5089 (0.26)
Pilot W. spp.	Up Low Dup	0 1 0	- 16.0 -	38 (1.42)
Sperm W.	Up Low Dup	14 20 6	1.4 1.4 1.3	329 (0.34)
Striped D.	Up Low Dup	3 5 2	50.3 31.0 55.0	1161 (0.92)
Unid Large W.	Up Low Dup	0 1 0	- 1.0 -	3 (1.56)
Total	-	-	-	15,959 (0.19)

Shelf West

Species	Team	Num of groups	Avg group size	Abundance (CV)
Beaked W. spp	Up Low Dup	8 9 5	2.6 2.7 3.2	251 (0.49)
Offshore Bottlenose D.	Up Low Dup	8 12 6	13.0 9.8 10.3	1364 (0.51)
Common D.	Up Low Dup	15 15 8	49.8 66.5 59.5	10,382 (0.32)
Fin or Sei whale	Up Low Dup	1 1 -	1.0 1.0 -	7 (0.99)
Risso's D.	Up Low Dup	30 48 17	7.4 12.1 18.1	4,828 (0.25)
Humpback W.	Up Low Dup	1 2 1	1.0 1.0 1.0	9 (0.87)
Kogia spp.	Up Low Dup	5 3 1	1.2 1.0 1.0	225 (1.14)
Pilot W. spp.	Up Low Dup	6 8 5	12.3 11.8 16.6	323 (0.57)
Sperm W.	Up Low Dup	15 21 8	2.1 1.6 2.0	333 (0.40)
Spotted D.	Up Low Dup	1 3 1	72.0 35.3 50.0	1,442 (0.83)
Striped D.	Up Low Dup	3 5 2	77.0 44.2 99.0	1,500 (0.74)
Unid Large W.	Up Low Dup	5 1 0	1.0 1.0 -	17 (0.96)
Total	-	-	-	20,681 (0.19)

Table 14. 2004 aerial abundance estimates (and its components) for each species within each NE OPAREA stratum. N = number of groups. S=average group size. sm= small groups (<=5), lg = large groups (>5). SL = leading and single portion of the track line. Trail = trailing portion of track line. Dup = sightings detected on both the leading and trailing portions of the track line, that is, duplicates sightings.

Gulf of Maine North

Species	Team	N Sm	N Lg	S Sm	S lg	Abun (CV)
Fin or Sei W.	SL	1	0	1.0	-	71 (1.21)
	trail	0	0			
	dup	0	0			
Harbor porpoise	SL	44	0	1.6	-	27,224 (0.70)
	trail	4	0			
	dup	2	0			
Humpback W.	SL	1	0	1.0	-	38 (1.13)
	trail	1	0			
	dup	1	0			
Minke W.	SL	4	0	1.0	-	145 (0.55)
	trail	0	0			
	dup	0	0			
Unid W.	SL	3	0	1.0	-	98 (0.83)
	trail	0	0			
	dup	0	0			
Total	-	-	-	-	-	27,576 (0.69)

Gulf of Maine Central

Species	Team	N Sm	N Lg	S Sm	S Lg	Abun (CV)
Beaked W.	SL	2	0	1.0	-	147 (0.86)
	trail	0	0			
	dup	0	0			
Common D.	SL	3	4	2.3	15,8	3793 (0.64)
	trail	0	0			
	dup	0	0			
Fin W.	SL	5	0	1.0	-	429 (0.68)
	trail	2	0			
	dup	1	0			
Fin or Sei W.	SL	3	0	1.3	-	309 (0.95)
	trail	0	0			
	dup	0	0			
Harbor porpoise	SL	37	1	1.5	15.0	25,028 (0.65)
	trail	4	0			
	dup	2	0			
Humpback W.	SL	1	0	1.0	-	41 (1.13)
	trail	1	0			
	dup	0	0			
Pilot W.	SL	0	1	-	14.0	874 (1.01)
	trail	0	0			
	dup	0	0			
Right W.	SL	2	0	1.0	-	177 (0.86)
	trail	0	0			
	dup	0	0			
Sei W.	SL	1	0	1.0	-	94 (1.13)
	trail	0	0			
	dup	0	0			
Unid D.	SL	3	2	2.3	10.5	1078 (0.63)
	trail	1	0			
	dup	0	0			
Unid W.	SL	3	0	1.0	-	106 (0.78)
	trail	0	0			
	dup	0	0			
Whitesided D.	SL	0	1	-	8.0	693 (1.01)
	trail	0	1			
	dup	0	1			
Total	-	-	-	-	-	32,769 (0.5)

Gulf of Maine South

Species	Team	N Sm	N Lg	S Sm	S Lg	Abun (CV)
Common D.	SL	12	14	2.8	12.9	8891 (0.42)
	trail	7	0			
	dup	3	0			
Fin W.	SL	7	0	1.7	-	734 (0.82)
	trail	0	0			
	dup	0	0			
Fin or Sei W.	SL	3	0	1.3	-	221 (0.86)
	trail	0	0			
	dup	0	0			
Minke W.	SL	1	0	1.0	-	28 (1.13)
	trail	0	0			
	dup	0	0			
Pilot W.	SL	3	1	2.3	7.0	1044 (0.86)
	trail	0	0			
	dup	0	0			
Right W.	SL	1	0	3.0	-	190 (0.99)
	trail	1	0			
	dup	0	0			
Sei W.	SL	1	0	3.0	-	200 (0.99)
	trail	0	0			
	dup	0	0			
Unid. W.	SL	4	0	1.3	-	126 (0.70)
	trail	0	0			
	dup	0	0			
Whitesided D.	SL	0	2	-	17.0	2102 (1.14)
	trail	0	0			
	dup	0	0			
Total	-	-	-	-	-	13,536 (0.34)

Table 14. Continued. 2004 aerial abundance estimates (and its components) for each species within each NE OPAREA stratum. N = number of groups. S=average group size. sm= small groups (<=5), lg = large groups (>5). SL = leading and single portion of the track line. Trail = trailing portion of track line. Dup = sightings detected on both the leading and trailing portions of the track line, that is, duplicates sightings.

Georges BankWest

Species	Team	N		S		Abun
		Sm	Lg	Sm	Lg	(CV)
Common D.	SL trail dup	2 0 0	6 0 0	3.0	17.7	5,263 (0.86)
Fin W.	SL trail dup	1 0 0	0 0 0	2.0	-	157 (1.17)
Total	-	-	-	-	-	5420 (0.84)

Shelf East

Species	Team	N		S		Abun
		Sm	Lg	Sm	Lg	(CV)
Common D.	SL trail dup	6 0 0	2 0 0	2.7	6.5	13,033 (0.59)
Minke W.	SL trail dup	1 0 0	0 0 0	1.0	-	212 (1.47)
Total	-	-	-	-	-	13,245 (0.58)

Georges Bank Cemtral

Species	Team	N		S		Abun
		Sm	Lg	Sm	Lg	(CV)
Common D.	SL trail dup	3 0 0	12 0 0	4.0	19.6	11,551 (0.47)
Humpback W.	SL trail dup	6 0 0	0 0 0	1.0	-	227 (1.08)
Pilot W.	SL trail dup	9 3 2	4 0 0	1.9	9.3	4,412 (0.49)
Unid. D.	SL trail dup	0 0 0	3 0 0	-	17.3	1,377 (0.87)
Total	-	-	-	-	-	17,567 (0.34)

MidAtlantic

Species	Team	N		S		Abun
		Sm	Lg	Sm	Lg	(CV)
Bottlenose D., offshore	SL trail dup	5 0 0	0 0 0	1.8	-	370 (0.66)
Minke W.	SL trail dup	1 0 0	0 0 0	1.0	-	55 (1.14)
Unid W.	SL trail dup	1 0 0	0 0 0	1.0	-	49 (1.27)
Total	-	-	-	-	-	474 (0.55)

Georges Bank East

Species	Team	N		S		Abun
		Sm	Lg	Sm	Lg	(CV)
Common D.	SL trail dup	8 0 0	6 0 0	2.3	15.0	10,939 (0.48)
Fin W.	SL trail dup	1 0 0	0 0 0	1.0	-	149 (1.14)
Fin or Sei W.	SL trail dup	1 0 0	0 0 0	1.0	-	134 (1.14)
Harbor porpoise	SL trail dup	1 0 0	0 0 0	1.0	-	730 (1.14)
Pilot W.	SL trail dup	5 1 0	1 0 0	3.2	6.0	4,708 (0.78)
Total	-	-	-	-	-	16,660 (0.39)

Scotian

Species	Team	N		S		Abun
		Sm	Lg	Sm	Lg	(CV)
Common D.	SL trail dup	1 0 0	0 0 0	4.0	-	1,815 (1.11)
Humpback W.	SL trail dup	2 0 0	0 0 0	1.5	-	501 (1.23)
Unid W.	SL trail dup	1 0 0	0 0 0	3.0	-	429 (1.18)
Total	-	-	-	-	-	2,745 (0.79)

Figure 1. NE OPAREA, strata defined by Navy. Depth contours are labeled.

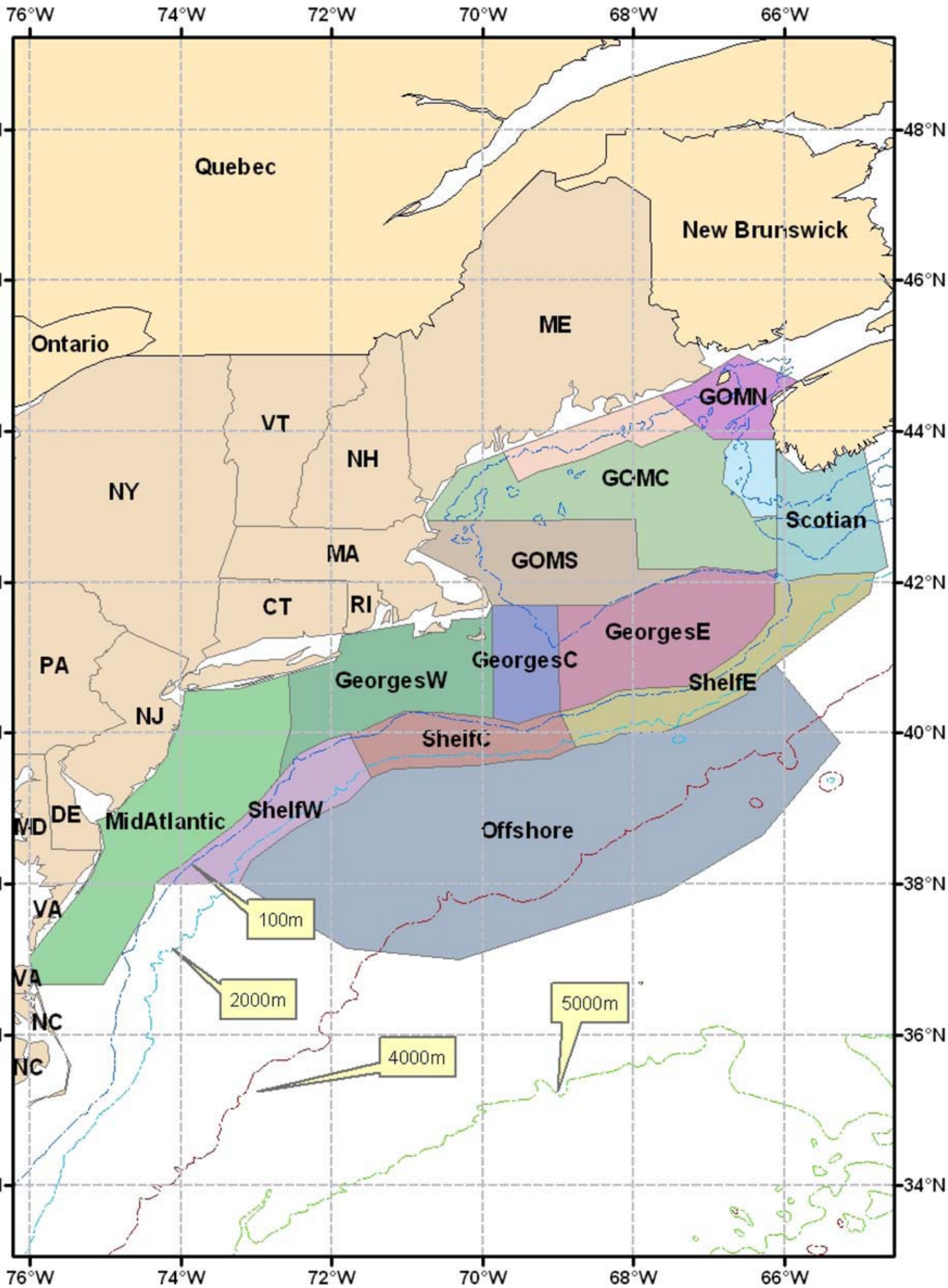


Figure 2. Track lines within the NE OPAREAs covered during the 1998 abundance surveys. Track line colors differ for each NE OPAREA. Tracks lines (solid line) in the Offshore and three Shelf (ShelfE, ShelfC, and ShelfW) strata were surveyed by a ship. Track lines (hashed) in the Mid-Atlantic stratum were surveyed by plane.

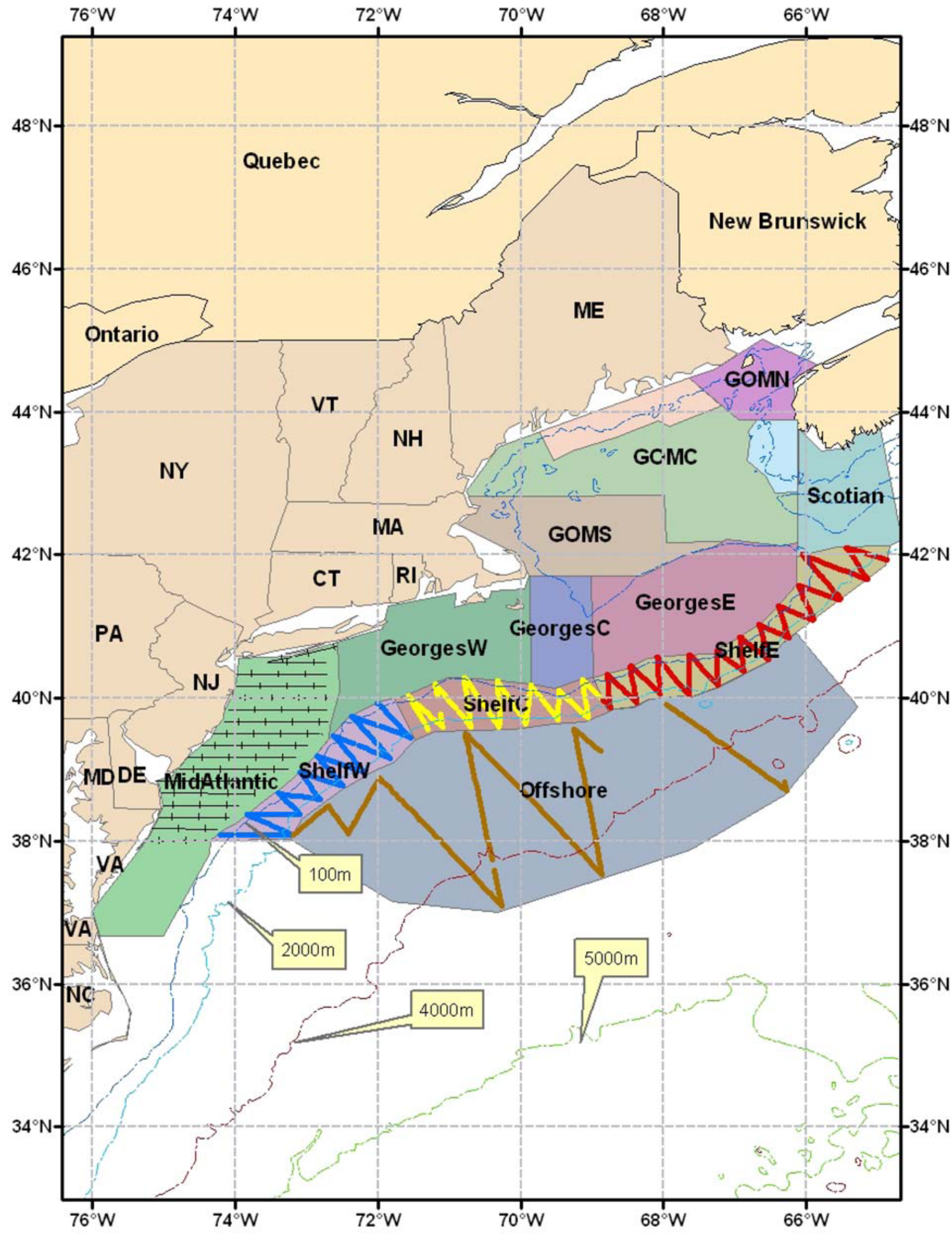


Figure 3. Track lines within the NE OPAREAs covered during the 1999 abundance surveys. Track line colors differ for each NE OPAREA. Tracks lines (solid line) in the coastal portion of the Gulf of Maine central (GOMC), northern portion of the Scotian stratum, and the Gulf of Maine north (GOMN) stratum were surveyed by ship. Track lines (hashed) in two of the Georges Bank strata (GeorgesE and GeorgesC), the central portion of the GOMC, and the southern portion of the Scotian strata were surveyed by plane.

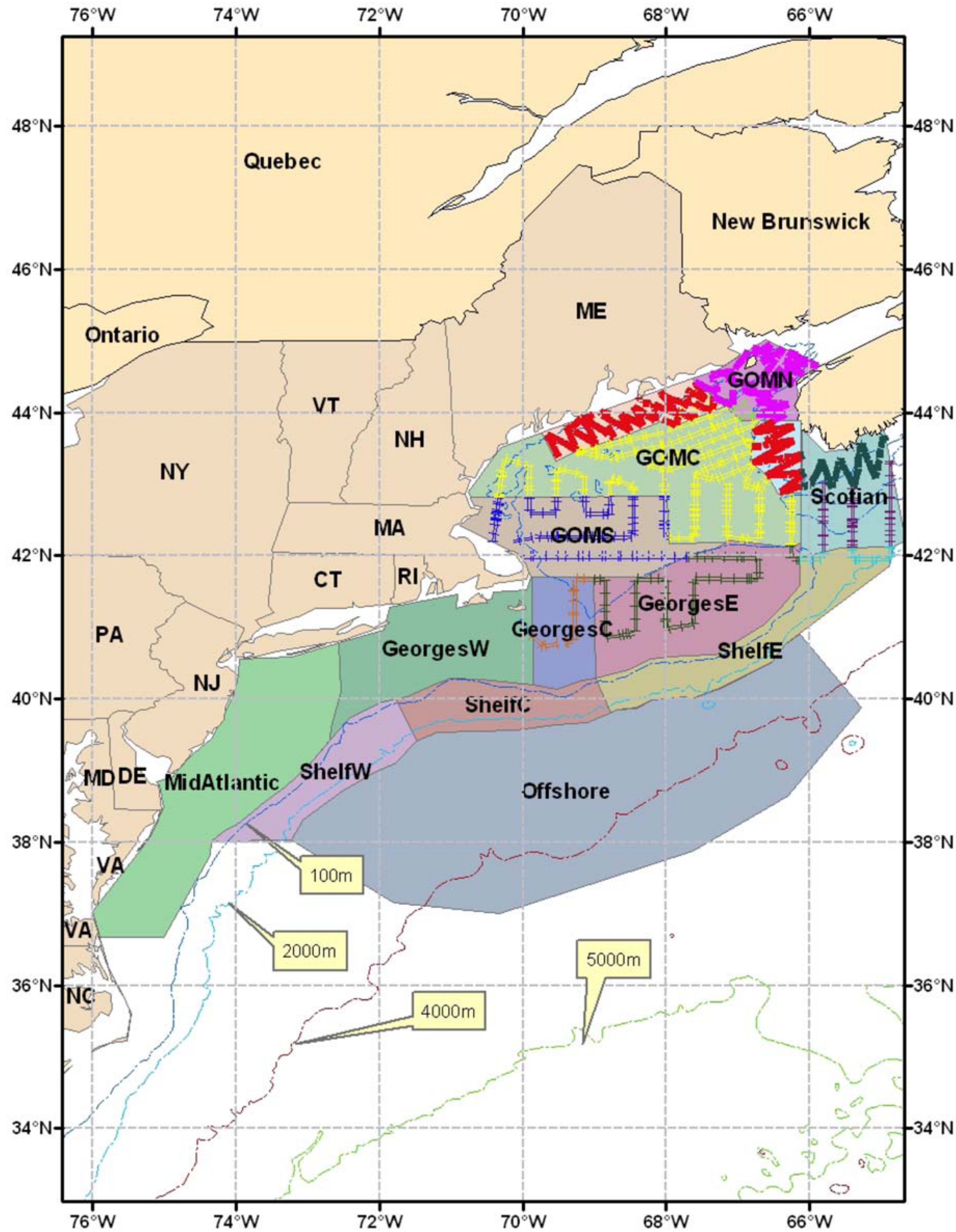


Figure 4. Track lines within the NE OPAREAs covered during the 2004 abundance survey. Track line colors differ for each NE OPAREA. Tracks lines in the Offshore and three Shelf strata were surveyed by ship, other track lines were surveyed by plane.

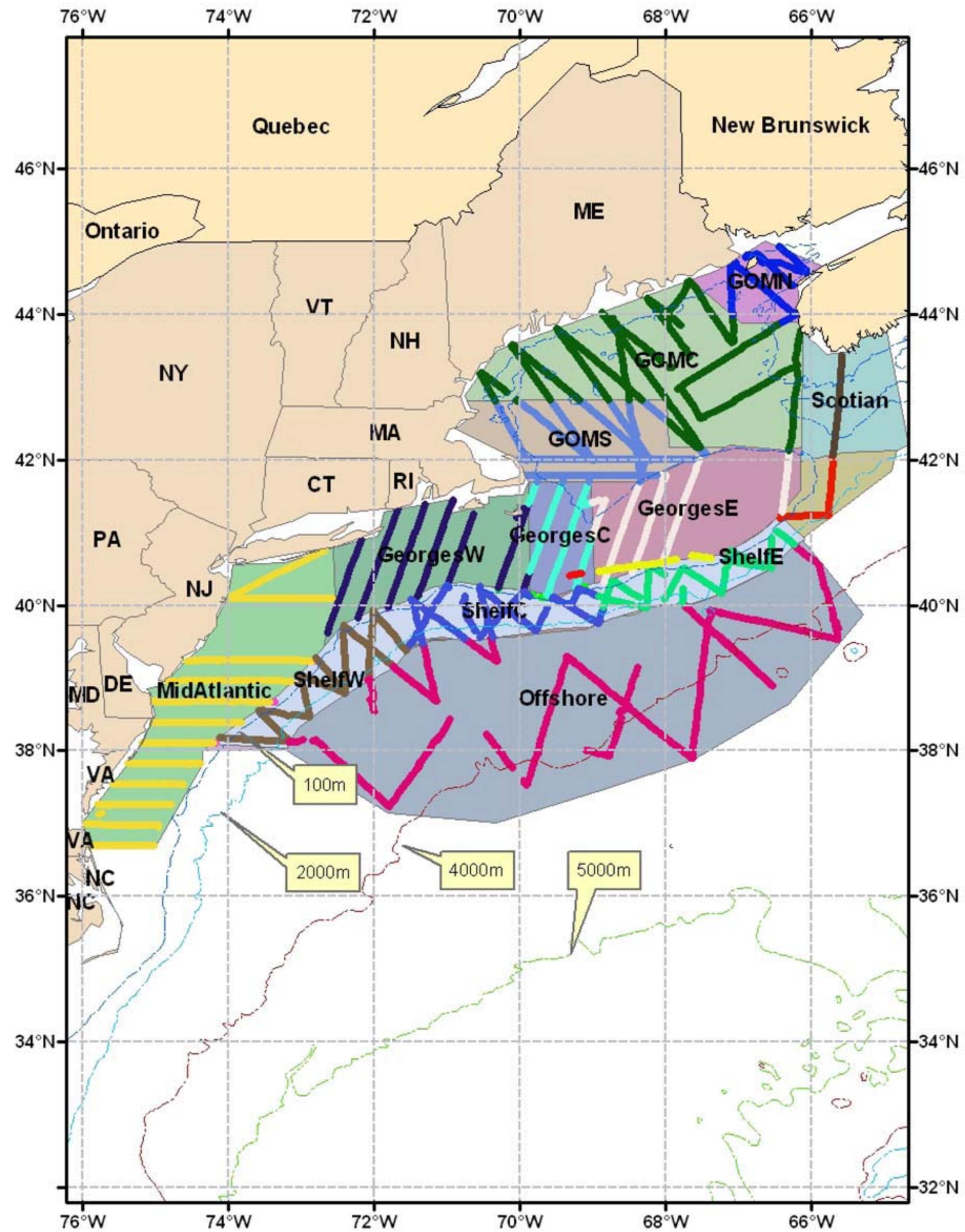


Figure 5. Track lines within the NE OPAREAs covered during the 2002 aerial abundance survey. Track line colors differ for each NE OPAREA.

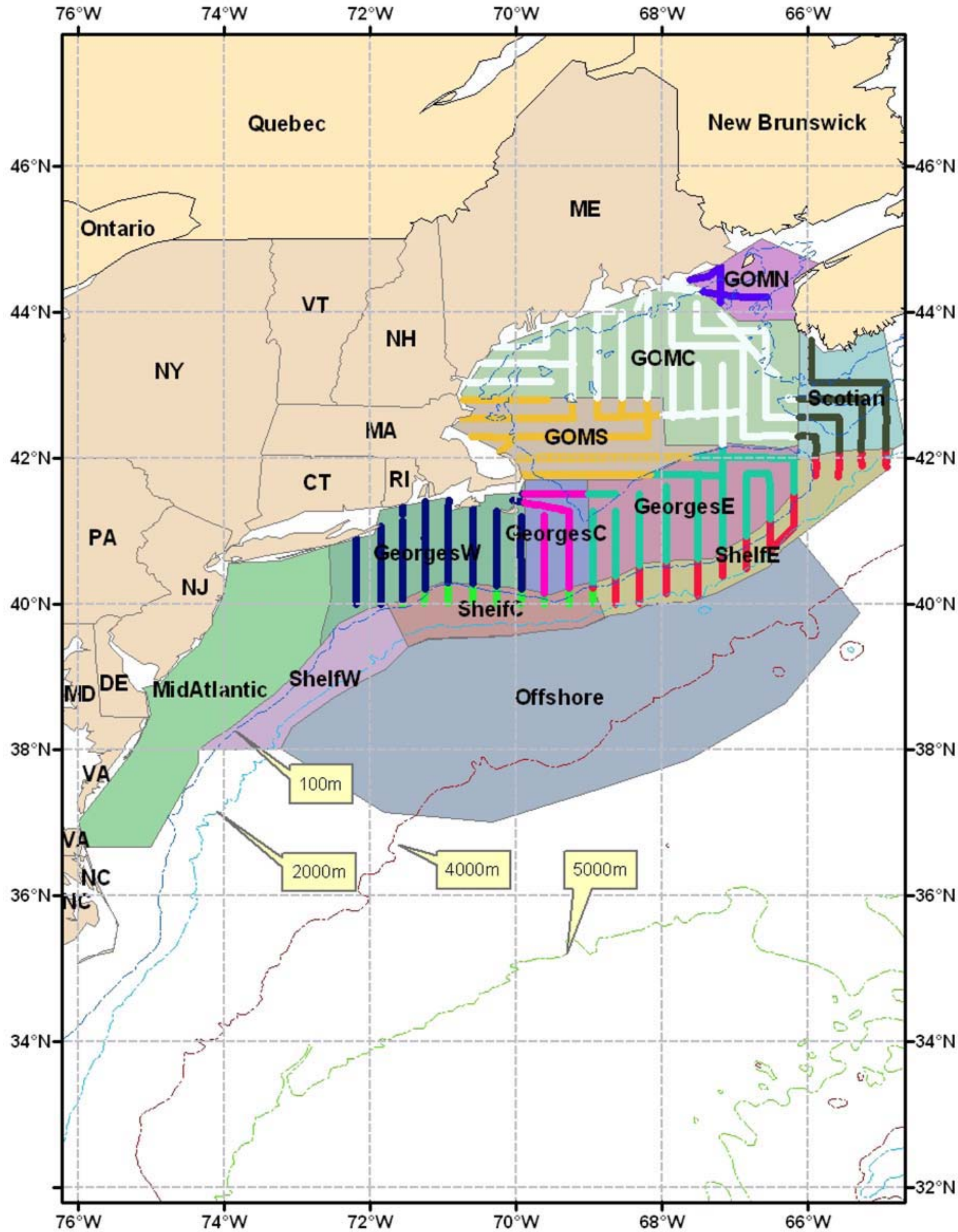
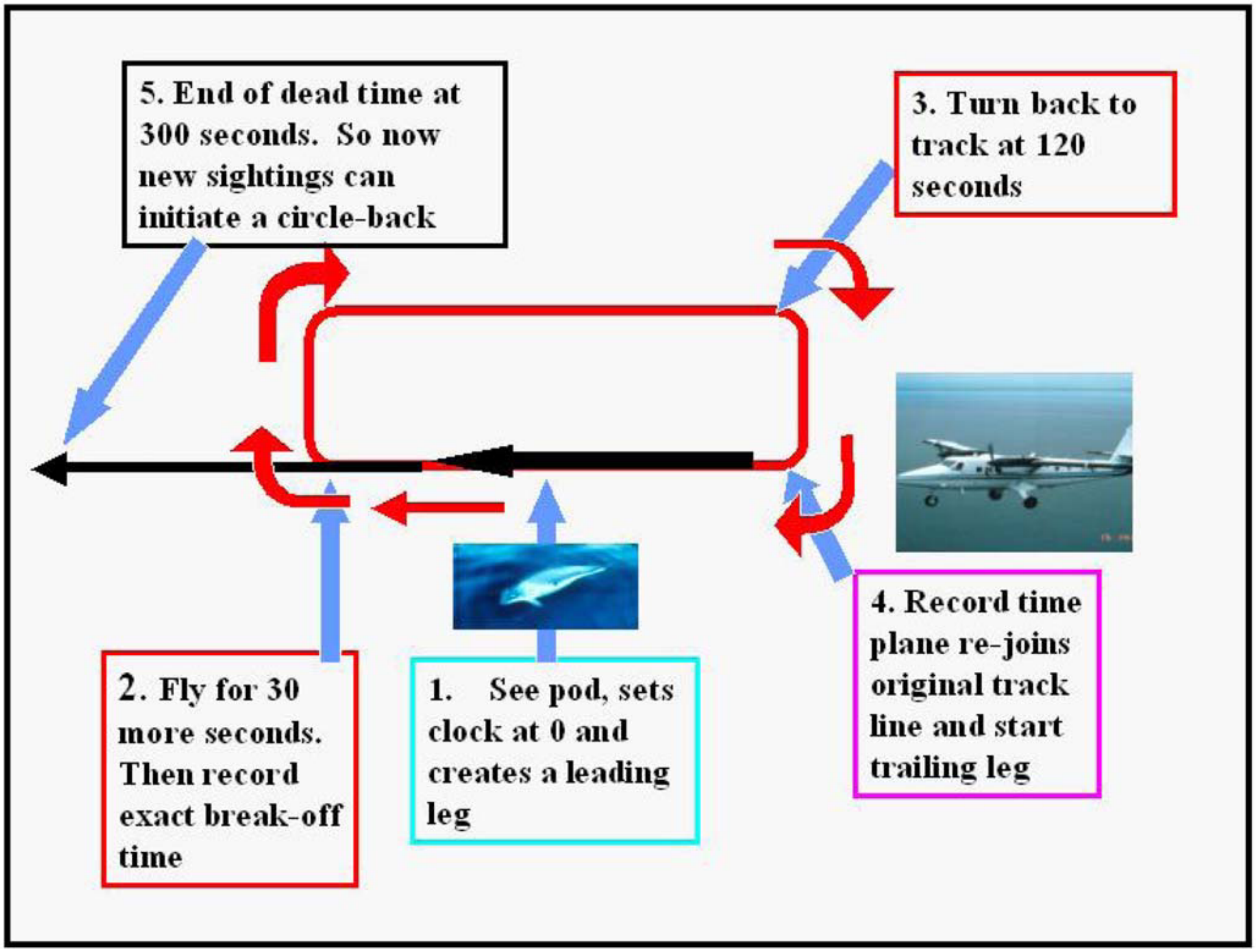


Figure 6. Diagram of how the circle-back technique was performed.



Appendix I.

Original abundance estimates by year and platform.

Species	Abundance estimate						
	1998 plane	1998 ship	1999 plane	1999 ship	2002 plane	2004 plane	2004 ship
Beaked W.		2,882			688	147	2,692
Kogia spp.		115					358
Offshore Bottlenose D.	13,074	6,073			4,279	370	9,416
Common D.		11,349			6,897	55,284	35,263
Striped D.		41,770					52,055
Spotted D.		32,043					3,578
Risso's D.		16,091			10,210		15,053
Pilot W. spp.		4,451			7,194	11,039	4,689
Whitesided D.	199		30,850	20,727	76,985	2,795	
UID D.					5,240	2,454	
Harbor P.			52,982	64,759	46,014	52,982	
Sperm W.		3,199			402		2,607
Fin W.	62	351	814	620	2,187	1,469	
Sei W.				94	57	294	7
Fin or Sei W.				172	212	734	156
Humpback W.			130	686	1,073	808	24
Minke W.				2,004	401	441	
Right W.				194	172	367	
Bottlenose W.							292
UID W.					436	808	576

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